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Action Research for the prevention of littering at riverside: A field experiment measuring the effects of interventions

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Keywords: littering, action research, field experiment, intervention

INTRODUCTION

Marine pollution by plastic litter is getting more serious. Approximately 12.7 million tons of plastics flowed into the ocean (Jambeck et al., 2015). To tackle the problem, it is urgent to develop efficient intervention measures for preventing littering. This study conducted a field experiment at a riverside to examine the effects of interventions for verifying their usefulness.

Action research, which carries out field research with the collaboration of multiple stakeholders, is essential for a successful and efficient field study. They have useful local knowledge specific to the regional contexts. It is difficult to find appropriate interventions suitable for the field without their cooperation. Prior to the experiment, we inspected the field to settle on the intervention measures with stakeholders as action research.

MATERIALS AND METHODS

Selection of the site for the field experiment at the riverside

Observational surveys and interviews with stakeholders were conducted to find a site where littering was serious and to settle on the intervention measures. Through dialogues and collaborative observations, the researchers built cooperative relationships with stakeholders such as officers of the Environmental Bureau and Sewerage and Rivers Bureau Sapporo, the Community Center, residents particularly chairpersons of the neighborhood associations, and an NPO engaging in environmental protection.

After dialogues and collaborative observations with the stakeholders that took five months, we chose Naebo river as the experimental site and selected two intervention measures. Naebo river lies between the roadway, and anyone is not allowed to enter the riverside. Nevertheless, much litter was found. The researchers and stakeholders inferred various types of suspects, such as those who littered from the automobiles and those who walked in and littered there. Therefore, two intervention measures were proposed below.

Intervention measures and experimental design

Setting flowers and illuminations were chosen as the intervention measures. A blocked design was implemented, setting the experimental and control conditions. To test the effects of setting flowers, we set "flower aria" and "non-flower area." Each area was about 20m, and the two areas were distanced over 20m. In the flower aria, 20 planters planted flowers were put at 1m intervals along the inside of the guardrail (Figure 1). In the non-flower area, nothing was put. Similarly,

Figure 1 planted flower used for the intervention

about 20m of the “illumination area” and “non-illumination area” were set and distanced over 20m between the two areas. In the illumination area, Illuminations were put along the riverside (Figure 2). Nothing was put in the non-illumination area. Flower areas and illumination areas were distanced about 400m.

Figure 2 illuminations used for the intervention

The experiment was pre- and post-designed. First, the base rate was measured for 2 weeks. Then, cleanup and mowing were executed, and the intervention materials were set. The intervention period was 6 weeks. After removing intervention materials, the follow-up period was 2 weeks to see the rebound effects. The observers counted the number of littering objects during all periods. The objects were categorized into 25: cans, plastic bottles, plastic cases, cigarette butts, papers, and so on.

RESULTS AND DISCUSSION

Figure 3 shows the changes in the number of littering by the intervention areas. χ^2 test and the residual analysis were conducted. The results revealed a significant effect of flower ($\chi^2 = 20.83$, $p < .01$), indicating that littering was less in the flower area than non-flower area during the intervention period. A significant effect was obtained for the illuminations ($\chi^2 = 9.80$, $p < .01$). However, the residual analysis indicated no significant difference during the intervention period. The effect might be found due to the areas' features. The effect of cleanup and mowing was strong.

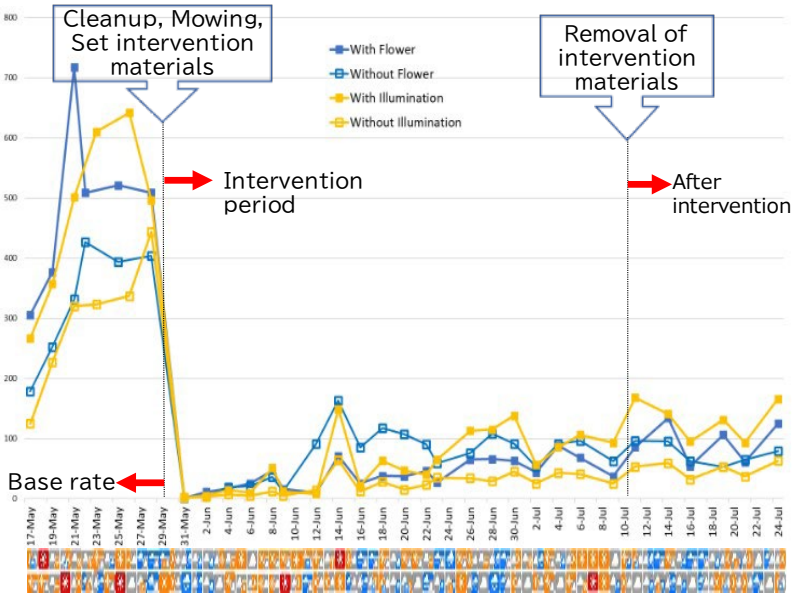

Figure 3 Changes in the number of littering by the intervention

CONCLUSION

This study aimed to examine the effects of interventions with action research for reducing littering. The effect of setting flowers was found, while that of illumination was not. Further field experiments should be accumulated as the features of the field affording littering vary.

ACKNOWLEDGEMENT

This research was supported by Environment Research Fund (S19-2 JPMEERF21S11920) by MOE, Japan. The field experiment was conducted in collaboration with the NPO Ezorock.

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Behavior and Inventory of Microplastics via Wastewater from Various Municipal Solid Waste Incinerator in Japan

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Keywords: microplastic, municipal solid waste incinerator, wastewater, material recycling facility

INTRODUCTION

Recently, microplastics (MPs) have become a problem in marine pollution, and we need to identify sources and effluence pathways and take countermeasures to control the release and accumulation of MPs. Recent reports suggest that municipal solid waste incinerators (MSWIs) are a new source of MPs. Yang et al., (2021) targeted MPs greater than 50 μm in bottom ash from 17 MSWIs in China and noted that 360 to 102,000 MPs/ MSW-t could be produced from bottom ash and released to the environment through its reuse or landfill. In MSWIs in Japan, wastewater discharges that may contain MPs such as wastewater from on-site floor washing, domestic wastewater, collection vehicle washing water, wastewater from bulky and incombustible waste shredding, and material recycling facilities. However, data on MPs emissions from MSWIs are few in the world, and even in Japan, there are only a few cases (Kawai et al., 2021, Harada et al., 2021).

In this research, to understand the MPs emissions from MSWIs in Japan, the number concentration of MPs, their types, and removal behavior in the wastewater treatment process of each facility were clarified for various wastewater discharged from three MSWIs with different incineration methods, waste gas treatment methods, and adjacent facilities. In addition, a questionnaire survey was conducted for several MSWIs to summarize the amount of wastewater per unit of treated waste by type, considering the incineration method, waste gas treatment method, and destination of wastewater discharge. Based on these results, the emission intensity of MPs from different types of MSWIs was estimated, and then developed, estimated, and discussed into an emission inventory of MPs from all MSWIs in Japan.

MATERIALS AND METHODS

Sampling of MPs

Samples were taken at each MSWIs. Wastewater from MSWIs passed through a plankton net with a 100 μm mesh opening. Fig.1 shows wastewater treatment flow diagram and five sampling points of one stoker type MSWI. There are some kinds of wastewater from MSWI: I. Plant wastewater (wastewater from on-site floor washing, domestic wastewater, collection vehicle washing water, ash cooling and boiler), II. Wastewater from adjacent facilities (bulky and incombustible waste shredding and recycling

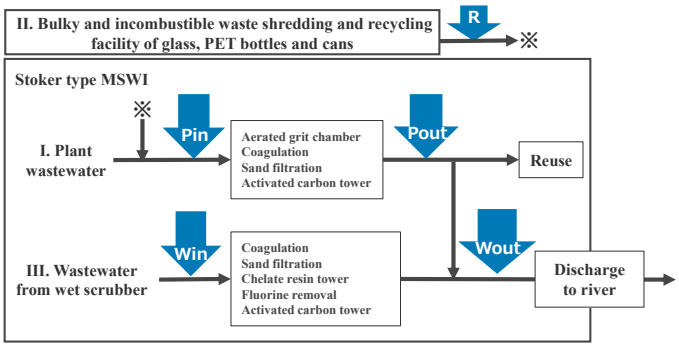

Fig.1 Wastewater treatment flow diagram and five sampling points of one stoker type MSWI.

facility of glass, PET bottles and cans), and III. wastewater from wet scrubber. There are some sampling points such as before and after wastewater treatment and composite samples were taken by sampling every 3 hours for 24 hours. The amount of wastewater passing through the plankton net was measured separately and used to calculate the MPs concentration. Collected MPs were analyzed by optical microscope and Fourier Transform Infrared Spectroscopy (FT-IR) after pretreatment using by H_2O_2 and NaI.

Estimation of Inventory of MPs from MSWI via wastewater

A questionnaire survey was conducted for several MSWIs and the amount of water discharged per volume of waste processed was calculated. Based on these results, annual inventory of MPs from MSWI in all Japan was estimated.

RESULTS AND DISCUSSION

MPs conc. in wastewater discharged from recycling facilities was an order of magnitude greater and has a significant impact on raw plant wastewater. However, MPs conc. was dramatically decreased, and MPs were efficiently removed by wastewater treatment. In addition, the plant raw wastewater fluctuated greatly, being higher during the day when there were many waste deliveries and lower at night or when the plant was shut down. Therefore, 24-hour composite sampling is important. The material flow calculation results for MPs estimated that 99.7% of MPs were removed and that the inventory to the water body was low.

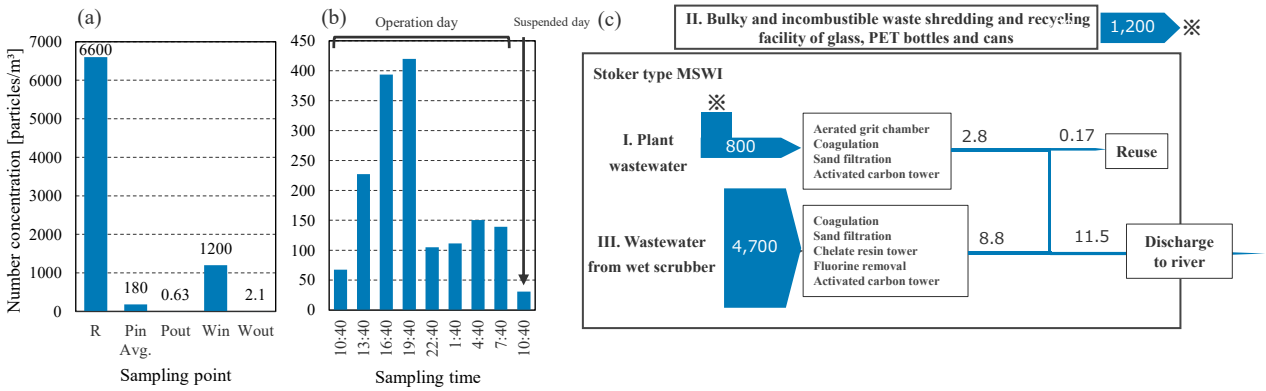

Fig.2 (a) Number conc. of MPs at each sampling point, (b) Time trend of MPs conc. at raw plant wastewater (Pin) and (c) MPs flow in wastewater treatment flow at one stoker type MSWI.

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MICROPLASTICS IN A SOLID WASTE LANDFILL IN JAPAN : THEIR CONCENTRATION IN LANDFILLED WASTE, COVERSOIL, RAINWATER AND LEACHATE

Hirofumi Nakayama, Atsuki Fukuda and Takayuki Shimaoka (Kyushu University)

Focusing on landfilled waste in municipal solid waste landfill sites in Japan, there are wastes containing Microplastics (MPs), such as recycling residues from crushing and sorting facility. The non-woven fabric used as a light-shielding protective mat on geomembrane liners at the slope of the landfill site is made of chemical fiber and there is a possibility that part of the chemical fibers are detached and becomes MPs. It is thought that the MPs carried into the landfill site and the MPs generated in the site move together with the rainwater and reach to the rainwater reservoir pond. Also, part of MPs may move to the leachate treatment facility. However, research on f MPs in landfill sites is insufficient. The purpose of this study is to understand density and migration of MPs in a municipal solid waste landfill site in Fukuoka city, Japan.

In this study, landfilled waste, cover soil, rainwater, and leachate were collected from a municipal solid waste landfill site in Fukuoka city. MPs density was measured by counting the number of MPs in the collected samples and the composition of MPs were identified by FT-IR. As a result, MPs were found in the samples collected from landfilled waste, intermediate cover soil, final cover soil, sediment in rainwater reservoir pond, though MPs were not found from the samples collected from the discharged water after leachate treatment.

Quantity- and quality-oriented strategies for the material recycling of plastic packaging in Japan focusing on source separation and sorting processes

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Keywords: single-use plastic, source separation, sorting technology, resin demand, quality requirement

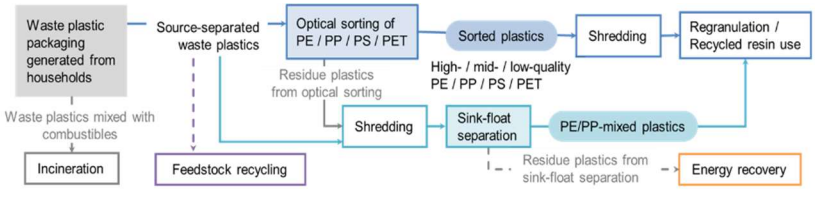
INTRODUCTION

In Japan, post-consumer plastic containers and packaging other than PET bottles (hereinafter referred to as plastic packaging waste), are source separated and collected for recycling from households. However, with the current composition of collected plastic packaging, almost half of the waste plastic input into sink-float-based material recycling (MR) processes becomes residue. There could exist better combinations of plastic types or resin types targeted for MR that enable to increase the amount of recycled resin or to get purer recycled resin (Kawai et al., 2022). We develop recycling scenarios that optimize the quantity and/or quality of recovered plastics under constraints related to the nationwide resin demand and quality level by identifying the best combination of target plastic types of source separation and sorting processes.

MATERIALS AND METHODS

Source separation and sorting schemes

We defined 5 source-separation schemes, and the target plastic types are as follows: a) All types of plastic packaging, b) Plastic trays, c) Plastic bottles and foam PS trays, d) Rigid plastic packaging, e) Rigid and transparent plastic packaging. In total, 80 source-separation/sorting schemes were designed based on combinations of 5 source-separation schemes (a–e) and 16 sorting schemes (sorting schemes 1 to 16 as shown in Figure 1). Based on the sorting accuracy observed in the experiments conducted with an actual NIR optical sorter and the annual quantities of plastic packaging waste generation (Nakatani et al., 2020), we calculated the expected amounts of plastics recovered by optical sorting by resin type and the quality levels.



Resin type	Sorting scheme 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
PE	-	-	-	-	-	-	-	-	✓	✓	✓	✓	✓	✓	✓	✓
PP	-	-	-	-	✓	✓	✓	✓	-	-	-	-	✓	✓	✓	✓
PS	-	-	✓	✓	-	-	✓	✓	-	-	✓	✓	-	-	✓	✓
PET	-	✓	-	✓	-	✓	-	✓	-	✓	-	✓	-	✓	-	✓

Figure 1 A flow chart of the source separation and sorting processes considered in this study

Demand and quality requirements for recycled resins

Based on the nationwide material flows (Nakatani et al., 2020) and current recycled resin use, domestic plastic demand and quality requirements by resin type and product category in Japan were estimated.

RESULTS AND DISCUSSION

Quantities and qualities of recovered plastics

The quantities of plastics recovered by optical sorting and sink-float separation by quality level in each source-separation/sorting scheme are illustrated in Figure 2. In scheme a), the quantities of recovered plastics are larger than those observed for other schemes, however, high-quality plastics are not recovered.

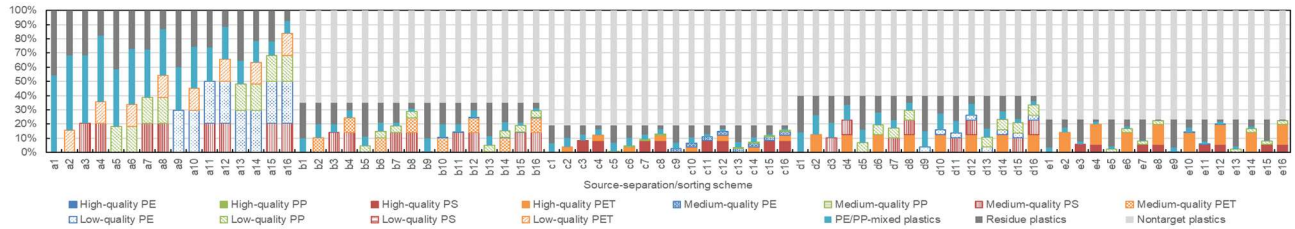


Figure 2 The quantities and quality level of plastics recovered in each scheme (Kawai et al., 2022)

Optimized recycling scenarios

The recycling scenarios for household plastic packaging waste were designed by allocating waste plastics to 80 source-separation/sorting schemes. Three different scenarios were developed: quantity-oriented, quantity/quality-balanced, and quality-oriented optimization scenarios. In each scenario, three different level of use of recycled resin were considered (conservative use, moderate use, and proactive use). The solutions of the scenario optimizations of proactive use scenarios are shown in Figure 3. The quantity-oriented optimization scenario involves schemes a4, a11, and a12, and the recycling target in Japan could be reached based on the quantities of plastics recovered through optical sorting and sink-float separation. In the quality-oriented optimization scenario, it is possible to maintain the current rate of MR based on scheme e12.

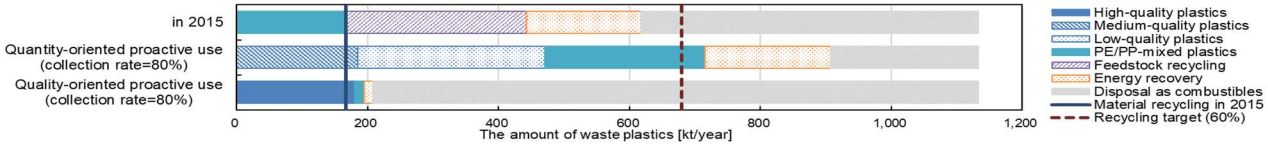


Figure 3 The solutions of the scenario optimizations of proactive recycled resin use scenarios

CONCLUSION

In this study, we developed recycling scenarios for plastic packaging waste in Japan through quantity-oriented, quantity/quality-balanced, and quality-oriented optimizations.

ACKNOWLEDGEMENT

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Management of Mercury Wastes in Japan

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Keywords : Minamata convention,

INTRODUCTION

Based on its response to the history of industrial pollution, Japan contributed to the formulation of the Minamata Convention on Mercury and ratified it in February 2016. Since then, Japan has implemented various initiatives to prevent mercury pollution, including legal mandates and the creation of guidelines.
Two main standards have been established for mercury waste, and environmentally sounds management is being implemented.

In this issue, I will address Japan's efforts and international discussion and issues related to mercury waste.

Obligation for Proper Treatment

Minamata Convention and Domestic Laws

The Minamata Convention aims to prevent mercury pollution in developed and developing countries by reducing anthropogenic emissions. Regarding mercury wastes.

In accordance with the provisions of the Minamata Convention, Japan implements regulations under the Waste Management and Public Cleansing Act and other laws and regulations, and provides guidance through guidelines for the proper disposal of mercury waste in order to prevent the release of mercury into the environment from wastes.

The Waste Disposal and Public Cleansing Law classifies industrial waste contaminated with mercury or mercury compounds as "Specially-controlled industrial waste," "Dust and others contaminated with mercury" and "other industrial waste," and stipulates necessary measures for environmental preservation for each.

Table1 Types and Threshold of Mercury Waste

Category	Threshold	Approach
Specially-controlled industrial wastes (slag, soot and dust, sludge, treated substances or objects thereof and treated waste acid and waste alkali)	0.005 mg/L	Leachate
Specially-controlled industrial wastes (waste acid and waste alkali)	0.05 mg/L	Leachate
Dust and others contaminated with mercury or mercury compounds	15 mg/kg	Total concentration
Recyclable materials containing mercury	0.10 %	Total concentration

In Japan, wastes are evaluated in two stages: the first stage determines whether they are classified as Specially-controlled industrial waste based on the elution potential of hazardous substances; the second stage determines whether they are not classified as Specially-controlled industrial waste and are classified as “Dust and others contaminated with mercury or mercury compounds” based on their mercury content concentration.
Untreated Specially-controlled industrial wastes are not allowed to be disposed of in leachate control-type landfills.

“Dust and others contaminated with mercury or mercury compounds” requires measures to prevent emissions of mercury when heat treatment is performed.
Among the wastes covered by the Convention, those that are traded for value do not fall under the category of wastes under domestic law. The Mercury Pollution Prevention Law covers the standard values and handling obligations for these wastes.

International Trends

The Minamata Convention defines the following three types of mercury wastes.

(a) Consisting of mercury or mercury compounds;
(b) Containing mercury or mercury compounds; or
(c) Contaminated with mercury or mercury compounds,

At COP4 of the Minamata Convention, it was decided not to set thresholds for (a) and (b), and the threshold for (c) is currently under discussion. There are opinions that the threshold value should be a uniform content concentration on a hazard basis, or that a value based on risk assessment according to individual situations, such as waste types and treatment sites, should be considered. Since the types, quantities, and handling of waste generated differ from country to country, it is not easy to reach a consensus.

Domestic Trends

In Japan, while it is of course necessary to respond to the above-mentioned international discussion of mercury-contaminated waste, there are also issues related to final disposal. Although demonstrations of landfill disposal technologies have been conducted, no final disposal sites for mercury waste, which is a Specially-controlled industrial waste, have yet been established in Japan.
Continued demonstration of safety and communication with the local community are needed.

Conclusion

Based on Japan's tragic history of industrial pollution caused by mercury, which was also the origin of the Minamata Convention, Japan has made many efforts to date. Currently, international efforts to further reduce pollution are being discussed, and it is necessary to work toward this goal while also considering compatibility with a circular economy.
In addition, further consideration must be given to securing final disposal sites for mercury waste in order to prevent illegal dumping and accidents during storage.

Current status of mercury waste in China

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Keywords: Hg wastes, mass flow analysis, emission, release

INTRODUCTION

Mercury (Hg) is widely distributed in the biophysical environment and can be transported globally. The long-term use of Hg and Hg-containing materials (e.g., coal, ore concentrates) have liberated a large amount of Hg from lithosphere to earth surface ecosystems and risks wildlife and human beings. To reduce global Hg pollution, 139 nations have signed the Minamata Convention on Hg. The Convention sets out the control obligations for Hg wastes, which means substances or objects consisting of Hg or Hg compounds, containing Hg or Hg compounds, or contaminated with Hg or Hg compounds. Hg wastes in a quantity above the relevant thresholds defined by the Conference of the Parties are required to be controlled by the provisions of national law or the Convention. However, the relevant thresholds for Hg wastes are still under argument and the detailed inventory of Hg wastes have not yet been fully determined.

China, the world's second large economy, has witnessed astonishing growth over the last few decades. To support the rapid economy development, it also consumed massive fuels and materials and simultaneously produced lots of wastes including Hg wastes. The Hg wastes can be from either industrial or residential activities, especially from the air pollution control devices where volatile Hg was captured from flue gas to wastes. Actions to control air, water and soil pollution will significantly impact Hg amount and Hg concentrations in the wastes, and the detailed disposal method of Hg wastes will determine the final fates of Hg in the wastes. Here we used a cross-industry Hg flow model to trace the source and fates of Hg in the wastes. We hope the results will aid to the determination of Hg wastes inventory and future control measures.

MATERIALS AND METHODS

Our cross-industry Hg flow model comprise three tiers: Hg input tier (Tier 1), Hg distribution tier (Tier 2), and Hg re-distribution tier (Tier 3). In Tier 1, we consider Hg input to 8 sectors (further divided into 31 subsectors). For sectors where Hg is an impurity in raw materials, the corresponding Hg input is calculated by multiplying activity levels with Hg input factors. In Tier 2, the Hg input from Tier 1 flows to multiple environmental media and wastes. Based on Tier 1 and Tier 2, we can trace the source of Hg wastes. In Tier 3 Hg in wastes finally flows to different fates after disposal. We classify Hg output into six categories: Hg emissions to air, Hg releases to water, Hg releases to soil Hg exports, Hg stabilization, and Hg stocks. Hg emissions/releases in this study do not consider Hg transportation across different environmental media through biogeochemical cycling. The term "stabilization" means that Hg is properly treated with little potential environmental risks. The term "stock" implies that Hg is stored in wastes and byproducts due to the delay of sales or disposal (more than 1 year), such as the Hg stored in the acid slags produced in nonferrous metal

smelters. Wastes and products containing Hg are generally sealed-stored. Thus, they are regarded to have few environmental impacts during the storage period. However, once these wastes and products are reused, the embedded Hg will re-enter production activities and cause potential environmental impacts. The term "export" indicates Hg flowing abroad by embedding in exported products. For example, Hg in the exported Hg-containing thermometers is regarded as Hg exports.

RESULTS AND DISCUSSION

Figure 1 shows the embodied Hg amounts in key source sectors and Hg wastes. It was estimated that total Hg embodied in the Hg wastes reached ~1900 t in China. Zinc smelting is the top one source sector of Hg wastes, which is followed by coal-fired power plants, lead smelting, copper smelting and power coal washing. These five sectors contribute to ~85% of total embodied Hg in Hg wastes. Waste acid sludge, mainly from nonferrous metal smelting (zinc, lead, copper and large-scale gold production), embodies the largest amount of Hg in all types of Hg wastes. Hg in the waste acid sludge is mainly recovered in the following recovery company due to its high Hg content. Hg content of the waste acid sludge can be over 5% in smelters using high-content ore concentrates. Fly ash from coal combustion process and sulfuric acid from nonferrous metal smelting embody over 500 t of Hg in sum. Compared to waste acid sludge, the produced amounts of fly ash are much larger and its Hg content were generally lower. The actions to control atmospheric Hg emissions have led to increased the median Hg concentration in the fly ash of China's coal-fired power plants from 0.16 mg/kg to 0.33 mg/kg. Sulfuric acid is one common chemicals for downstream industry such as fertilizer production. The utilization requirement of downstream industries has negatively constrained the Hg content of sulfuric acid and its Hg control measures. Based on the disposal method of Hg wastes, we estimate that over 200 t of Hg in the Hg wastes is finally released to environmental media (air, water, and soil), and over 1000 t of Hg is either recovered or stabilized. The rests are mainly stocked in the wastes.

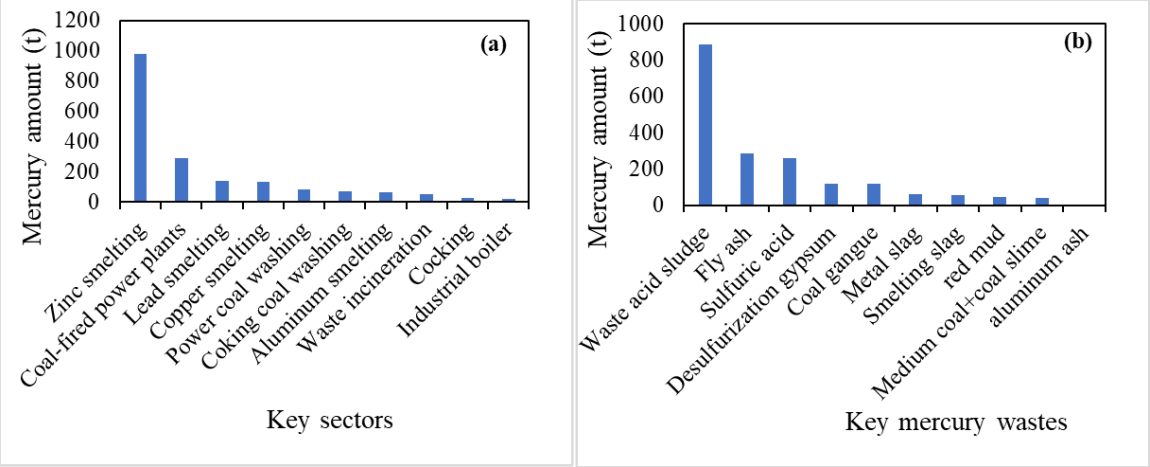

Figure 1 Embodied Hg amount in (a) key source sectors and (b) Hg wastes

CONCLUSION

This study aims to trace the current sources and fates of Hg wastes in China based on a mass flow analysis. We develop a cross-media Hg mass flow model and estimate that ~1900 t of Hg is embodied in Hg wastes. These wastes are mainly from nonferrous metal smelting and coal combustion sectors. Waste acid sludge embody with the largest amount of Hg.

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Management System of Mercury Waste in Korea

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Keywords: Mercury, Minamata Convention, Mercury Waste, Management System

INTRODUCTION

Specifically, mercury is a toxic substance that can cause a damage to nervous system, brain, and kidney. If mercury waste is not properly managed, it can be caused an adverse effect through food chain system, which can lead a toxic effect to human health and the environment. The Minamata Convention is an important international agreement that aims to protect human health and the environment from the adverse effect of mercury by phasing out its use in various industrial processes and managing mercury waste properly. The Korea (Republic of) signed the Minamata Convention in 2014 to manage mercury and its wastes properly, and became a party to the Minamata Convention in February 2020.

In order to manage the entire life of mercury from production to final disposal, in fact, Korea has been establishing several management policies for mercury waste starting with “the Comprehensive Measures for Mercury Management” in 2006. In this presentation, it will be described the management system for the entire life of mercury waste through several stages such as the manufacturing and import/export stages, the discharge stage, and the recycling and disposal stage in Korea by reviewing several policies measures on mercury waste

MANAGEMENT SYSTEM OF MERCURY WASTE IN KOREA

The manufacturing and import/export stages

Since 2020, Korea has been managing mercury and mercury waste under the Persistent Pollutant Control Act (PPC Act), including the management standards and the restriction of mercury usage. In the PPC Act, the eight types of mercury-added products stipulated by the Minamata Convention such as batteries, fluorescent lamps, mercury lamps, switches and relays, fluorescent lamps for electronic displays, cosmetics, pesticides, and non-electronic measuring devices such as blood pressure monitors and thermometers were prohibited to manufacture, import and export.

The discharge stage

When products or materials containing mercury are discharged, they are managed as mercury wastes under the Waste Management Act in Korea. In July 2021, mercury waste was added to hazardous waste list in the Waste Management Act. As shown in <Table 1>, mercury waste can be classified into mercury-containing waste, mercury-consisting waste, and treatment residues of mercury-containing waste.

Discharge of mercury-containing waste should be double-packed in an airtight container, and mercury-consisting waste should be stored in a special container. Treatment residues of mercury-containing waste should be discharged by sealing and double-packing only if the leaching mercury concentration of them is

0.005mg/L or more in Korean Extraction Test (KET).

Table 1 Types of mercury waste in the Waste Management Act

Type	Content
Mercury-containing waste	Waste lamps (Excluding spent fluorescent lamps), waste measuring devices such as blood pressure gauges and thermometers, waste batteries
Mercury-consisting waste	Mercury and its compounds separated from mercury-containing waste
Treatment residues of mercury-containing waste	Residues from the treatment of mercury-containing waste including spent fluorescent lamps

The recycling and disposal stage

In the recycling and disposal stage, Korea is adopting an option to recover mercury and completely isolate it from the environment. In Korea, mercury-containing waste must be recycled after recovery of mercury. The mercury-containing waste can be recycled in the R-3-3 (type of manufacturing raw materials by separation, sorting, compression, etc.), R-4-1 (type of manufacturing metallic products), R-4-7 (type of manufacturing chemical products such as chemicals, pigments, paints, etc.), and R-10 (Type of intermediate processing waste for product manufacturing, etc.). The recovered mercury from mercury wastes should be permanently stored by special containers in a storage warehouse. The treatment residues of mercury-containing wastes should be stabilized/solidified or landfilled in double sealed packaging if they were not satisfied with the regulated level of the leaching mercury concentration.

CONCLUSION

The mercury waste management system in Korea can be divided into several stages such as the manufacturing and import/export stages, the discharge stage, and the recycling and disposal stage. Since 2020, Korea has been managing mercury by Persistent Pollutant Control Act which prohibits the manufacture, import and export of mercury-added products. Mercury-containing wastes are discharged as hazardous wastes with a double-packed in an airtight container under the Waste Management Act. In the recycling and disposal stage, Korea adopts an option to recover mercury and completely isolate it from the environment.

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Status of Mercury Waste in the European Union

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Keywords: greenhouse gas, landfill cover soil *(3-5 keywords should be appeared)*

CATEGORIES FOR MERCURY WASTE IN THE EU

According to the Minamata Convention, the waste of category a) 'consisting of mercury and mercury compounds', b) 'containing mercury and mercury compounds' and c) 'contaminated with mercury and mercury compounds' are managed in the European Union according to the strict "Environmentally Sound Management" (ESM) operations of the UNEP's 2015 Technical Guidance. The extremely demanding ESM operations aims to permanently store mercury in a stable insoluble form, and to avoid any emissions to the biosphere.

There are today discussions on the concentration limit or threshold that should define any waste contaminated with mercury as 'c' (and hence to be managed by ESM operations) or not. The EU has proposed since 2019 a threshold of 25 mg total Hg/kg dry matter of waste (Hennebert 2019). Below that concentration and above 1 mg Hg/kg, wastes are managed by risk in specific legislations dealing of the material and its use, recycling or storage. Below 1 mg/kg, the waste is not hazardous for mercury.

The attribution of one category (a, b, or c, or none) to a waste is defined in the EU by the industry from where they stem (EU 2017), or by articles with a maximum content of Hg, or by practice.

The industries of chlor-alkali, the cleaning of natural gas, the non-ferrous mining and smelting operations and the extraction from cinnabar ore in the Union are considered as a) waste.

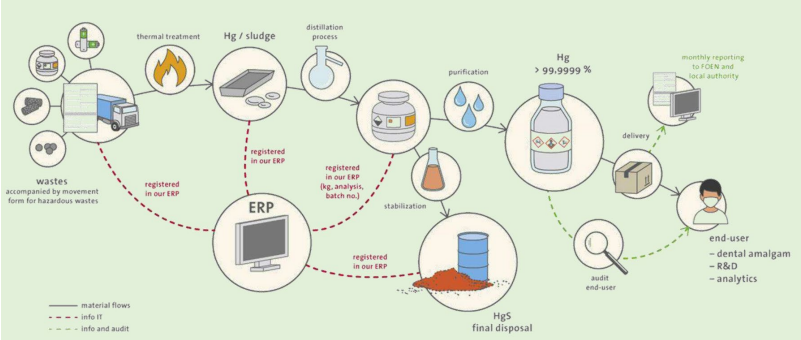
Some articles cannot be manufactured anymore and are considered as b) waste: batteries and accumulators (> 5 mg Hg/kg), switches and relay (max 20 mg/item), compact fluorescent lamps (> 2.5 or 3.5 mg Hg/item), linear fluorescent lamps (5 or 10 mg Hg/item), mercury lamps (> 3.5, 5 or 13 mg Hg/item), cosmetics, pesticides, biocides and topical antiseptics, non-electronic measuring devices: barometers, hygrometers, manometers, thermometers and other non-electrical thermometric applications, sphygmomanometers, strain gauges to be used with plethysmographs, mercury pycnometers, mercury metering devices for determination of the softening point.

No official definition is given for c) waste. The available data (including this paper) indicate that if the concentration is lower than 25 mg/kg, the wastes are not managed by ESM but are recycled or stored in unspecific landfills. That limit is consistent with numerous waste/use regulations (Hennebert 2019).

MANAGEMENT OF WASTE THAT CONTAINS MERCURY (a, b, c) IN THE EU

The waste are collected, transported as hazardous waste, and when relevant incinerated or treated by physical-chemical treatment. The mercury is then distilled, "converted" (transformed into mercuric sulphide) and stored. A general scheme is presented in Figure 1. The liquid mercury is converted by four companies (a mobile installation and facilities in Germany, Spain and Switzerland), and stored in two salt mines in Germany.

Above-ground facilities are allowed if they provide the same level of safety and confinement.



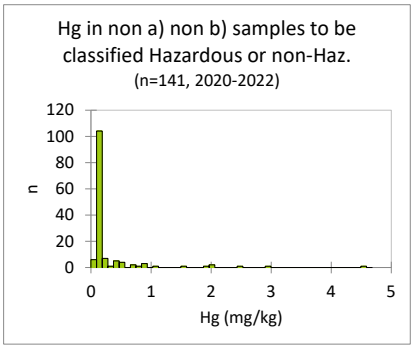


Figure 1 (left) General management of waste containing mercury with disposal in salt mine (BATREC sheet of UNEP 2022)

Figure 2 (right) Distribution of Hg in non a) non b) waste (this paper)

WHAT TRESHOLD FOR "WASTE CONTAMINATED WITH MERCURY" FOR ESM?

Original data provided by an independent service laboratory of mercury concentration of waste that are "mirror entries" (hazardous or not depending on the concentration of hazardous substances) in the EU list of waste are presented in Figure 2. These wastes undergo a representative sampling and an analysis for total concentration of elements and substances, among which mercury, in an accredited laboratory. The maximum concentration of mercury is 4.6 mg/kg (median = 0.1 mg/kg, mean = 0.3 mg/kg, n=141). It was found earlier that a representative concentration in mixed household waste that are incinerated is 0.3 mg/kg (Hennebert 2022). These facts demonstrates that the separate collection for articles containing mercury and waste of a), b) and c) categories and their correct management is effective in the EU. It is a confirmation that the limit of 25 mg/kg is seldom if ever exceeded in non a) and non b) waste, and that these waste that should be managed by a risk case-by-case waste composition/use approach and corresponding threshold, and not by hazard/ESM approach, because as they enter in a controlled loop the risk is under control. Much more data and details will be presented in the Congress.

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Status of Mercury in Indonesia

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Keywords: National Action Plan for Reduction and Abolishment Mercury, mercury in Indonesia, ASGM

INTRODUCTION

Since the past few years, mercury has been a cause of concern in Indonesia. These includes the illegal trade in mercury, the mining of cinnabar, the use of mercury for gold mining, and the making of medical instruments and other products that contain mercury (Sari et al., 2021). Indonesia has been joining the agreement after ratifying the Minamata Convention on Mercury in September 2017,. Then the ratification was legally acknowledged through n Law No. 11, 2017. The purpose of this study was to explore how Indonesia manage the mercury use in the four key areas listed on the National Action Plan.

MATERIALS AND METHODS

The secondary data were used to analyzed the current status of mercury in Indonesia.

RESULTS AND DISCUSSION

Target of National Action Plan for Mercury Reduction and Abolishment

Presidential Regulation Number 21 of 2019 concerns the National Action Plan for Mercury Reduction and Abolishment (*NAP RAM*), that regulates the scope, priority areas, strategies, activities, and targets for four sectors. This regulation covers how mercury can be reduced and eliminated by the stakeholders. . The target for mercury reduction and elimination based on NAP RAM for the fourth sectors are listed on the Table 1.

Table 1. The target for mercury reduction and abolishment based on NAP RAM

Sectors	Targets		Year
	Mercury Reduction	Mercury Abolishment	
Manufacture	50%		2030
Energy	33.2%		2030
ASGM		100%	2025
Health		100%	2020

Source: Presidential Regulation Number 21 of 2019 (Sari et al., 2021)

Energy Sector

Mercury emissions resulting from burning coal in boiler unit from electric steam power plant in Indonesia are controlled by the technologies provided to control the air pollution, such as Low NOx Burner, Electrostatic Precipitator, Fabric Filters, and Flue Gas Desulphurization. The policy in using clean and environmentally coal technology such as the super critical and ultra-super critical boiler technology are expected to reduce mercury releases and may support the 33.2% mercury reduction target in 2030.

Manufacture Sector

In the manufacture sector, the Ministry of Energy and Mineral Resources is suspected to contributes to reduce mercury in the lighting industry. Currently, it is recommended to terminate the use of mercury-containing lamps by LED lamp as an alternative. Since no mercury used and use less energy, the LED lamp is more safe and efficient.

Artisanal and Small-Scale Gold Mining (ASGM) Sector

The ASGM is the main sources of mercury pollution in the surface water in several provinces in Indonesia. Although the mercury concentration found in the surface water was lower than the national regulation (Government Act No. 82/2001), however, the value was exceeded the WHO regulation. Moreover, the mercury threshold set by national regulation is higher than value set by international regulations such as the USEPA (the United State Environmental Protection Agency) or WHO (World Health Organization).

Health Sector

Since December 31, 2018, medical devices containing mercury have been prohibited from being traded in the health sector. This step is in-line with the goal on eliminating the mercury from health sector by 2025.

CONCLUSION

The National Action Plan for Mercury Reduction and Abolition, as outlined in Presidential Regulation No. 21 of 2019, is an important step toward reducing and eliminating mercury. The government has made efforts to reduce and eliminate mercury for four main sectors includes energy, manufacturing, ASGM, and health sectors.

ACKNOWLEDGEMENT

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Life Cycle Assessment of Recycling on Mercury Collected from Spent Mercury Containing Products in Japan

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Keywords: mercury, greenhouse gas, resource consumption, recycling, life cycle assessment

INTRODUCTION

The Minamata Convention on Mercury came into force in 2017 to reduce the discharge of mercury into the environment. Mercury-containing products are collected separately from households in Japan for recovery of mercury and other valuable materials as well as for disposal. Resource recovery and reducing greenhouse gas (GHG) emissions are important issues in the waste treatment sector. In this study, we aimed to clarify the important factors for reducing GHG emissions and increasing resource recovery in a mercury-containing product treatment system. There are anticipated changes in the field, because the demand for mercury is expected to decrease and the recovered mercury can be chemically stabilized to store it underground in the future (Takaoka M, 2015). Therefore, we also aimed to assess the current and future treatment systems.

MATERIALS AND METHODS

Scope: System boundary and functional unit

The impacts of climate change and resource consumption were assessed by life cycle assessment (LCA) (ISO, 2006). The system boundary was specified as spent fluorescent lamps and dry cell batteries relinquished by households to the mercury recovery process. The substitution effect was attributed to the aforementioned relinquished materials due to the valuable resources recovered from them. Substitution products were evaluated as credit with negative environmental impacts. Currently, mercury mining is still active. The mercury substitution effect equivalent to the amount of mercury recovered was included for assessing current cases, but excluded from future cases (FL-D and DB-C) as follows.

Spent fluorescent lamps

Case FL-A: Collected and crushed by a municipality and transported to a mercury recovery plant.

Case FL-B: Transported to a mercury recovery plant without crushing.

Case FL-C: Crushed, incinerated, and landfilled.

Case FL-D: Recovered mercury is chemically stabilized, whereas the others are the same as in Case FL-A.

Spent dry cell batteries

Case DB-A: Recovering metals, including mercury, after collection.

Case DB-B: Incinerated with combustible municipal solid waste, iron was recovered from the residue.

Case DB-C: Recovered mercury is chemically stabilized, whereas the others are the same as in Case DB-A.

Data collection

Data on material recovery were collected from a business that recovers mercury and other valuable materials from spent fluorescent lamps and dry-cell batteries. Materials were transported to the recovery center by cargo trucks (fluorescent lamps, 100 km; dry-cell batteries, 200 km) and by trains (fluorescent lamps, 1500 km) Data from the Ministry of the Environment Japan, 2021 were used to estimate the material consumption for chemical stabilization. The Japanese process-based LCA database, IDEA ver.3.2 (AIST, 2021), was used as background data for the assessment.

RESULTS AND DISCUSSION

Material recovery contributed significantly to reducing environmental impacts. It is important not only to treat waste, but also to recover valuable resources. The transportation of spent fluorescent lamps without crushing increases the environmental impact (Fig.1a). It is essential to improve the transportation efficiency by crushing. The environmental impacts of chemical stabilization were small. No significant increase in GHG emissions and resource consumption associated with the transition to chemical stabilization was expected.

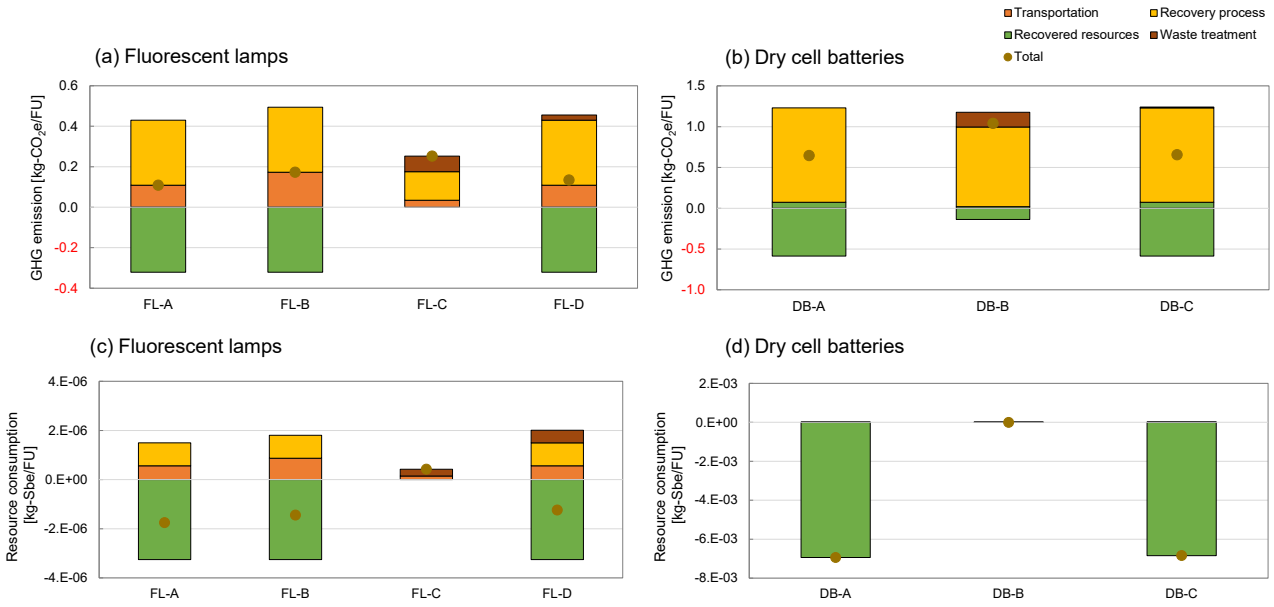

Figure 1 Results: (a) and (b) GHG emissions; (c) and (d) resource consumptions

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Mercury diffusion from sulfide/solidified mercury waste in landfill lysimeters

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Keywords: mercury diffusion, landfill lysimeters, sulfide/solidified mercury waste

INTRODUCTION

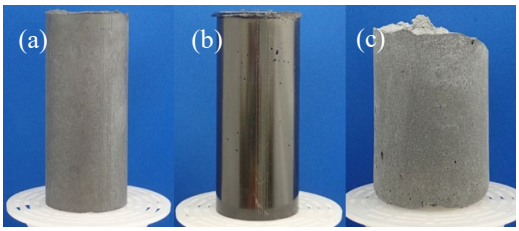
The Minamata Convention, enforced in August 2017, aims to protect human health and the environment from anthropogenic emissions and releases of mercury. This research aims to confirm the safety of sulfurized/solidified mercury. Therefore, two additional types of solidification were adopted: cement solidification and epoxy resin solidification. The existing sulfur solidification method was modified as well. Mercury diffusion from all lysimeters are analyzed during the landfilling period for 25 months. After this experimental period, the lysimeters were dismantled and the sulfurized/solidified mercury were sampled to measure the mercury diffusion capacity to compare the difference before and after landfilling. Finally, the purpose of this research is to clarify the influence of landfilling for mercury diffusion from sulfurized/solidified mercury inside the real condition of landfill site.

MATERIALS AND METHODS

Landfills were simulated using lysimeters (length 250 × width 250 × depth 600 mm) operated under the semi-aerobic landfill type and the anaerobic landfill type, as shown in Fig. 1. Three sulfurized/solidified mercury specimens are tested in the experiments. The solidification methods used include modified sulfur solidification (MS), epoxy resin solidification (EPR) and low alkali cement solidification (LAC). The specimens used are were received from other based on those used in the experiment which is published by Kusakabe (Kusakabe T. et al., 2020[1)]). The gas in the head space of lysimeters was vacuum-aspirated for 20 min at a rate of 0.5L/min and passed through tubes packed with gold amalgam to capture the mercury. A direct thermal decomposition mercury analyzer equipped with an atomizer (RH-MA3; Nippon Instruments Co., Ltd., Japan) was used to analyze the mercury in these tubes. The amount of mercury diffused through the lysimeters was calculated as in a previous study (A. Sano et al., 2020[2)]). Mercury volatilization testing with a large desiccator was used for analyzing the mercury volatilization in the solidified specimens. The experimental temperature was fixed as 30 °C, as in a previous study (K. Kawase et al., 2018[3)]).

Table1. Experimental condition and photos of sulfide/solidified mercury (a:MS, b:EPR, c:LAC)

Name of lysimeter	No.1	No.2	No.3	No.4(Blank)	No.5	No.6	No.7(Blank)
Landfill type	Semi-aerobic				Anaerobic		
Mercury waste samples	MS	EPR	LAC	none	MS	EPR	none
Mercury content in landfilled wastes	449.059	696.013	362.04	-	450.998	836.968	-
Composition of solid waste	Incineration residue 80% Sewage sludge compost 20%						
Weight of solid waste (kg-wet)	36.0 kg-wet (1.29 kg/L of layer)				34.9 kg-wet (1.25 kg/L of layer)		



RESULTS AND DISCUSSION

Mercury diffusion during experimental period

Figure 2 showed the changes over time of the amount of mercury diffused from the lysimeters. The amount of Hg from the mixed solid waste showed close to the Environmental Quality Standards for Air Quality(40ng/ m^3) after one years of experimental time. Also, these results showed as same as the blank lysimeters, which have no sulfurized/solidified mercury. It means that these mercury volatilizations resulted from the solid waste.

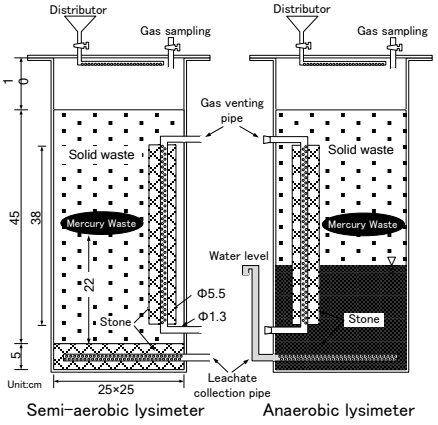


Figure1. Schematic diagram of simulated-landfill lysimeters

From a comparison of all sulfurized/solidified mercury, Epoxy Resin solidification (No. 6) showed higher concentration than others in mixed solid waste lysimeters, and it might have diffused from sulfurized/solidified mercury. Therefore, the lysimeters were dismantled after 25 months to understand the phenomenon inside landfilled waste.

Changing of mercury diffusion of sulfide/solidified mercury after landfilling

Table 2 showed mercury diffusion amount before and after landfill experiment. After 25 month of experiment, all three sulfide/solidified mercury showed 2 to 10 time smaller amount of mercury volatilization than initial period, because of the washing out the attached mercury by the artificial precipitation. EPR showed higher volatilization amount than others at initial and also after 25 month. No.6-2 showed highest result after 25 months, because that specimen was damaged on surface area from some reaction in landfilled waste. This might be the reason of higher mercury diffusion in No.6 lysimeters.

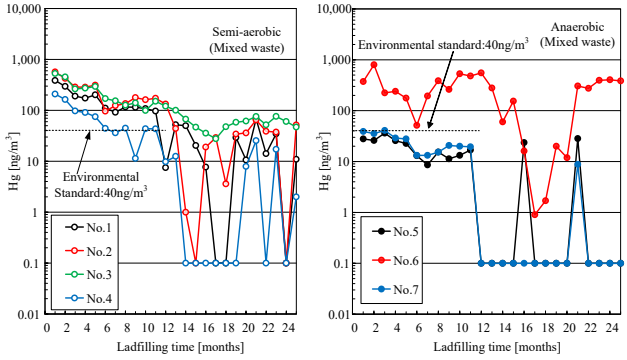


Figure 2. Mercury diffusion from lysimeters

Table 2. Mercury volatilization amount and decay ratio from mercury waste

Landfill type	Sulfied/solidified Mercury Waste	Lysimeter No.	Mercury volatilization (ng/m^3) Initial period	Mercury volatilization (ng/m^3) After 25 months	Decay Rate (%)
Semi-aerobic	MS	No.1-①	977.2	396.0	59.5
		No.1-②		517.5	47.0
Anaerobic		No.5-①		37.3	96.2
		No.5-②		36.6	96.3
Semi-aerobic	EPR	No.2-①	24237.2	1288.1	94.7
		No.2-②		1786.4	92.6
Anaerobic		No.6-①		132.2	99.5
		No.6-②		2902.1	88.0
Semi-aerobic	LAC	No.3-①	16005.9	1092.3	93.2
		No.3-②		716.5	95.5

CONCLUSION

Most of lysimeters with sulfide/solidified mercury showed smaller mercury diffusion amount than environmental standard after one year. After 25 month of landfill, the mercury volatilization amount from species were decreased as expected, but the decay rate showed wide range of different conditions.

AKNOWLEDGEMENT

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Potential of Greenhouse Gas Emission Mitigation of Municipal Solid Waste Management in Bangkok Metropolitan

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Keywords: greenhouse gas emission, IPCC methodology, mitigation, solid waste management, waste disposal

INTRODUCTION

Municipal solid waste (MSW) generation in Bangkok Metropolitan, capital city of Thailand, has steadily increasing from its urbanization, economic growth and people life-style changes. In 2021, there was 12,214 tons of MSW generated daily in Bangkok in which 3,564 tons was recycled and 8,650 tons was disposed [1]. The disposed MSW was managed in composting plant at 1,600 tons/day, incineration plant at 500 tons/day, mechanical biological treatment (MBT) facility at 800 tons/day, and the remaining wastes at 2 sanitary landfill sites [2]. The MSW management by these combined methods results in significant greenhouse gas (GHG) emissions. In 2015, Thailand has submitted its national determined contribution aiming to reduce its GHG emissions by 20-25% [3]. Meanwhile, Bangkok Metropolitan Administration (BMA) has issued its development plan (20 years: 2013-2032) in 2014 targeting reduction of MSW amount to be disposed by 20% and increase waste utilization by 40% from the base year (2013) to achieve sustainable MSW management while reducing impacts to the environment and climate change [4]. Nevertheless, the extent of GHG mitigation to be achieved from the implementation of MSW management following BMA development plan has not been evaluated. Therefore, this research determined GHG emission from MSW management in Bangkok Metropolitan by comparing 3 different scenarios, i.e., business as usual (BAU), Bangkok solid waste management plan, and National GHG mitigation policy which include increased methane gas recovery from solid waste disposal sites, increased waste treatment by composting and incineration.

METHODOLOGY

The estimation of GHG emission was carried out following 2006 IPCC Guidelines for National GHG Inventories [5] and 2019 Refinement to the 2006 IPCC Guidelines [6]. The MSW management activities resulting in GHG emissions were 1) Solid waste disposal on land 2) Biological treatment of solid waste 3) Incineration of waste. Information on the quantity and most recent physical composition of MSW from BMA statistics was used. Default parameters recommended in the guidelines were applied for the estimation of GHG emissions.

RESULTS

In this study, GHG emission from waste sector in Bangkok Metropolitan under BAU was estimated at 1,216.31 $GgCO_2eq$ in 2032 but will reduce to 714.23 $GgCO_2eq$ under Bangkok solid waste management plan. Adoption of National GHG mitigation policy in terms of increase in methane recovery from landfill disposal will emit 771.65 $GgCO_2eq$ whereas increasing waste treatment through composting and incineration will yield

1,163.18 and 930.64 $GgCO_2eq$ emissions. Implementation of all 3 measures will emit 633 $GgCO_2eq$. This lowest emission scenario can reduce the emissions by 47.69% from the BAU scenario in 2032. To achieve this maximum GHG emission reduction scheme, 2400 tons/day of composting, 3,500 tons/day of incineration, and 43% of methane gas recovery from landfills needs to be implemented in 2032.

ACKNOWLEDGMENT

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Plastic reduction and firm characteristics: Evidence from financial and non-financial information in the securities reports

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Keywords: Plastic reduction, Firm initiative, Econometrics, Eco-innovation

INTRODUCTION

Marine pollution is a challenging problem for the world. There are two ways to solve this problem. Firstly, government environmental policies are expected to have short-term effects. Second, voluntary innovation by firms is expected to emit long-term effects. Firms have been under pressure from stakeholders to adopt environmentally sustainable initiatives, especially concerning plastic reduction.

With respect to environmental innovation in the broad sense, previous studies (Horbach, Rammer et al., 2012; Demiral and Kesidou, 2012) analyze the determinants of R&D. However, these studies are more generalized than the discussion on plastic reduction because they are based on questionnaire-based analysis. Their innovation indicators are limited to R&D expenditures and specific environmental improvement behaviors. We focus on firms' efforts to reduce plastics and use a unique dataset on Japanese firms to examine which characteristics of firms are actively engaged.

MATERIALS AND METHODS

Data

We use a survey conducted by Toyo Keizai Inc.'s "CSR Company Handbook (ESG Edition)" to determine whether companies are taking initiatives to reduce plastics. This survey was sent mainly to listed companies in Japan, and 1,631 companies responded. We make a dummy variable from these responses and analyze the 400 companies that responded to the question "whether or not they are engaged in plastic reduction initiatives." We also analyze the content for which type of initiatives are implemented by dividing them into the following subgroups in Figure 1: "Input," "Bioplastic," "Substitute," "Recycle," "Reuse," and "Inside.

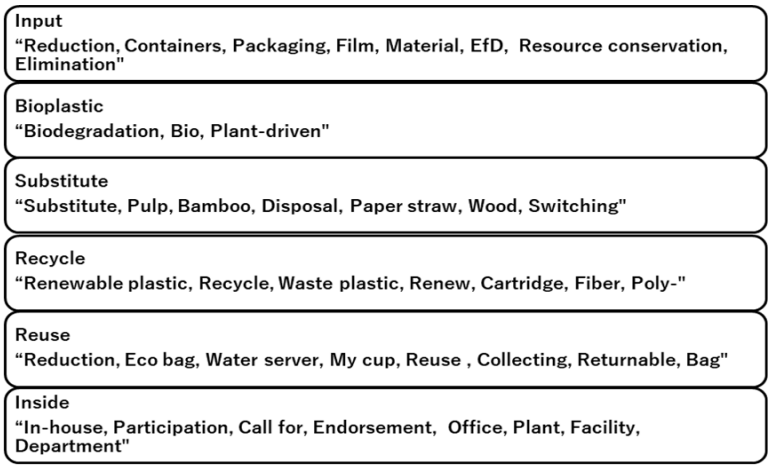

Figure. 1 Subgroups of environmental friendly initiatives

Estimation

We estimate the following specification to evaluate the determinants of firm efforts to reduce plastic and container packaging. Because the independents are dummy variables, we adopt the Probit model.

$$P(Y_i = 1|X_i) = F(X_i'\beta) = X_i\beta + \epsilon_i \quad (1)$$

where y_i is a dummy variable that indicates the firm's answer to implementing any initiative to reduce plastic for i firm. X_i is the vector of control variables and ϵ_i is the random error term.

RESULTS AND DISCUSSION

Characteristic of aggressive firms for reduction plastic

Table 1 shows that the estimation results in characteristics of the aggressive firm for reducing plastics. The first column shows the analysis of the determinants of whether or not a company implements reducing plastic activity. From this result, the firms which are interested in environment and governance and building EMS are likely to implement to reduce plastics. The second columns through the seventh show the results for the estimation by content category.

Table. 1 Significant signs and variable names in the estimation results

	Initiatives	Input	Bioplastics	Substitute	Recycle	Reuse	Inside
Positive	log(Employee), G ratio, EMS, Risk	log(Employee), G ratio, EMS, Risk, MDA2	log(Employee)	EMS	G ratio, EMS, Risk	log(Employee), log(Sales)	EMS
Negative	None	None	None	None	MDA1	log(Total asset)	None

CONCLUSION

The purpose of this study is to use Japanese firm data to understand the characteristics of firms that are active in efforts related to plastics reduction. In the estimation, Probit analysis shows the characteristics of companies that are implementing initiatives. The characteristics of the companies that efforts were identified as being large, interested in corporate governance, implementing an EMS, and mentioning plastics as a future risk to the company as positive factors. These results also reveal that the correlated characteristics differ depending on the type of effort. Based on the results of this study, it can be expected that when the government encourages companies to take initiatives to reduce plastics, efficient interventions will focus on companies that are more concerned about governance and future corporate risks.

ACKNOWLEDGEMENT

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Gas monitoring at landfill sites approaching the end of aftercare: Case studies in Japan

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Keywords: landfill gas, end of aftercare, waste landfill, methane, nitrogen, hydrogen sulfide

INTRODUCTION

Landfill gas (LFG) generation and emission are important parameters to estimate the stabilization of landfills and judge whether to end the aftercare of landfills. The emission behavior of landfill gas which mainly consisted of carbon dioxide and methane in general highly fluctuates in its emission rate, composition, and planar emission points. The gas emission behavior which is out of the theoretical expectation shall make the landfill operators and practitioners confused to understand the real situation of the landfill. We have studied a few unexpected cases of landfill gas emissions and have tried to elucidate these mechanisms. The first case is the landfill that had exhibited a high concentration (more than 90%) of nitrogen in the landfill gas. This landfill had disposed of inert industrial waste such as concrete rubbles, gypsum boards, plastics, soils, and so on. It was operated for 20 years and 7 years had passed from the end of disposal when we conducted the monitoring event. Methane emission was not observed at the surface cover though it was detected under the cover soil layer. A high concentration of Nitrogen gas in the monitoring pipe was not only ascribed to the penetration of the air, as its contribution was calculated to be 35-50%. Therefore gas generation by the conversion of the waste in the landfill should be the reason for to increase in the concentration of Nitrogen in this landfill. In another case, we investigated the landfill which exhibited a high emission of carbon dioxide together with low emission of methane. The section which we have targeted in this landfill had been disposed of industrial waste, such as incineration ash, sludge, and gypsum board waste. The section was operated for 8 years under anaerobic conditions, and we have surveyed from 2 years after the end of the disposal. During the 6-year campaign of the survey, methane emission was rarely observed at the landfill surface. The trend of carbon dioxide emission followed the first-order decay model of LFG generation, suggesting the biological waste conversion process in the waste layer. Methane oxidation at the cover soil layer contributed to reducing the methane emission though it was not able to fully explain the mechanisms of the formation of the gas in this landfill. The high concentration of sulfate in the landfill layer, which is mainly derived from gypsum board waste, indicated that the active reduction of sulfate would consume the organic carbon and result in the generation of carbon dioxide and avoidance of the generation of methane. These results indicate that assessments of the landfill stabilization and the end of aftercare must be conducted by the cross-sectional evaluation of several indicators (gas emission/concentration, water quality in landfill, microbial activity, etc.), even though the gas monitoring will give the important implications on the situation of the landfill.

ACKNOWLEDGEMENT

The author appreciates the academic research committee on waste landfill in JSMCWM.

General Sessions

Occurrence, Attenuation and Dynamic Modeling of Pesticides Transport along Pampanga River Basins

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Keywords: water quality modeling, pesticides, solid phase extraction, elution, Monte Carlo simulation

INTRODUCTION

The purpose of this research is to determine the presence of pesticide, chlorpyrifos in Pampanga River basin and to develop existing model to make it useful in predicting concentration levels of micro contaminants along the river channel. Sampling done within a period of one year to cover the entire dry and wet seasons. Method of analysis include the preparation of samples in accordance with the standard test available using GC-MS. The analyses were conducted at the National Sciences Research Institute- Research Analytical Services Laboratory. The widely acceptable water quality model (WASP8) provided by the USEPA is used with an added feature like Monte Carlo Program is incorporated in this model to predict future concentration results. Risk assessment is also added in the study where target/non target organisms are points of concern.

RESULTS AND DISCUSSION

Initial samples were obtained from identified sampling sites with high concentration of target pollutants from nearby farmlands and tributaries. Identified sampling sites with high concentrations of target pesticides (chlorpyrifos, endosulfan and malathion) are to be used in the model. A dynamic box model was used in the Pampanga River channel with loads based from the laboratory results. Actual test results from GC-MS revealed that the model, with parameters and constants provided, can predict concentrations of pesticides at the downstream of the river water. Model validation was done resulted a mean standard error of 1.994 when used in the main channel.

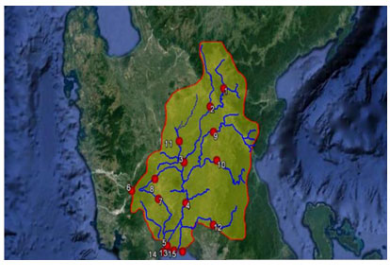

Figure 1. Sampling sites along Pampanga River

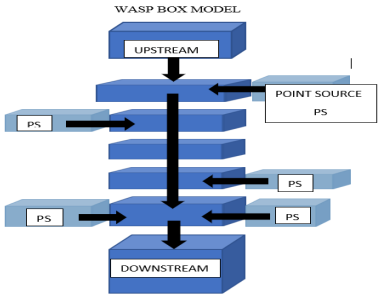

Figure 2. The WASP Box Model representing the selected water sampling stations

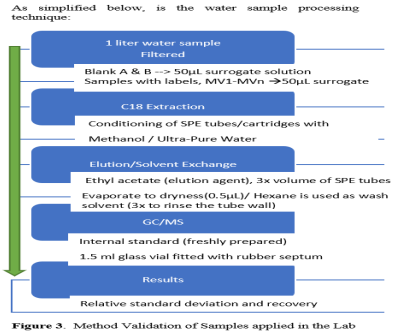

Figure 3. Method Validation of Samples applied in the Lab

Table 1. Summary of Calculated Standard Error based from the Actual Laboratory Results

	1.994				
STANDARD ERROR			ACTUAL LAB RESULTS		
Chlorpyrifos	Endosulfan	Malathion	Chlorpyrifos	Endosulfan	Malathion
0.638	0.275	5.068	24.4	22.6	415

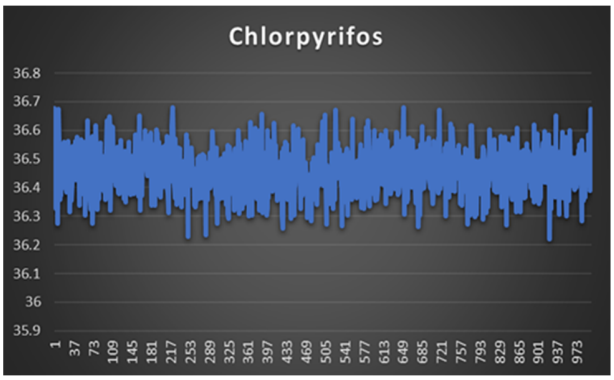

Figure 4. Predicted Model Simulation of Analyte

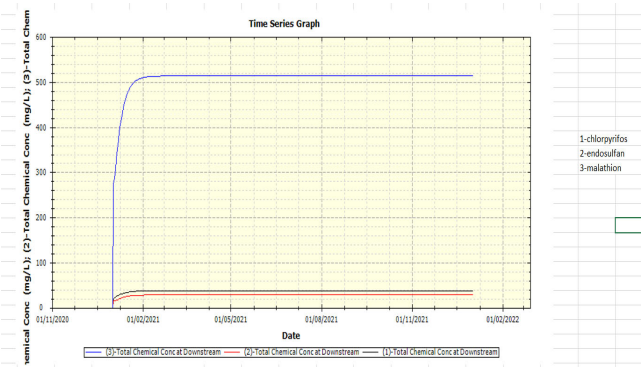

Figure 5. WASP Model Output Concentration of Analytes

Table 2. Fish Samples Exposed to Selected Pesticides

Target Chemicals	Fish Species	LC50 (ppb)	TER
Chlorpyrifos	cyprinodon variegatus	136	0.0408
	menidia menidia	3	0.0009
	M. peninsulae	1.3	0.00039
	M. beryllina	4.2	0.00126
	Lauresthes tenuis	1.3	0.00039
	Opsanus beta	520	0.156
	Mugil cephalus	5.4	0.00162
	Fundulus heteroclitus	4.7	0.00141
	Morone saxatilis	0.58	0.000174
Endosulfan	Nile tilapia	12.795	0.003839
	Tilapia	1.42	0.000426
	Catfish	1.5	0.00045
	Spotted Snakehead fish	7.75	0.002325
	Bluegill sunfish	1.2	0.00036
	Penaeid shrimp	199.3	0.05979
	Bluegills	1	0.0003
	Striped dwarf catfish	2	0.0006
Malathion	Bluegill sunfish	30	0.009
	Redear sunfish	62	0.0186
	Rainbow trout	30	0.009
	Yellow perch	263	0.0789
	Largemouth bass	250	0.075
	Carp	6590	1.977
	Fathead minnow	8650	2.595
	Channel catfish	7620	2.286
	Salmon	170	0.051
	Cutthroat trout	174	0.0522
	Brown trout	101	0.0303
	Lake trout	76	0.0228
	Black bullhead catfish	11700	3.51
	Green sunfish	146	0.0438
	Walleye	64	0.0192
	Tilapia	2000	0.6
	Gold fish	10700	3.21

Assessing the risks for aquatic organisms observed that for most of the selected pesticides, the calculated exposure concentrations were higher than the regulatory acceptable concentration. To implement the exposure scenarios and models for pesticide authorization in the Philippines, further research on the acceptable concentrations is needed. Further studies are also recommended to develop top-tier model and risk management that can be applied in the Philippine setting.

This model is needed to aid people in their decisions on the proper management of micro-pollutants, pesticides. The results of this analysis can be used as a basis of social and industrial policies.

Environmental friendly and efficient approach for the recovery of metals from waste random access memory using greener solvents

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KEYWORDS:

Electronic waste, Supercritical fluids, greener solvents, greener approach, Metal recovery

INTRODUCTION:

Rapid technological development leads to the production of electrical and electronic equipment (EEE) manufacturing industry and hence the generation of e-waste. Treating electronics waste is very important for sustainable growth. Electronic waste is a heterogeneous mixture of ceramics, metals, and polymers, making it very difficult to treat them. On the other hand, most electronic waste consists of valuable metals such as gold, silver copper, which are essential and beneficial to recycle(Zhang & Xu, 2016). Random access memory (RAM) is the primary component involved in e-waste (Preetam et al., 2022). RAM is a rich source of several precious and base metals along with various polymers. The supercritical fluid technique is a novel and eco-friendly approach for treating electronic waste(Preetam et al., 2023). A feasible experiment was performed using supercritical fluids (acetone) SCA to decompose electronic waste polymers and recover enriched metal components and glass fibre simultaneously. The enriched metal is then treated with $C_6H_8O_7$ and H_2O_2 to extract the metals from waste RAM. The study demonstrates a feasible and sustainable approach to the treatment of waste electronics.

MATERIALS AND METHODS:

Waste RAM used in this study was collected from the IIT Delhi campus. All the reagents used in this work are of analytical grade and used as received. Supercritical fluid experiments were performed in a high-pressure batch type of reactor, in temperatures ranging from subcritical to supercritical range from 150 to 250°C, with residence time between 60 to 120 min at a solid/liquid (S/L) ratio of 1:20, and pressure was autogenously set as per vapor pressure. The concentrated metal fraction obtained is then treated with 2 M $C_6H_8O_7$ with 10% H_2O_2 as an oxidizing agent at 45°C, 1:20 S/L ratio, 450 agitations, and time and 12h of reaction time.

RESULTS AND DISCUSSION:

The output showed that the organics are quickly and efficiently decomposed into desired products with an oil yield of 80%. The solid product mainly consists of concentred metals and glass fiber quickly recovered after the supercritical fluid treatment. The enriched metals are analyzed by ICP-OES as shown in Table.1. The Cu is enriched by 30.6% as compared to that of raw RAM with 24.08% of initial wt%. The enrichment of other metals is shown in Table.1 below. More than 85% of acetone(solvent) is recovered using a rotary evaporator after the supercritical fluid technology experiment.

Table.1. Elemental analysis of Raw Waste RAM and SCA-treated Waste RAM

Metals	Raw (untreated) WRAM (wt%)	SCA treated WRAM (wt%)
Al	2.73	3.9
.Cu	24.08	30.6
Fe	0.15	0.7
Ni	0.7	1.9

Zn	0.18	0.9
Ag	0.12	1.1
Au	0.005	0.009

The enriched metals are treated with citric acid as a leaching agent to extract the metals from them. The Cu was extracted with 90.9%, and Ni was extracted with 84.5%. The extraction of Cu and Ni is shown in Figure.1.

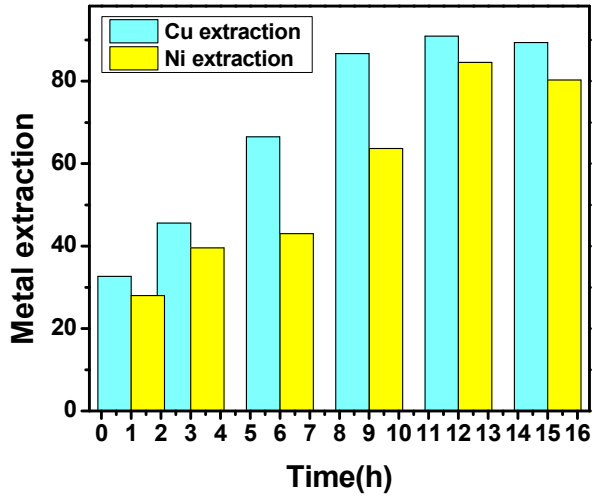

Figure.1. Metal (Cu and Ni) extraction in the presence of citric agent as a leaching solvent.

CONCLUSION:

Supercritical acetone can potentially convert e-waste plastic into value-added products. The liquid product (oil) with more than 80% yield was obtained. More than 85% of acetone(solvent) is recovered using a rotary evaporator after the supercritical fluid technology experiment. The Cu was extracted with 90.9%, and Ni was extracted with 84.5% using $C_6H_8O_7$ as a leaching agent. This work provides an efficient and integrated approach for recovering metals from waste RAM as electronic waste and simultaneously decomposing the plastics component of it.

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How the COVID-19 lockdown measures impacted Construction and Demolition waste generation? A Canadian case study

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Keywords: construction and demolition waste, COVID-19 pandemic, municipal landfill, Canadian waste management system

INTRODUCTION

In January 2020, the World Health Organization (WHO) declared COVID-19 a public health emergency of international concern. Most countries have implemented WHO-recommended measures to minimize public safety risk, including promotion of masking, vaccination, and social distancing. The first suspected COVID-19 case was reported in Saskatchewan, Canada, in March 2020, and administrative lockdown was shortly implemented. In Canada, construction and demolition (C&D) waste represented about one-third of total solid waste (Yeheyis et al., 2013). The COVID-19 lockdowns have had a substantial impact on many Canadian industries, including the construction sector (Richter et al., 2021). This study aims to understand the impacts of the pandemic and the government imposed administrative measures on C&D waste disposal behaviors in a mid-sized Canadian city. The objectives of the paper are to (i) quantify the changes of C&D disposal rates at the Regina landfill in three user-defined periods and (ii) examine the potential factors on the evolution of C&D waste disposal behaviors. Most of the COVID-19 waste studies focused on municipal solid waste, medical waste, and plastic waste, and there are very few studies on C&D waste disposal behaviors. Lessons learnt from this Canadian study will help regulators across the globe to better schedule and budget their operations during future pandemics and emergencies.

MATERIALS AND METHODS

Regina is the capital city of Saskatchewan, Canada, and is selected as the study area. Regina C&D waste is originated from both the residential and the non-residential streams, and C&D waste is primarily collected by the private sector. Most C&D waste is disposed of at the City's municipal landfill, with little to no processing. Regina landfill is the sole landfill at the city and it serves both of the city and the surrounding regions. Disposal records were collected at Regina landfill from January 2019 to June 2021. Three 6-month periods were defined: Pre-COVID (January to June 2019), First wave (January to June 2020), and Subsequent waves (January to June 2021). Both waste tonnages and load counts were considered. Boxplots were used to quantify data variations. Python pandas and matplotlib libraries were used for data analysis and visualization.

RESULTS AND DISCUSSION

Figure 1 shows the monthly C&D waste disposal rates from the three study periods. On average, there were more C&D wastes Pre-COVID-19, ranged from 33 tonnes/m to 62 tonnes/m (left-hand-side axis, Fig 1a). Seasonally variations were observed pre-COVID, probably due to the intensified construction activities in spring (April to June) than in winter (January to March). More fluctuations were observed after the lockdown

in March 2020 (Figure 1b). For instance, the disposal rate in April 2020 (31 tonnes/m) were considerably lower than other years. The disposal behaviors appeared normal in 2021 (Figure 1c). It is interesting to note that the lockdown also affected load counts. The load counts were noticeably lower in 2020 and 2021 (right-hand-side axis, Figures 1b and 1c), suggesting the wastes in the trucks during COVID-19 periods were denser. The truck driver might have reduced landfill visit frequency to minimize possible COVID exposure risks.

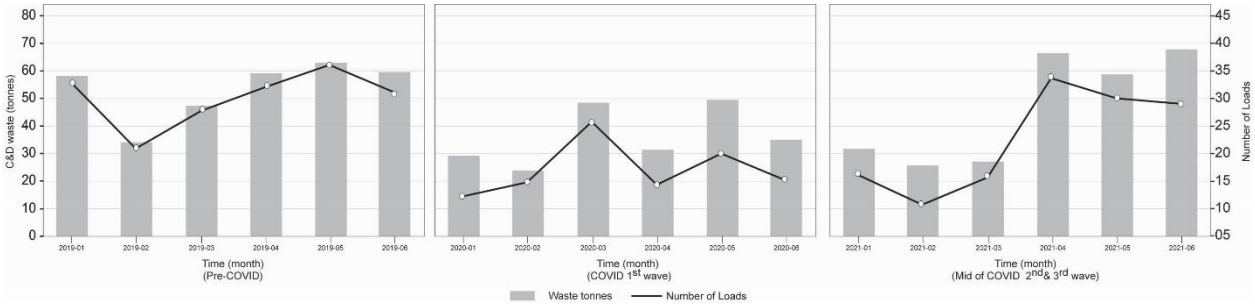

Figure 1. Disposal rates in the three periods. (a) Pre-COVID, (b) First wave, and (c) Subsequent waves.

The average daily disposal rates were quite consistent across the week (white circles, Figure 2a-c). However, more outliers were observed in 2020 and 2021 (black diamonds, Figures 2b and 2c). The interquartile ranges were wider in 2020 and 2021, suggesting higher variations. Variations in daily disposal rates make human resource planning and scheduling difficult and may be less desirable from an operational point of view. Overall, slightly less C&D waste was disposed of in the first half of 2020. This finding is consistent with Figure 1.

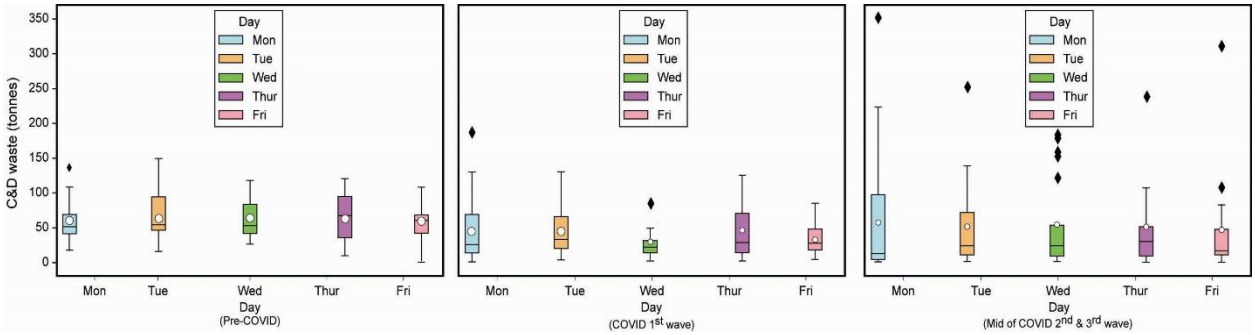

Figure 2. Disposal rates during the week. (a) Pre-COVID, (b) First wave, and (c) Subsequent waves.

CONCLUSION

The lockdown has impacted C&D waste disposal behaviors in Regina. We found that C&D waste disposal rates were reduced during the COVID-19 periods. The average waste density of the trucks however increased. Despite of the study periods, the average daily C&D disposal rates were similar across the days of the week. More fluctuations in daily C&D disposal rates were observed during the lockdown. Landfill crew scheduling and budgeting should be carefully monitored during future pandemics and emergencies.

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Preliminary Evaluation of Landfill Gas to Energy Project Development by Measuring Surface Methane Emissions: A Case Study of Pulau Burung Sanitary Landfill-Phase 1, Malaysia

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Keywords: landfill gas to energy, methane emission, closed flux chamber, laser methane detector

INTRODUCTION

Municipal solid waste disposal in most developing countries still uses open dumping and landfilling methods. However, when waste is degraded under anaerobic conditions, organic matter is decomposed and changed to degraded waste, leachate, and landfill gas (LFG). The LFG contains about 50% methane (IPCC 2019). This landfill methane is generally used as fuel in landfill gas-to-energy projects. Southeast Asian countries have already developed several LFGTE projects. However, for landfills that have stopped landfill operations for a long time and wish to use LFG for energy purposes, it is essential to predict the amount of LFG that can be collected. Several methods, such as model estimation and pumping tests, can perform this. However, model estimates may give inaccurate quantitative values for LFG if necessary data are insufficient. In addition, due to the costly method, the pumping test may only provide accurate information for certain locations in the landfill. The Pulau Burung landfill also needs to be developed as an energy source. However, the characteristics of waste degradation in this landfill vary significantly due to the different techniques used throughout the operation. The objective of this study is to assess the energy production potential from LFG using a backward assessment with surface methane emissions.

MATERIALS AND METHODS

Study site

The Pulau Burung sanitary landfill is located within the Byram forest reserve in Penang, Malaysia, at 5°24' N latitude and 100°24' E longitude, some 20 kilometers southeast of Penang Island. Its total area is 62.4 ha. It receives daily solid waste of roughly 1800 tons. This potential assessment was conducted only in Phase 1, which was in use before 1990 and discontinued in 2008. However, this phase was used again between 2015 and 2019.

Methane emission measurement

The closed flux chamber technique was used in this investigation. The chamber was constructed of ϕ0.20 m x 1.00 m - PVC pipe with a plexiglass cover on top of the chamber for placing the Laser methane mini™ (Tokyo Gas Engineering Solutions Corporation, Japan). The chamber was sealed to the ground to prevent air

intrusion by compacting the surrounding soil. Then, the methane content was measured within the chamber for 5 minutes with the second interval of methane data collection. Finally, the methane concentration was plotted against the time to determine the methane flux. The 150 sampling points were specific regularly within the Phase 1 area, then 50 hot spots with high methane emissions were added.

RESULTS AND DISCUSSION

Methane emissions

Figure 1 shows the spatial distribution of methane flux. From the results, the average spatial methane emission rate was 58.59 g/m^2/d. Then methane emission was 24,962.33 kg/d. Therefore, total methane generation was approximately 1,656 m^3/hr, calculated from the methane oxidation factor equal to 0.15. Hence, the site's potential LFG recovery rate was 992.74 m^3/hr (the average percentage area for landfill gas collection systems and collection efficiency were approximately 75% and 80%). Finally, the estimated power generation capacity was 3.14 MW in 2022. If the methane decay rate constant equals 0.15, the electricity can be used until 2030. In comparison, when the k value is 0.33 (Wangyao et al., 2010), electricity can only be used for four years. As a result, it may be uneconomic to convert the LFG to energy in this landfill.

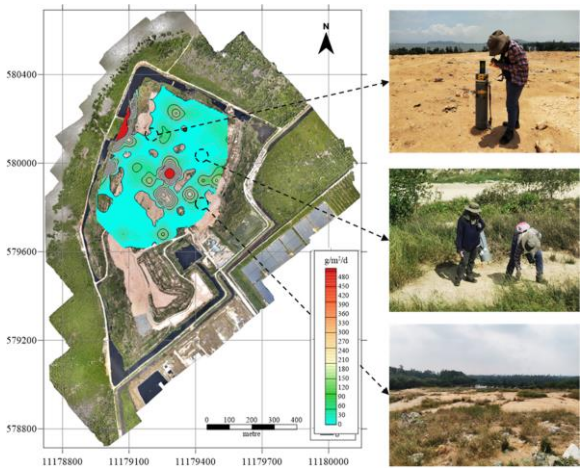

Figure 1 Spatial distribution of methane flux in Phase 1 of Pulau Burung sanitary landfill

CONCLUSION

The purpose of this study is to present a methodology for estimating landfill power generation capacity from surface methane emissions. This assessment method is suitable for landfills or open dumpsites where there is no historical data on landfilling practice, waste composition, and waste volume. This assessment, in addition to power generation capacity, provides useful spatial information to determine the location for constructing the landfill gas collection system.

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A Research on Technology and Application of Bio-Waste to Energy in Taiwan

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Keywords: Waste-to-energy, Bioenergy, Solid recovered fuel, Co-digestion

INTRODUCTION

To mitigate climate change caused by greenhouse gas emissions, the United Nations Intergovernmental Panel for Environmental Changes (IPCC) proposed achieving net zero greenhouse gas emissions by 2050. Therefore, many countries actively develop renewable energy, such as solar and wind energy. Among all renewable energy sources, biomass energy has great potential to achieve net zero emissions. Compared with solar and wind energy, which depend on the instability of the weather, biomass energy uses the waste produced by the existing society as raw materials, which can provide stable energy and achieve the goal of zero waste. At present, there are many cases of recycling waste biomass in Taiwan. Industrial waste from the manufacturing industry, such as paper and plastic factories, or waste from agriculture, forestry, fishery, and animal husbandry, can be used as raw materials for solid recovered fuel (SRF). It can be formulated to meet the needs of boiler calorific value and has the advantages of convenient transportation and storage. Taiwan's solid renewable fuel quality standard currently stipulates that the net calorific value must be greater than 2,392 kcal/kg. According to research, domestic manufacturers' SRF net calorific value is about 3,500 kcal/kg to 5,500 kcal/kg, which can effectively replace some coal-fired fuels. In addition, the sludge generated in the treatment process of the centralized sewage treatment plant can be anaerobically digested to generate biogas. After the biogas is collected and purified, it can be used for chemical manufacturing or as a clean energy supply with carbon capture technology.

DISCUSSION AND CONCLUSION

This study will introduce biomass energy technologies and actual business cases adopted in Taiwan. Solid renewable fuel (SRF) related technologies can be divided into three parts: pre-treatment, manufacturing, and fly ash recovery. The pre-treatment includes shredding, magnetic separation, Eddy current sorting, etc. In addition, the calorific value of SRF and other factors must be considered in the granulation stage. Depending on what type of SRF is needed. It can be made by single material granulation and composite material granulation. The fly ash produced after combustion can be made into CLSM and other products. But because the nature of the fly ash produced by SRF combustion is different from that of coal combustion, the previous recycling procedures cannot be directly used, and the subsequent recycling goals must be determined according to the data at the time of feeding.

Referring to the SRF usage regulations proposed by countries such as Europe, Taiwan provides fundamental

domestic regulatory limits, including calorific value, chloride ion, mercury, lead, and cadmium metal content. On this basis, the government allows the companies that use SRF can propose the most suitable SRF quality according to their own needs. Table 1 shows the survey conducted for the four companies.

Table 1 Taiwan industry's requirements for SRF quality

company	NCV (kacl/kg)	Cl (%)	Hg (ppm)	Pb (ppm)	Cd (ppm)	Size (mm)
A	>=3000 (average is 5000)	<3.5	<=0.2	5	1	80~100
B	>=2392	< 3	<=5	<=150	<=5	-
C	>=4000	< 3	<=50*	<=150	<=50*	-
D	>=3000	< 2	<=5	<=150	<=5	<=30

***This data is filled in by the company itself, and the Hg and Cd must be less than 5 ppm according to the Taiwan SRF quality regulations.**

Study the economic and environmental impact of using SRF as fuel supply on existing industries, cooperate with regulations and market conditions, etc. And use SWOT to analyze the advantages and disadvantages of using SRF as factory fuel in Taiwan.

Economic analysis should include the cost of purchasing fuel, the capital expenditure of existing boiler renovation, or the construction of new boilers. With the trend of net zero emissions globally, the cost of carbon dioxide emissions and the economy brought about by carbon offset mechanism transactions will be included benefits.

The most direct factor in environmental impact analysis is the emission of greenhouse gases such as carbon dioxide. The greenhouse gas emissions generated by burning fuel are calculated without considering any emission reduction measures implemented by the company. In addition, since SRF is made from waste. Considering that waste disposal will generate a large amount of greenhouse gas emissions and open-air landfill will directly impact the environment, SRF can effectively solve the problem of storing a large amount of waste. The factor should not be ignored.

There have been successful cases of using SRF as fuel in Taiwan. The obvious advantage is that it reduces greenhouse gas emissions and consumes a lot of waste compared to using coal. The potential threat is that many wastes still contain chloride ions, such as kitchen waste, PVC plastic, etc., which may cause damage to the boiler and affect the company's operation. In addition, there are still many imperfect regulations on the use of SRF, including the definition and calculation method of SRF. Carbon offset. This study recommends that the relevant legal framework be formulated as soon as possible to promote more companies to use SRF as fuel, reduce greenhouse gas emissions caused by energy consumption, and achieve the goal of net zero emissions.

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Enhanced Recovery of Waste Photoresister Thinners from Semiconductor Industry by Exploitation of Fully Intensified and Integrated Distillation

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Keywords: waste solvent recovery, photoresister thinner, semiconductor process, intensified distillation

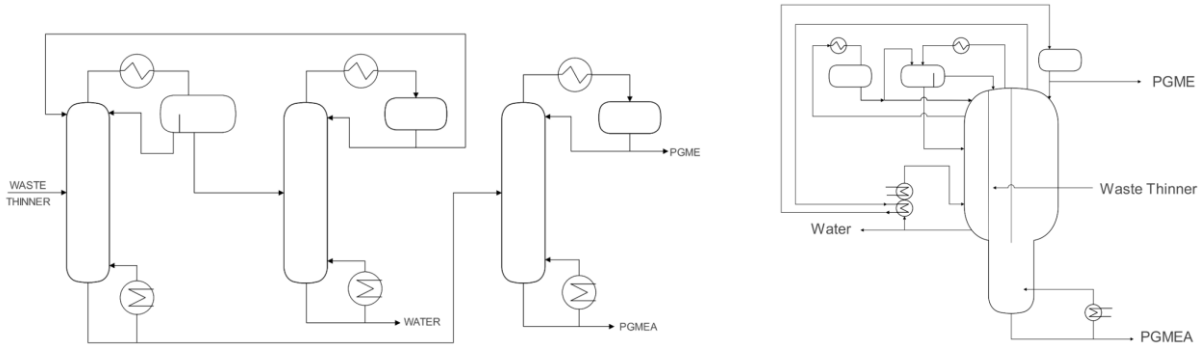
INTRODUCTION

The semiconductor material manufacturing industry has undergone rapid growth in the past few decades, and is one of the biggest industries that exhaust a large amount of waste solvent. Propylene glycol monomethyl ether acetate (PGMEA) and propylene glycol monomethyl ether (PGME) are most representative photoresistor thinner components for removing the photoresistor from the substrate edges or dispensing nozzles in the semiconductor material manufacturing industry (Hussain, A. et al. 2019). A large amount of waste thinners containing PGME and PGMEA is generated when the unreacted photoresistor is removed using a photoresistor thinner. Nevertheless of their expensive cost, the use of PGME and PGMEA has rapidly increased in a wide range of products because of their important advantages such as low systemic toxicity and minor particle formation. This great value of PGME and PGMEA from economic and environmental considerations highlights the need of their efficient recovery (Chaniago, Y.D. et al., 2015, 2016). The waste photoresistor thinner can be generally reclaimed by distillation. However, the energy-intensive character of distillation restricts the economics of the waste thinner recovery process. Further, the existence of azeotropes in the waste thinners also hinders the efficient recovery by simple distillation approaches. This study was aimed to develop a novel intensified distillation process for enhanced waste PGME and PGMEA recovery. A heat integrated double dividing wall column was proposed to achieve the separation task while minimizing the capital and operating costs for the recovery process.

RESULTS and DISCUSSION

A waste thinner feed of 1000 kg/hr was considered for process design. Based on the composition of the waste thinner samples from a real industry, the feed composition was chosen as 31 wt.% water, 23 wt.% PGME, and 46 wt.% PGMEA (Chaniago, Y.D. et al., 2016). The ternary mixture of water+PGME+PGMEA has two azeotropes that make separation of the mixture to required purity and recovery difficult. Figure 1a shows a process configuration using conventional heterogeneous azeotrope distillation configuration (Chaniago, Y.D. et al., 2016). The process consists of three simple distillation columns with a decanter for the liquid-liquid phase separation by the heterogeneous azeotrope. The product purity and recovery could be achieved higher than 99.95% with this conventional configuration. However, the remixing effect and multiple columns in this conventional sequence result in high energy requirement and capital cost required. A single shell dividing wall

column (DWC) is a representative fully intensified thermally coupled distillation column (Wright, 1949). The DWC technology has proven to significantly reduce the capital and operation cost by avoiding the remixing effect in the conventional distillation sequence only with a single shell. Energy savings in distillation process can also be achieved through clever heat integration. In this study, a novel fully intensified distillation process with heat integration was proposed to enhance the recovery and purification of the PGMEA and PGME from the waste photoresister thinner. As shown in Fig. 1b, the proposed distillation process consists of a single shell column containing double dividing walls. Further, the condenser and side reboiler of the column are thermally integrated to minimize the need of external energy required. With this novel intensified distillation process, both the required reboiler duty and capital cost were reduced by 30% compared with the conventional distillation process. The proposed recovery process is expected to provide an attractive option of both retrofit and grass root projects for enhancing the recovery efficiency of PGMEA and PGME in the semiconductor material manufacturing industries.



(a) **(b)**

Figure 1. Conventional (a) and proposed (b) distillation process for waste thinner PGMEA and PGME recovery

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Comparative Life Cycle CO_2 Assessment of Solar Panels Produced in Regionally Different Countries

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Keywords: Carbon Footprint, Global Warming Potential, Life Cycle Assessment, Solar Panel.

INTRODUCTION

Photovoltaic (PV) installations are heavily encouraged because solar energy is one of the most promising clean renewable energy source. As a consequence of high manufacturing, the waste of solar panel became a global problem. Various countries have conducted life cycle assessments (LCA) to identify the most sensitive source for global warming potential impacts during PV production. However, because the data were analyzed using different LCA methods with different functional units at different times, it was difficult to compare the impacts across different parts of the world. As a result, a comparative LCA of PV production for mono- and multi-crystalline silicon for Korea, China, European Union (EU) and the United States (US) was investigated.

METHODS

Life Cycle Assessment (LCA) is a structured, comprehensive method of quantifying material- and energy-flows and their associated impacts in the life cycles of products (LCA was performed to evaluate and compare the environmental burdens associated with solar panel production during their life cycle on the product production. The LCA procedure was performed in accordance with the ISO 14040 series of standards: goal and scope definition, life cycle inventory analysis (LCI), life cycle impact assessment (LCIA), and life cycle interpretation.

The goal of this LCA was to compare the environmental impacts of domestic solar production in four regions. The scope definition included the system, function, functional unit, reference flow, system boundaries, data qualities. The reference flow, one unit of the panel production (1 m^2), was used for quantify in the environmental impacts of solar production. System boundaries included all the contributors in the solar panel production. The data qualities were accessed from the Ref? for the comparative assessment. The time frame is. Mono and multi.

LCI was performed to quantify all inputs and outputs associated with solar panel production throughout its production process including metal grade solar production, solar grade solar production, wafer, cell and panel production. The Ecoinvent v databases were used for the LCI: the databases show the quantity of all the materials and energy required to obtain the unit quantity of an item. However, the characterization factor of electricity mix could not be readily obtained from Ecoinvent. There were seven sources for electricity mix. They were hard coal, nuclear, hydro, oil, natural gas, wind and solar sources for all regions. Among them, for hard coal, it was the summation of sub-bituminous coal, other bituminous coal, coking coal, coal tar, anthracite. For oil, it was the summation of crude oil, fuel oil, gas oil and diesel, oil shale and oil sand, oil and petroleum

products. For Europe, it was the weighted average value of Italy, Germany, France, Spain and UK. For US, the data were the weighted average for the North American Electric Reliability Corporation including Midwest Reliability Organization, Northeast Power Coordinating Council, Western Electricity Coordinating Council.

LCIA was performed to evaluate the significance of potential climate change impact on the basis of the results of the LCI. Recipe methodology was used for the classification and characterization, to evaluate the environmental burdens of the two water systems.

RESULTS AND DISCUSSION

For both mono and multi crystalline PV production, China had the greatest impact, followed by Korea, the US, and the EU, according to this study. Electricity mix was the most important key parameter for climate change impact among the various critical pollutants, followed by aluminum and solar glass. An intensive study of electricity mix showed that usage of highly-loaded carbon source in the electricity mix of China was the serious issue.

CONCLUSION

The observation of key sensitive parameters from this study would be useful to manage the end-of-life waste of solar panel effectively for cleaner solar industry production and resource recycling.

Innovative Business Models – example interior finishing systems

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Keywords: circular economy, resource conservation, reuse, sustainability

INTRODUCTION

It is common sense that current business models (so-called linear economy) are not sustainable and must be substituted by circular thinking and practicing – that means by circular economy business models.

In our research project we have developed a circular economy-based business model – not just as a theoretical tool or a set of recommendations but as a real applicable business model for the company Lindner Group KG, in Arnstorf, Germany. It is a tangible example of a circular based business model: real products and real markets.

The Lindner Group is Europe's largest manufacturer of interior finishing systems in the main areas of ceilings, floors and walls, as well as a complete service provider in the field of drywall construction. Besides the authors, the project team consists of experts from IWARU – Institute (Munster University of Applied Sciences) and Lindner Group.

MATERIALS AND METHODS

Starting with a specific gap-analysis, we worked out different scenarios by taking into account parameter variations and certain probable development paths. By doing so, we operated with real material flows, financial data, as well as logistics and cost data of the company Lindner Group. Verifying the commercial advantage of this model compared to the linear business model we developed a specific activity-based cost calculation.

The strategic approach has been developed according to the ruling doctrine of Strategic Management. Additionally, a specific simulation game was used. That means the real business model was tested by simulated sales talks with existing and potential customers.

RESULTS AND DISCUSSION

It turned out that one alternative, the so-called pull-approach (repurchase of used products, reuse, re-processing or re-cycling), although offering significant potentials in certain submarkets, involves rather high commercial risks. Therefore, we have concentrated on the so-called push-approach.

In this case the 1st- and 2nd-use of a product is linked by only one sales contract. However, the costumer can adjust the contractual terms according to his changed preferences at any time. This also includes the possibility of cancelling the contract. The general rule of this circular economy-based business model is: The more flexibility options the costumer claims the higher the price.

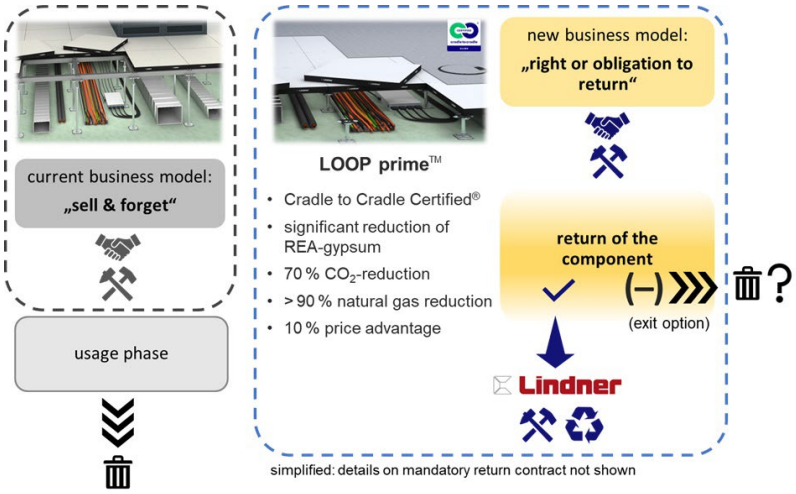

Figure 1 Linear and Circular Business Model

CONCLUSION

The advantageousness of this new business model (push approach) – compared to the existing linear business-model (“sell and forget”) – emerges not only on the cost side resp. in the consumer price but also in a significantly reduced CO2-impact and resource consumption.

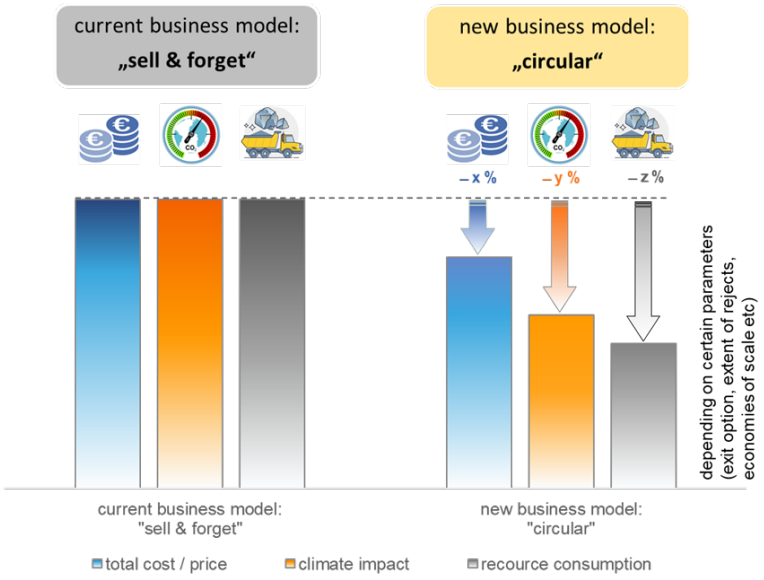

Figure 2 Comparison between Linear and Circular Business Model

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Physical properties of Synthetics Aggregate pelletized by waste concrete fines and fly ash in Vietnam

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Keywords: synthetic aggregate, waste concrete fines, fly ash, construction and demolition waste

INTRODUCTION

Nowadays, in Vietnam, due to the rapid increase for economic growth and urbanization, the demand of new construction, renovation, and demolition of old structures has increased. The demand of aggregate rapidly increases due to construction activities while the amount of natural aggregate is decreasing. According to a report by MONRE (2017), the amount of CDW in the northern key economic zones in Vietnam is about 3900 tons/day. Moreover, one of the other waste materials that are very popular in Vietnam is coal ash from coal burning at thermal power plants. By the end of 2020, the total amount of coal ash stored is reported to be approximately 47.65 million tons (MOC report).

Many researchers have used FA combined with other waste such as rice husk ash, waste glass powder, plastics, and sewage sludge to produce synthetic aggregate (SA) for concrete. Some of the studies show that SA have water absorption from 10% to 30% (Ren, 2020), the compressive strength decreased by 19-42% compared with control concrete (Alqahtani et al., 2014). A large amount of fly ash in production SA and clearly affected the physical properties of the materials. This research will focus on using waste concrete fines (WCF) combined with FA to produce SA match with Vietnamese Standards for coarse aggregate use in concrete.

MATERIALS AND METHODS

Materials

The materials were used in this study included waste concrete fines (WCF) collected from crushing line of SATREPS project in Dong Anh, FA of Pha Lai coal thermal power plant, blended Portland cement PCB40.

Waste concrete fines is generated during the processing crushing CDW. The particle size less than 300 μm.

Class F fly ash was used met to ASTM C618-19, the oxides content ($SiO_2 + Al_2O_3 + Fe_2O_3$) of 87.8%, 0.1% sulfur trioxide (SO_3) and strength activity index was 84.2% at 28 days (Bach D.T., Hoang V.L. et al, 2020).

This study is using eight levels of distribution of WCF and FA. Table 1 shows the mixing of SA.

Table 1. Mixtures of WCF and FA

Mix	CP0	CP1	CP2	CP3	CP4	CP5	CP6	CP7
WCF (%)	85	80	70	60	50	40	30	20
FA (%)	0	5	15	25	35	45	55	65
Cement (%)	15							
Water (%)	20-22%							

Methods

The method of semi-wet mixing was chosen because of higher effective and easier control to pellet aggregate particles. The aggregates were pelleted by a machine which has a disk with 1.5m of diameter and 0.3m of depth. The angle of disc varied from 40^0 to 65^0, and rotation speed of disk from 15 to 22rpm.

RESULTS AND DISCUSSION

After the pelletizing process, SA will be cured for 28 days in the humidification room. The aggregates were sieve to particle grades 5-10mm. The properties testing of each type of SA is presented in Table 2.

Table 2. Testing properties of SA size fraction 5-10mm (Test methods standard TCVN 7572-2006)

Testing properties	CP0	CP1	CP2	CP3	CP4	CP5	CP6	CP7
Apparent Specific gravity (g/cm^3)	2.66	2.50	2.63	2.63	2.53	2.50	2.49	2.49
Dry bulk specific gravity (g/cm^3)	2.02	1.75	1.96	1.79	1.70	1.63	1.62	1.61
Saturated bulk specific gravity (g/cm^3)	2.26	2.05	2.26	2.11	2.03	1.98	1.97	1.96
Crushing Value - ACV (%)	5.63	12.06	10.09	11.50	10.00	10.35	9.11	12.22
Los Angeles - LA (%)	23	35	27	30	29	30	29	28
Water absorption (%)	11.85	17.06	15.80	17.84	19.25	21.60	21.60	21.85

The use of WCF in production SA improved the bulk specific gravity of material (1.61-2.02 g/cm^3) and decrease water absorption (12-22%). The LA and ACV value of SA materials also less than 50% and 30%, respectively, and met with TCVN 11969-2018, the standard for recycled coarse aggregate for concrete.

However, when compared with TCVN 7570-2006, the standard for aggregate for concrete and mortar - specifications, only CP0 and CP2 met with crushed gravel aggregate for concrete. With the other mixtures, the value of ACV is unsatisfactory to TCVN 7570-2006.

CONCLUSION

This study aimed to propose a type of SA to replace coarse natural aggregate that uses in concrete. CP0 and CP2 have physical properties that satisfy with Vietnamese Standard for aggregate use in concrete. The next study will use SA (CP0 and CP2) in concrete and evaluate the effect of this aggregate on the properties of concrete. From there, to evaluate the scope of application of synthetic aggregates in concrete.

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Effectiveness and Challenges of Awareness Raising on 3Rs for School Children - A Case Study at Schools in Ramallah, Palestine -

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Keywords: School Awareness, 3R, Solid Waste Management, Palestine

INTRODUCTION

In Palestine, the amount of solid waste is increasing due to population growth and economic development, and there is a need to reduce the amount of solid waste generated daily. In addressing this issue, it is important to raise awareness to promote citizens' understanding of this issue. However, awareness-raising activities on waste management issues have been limited in Palestine so far. So, the Palestinian government has placed public and school awareness-raising as one of the priority policies in the National Solid Waste Management Strategy in Palestine (2017-2023).

In this study, a pilot project of school awareness-raising activities was conducted to develop effective methods of public awareness-raising in Palestine as a trial. In implementing the project, the actual status of solid waste-related activities in schools was surveyed, and the pilot project was conducted in two schools to verify the effectiveness of the awareness-raising activities. In the results of this study, the challenges and lessons learned for the future promotion of awareness-raising activities in Palestine were identified.

MATERIALS AND METHODS

Survey on Current Status of Environmental Education in Palestine

School environmental policies, existing curricula and actual educational activities in Palestine were surveyed through interview and site-visit to schools.

Pilot Project on School Awareness Raising

Two schools were selected for the pilot project, one is a girls' school located in an urban area and another is a small boys' school located in a suburban area of Ramallah governorate. In conducting the pilot project, changes in the students' understanding of waste management through three interventions: classroom lectures, site visits, and practical training, using a questionnaire survey, were analyzed, based on the “Two-phase decision-making model of environment-conscious behavior” (Hirose, 1994).

RESULTS AND DISCUSSION

The School Environmental Policy in Palestine promotes solid waste recycling, solid waste reduction and sanitation conservation as well as appropriate waste collection in school. In the current curriculum of schools in Palestine, as results of the MOE-JICA project launched in 2016, contents on solid waste issues including 3Rs (Reduce, Reuse and Recycle), etc. were added to the science curriculum. On the other hand, in some schools, such solid waste issues were addressed as part of that school's own education or activities (Environmental Club’s activities, etc.) that was not based on the curriculum.

In the pilot project, it was identified that awareness-raising activities in both targeted schools enhanced

students' knowledge and experience in solid waste management, however, the students in the 8th grade in the boys' school found it more difficult to separate waste after the awareness activities than before. Of the six evaluation items in the “Two-phase decision-making model of environment-conscious behavior”, only "feasibility" enhanced significantly for the students in 2nd-grade at the boys' school, but not so much for the students in 8th-grade at the boys' school after the activities (Fig.1). Therefore, in order to enhance feasibility through awareness-raising activities, it is considered necessary to improve the means of activities according to the grade level.

Figure 1. Two-phase decision-making model of environment-conscious behavior, and the result of six evaluation items in the model

CONCLUSION

The awareness-raising activities in this pilot project was basically effective in enhancing students' understanding of solid waste management knowledge and experience on solid waste management in school. However, more effective awareness-raising activities needs to be considered for students to be able to actually put them into action. In the past, school education and activities on solid waste management in schools have been conducted mainly through special classes and extracurricular activities only, which were dependent on the policy of each school, and some schools had no activities. However, a curriculum review has just taken place and solid waste management issues have been introduced in recent years, and it is expected that the environmental education will be implemented in all schools in the future, as the Palestinian government needs to consider the contents and methods of more effective awareness-raising activities for students in school and public based on the National Solid Waste Management Strategical goals, to put them into action based on the challenges identified in this study.

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Recovery of Phosphate as Hydroxyapatite from Semiconductor Wastewater

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Keywords: hydroxyapatite, phosphate, recovery, semiconductor wastewater.

INTRODUCTION

The global demand for electronic products has been increasing rapidly, and semiconductor industries have grown and made great progress. The etching and cleaning processes in semiconductor manufacturing utilize several chemical compounds, such as ammonium hydroxide (NH_4OH), sulfuric acid (H_2SO_4), phosphoric acid (H_3PO_4), and hydrofluoric acid (HF) (Warmadewanthi and Liu, 2009). Consequently, different streams of wastewater are generated. Among them, the phosphate (PO_4)-containing wastewater received much attention, since the removal of excess PO_4 is imperative to prevent eutrophication. In this study, we examined the recovery of PO_4 from semiconductor wastewater as hydroxyapatite ($Ca_5(PO_4)_3OH$, HAP), which can be used as a valuable fertilizer or material (Huang et al., 2023).

MATERIALS AND METHODS

Precipitation of calcium phosphate by adding $CaCl_2$

Jar test apparatus was used in the bench-scale experiments in which PO_4-containing wastewater was prepared by diluting the concentrated waste H_3PO_4 from a semiconductor manufacturer to 1,000-20,000 mg/L. Molar ratio of calcium to phosphate, ([Ca]:[PO_4]) was controlled at 5:3. Certain amount of $CaCl_2$ (Acros) was added to induce precipitation. The suspension was sampled and filtered by 0.22 μm PVDF membrane (Advantec) and the filtrate was analyzed by ICP-AES (JY 2000) to determine the PO_4 concentration. The filter cake was dried at 60℃ for at least 48 h and characterized by XRD (G2 Phaser Bruker) and FESEM (JOEL JSM-6500F). The pilot-scale reactor system was tailor-made with diameter of 0.2 m and height of 0.45 m and total of 10-L capacity (**Figure 1**). The test runs were controlled at pH 8.0±0.2, and $CaCl_2$ solution was added at flow rate of 4 mL/s to the reactor that contained 10 L of PO_4-containing wastewater. It was stirred at 200 rpm and allowed to react for 5 min, followed by slow mixing at 30 rpm for 30 min. Afterwards, the suspension was sampled and analyzed as in the aforementioned procedures.

RESULTS AND DISCUSSION

Effects of pH and initial PO_4 concentration

In bench-scale experiments at initial PO_4 concentration 6,000 mg/L, 91.1% of PO_4 was converted at pH 6 and it increased to 91.8% and 95.6% at pH 7 and 8, respectively. The pH had a significant effect on the precipitation of calcium phosphate, and it could form as monetite ($CaHPO_4$) at pH 6.0, while HAP was the major precipitate at pH 8.0 as evidenced by both XRD and wet chemical analysis. The conversion of PO_4 increased with increasing initial PO_4 concentration and reached 94.0%, 94.1%, 95.6%, 99.7%, and 99.8% when initial PO_4 concentration was 1,000, 3,000, 6,000, 12,000, and 20,000 mg/L, respectively.

Results of pilot study are shown in **Figure 2**. The conversion of PO_4 was 96.1%, 96.4%, 98.1%, 99.8%, and 99.9% when initial PO_4 concentration was 1,000, 3,000, 6,000, 12,000, and 20,000 mg/L, respectively. The XRD analysis confirmed the formation of HAP with different initial PO_4 concentration. It also showed that the higher the initial PO_4 concentration, the more favorable for HAP formation.

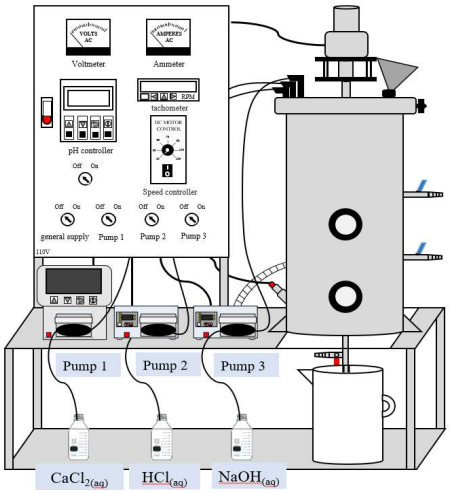

Fig. 1 Pilot reactor system

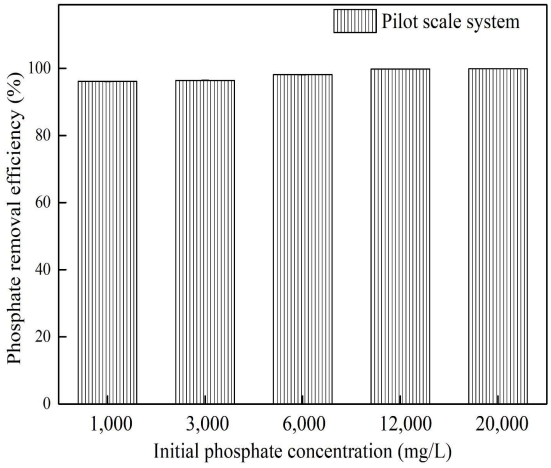

Fig. 2 Effect of initial PO_4^{3-} concentration

Preliminary cost assessment

The cost of recovery P as HAP of the pilot study was evaluated. It required 16.2 kg and 17.1 kg of $CaCl_2$ and NaOH, whose cost was 2.5 NTD/kg and 4.5 NTD/kg for $CaCl_2$ and NaOH, respectively, and 2.7 kwh of electricity to produce 1 kg of P. Considering that the price of HAP was 75.6 NTD/kg, it was found that total of 49.8 MTD could be lost per kg of P recovered as HAP. It was apparent that NaOH was costly, and it is suggested to look for its alternative source such as waste alkaline solution. However, it was the preliminary estimation without including the treatment and disposal cost of phosphate-containing sludge as a waste.

CONCLUSION

This study demonstrated that it was feasible to convert PO_4-containing wastewater to HAP with high conversion and purity of HAP. However, it could not generate profit unless alternative source of NaOH is available and the cost of sludge treatment and disposal is included.

ACKNOWLEDGEMENT

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Solid Waste Management on Important Buddhist Days at the Royal Monastery of Phuket

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Keywords: solid waste management, important Buddhist days, Royal Monastery of Phuket

INTRODUCTION

The Royal Monastery of Phuket (RMP) is a temple called Wat Mongkhon Nimit that was constructed by the kings and other members of the Thai royal family. Wat Mongkhon Nimit, also known as Wat Klang, is located in the city center of Phuket Town in Phuket Province, Thailand (Phuket Provincial Office of Buddhism, 2020). This temple is used for activities related to Buddhism on important Buddhist days that include Makha Bucha Day, Visakha Bucha Day, Asalha Bucha Day, and Buddhist Lent Day. The Buddhists pray, walk with lighted candles around the temple, listen to sermons, give offerings deliciated to the monks, and make merit, which is commonly practiced by doing good deeds such as praying and giving food to the monks. Therefore, much waste is produced on these important days of Buddhism. This research aimed to study solid waste management on three of the important days of Buddhism at the RMP.

MATERIALS AND METHODS

Solid waste management was studied within the RMP on Makha Bucha Day, Visakha Bucha Day, and Asalha Bucha Day. Waste was not collected on Buddhist Lent Day because activities were cancelled due to the COVID-19 situation. The study focused on the types and quantities of solid waste, waste collection and storage, waste transfer/transport, and disposal. The types and quantities of waste materials were studied by sort segregation, and all waste was weighed and classified into four types: compostable waste, general waste, recyclable waste, and hazardous waste. All data were classified into the time collected and type of waste.

RESULTS AND DISCUSSION

Types and quantities

The total amount of waste generated during the two main periods of time (daytime and twilight) on the three important days was 472.02 kg, which was collected on Makha Bucha Day (342.62 kg), Visakha Bucha Day (76.40 kg), and Asalha Bucha Day (53.00 kg). All waste from each day was categorized into daytime and twilight (Table 1). In addition, all waste was categorized into four types: compostable waste (74.87%), general waste (21.44%), recyclable waste (3.43%), and hazardous waste (0.26%). The rates of waste generation were in the range of 0.05–0.07 kg/person/day.

Table 1 Collection times and solid waste quantities

Time period	Day and quantity of solid waste (kg)				kg
	Makha Bucha Day	Visakha Bucha Day	Asalha Bucha Day	Buddhist Lent Day*	
Daytime	131.82	35.80	28.80	Not collected	196.42
Twilight	210.80	40.60	24.20	Not collected	275.60
Totals, kg (%)	342.62 (72.59)	76.40 (16.19)	53.00 (11.23)	N/A	472.02 (100)
Mean	171.31	38.20	26.50	N/A	236.01
S.D.	55.85	3.39	3.25	N/A	62.49

Note: * The abbot cancelled all activities due to the COVID-19 situation. N/A = not available.

Waste storage and collection

Three types of waste containers were available at the RMP. The first type was four 240-liter plastic bins that classified the type of waste by color and were fitted with black plastic bags. The second type was 300-liter dark blue plastic bins without plastic bags inserted in the bins. The third type was 26-liter black plastic bins fitted with black plastic bags. All waste in the areas was collected from the containers and moved to a waste storage point outside the RMP by an employee of the RMP. The waste materials waited for transfer to an incinerator plant.

Waste transfer/transport and disposal

The waste materials were transported from the RMP by three employees of a private company that was registered with the municipality. All waste was transported by a 5–8 tonne six-wheel truck of the open side type. Separation of the waste was not performed. The waste was transported twice a day at 11:00 a.m. and 8:00 p.m. for disposal by incineration. The vehicles for waste transfer/transport and the waste disposal method were suitable and met the guidelines. However, the waste should have been separated at the source before incineration.

CONCLUSION

The waste materials from the RMP were collected on three important Buddhist days. The waste was classified into compostable waste, general waste, recyclable waste, and hazardous waste. All waste materials were placed in plastic bins and finally transported by three employees of a private company that was registered with the municipality using a six-wheel truck. None of the waste was separated at the source. The final stage of all waste was disposal by incineration.

ACKNOWLEDGEMENT

The authors would like to thank Phuket Rajabhat University and the Monastery of Phuket (Wat Mongkhon Nimit) for the support facilities, information, and area site research

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Comparative Study of International Technical Cooperation Projects for 3R Promotion and Waste Minimization in Municipal Solid Waste Management – Approach, Effectiveness, Impacts, and Sustainability

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Keywords: waste minimization, 3R promotion, developing countries, international technical cooperation

INTRODUCTION

The rapid increase in waste generation is a global problem today. This causes the deterioration of public health conditions, environmental pollution, wasting of limited natural resources and land space, and loss of sustainability. This problem is particularly serious in developing countries, and it is becoming increasingly required to improve the operation of solid waste management (SWM), to promote 3R (Reduce, Reuse, Recycle) practice, and to accelerate waste minimization. Over the past three decades, international cooperation on solid waste management has taken place in many countries. Among them, in recent years, there have been cases of technical assistance particularly focusing on the promotion of the 3R and the waste minimization. In this paper, representative cases of technical assistance are compared from the view of aid approach, effectiveness, impacts, and sustainability, and explored the lessons and challenges for future cooperation.

MATERIALS AND METHOD

Table 1 is the summary of the outline of six representative projects (Vietnam, Fiji, Indonesia, Mozambique, Albania, and Palestine) for mainly focusing on 3R promotion and waste minimization in targeted city/country, which were supported by JICA as international technical cooperation. In comparing the cases, the following four issues were set as analysis axes: (1) relevance and appropriateness of the aid/cooperation approach, (2) effectiveness of the project design for achieving the goal and technologies adopted, (3) generated impacts by the project, and (4) prospect of sustainability.

RESULTS OF COMPARISON

The following points have been recognized as the lessons from the comparison of six projects:

- It is necessary to plan a capacity development (CD) program covering at individual, organizational, institutional, and societal levels, which ensures the holistic approach of technical cooperation.
- Issue on public awareness is a top priority in any project. This is because it is related from the upper stream waste generation side to lower stream recycling and disposal sides.
- Incorporation of pilot projects into the CD program is essential for technology transfer, establishing system, and verification of effectiveness.
- Formulation of 3R guidelines/strategy and legal/institutional development are effective outputs for promoting 3R and ensuring the sustainability when they are functional by the authorities.

- Organizing public-private partnership projects and/or promoting private investments will enhance financial sustainability, which need to be linked with the CD program.

Table 1. Six technical cooperation projects for 3Rs promotion and waste minimization

Project Name	Project Purpose	Brief Summary of Outputs/Activities
Project for Implementation support for 3R initiative of Hanoi City for Cyclical Society, Vietnam [2006-2009]	Harmonized 3R system based on source separation programs of organic waste is ready to familiarize to whole area of Hanoi City	1. Waste collection in pilot project area with source separation of organic waste and composting, 2. Awareness raising of residents and PR activities on 3R, 3. Environmental education of 3R are disseminated, 4. A strategic paper and action plan for improving SWM with source separation and composting.
Waste minimization and recycling promotion project in the Republic of Fiji [2008-2012]	Capacity of 3Rs of the Department of Environment (DOE), Lautoka City and Nadi Town is increased through developing a 3R model for Fiji.	1. SWM plans focusing on 3Rs, 2. Capacity for proper SWM through implementing pilot projects, 3. Capacity for 3R promotion activities, 4. Awareness of residents is raised through environmental education activities on 3R promotion, 5. 3R model for Fiji is recommended.
Project for capacity development of central and local governments for 3R and solid waste management in the Republic of Indonesia [2013-2017]	3R and SWM is appropriately implemented in target cities based on the Act on SWM (No.18/2008), the related government regulations, ministerial regulations as well as local regulations.	1. Drafting ministerial regulations for properly executing 3R and SWM, 2. SWM plans and mid-term action plans with emphasis on waste reduction are prepared based on the regulations, 3. The capacity of the target cities in terms of 3R and SWM is strengthened through the pilot projects.
The Project for Promotion of Sustainable 3R Activities in Maputo, Mozambique [2013-2017]	Capacity for Solid Waste Management (SWM) in Municipal Council of Maputo (CMM) is improved.	1. Capacity to analyze the current status of SWM in CMM is improved, 2. Capacity to collect and transport of SWM in project target area (cooperation with private sector) is improved, 3. Capacity for financial management of SWM in CMM is improved, 4. 3R activities for reduction of solid waste (including private sector) is introduced in project target area.
Project for the Support of Waste Minimization and 3R Promotion in Republic of Albania [2014-2017]	MOE's capacity is strengthened in terms of 3R policy development as well as providing support for local governments in order to implement the National Waste Management Strategy and Action Plan in Albania.	1. The status and challenges to introduce 3R in SWM at each local government are identified by MOE. 2. A draft 3R Guideline, 3. Pilot project of 3R practices in small scale local governments,4. Pilot project of 3R practices in medium scale local government, 5. Pilot project of 3R practices in large scale local government (Tirana Municipality), 6. MOE's assistance and cooperation to local governments in 3R practices is strengthened.
MoLG-JICA Project for Capacity Development in Solid Waste Management in Palestine Phase-III [2020-2024; presently executing]	Activities for minimizing waste generation and waste diversion are launched throughout Palestine, an initial draft of National Waste Reduction Program is recommended to the National Committee through MoLG.	1. Each JSC has strengthened the capacity of SWM, formulated JSC waste minimization plan, and start the plan, 2. The effectiveness of methodologies of waste minimization has been verified through pilot projects, 3. Law on 3R promotion is drafted and bylaws for promoting 3R practice are proposed, 4. National Waste Reduction Program and National Awareness Raising Program are proposed for next National SWM Strategy, 5. Human resource development in MoLG, JSCs and relevant organizations for 3R promotion and SWM, 6. Improving infectious waste management.

CONCLUSIONS

It is important to provide technical assistance according to the conditions and SWM development level of targeted city and country. A comprehensive capacity development approach is of vital importance in supporting 3R promotion and waste reduction. For this reason, when providing technical assistance, it is necessary to plan well-balanced cooperation activities at individual, organizational, institutional, and societal levels, according to the conditions of targeted city/country.

The view expressed in the paper is the authors' one and not necessarily reflect the official view of JICA.

Compaction and Particle Breakage Properties of Recycled Concrete Aggregates Blended with AAC Grains for Unbound Road Base and Subbase Materials in Vietnam

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Keywords: recycled concrete aggregate, autoclaved aerated concrete, compaction, particle breakage

INTRODUCTION

Recycled construction and demolition waste (CDW) [e.g., recycled concrete aggregate (RCA)] mixed with industrial-by products [e.g., autoclaved aerated concrete (AAC)], has been confirmed to increase water retention (Thai et al., 2021) for roadbed materials. To fully use RCA and AAC as roadbed materials, however, mechanical properties require to be carefully investigated. In this study, therefore, RCA and AAC grains were used to examine the applicability of scrap AAC for unbound roadbed materials in Vietnam. This study aims to examine the compaction property under a wide range of water content (w_i) and particle breakage.

MATERIALS AND METHODS

Waste concrete was collected from the CDW dumping site in Hanoi, Vietnam, and scrap AAC taken from Viglacera JSC in Bacninh, Vietnam, were crushed by jaw and hammer crusher (i.e., RCA), and by stainless hammer (i.e., AAC). Well- and poor-graded samples as classified in ASTM D2487 (ASTM D2487., 2006) were prepared with the particle size distribution (PSD) as shown in Table 1. Ten samples of RCA blended with AAC grains with % substitution on the mass basis (f_s) varies from 0 to 50 % (see Figure 2). The compaction test followed the Modified Proctor compaction method (ASTM D1557., 2012) with the compaction energy (E_c) of 2673 kJ/m^3. Retained mass in each fraction of tested samples at the optimum moisture content (w_{opt}) after compaction was compared to that of before compaction to determine the % increment and/or decrement.

Table 1 Particles size distribution for tested samples

Particle size (mm)		50	37.5	25	19	9.5	4.75	2.36	0.425	0.075	<0.075	C_c	C_u	G_s (g/cm^3)
% passing	Well-graded	100	95	82	70	50	30	21	10	5	0	3.0	25.3	2.67[a)]
	Poor-graded	100	98	89	80	50	30	10	0	0	0	5.1	0.8	2.60[b)]

C_c: Coefficient of curvature, C_u: Coefficient of uniformity, G_s: Specific gravity (g/cm^3), [a)] G_s of RCA100%, [b)] G_s of AAC100%

RESULTS AND DISCUSSION

Compaction curves

Measured dry density (DD) as a function w_i (compaction curves) are shown in Figure 1. Results showed that minimum (mDD) and/or maximum (MDD) dry density were affected by w_i, PSD, and fine particles (< 0.075 mm). Under a wide range of w_i, the compaction curve for well-graded samples with low f_s (i.e., 0; 5; and 10%) showed a clear mDD and MDD, while only clear MDD was observed for poor-graded samples. The DD decreased with increasing f_s, and the compaction curves became flattered with high f_s (i.e., 30 and 50%) for

both well- and poor-graded samples. Compacted samples close to ZVC cannot exist for poor-graded samples.

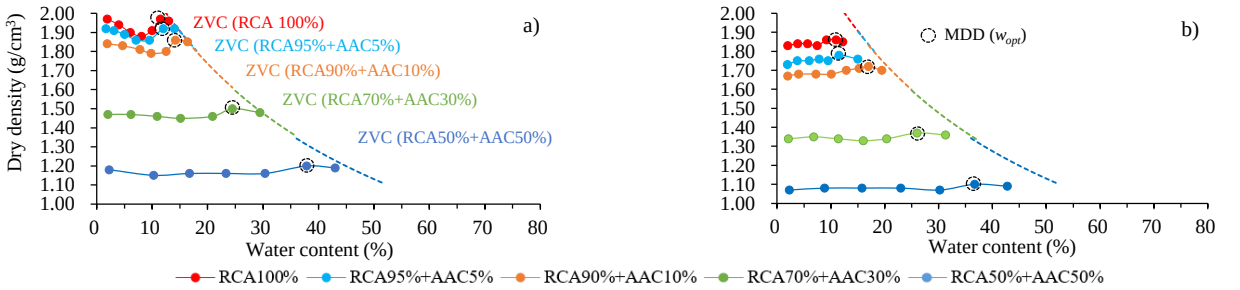

Figure 1 Compaction curves for tested samples. a) well- and b) poor-graded. Zero void curves (ZVC)

Particle breakage under the compaction process

The % increment and/or decrement in each fraction after and before compaction (particle breakage mode) were shown in Figure 2. All coarse aggregates of 37.5-50 mm fraction were broken (Figure 2 and Table 1) for both well-and poor-graded samples under E_c of 2673 kJ/m^3. The % decrement of the coarse fraction of 25-37.5 mm and/ or 19-25 mm for both well- and poor-graded samples decreased with increasing f_s may be due to the cushioning effect of AAC grains. However, the samples with high f_s (i.e., 30 and 50%) had higher % decrement in 4.75-9.5 mm and/or 2.36-4.75 mm fractions may be indicating that AAC grains are easily breakable.

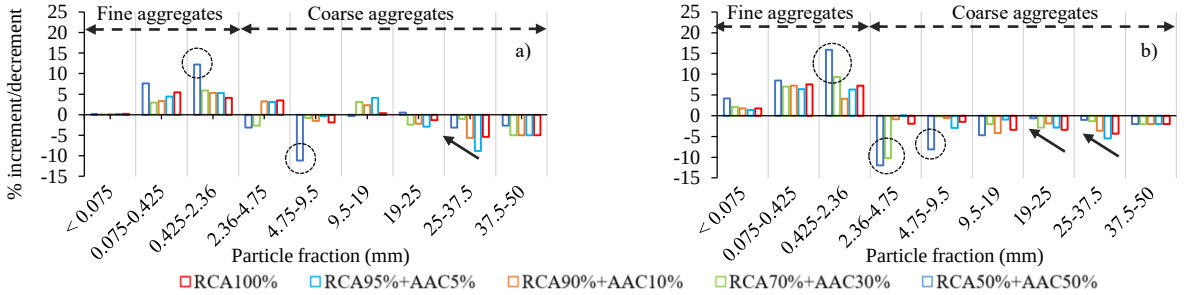

Figure 2 Particle breakage mode for tested samples at w_{opt}, E_c= 2673 kJ/m^3. a) well- and b) poor-graded

CONCLUSION

The decrease in DD with increasing f_s may affect the bearing capacity of the road base and subbase layers. Particle breakage plays an important role in examining the combination cushioning effect and easy breakage of AAC, and the long-term performance of roadbed materials. Further studies are needed to examine the bearing capacity and individual contribution of RCA and AAC in each fraction of particle breakage mode.

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Compositional Characteristics, Greenhouse Gases Mitigation, and Recycling Potential of Municipal Solid Waste Generated in West Bank Area, Palestine

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Keywords: waste composition, municipal solid waste management, greenhouse gas emission, material recycle

INTRODUCTION

The rapid increase of waste generation is an urgent issue for all stakeholders, urban planners, policies and decisions makers when considering sustainable integrated waste management in Palestine. An assessment of the current situation of waste management in Palestinian context is required from all aspects for moving to start thinking about more sustainable waste management scenarios. Disposing of over than 97% of generated waste either as regular or randomly (approx. 2,190 ton/day) [1], which is feared as not only the threats to public health and the environment but resources depletion. In order to avoid such threats and depletion, at first, it is necessary to understand the composition of the waste. Then need to formulate policies, laws, plans, and management models that enable to reduce the waste generation and achieve the sustainable consumptions through applying 3R (Reduce, Reuse Recycle), which is going on line with strategical goals of the National Solid Waste Management Strategy (2017-2022) of Palestine [1]. This paper examines the mitigation of greenhouse gases emission and recycling potential based on the latest waste composition survey in West Bank [2] and discusses the direction for further promotion of the 3R in Palestine.

OUTLINE OF WASTE COMPOSITION SURVEY

Solid Waste samples were taken daily for 1 week (6 days) at each site: Zahrat Al Finjan Landfill (representing waste samples from the northern area of the West Bank), Beit Anan Controlled Dumpsite (representing the waste from middle area of West Bank by NW+N Jerusalem), and Yatta Transfer Station (representing the waste from southern part of the West Bank), in August 2022 (dry season).

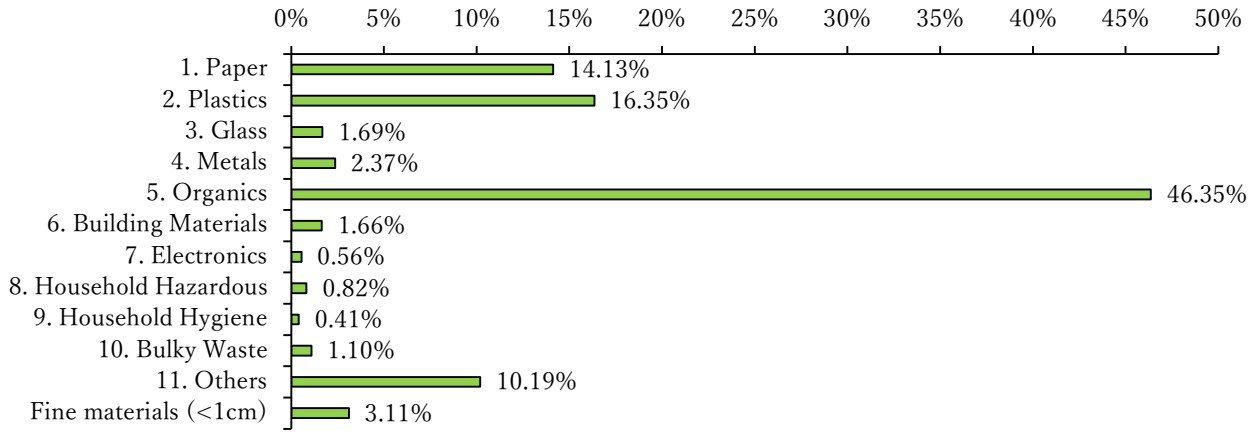

Figure 1. Averaged waste composition (wet weight %) in West Bank, Palestine (Data source: [2])

A total of 6 x 3 = 18 samples were obtained and on-site sorting and measurement in wet weight basis was implemented. The averaged composition of these three sites is shown in Figure 1.

RESULTS AND DISCUSSION

The largest component of waste is biodegradable organic waste (46.35 %). Recycling and energy recovery from the organic waste is possible through composting or anaerobic digestion, which are the highest potentiality for promoting Recycle. Moreover, the treatment of organic waste can contribute to the mitigation of greenhouse gases (GHGs) emission capacity. Composting all the organic waste fraction could save up to 250 tons (CO_2 equivalent per year). In addition, used paper/cardboard (14.13 %) and plastic (16.35%) are promising targets for material recycling. Although the development of a private recycling industry is indispensable for these recycling, currently, the recycling industry in Palestine is very small scale and lacks processing capacity of total recyclables [3].

The composition of municipal waste shows that infectious waste generated from households and/or small clinics is contained in a non-negligible amount in all sites (up to 0.82%). Untreated infectious waste undoubtedly increases the risk of infection for waste collection workers and the public, and thorough source separation and separate collection of infectious waste must be ensured based on the Medical Waste Management Bylaw (2012). In addition, a non-negligible amount of construction and demolition waste (1.66%) is sometimes dumped in street containers. This leads to damage and failure of waste collection compacter vehicles, and it is necessary to set rules and strongly regulate it.

CONCLUSIONS

In the West Bank of Palestine, a comprehensive waste composition survey was insufficient, but this time the details became clear for the first time. This composition clarified the big recycling potential of biodegradable organic and plastics wastes, which may contribute the mitigation of GHGs emission and climate change issue. It also unveils the risk factors for solid waste management service. Periodical updating of waste composition data will be required.

ACKNOWLEDGEMENT

This study was supported by the MoLG-JICA Project for Capacity Development in Solid Waste Management in Palestine Phase-III (CDSWMP-III).

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Evaluation of Attitudes and Knowledge toward Organic Waste Recycling Practices through House Composting: A Pilot Project in Gaza Strip, Palestine

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Keywords: house composting, rotary composter, organic waste recycling, waste reduction

INTRODUCTION

Municipal solid waste generation in Gaza strip has been increasing with the increase of population and generation per capita. Gaza Strip produce nearly 2,000 tons of municipal waste in daily manner, with the composition of 56.6% is organic waste [1]. North Gaza and Gaza governorates occupy 60% out of the total organic waste generated in Gaza. The previous reports estimated that approximately 2% of the total solid waste generated is being composted [2], while the major amount of organic waste was directly landfilled. Several composting initiatives at commercial level were implemented in the past years applying windrows active pile systems but faced many challenges and obstacles due to marketing issues, low quality of the compost products and the high competition with imported compost [2]. Joint Service Council for Solid Waste Management in Gaza and North Gaza Governorates (JSC-GNG) implemented a pilot model for waste minimization through home composting in the governorates of Gaza and North Gaza in 2022 as a pilot project for studying waste reduction measures, which is supervised by the MoLG-JICA Project for Capacity Development in Solid Waste Management in Palestine Phase-IIII (CDSWMP-III). The objective for this pilot project is to promote 3R practice and waste reduction at household level in Gaza, through distributing 170 rotary composter units with capacity of 220 L and waste separation bins coupled with launching a community-based campaign for awareness raising [3]. This paper presents the evaluation and impacts through assessing the post-intervention status of targeted beneficiaries in terms of project indicators and measuring the awareness level of beneficiaries.

MATERIALS AND METHOD

Comprehensive data collection tools are applied for the purpose evaluating the impact of the pilot model on selected beneficiaries utilizing the triangulation approach includes questionnaires, interviews and focus group discussions. Baseline (BL) survey, field interviews visits and focus meetings groups are conducted, and then Endline (EL) survey for assessing the post-intervention status of attitudes and willingness to segregate, the level of knowledge about waste reduction and about composting process.

RESULTS AND DISCUSSION

The following bar chart illustrate the result impact on applying home waste separation and composting practices on households' behaviors and waste management practices.

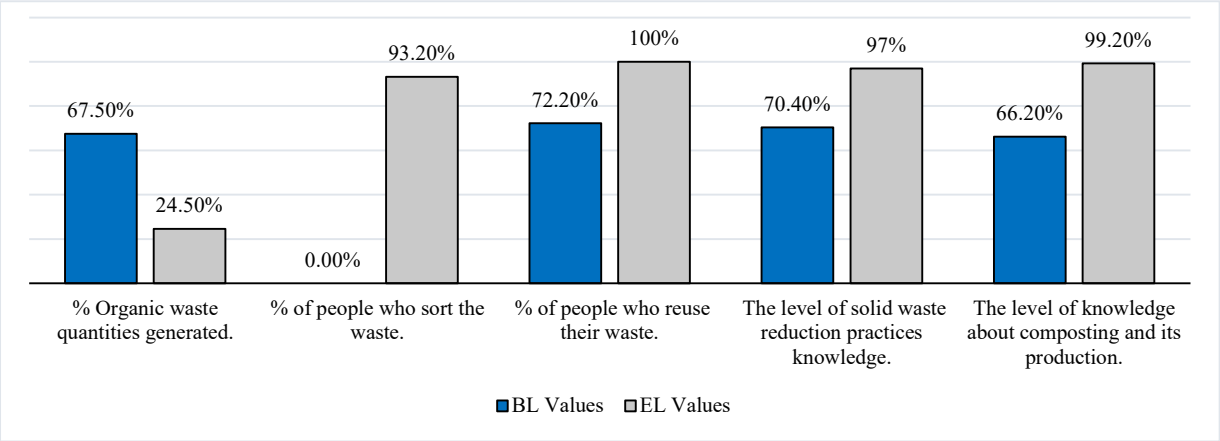

Figure 1. The Different of Baseline (BL) Survey & Endline (EL) Survey Values Indicators

The most significant finding obtained from the beneficiaries is that disposal of organic wastes was dramatically reduced down to 22.4% from 67.5%; these dropped amounts were utilized and placed inside the composter units. Furthermore, the knowledge level about solid waste reduction practices and composting production reached very high levels comparing to baseline results. The majority started to adopt waste sorting, reuse, reduce principles at93.2%, 84.2%, and 68.4%, respectively [3]. It is estimated that the composter unit could produce average of 40kg per each batch, with average of 4-5 weeks per each batch in spring and summer weather condition. Approximately 6 tons of organics wastes are being recycled monthly though house composting system. This concludes about 28% reduction rate through customizing material flow data for beneficiaries who committed to use the composters [4].

CONCLUSIONS

The result proves Gaza people are ready to manage the waste reduction and recycling practices at house holds levels in line with awareness programs. In addition, setting specific criteria for selecting beneficiaries, utilized additional resources for the follow us is a key factor. Additionally, the success of this initiative powerfully boosts toward adopting other advanced waste reduction technology at the house level.

ACKNOWLEDGEMENT

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Activities to Increase Awareness for the Wastes Issues in Palestine

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Keywords: waste reduction, awareness raising, Palestine

INTRODUCTION

In Palestine, the basic system of the collection, transferring, and final deposition are working well through Joint Service Council (hereafter JSC), municipalities and the private sector (Ramadan and Tojo, 2021). Rapid growth of the waste amount is one of the serious problems, because the capacity of the final disposals is limited, and there will be no place to dispose of it in the next several years (Tawafsheh, Yoshida et al., 2021). The Project for Capacity Development in Solid Waste Management in Palestine Phase-III (hereafter CDSWMP-III) has strengthened through social networking service (SNS) such as Facebook™ page and on-ground activities, based on the conducted questionnaire survey during January to March of 2021. We observe that people prefer to get information by their own initiative or participating as a part of the activities, rather than just receiving information in a passive way and from the one-way communication.

In this article, we will analyze influences from implemented activities conducted by CDSWMP-III to increase public awareness and its influences on the participants.

MATERIALS AND METHODS

First, CDSWMP-III has improved the Facebook page to transfer the information on the waste management in Palestine. MoLG changed the name from “JSC Today” to “Solid waste management in Palestine”, second design project logo with the concept of sustainability and harmonization to the environment. Then CDSWMP-III project staff has developed series of posters and videos related to the waste management such as “3R”, the effect of open burning, etc. Next is the approach to the formal education system through on-ground activities. We developed the coloring book related to the waste management for school children age around 8-10. It was shared through the Ministry of Education and the JSCs. Also, on the World Environmental Day, June 5, 2022, we involved the Birzeit University which is one of the biggest universities in Palestine to one day activities. The university students and local school children worked together on clean up, the separation game, furniture making from used drums for electric wires and drawing environmental pictures on the walls.

RESULTS AND DISCUSSION

(1) Facebook page: After several trials like changing name of the Facebook, upload series of posters and videos related to the waste issues, the access to the Facebook increased 266.5% and the number of “Likes” 131.1% from 1 April 2022 to 20 July 2022.

(2) World Environmental Day Activities: CDSWMP-III collected answers from the 22 university participants. 73% of the participated students said that they obtained new information on the waste reduction through

participating this event. Among them, waste separation was a top issue with 38%, the second was waste recycling with 25%, following keeping the environment clean 19%. What we noticed is that 86% of the students answered "Yes" for the question "Has your behavior changed in use the waste?". The activities surveyed for changing behavior of the participants.

Table1. Questions to participants of the activities

Questions	Yes (%)	No (%)
Have you ever participated in the activities of the World Environment Day?	73%	27%
Did you get new information about waste reduction through the activity?	73%	27%
Have you ever participated in cleaning your area or other areas?	82%	18%
Did you learn how to separate waste?	100%	0%
Will you to separate waste inside your home or your university?	90%	10%
Has your behavior changed in use the waste?	86%	14%
Did you know that electric drums can be used to make chairs and tables?	55%	45%
Did you provide awareness information through the activity of writing phrases and hanging them on the tree?	73%	27%
Did the mural painted on the wall provide an awareness message?	100%	0%
Do you support to do awareness-raising workshops on health and the environment in your university?	95%	5%

Note: Number of participated students is 22. The percentage is caluculated excluding "No answer".
Source: unpublished data of CDSWMP-III

(3) Coloring book use: 36 Schools which received coloring book replied to questions. All the schools said that trough the coloring book, the school children got new information about the waste, and almost 92% answered that the children who bring their own lunch box after this activity increase. We recognize the children received the messages about the reduction of waste through coloring pictures and there is a positive effect of the coloring book.

CONCLUSION

This article aimed to see the influences by the conducted activities for the awareness raising on the waste. Checking the answers from the participants, we observed these implemented activities served to change of the behaviors. We know the conducted surveys are insufficient to assess the effects of the approaches, but at least we can say the participants learn from the activities. CDSWMP-III will carry out more surveys to see which kind of approach will motivate people and aware more on the waste to bring them waste reduction.

ACKNOWLEDGEMENT

Conducted awareness activities were supported by the MoLG-JICA Project for Capacity Development in Solid Waste Management in Palestine Phase-III. The views expressed in this paper is not represent the official view of MoLG or JICA.

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Environmental Sustainability Assessment of Municipal and Small-scale Plastics Waste Management

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Keywords: life cycle assessment, plastics recycling, high-density polyethylene (HDPE)

INTRODUCTION

The rapid urbanization and population increase in the cities of Metro Manila through the years has caused the rise in the volume of municipal solid waste (MSW). Landfilling and resource recovery technologies such as plastic recycling, are the primary waste management options to treat MSW in the region. Specifically for plastic wastes, the fraction diverted from landfills has increased due to enactment of national and local laws (NSWMC, 2007) as well as corporate influence and the emergence of social enterprises in this sector. To determine the effectiveness of plastics recycling as a waste management strategy in Metro Manila, the life cycle environmental impacts of these enterprises should be compared with the business-as-usual practice of landfilling. Hence, this study aims to evaluate the environmental sustainability of landfilling and recycling of plastic wastes in Metro Manila and provide insight on the development of waste management plans of local government units.

MATERIALS AND METHODS

Life cycle assessment on a cradle-to-grave approach is applied in this study to meet the stated objectives. The functional unit is selected to be 1 ton of collected high-density polyethylene (HDPE) waste in Metro Manila. The system boundary includes collection, transportation, and segregation of plastic waste, and small-scale processing to form recycled plastic trays (Cloop, 2021). Calculations are performed in openLCA with ecoinvent 3.7 as the background database and the ReCiPe 2016 (H) impact assessment method.

RESULTS AND DISCUSSION

Figure 1 shows the comparison of life cycle impacts between recycling and landfilling of post-consumer HDPE. The modeled recycling process is found to have greater impacts in 8 out of the 10 categories investigated. Contribution analysis shows that collection and transport (up to 96%), and energy use in the recycling process (up to 41%) are the main sources of environmental impacts of recycling. Because of the energy mix in the Philippines still reliant on coal and gas, operating recycling enterprises can yield almost double the greenhouse emissions compared to direct landfilling of the same waste.

Sensitivity analysis reveals that potentials for photochemical oxidant formation, ozone depletion and terrestrial acidification are sensitive to transportation distance while freshwater eutrophication potential and terrestrial acidification potential are the most sensitive to electricity use in the recycling process. These findings suggest that optimization of the reverse logistics of post-consumer plastics and energy efficiency in the plastics processing are the key areas of improvement.

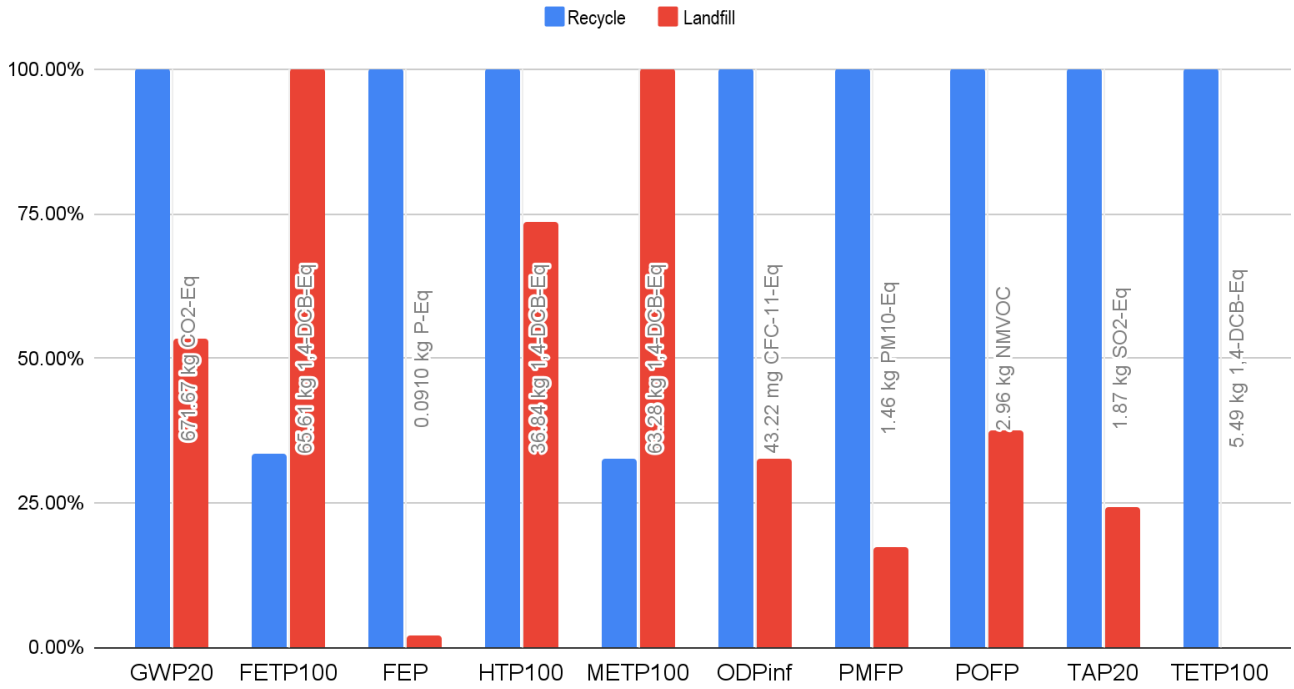

Figure 1. Life cycle environmental impacts of recycling and landfilling of plastic waste

(GWP: global warming potential, FETP: freshwater ecotoxicity potential, FEP: freshwater eutrophication potential, HTTP: human toxicity potential, METP: marine ecotoxicity potential, ODP: ozone depletion potential, PMFP: particulate matter formation potential, POFP: photochemical oxidant formation potential, TAP: terrestrial acidification potential, TETP: terrestrial ecotoxicity potential)

CONCLUSION

This study investigated the operations of a small-scale enterprise which recycles HDPE waste and compared its environmental sustainability to business-as-usual landfilling. The results of this work indicate that environmental impacts are strongly dependent on the emissions during transport and processing, and the corresponding process energy consumption. The plastics recycling scenario may need further improvement on its collection efficiency and energy utilization to further reduce its impact should it be implemented as a large-scale alternative. Moreover, economic feasibility studies can also be performed to form a more holistic recommendation for community-led solid waste management planning.

ACKNOWLEDGEMENT

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Gold Adsorption from Aqua Regia Using Dithiocarbamate-Modified Cellulose and Comparison with Commercial Resins

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Keywords: adsorption, aqua regia, gold, dithiocarbamate, DMC.

INTRODUCTION

The dithiocarbamate-modified cellulose (DMC) is a promising adsorbent for the recovery of precious metals (PMs), including gold (Au), silver (Ag), and platinum (Pt) group metals. DMC shows high affinity and improved selectivity toward PMs (soft acids) due to its dithiocarbamates (DTC) group (Biswas et al., 2021). The proline-incorporated DMC with epoxy-cross-linkage (DMC-Pro-Epo6) has been introduced recently and exhibits enhanced thermal stability (Nakakubo et al., 2022). Though selective recovery of Au by DMC has been reported, the application of DMCs (DMC and DMC-Pro-Epo6) has not been investigated yet in actual industrial waste conditions. Aqua regia (AR) is used to dissolve base and PMs from e-waste with high leaching rates for Au (Ding et al., 2019). In this study, the stability and suitability of DMCs for the adsorption of Au^{III} from AR were examined at different dilutions and compared with common commercial resins (CRs).

MATERIALS AND METHODS

Standard solutions (1000 mg L^{-1}) of Au^{III}, $HAuCl_4 \cdot 4H_2O$, HCl (35%), and HNO_3 (60%) were purchased from Kanto Chemical (Tokyo, Japan). Two cellulose-based bioadsorbent (DMC and DMC-Pro-Epo6), four anion exchange type CRs (Lewatit MonoPlus TP 214, Diaion WA30, Dowex 1X8, and AmberChrom 1X8), and one chelating CR (Q–10R) were used in this study. Ultrapure water with a resistivity of >18.2 MΩ·cm was used throughout. Batch sorption tests were performed by soaking 5–25 mg of adsorbents into 10 mL of Au^{III}-containing AR solution. The mixture was shaken at room temperature for a fixed duration and then filtered. The Au^{III} concentrations in the filtrates were determined by an inductively coupled plasma atomic emission spectrometer (ICP–AES). The solubility of DMCs in AR was checked in a similar batch test without adding metal ions. The characterization of the adsorbent before and after AR treatment was carried out using Field-emission scanning electron microscopy (FE-SEM) and Fourier transform infrared (FT-IR) spectroscopy.

RESULTS AND DISCUSSION

The comparative adsorption behavior of DMC, DMC-Pro-Epo6, and five CRs toward Au^{III} in 2–4 times diluted AR were investigated (Figure 1). DMCs showed markedly better adsorption capacities for Au^{III} than CRs. It might be due to the sorption-active DTC groups in DMC, which have functionalized to a significant degree, resulting in a large density of donor atoms (S).

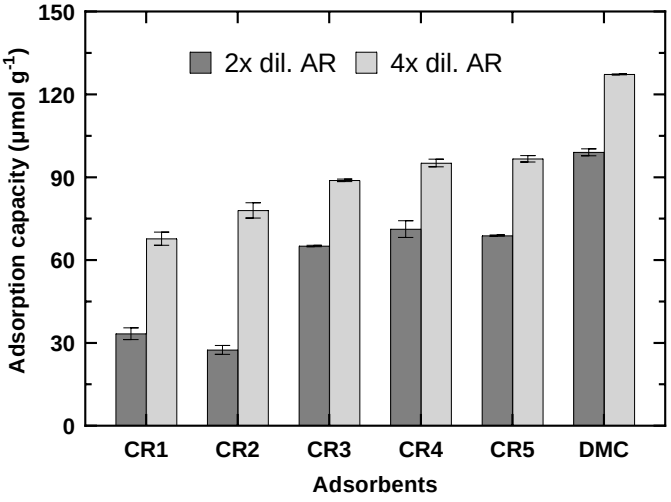

Figure 1. Adsorption capacity (μmol g^{-1}) of DMC and CRs for Au^{III} in 2 and 4-times diluted AR. Adsorption conditions: [Au^{III}], 250 μmol L^{-1}; adsorbent dose, 25 mg for DMC and CRs (CR1: Lewatit MonoPlus TP 214, CR2: Q–10R, CR3: Diaion WA30, CR4: AmberChrom 1X8, and CR5: Dowex 1X8); solution volume, 10 mL; agitation rate, 200 rpm; contact time, 2 h for CRs, and 1 h for DMC, *T*, 25 ± 1.0 °C.

The poor Au-adsorption efficiency in undiluted AR may be due to the change in the active sites caused by the strong oxidative nature of AR. However, with the increase in dilution of AR, the adsorption efficiencies of both DMC and DMC-Pro-Epo6 increased steadily. The solubility test data demonstrated that both adsorbents are partially dissolved in undiluted AR. The SEM images of pure and AR-treated adsorbents suggested a change in the surface morphology. The intensity and positions of the characteristic peaks in the FT-IR plot of pure and AR-treated DMCs were nearly identical except the intense S-S peak. Thus, the lower adsorption capacity of DMCs in undiluted AR may be attributed to the oxidation of the DTC group.

CONCLUSION

The adsorption ability of DMC, DMC-Pro-Epo6, and five CRs toward Au^{III} in 2-4 times diluted AR was examined by a batch adsorption experiment. Due to the active DTC groups in the carbon backbone, DMCs demonstrated significantly higher adsorption capabilities for Au^{III} compared to CRs. Lower adsorption of DMCs in undiluted AR accounted for the oxidation of the DTC group as a distinctive S-S peak was seen in the FT-IR plot.

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Freshwater Phytoplankton: Uptake and Biotransformation of Arsenate Under Salinity Gradients Using Single-Cell ICP-MS and CT-HG-AAS

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Keywords: Biotransformation, Phytoplankton, Morphological changes, SC-ICP-MS, Salinity

INTRODUCTION

Environmentally toxic arsenic (As) is often found in aquatic systems. High concentrations of As in freshwater systems cause serious environmental and human health problems (Ghosh et al., 2022; Rahaman et al., 2021). As is persistent in aquatic environments, especially its distribution, accumulation, and subsequent transfer via trophic pathways throughout aquatic food chains (Hasegawa et al., 2001; Papry et al., 2021). Some microalgae or phytoplankton can oxidize, reduce, and methylate As in the environment (Hasegawa et al., 2010). Consequently, macroalgae have been increasingly used as a biomonitor of trace elements, especially As, in the aquatic environment. A change in salinity impacts phytoplankton metabolism and biochemical activities, including growth, photosynthesis, uptake, and accumulation of As. However, studies focused on morphological changes, biochemical changes and As uptake by freshwater phytoplankton under salinity gradients are still limited. Therefore, the present study aims to evaluate the effect of salinity stress on the growth, As uptake, accumulation, and biotransformation of freshwater phytoplankton in the presence of As. The current research proposes a technique that measures the metal content of individual cells using single-cell ICP-MS.

MATERIALS AND METHODS

Three freshwater phytoplankton, namely *Scenedesmus acutus (S. acutus)*, *Pediastrum duplex (P. duplex)* , and *Staurastrum paradoxum* (*S. paradoxum),* were cultured. They were maintained in a modified C medium containing phosphoric acid, As(V), and artificial seawater (35 ‰). For the salinity experiment, 5 levels were examined: 0, 1, 2, 3, 4, and 5‰. Such wide-range salinity was chosen to investigate the overall performance of three freshwater phytoplankton, e.g., *P. duplex*, *S. acutus, and S. paradoxum,* in terms of their growth. After incubating, the phytoplankton species were grown for 14 days. An automated cell counter was used to measure cell density. In addition, the uptake and metabolism of As were measured by SC-ICP-MS and CT-HG-AAS.

RESULTS AND DISCUSSION

This study used single-cell ICP-MS to quantify the metal distribution within the cells. In the case of *S. paradoxum* and *P. duplex,* the average intracellular As-content was decreased with increasing salinity. Meanwhile, the average intracellular As-content of *S. acutus* showed a slight increase in As-content with increasing salinity. The chemical, morphological analysis of dissolved As in the culture medium on the 14th day of the main culture is illustrated in Fig. 1. Phytoplankton consumes As(V) from nearby environments; they

either excrete As(III) into the medium or methylate it into methyl As species. As observed with all the species, the reduction rate of As(V) to As(III) and methyl As species decreased as the salinity increased. In the case of *S. acutus*, the reduction of As(V) to As(III) occurred at low and high salinities; however, no methylation was observed at all salinity levels. Similar to *S. acutus*, no methyl As species was observed in all salinity levels for *S. paradoxum*. Higher organic As (HOAs), such as arsenobetaine, might be produced in *S. acutus*. *P. duplex* could grow and biotransform toxic As(V) to As(III) and then methylate it to form dimethyl arsenate (DMAA) species at certain salinities during their logarithmic growth phase. In all of the phytoplankton samples tested, no monomethylarsonate (MMAA) was detected as an intermediate product during the methylation reaction.

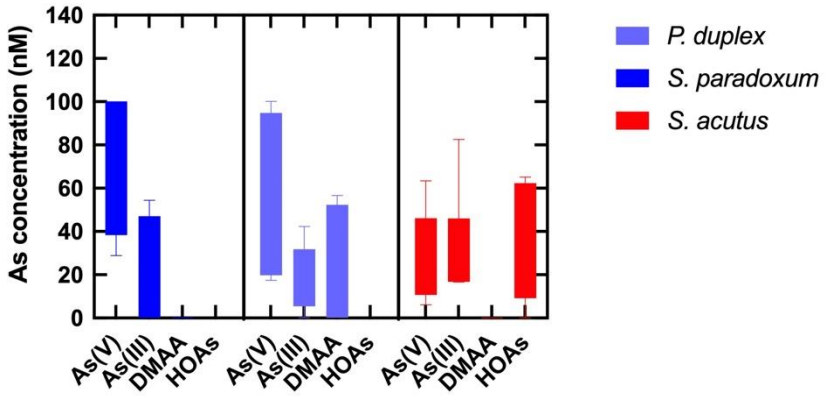

Fig. 1 As biotransformation by three freshwater phytoplankton under different salinity stress levels.

CONCLUSION

Under diverse salinity stress conditions, three freshwater phytoplankton showed distinctive patterns of As accumulation, As biotransformation, and growth. The introduction of salinity into freshwater systems is a global phenomenon. The findings of this study suggest that As accumulation and speciation by freshwater phytoplankton under low salinity stress might be helpful for As remediation.

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Analyzing Waste Photovoltaic Panels Generation and Influence Based on the Long-term Capacity

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Keywords: photovoltaic panels, waste, resource circulation

INTRODUCTION

The Sixth Strategic Energy Plan states that Japan will address maximum introduction of renewable energy as major power sources on the top priority. Prior to the large-scale facilities introduction, it is important to consider resource recycling after the facilities are decommissioned.

In the case of photovoltaic power generation facilities, the timing and scale of future generation of waste photovoltaic panels estimated in several previous studies. However, these estimates are based on the forecast of future installed capacity considering state of the society at the time of the estimates, and the estimates are nationwide scale. In this study, we analyzed the long-term waste photovoltaic panels generation in each prefecture and influence of their disposal in a manner consistent with The Sixth Strategic Energy Plan.

METHODS

Assumptions for installed capacity, etc.

First, the long-term installed capacity and the amount of annual introduced capacity in each prefecture were assumed. The installed capacity for all of Japan, which is reported by New Energy and Industrial Technology Development Organization (NEDO) to International Energy Agency Photovoltaic Power Systems Research Cooperation Program (IEA PVPS) until 2020, was allocated to each prefecture in the same share as the authorized capacity based on the FIT Law. After 2021, it is assumed that by 2050, each prefecture will achieve the top case of the Possible Introduction Amount in the project by the Ministry of the Environment, and maintain the same level thereafter until the year 2200. Then, the amount of annual introduced capacity in each prefecture was assumed so that the installed capacity in each year would be achieved even after taking annual generations of waste photovoltaic panels (see below) into account.

The total installed capacity in Japan under the top case is approximately 400 GW. This is consistent with the scenario (approximately 370 GW, when 50-60% of power generation in 2050 would be from renewable energy sources with the maximum introduction of solar power generation facilities), which was presented as a "reference value for further discussion" by the Advisory Committee for Natural Resources and Energy.

Generation model and weight conversion factor

The annual amount of generation was estimated on a per-capacity basis by giving several Weibull distributions for equipment failures after installation, based on estimates by International Renewable Energy Agency (IRENA) / IEA PVPS and The National Renewable Energy Laboratory (NREL).

For weight conversion, we used IRENA estimates based on product information databases and technology forecasts from manufacturers, etc. We assumed that the weight per unit capacity of produced facilities would decrease until 2050 and remain unchanged thereafter. It is also assumed that after failure, facilities become waste.

RESULTS AND DISCUSSION

Examples of the estimation is shown in Figure 1. The annual amount of generation in Japan was estimated to sequentially increase to about 700,000 tons by around 2060, and then to decrease to about 500,000 tons, but to remain at the same level thereafter in the case with highest annual amount peak. When α shape parameter of the Weibull distribution was varied with reference to existing studies, there was a trade-off between total and annual amounts of generation. On the other hand, the β shape parameter decreased both of them (Figure 2).

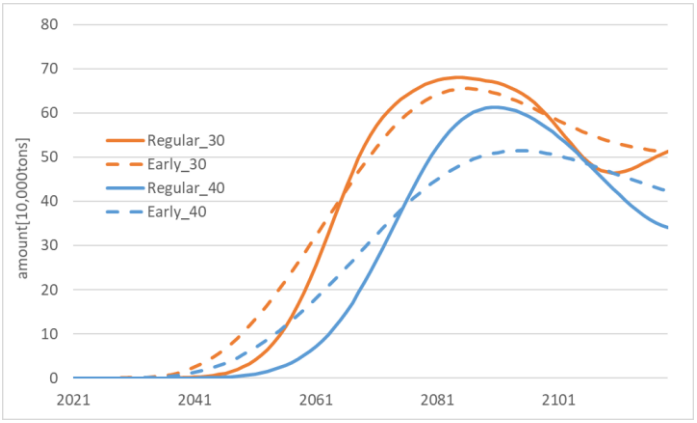

Figure 1 examples of the estimation

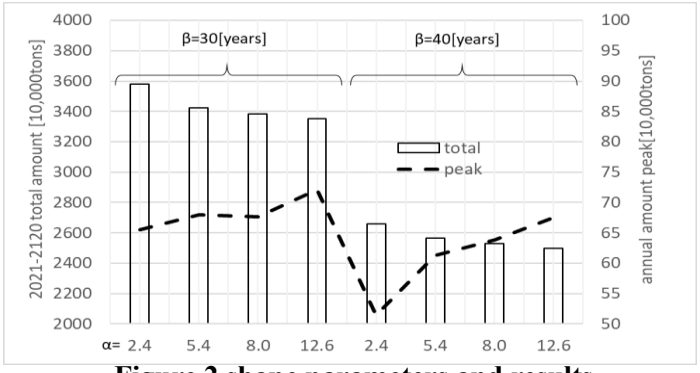

Figure 2 shape parameters and results

Thus, it is assumed that generation from post-decommissioning facilities will not only have a transient peak, but will continue on a certain scale in anyway. If photovoltaic panels continue to be shipped using the same material composition as at present, approximately 60% of the emissions by weight will be glass and 20% will be aluminum. If half of the glass and aluminum are recycled, the amount of glass and aluminum requiring final disposal would be limited to about 400,000 tons at most, according to the above-mentioned estimation of annual amount of generation in Japan. If an appropriate resource circulation route is designed, it is expected to have an economic ripple effect on the companies that manufacture these recycled materials and, depending on the characteristics of the virgin material to be substituted, to reduce the environmental impact associated with its manufacture.

The above results suggest that it is important to consider long-term resource recycling in advance.

ACKNOWLEDGEMENT

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Extractive Remediation of Fluoride-Contaminated Soil Using Biodegradable Chelators and Surfactants

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Keywords: Fluoride, Soil washing, Biodegradable chelator, Surfactant, Zeta potential

INTRODUCTION

With rapid industrialization and urbanization, soil contamination by heavy metals has become one of the global concerns. Fluoride is classified as a heavy metal by soil contamination countermeasures law, as fluoride is the second most common soil contaminants in Japan (Anonymous., 2002). Long-term exposure to fluoride can affect human health, and may cause dental fluorosis and osteosclerosis (Ando, M., et al., 2001). For the treatment of fluoride-contaminated soil, excavation and soil washing have been widely used (Moon, D. H., et al., 2015). However, most of the conventional techniques are not well-accepted in terms of remediation cost and environmental burden. In a recent study, blending of surfactants with chelators were found promising for the remediation of heavy metal contaminated soil (Rahman, S., et al., 2022). In this study, six types of chelators and four types of surfactants were employed as washing agents for the remediation of fluoride-contaminated soil. The objectives of this study are: 1) to combine surfactants with chelators to promote fluoride extraction, and 2) to propose the probable mechanism of fluoride removal by a surfactant and chelator blended washing system.

MATERIALS AND METHODS

Reagents

Three biodegradable chelators, 3-hydroxy-2,2'-iminodisuccinic acid (HIDS), ethylenediamine *N*,*N*'-disuccinic acid (EDDS), *DL*-2-(2-carboxymethyl) nitrilotriacetic acid (GLDA), and three persistent chelators, ethylenediaminetetraacetic acid (EDTA), diethylene triamine pentaacetic acid (DTPA), nitrilotriacetic acid (NTA) were employed as washing agents. Two anionic surfactants (SDT: sodium *N*-dodecanoyl-taurinate, SDS: sodium dodecyl sulfate) and two cationic surfactants (CTAB: cetyltrimethylammonium bromide, CPC: cetylpyridinium chloride) were used to evaluate the surfactant-enhanced soil remediation.

Batch washing experiments

The soil sample was mixed with a chelator or surfactant solution at different pH, concentrations, and washing time at a 10:1 liquid-to-solid ratio. The suspensions were then centrifuged, and the supernatants were subsequently collected via filtration for ion chromatography analysis (Tosoh, Tokyo, Japan) to determine the fluoride concentrations. An FTIR-460 spectrophotometer (JASCO, Hachioji, Japan) was used to characterize the pre- and post-washed soil. The zeta potential and particle size measurement of the soil suspension were performed using a SZ-100 NanoPartica analyzer (Horiba Instruments, Kyoto, Japan).

RESULTS AND DISCUSSION

Fluoride extraction

The effect of pH on fluoride extraction was examined at chelator concentrations of 10 mM (**Fig. 1a**). All chelators exhibited higher fluoride extraction than that of the control due to the chelation with the fluoride-bounding minerals (e.g., Ca, Fe, and Al). Among the biodegradable chelators, HIDS (pH 3) showed the highest extraction efficiency. Combining SDT and HIDS enhanced fluoride extraction, while CTAB decreased the fluoride extraction.

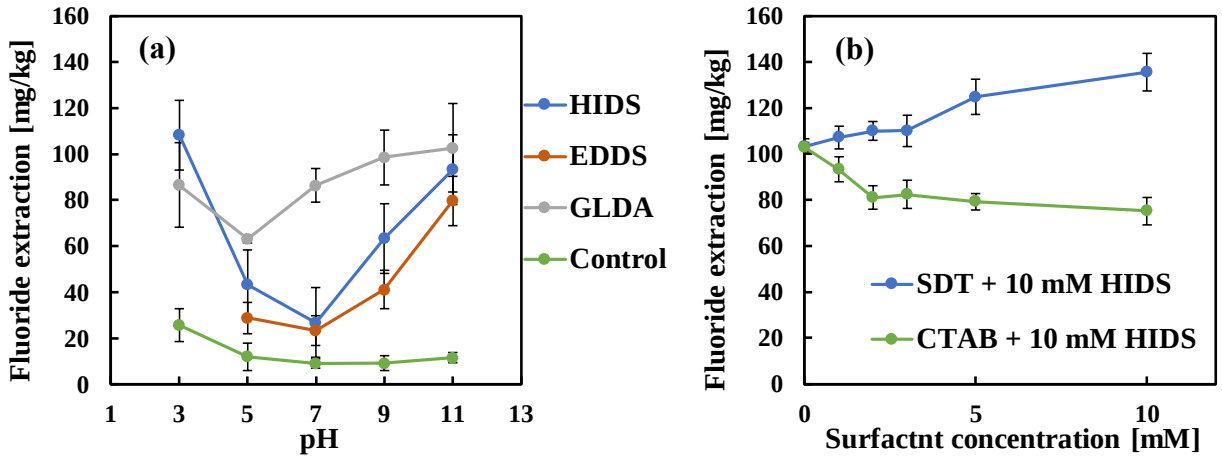

Fig. 1 Fluoride extraction with (a) chelator-assisted washing (10 mM, 3h), (b) blending of surfactants and HIDS (pH 3, 3h)

Mechanism of enhanced fluoride extraction

In the FT-IR spectrum of the SDT-washed soil, two peaks corresponding to N-H and C=O newly appeared, suggesting the adsorption of SDT onto the soil particle surfaces. In addition, the zeta potential of the colloidal particles in the post-washed solution became more negative. Those imply that the enhanced negative charge of the soil surface is due to SDT adsorption. This might inhibit fluoride re-adsorption, promoting fluoride extraction in the presence of HIDS and SDT.

CONCLUSION

In this study, the chelator or surfactant-assisted removal of fluoride from contaminated soil was investigated and optimized as follows: 10 mM HIDS, 10 mM SDT, pH 3, and washing time of 3 h. The combined application of SDT with HIDS demonstrated the highest fluoride removal performance, possibly due to the adsorption of SDT and HIDS onto the soil particle surfaces to mitigate the re-adsorption of fluoride.

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Analysis of Performance of Cover soil in Attenuating the Physico-chemical Parameters of Landfill Leachate by Soil Column Test

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Keywords: Landfill Leachate, Landfill Cover Soil, Attenuation, Soil Column Test

INTRODUCTION

Municipal Solid Waste (MSW) management is the burning issues in the developing countries which has been increasing due to population, economic growth and living standards of people (Pathak et al., 2020). In Nepal, the methods of waste management adopted by the municipalities are: i) piling up in landfill site by 48.6% municipalities and rest by burning and piling up in the river side (CBS, 2020). Leachate is the liquid generated from the bottom of the solid waste disposal facilities is the serious pollutant that affects the surface and ground water, soil, human health, hygiene and aquatic life (Nawaz et al., 2020). In landfill operation technique Cover Soil can be considered a major requirement for isolating waste from the surrounding environment and used as a medium for the reduction of organic loads and certain heavy metals in leachate. The scope of this study is to understand the mechanism of natural attenuation of Landfill Leachate in soil used as cover soil and subsequently find the contamination level in soil due to leachate infiltration.

MATERIALS AND METHODS

Study Area

The study area is Sisdole Landfill Site (SLS) which was designed for 2-3 years. However, it is still in operation and leachate system does not function properly hence polluting water bodies and soil.

Experimental Setup and Design

Leachate and cover soil were collected from base of SLS while maintaining the Standard Methods for the Examination of Water and Wastewater (APHA, 1990). Two soil columns consisting of Cover soils of SLS and another cover soil mixed with Laterite and Compost mixture (SCL) at 1:1 ratio were used in the experiment.

RESULTS AND DISCUSSION

Initial characteristics of Leachate

The initial characteristics of SLS shows pH value, Turbidity, Electrical conductivity (EC), COD & Ammonia is 8.4; 200 NTU; 27,880 µS/cm; 8,475 mg/L and 2,368 mg/L respectively. The initial values of Iron (Fe), Nickel (Ni) and Lead (Pb) are 7.6 mg/L, 2.85 mg/L and 2.2 mg/L respectively. The soil texture of SLS is sandy loam type which has sand (63.99%), clay (15%) and Silt (21%).

Leachate characteristics after to soil column test

The Changes in the values of the selected parameters occurred in the collected leachate throughout the

column test in 10 days of time period is given in Table 1. The pH reading for the effluent leachate on the first day showed a value of 6.88 and 7.2 for SLS Column and SCL column respectively which is lower than the alkaline value of 8.4 of the initial raw leachate and in later days it shows in increasing trend. For SCL soil column, the value of turbidity was 100 NTU up to the 10^{th} day. The initial decrease of EC in SCL column was 8,000 µS/cm can be due to the complexation of minerals in the raw soil and to the chemical exchanges between the leachate and soil and adsorption of cations of leachate (Ca2+, Mg2+, K+, Na+) to the soil. The decline of COD (>80%) in the first three days in SCL column can be linked to a combination of reduction in organic contaminants available for leaching and the increased biodegradation of organic compounds. The greater removal of Ammonia (>80%) in the first three days shows in SCL could be chiefly driven by adsorption and ion exchange.

Table 1: Comparison of Average Effluent Characteristics

Parameters	**SLS Column**	**SCL Column**
pH	8.06	8.135
Turbidity (NTU)	80.74	82.41
Electrical conductivity (EC) µS/cm	22065.2	19468
COD (mg/L)	1921.1	1562.6
Ammonia (mg/L)	1127.5	608.6

Heavy Metals

Iron (Fe), Nickel (Ni) and Lead (Pb) in the soil column of SLS exhibit higher removal percentage for Nickel and Lead (>90%) than Iron (68.8%). The sorption capacity of the clay particles within the matrix of the soil can already promise partial sorption of the selected heavy metals. The decrease in removal percentage of Fe can be associated with the decreasing sorption capacity of the soil with the increasing number of days.

CONCLUSION

The result from this study shows the average removal percentage in SLS soil were 60%, 97% 84%, 68.8%, 95.6%, 94.6% approximately for ammonia, phosphate, COD, Fe, Ni and Pb respectively for seven days. In SCL consistent and greater removal percentage for COD and ammonia was observed than in SLS. This study concludes that sandy loam is capable of removing pollutants from leachate to a satisfactory level but adding materials with higher sorption capacity such as laterite and compost to the soil can enhance removal ability.

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The Environmental Policy Latent Effects on Plastic Waste Recycling: A Comparison Between the United States and Japan

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Keywords: environmental tax revenue,plastic waste, waste management, ordinary least squares

INTRODUCTION

Since the 2017 China ban PW (plastic waste) import, major PW exporters such as Japan and the United States (US) have adopted new strategies to recycled PW (Wen et al., 2021). The USA government have been working to integrate recycled materials in polycarbonate product production (US EPA, 2022). Japan enacted an act promoting eco-friendly plastics life cycle practices. Furthermore, the two major PW exporting countries have adjusted their environmental taxes regulations. This research aims to examine how environmental taxes in these countries have changed PW situation. Specifically, we employed multiple regression analysis to plot the curve fitting of variables concerning the trend of PW recycling and environmental policy.

MATERIALS AND METHODS

In the Ordinary Least Square (OLS) regression model (*Eq.1)* we use PW outflow, environmental tax revenue (ETR), and recycled PW as parameters. Data were taken from the *Environmental statistics datasets* from the Organization for Economic Co-operation and Development (OECD, 2022) and the *Trends of the utilization of PW* from Japan's PW management institution (PWMI, 2019) from the year 2010 to 2019. The independent variables (Table 1) used for the constructed model are aggregate tax-base revenue that includes four types of tax resources: energy products, transportation, pollution, and resource extraction. The dependent variables (Table 2) is the annual recycled PW amount (Unit is millions of tons), ETR units are JPY for Japan and USD for the US.

$$z = f(x, y) = a_o + \alpha * x + \beta * y \qquad (Eq.1)$$

Table 1 The statistic of independent variables (IVA) in the model

Variables	Abbreviation	Nation	N	Mean	St.d	[Min, Max]
IVA (x):PW Outflow	PWJ	Japan	10	9.E+00	4.E-01	[9.E+00,1.E+01]
	PWU	US	10	7.E+01	3.E+00	[6.E+01,7.E+01]
IVA(y): ETR	ETRJ	Japan	10	7.E+04	1.E+04	[6.E+04,9.E+04]
	ETRU	US	10	1.E+05	1.E+04	[1.E+05 ,2.E+05]

Table 2 The statistic of dependent variables (DV) in the model

Variables	Abbreviation	Nation	N	Mean	St.d	[Min, Max]

DV (z): Recycled PW	RPW_J	Japan	10	7.E+00	3.E-01	[7.E+00,8.E+00]
	RPT_U	US	10	3.E+00	4.E-01	[2E+00, 3.E+00]

RESULTS AND DISCUSSION:

Multiple linear regression results are shown in Table 3 and 4 for Japan and US. Respectively, in Table 3, the β= -0.21 implies annual increase in recycled PW due to ETRJ residents' harmful environmental activities in Japan. Similarly, the US' negative β implied an increasing amount of recycled PW influenced by the tax.

Table 3 The multiple regression analysis score related to Japan (CI is confidential interval,$\alpha = 0.05$)

Variables	Normalized	Std	Coefficients	CI
PWJ	9E+00	4.E-01	0.32	(0.20, 0.43)
ETRJ	7E+06	2E+05	-0.21	(-0.33, -0.09)
Constant	N.a	N.a	7.33	(7.25,7.41)
Sum of Squares Due to Error**(**SSE)=0.06**,** R^2=0.87<1**,** Adjusted R^2=0.83, Root Mean Squared Error**(**RMSE)=0.1 $f_j(x_j, y_j) = 7.33 + 0.32 * x_j - 0.21 * y_j$				

Table 4 The multiple regression analysis scores related to US(CI is confidential interval, $\alpha = 0.05$)

Variables	Normalized	Std	Coefficients	CI
PWU	2.69	0.37	0.37	(0.37, 0.37)
ETRU	1E+05	1E+04	-9E-16	(-4E-15, 2.E-15)
Constant	N.a	N.a	2.69	(2.69, 2.69)
SSE =3E-30**,** R^2=1**,** Adjusted R^2=1 RMSE=6E-16 $f_u(x_u, y_u) = 2.69 + 0.37 * x_u + (-9E-16) * y_u$				

CONCLUSION

This study empirically analyzed the correlation between environmental tax revenue with PW recycling in US and Japan. Using 9-year data of both countries, the constructed OLS models showed that an increasing environmental tax revenue reduces recycling. Furthermore, the comparison between the two countries shows that the ETR latent effect impacts recycled PW in Japan more strongly than in the US. However, there was a limitation in this study: the independent variable (environmental tax revenue) used was an integrated value. Therefore, future studies should investigate the more specific tax-type impacts on recycled plastic waste.

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THE CARBON DIOXIDE CAPTURE PROCESS UTILIZING SEA-WATER AND OXALIC ACID

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Keywords: Carbon dioxide, Sea water, Oxalic acid, CCUS, Ion separation

INTRODUCTION

Since the Industrial Revolution, humankind has achieved exponential technological development. Accordingly, fossil fuel-based energy production has increased, resulting in carbon dioxide emissions and accelerating global warming. Recently, carbon capture, utilization, and storage (CCUS) technology have been actively studied worldwide to mitigate global warming. It captures carbon dioxide as absorption, adsorption, membrane separation, or other processes and then converts it into usable resources or stored underground or deep beneath the sea. The carbon dioxide mineralization method (CM) is one of the CCUS technologies that react carbon dioxide with various cations to obtain high-value chemical products. However, CM has difficulties commercializing because it is hard to secure sufficient cations. Therefore, this research team focused on the seawater with enough cations and proposed the seawater utilization process. The seawater utilization process comprises four steps: calcium separation, magnesium separation, sodium carbonate production, and electrolysis for sodium hydroxide regeneration.

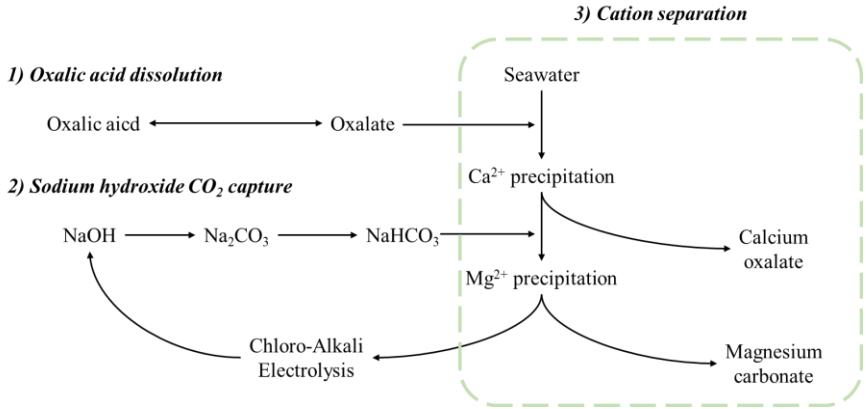

Figure 1. Process Schematic Design

MATERIALS AND METHODS

Cation separation: calcium separation & magnesium separation

Oxalic acid (OA) selectively reacts with calcium ions in seawater and precipitates calcium oxalate. Therefore, the optimal condition of OA solution for the calcium separation process is determined by adding the reaction ratio of OA solution in 5M calcium chloride solution. As a result, the determined optimal OA solution was added to seawater, and the precipitate was analyzed through X-Ray Diffraction.

Also, many researchers focus on the reaction of sodium carbonate and magnesium ions, which precipitate

magnesium carbonate. On this principle, magnesium ions can be separated from the sodium-magnesium mixture. The optimal amount of sodium carbonate as reactant was determined by analyzing XRD analysis by input amount of sodium carbonate. Finally, the final supernatant contained an excessive amount of sodium ions, and the supernatant was electrolysis to regenerate sodium hydroxide used in the sodium carbonate production step.

Sodium carbonate production

In this section, sodium carbonate was produced by sodium hydroxide carbonation to separate magnesium as magnesium carbonate from the seawater. The optimal product extraction point is defined by extracting samples from the reactor by carbon dioxide absorption time, and FT-IR analysis was performed. The research team proposed the carbon dioxide absorption process in a previous paper.

RESULTS AND DISCUSSION

The present study uses oxalic acid and seawater to show the carbon dioxide capture process. In addition, it explores the material balance variables that can help to demonstrate technology for the carbon dioxide capture process. To ensure the accuracy of the prediction of the reaction described, calcium oxalate, magnesium carbonate, and sodium carbonate produced at each stage are confirmed through various analyses such as XRD and FT-IR. Additionally, the electrolysis experiment process confirmed the circulation potential of sodium ions.

CONCLUSION

This research team proposed a seawater utilization process that captures carbon dioxide and separates ions simultaneously using oxalic acid and seawater. Seawater is a feedstock that can be used at any time and is ensured in sufficient amounts, and cations in seawater are highly utilized. Oxalic acid used in calcium ion separation can also be easily obtained in nature. Calcium oxalate produced in the proposed seawater utilization process is unlikely to be utilized by itself but can be converted into calcium carbonate that is highly utilized through processing.

ACKNOWLEDGEMENT

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Environmental Sustainability Assessment of Direct and Syngas Fermentation of Banana Peels

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Keywords: life cycle assessment, waste-to-energy, bioethanol, waste utilization

INTRODUCTION

Banana peels (BP) are agricultural residues generated throughout the production and consumption stages of bananas. In major banana producing countries such as the Philippines, the current management practice often ends with BP in landfill. This leaves BP underutilized despite its potential to be part of a circular economy . Because of the organic content of BP, direct fermentation and syngas fermentation can be used to produce bioethanol from BP. While previous studies have shown the potential of bioethanol production from BP using these two technologies, the environmental sustainability of these processes are yet to be measured. This study aims to report the life cycle impacts of banana peel waste utilization using these two technologies and identify process improvements to maximize the environmental benefits.

MATERIALS AND METHODS

To measure the environmental sustainability of banana peel utilization, life cycle assessment is performed with an attributional cradle-to-gate approach and a functional unit of 1 kg of banana peel generated post-consumption in the Philippines . The study will be limited to the production of bioethanol from the two chosen methods which are syngas fermentation and direct fermentation in which impact categories will be measured. The life cycle inventory is obtained from simulation of process models reported in literature(Gebregergs et al., 2016; Safarian et al., 2020). following a scaling-up framework (Piccinno et al., 2016) for laboratory results. The environmental impacts are assessed using 18 ReCiPe 2016 Midpoint (H) indicators.

RESULTS AND DISCUSSION

The life cycle impacts in the 18 midpoint indicators are summarized in Figure 1. The ethanol yields for both the processes were 70% for syngas fermentation and 44.37% for direct fermentation. Comparing the two utilization pathways, direct fermentation is found to have lower impacts in 16 impact categories, including climate change potential, freshwater eutrophication, and agricultural land occupation, while syngas fermentation is environmentally better for metal depletion and water depletion. Contribution analysis shows that energy use is the dominant cause of impacts in the 15 categories in syngas fermentation, particularly the purification of bioethanol

Heat integration, use of renewable energy, and less energy intensive purification process for bioethanol are recommended.

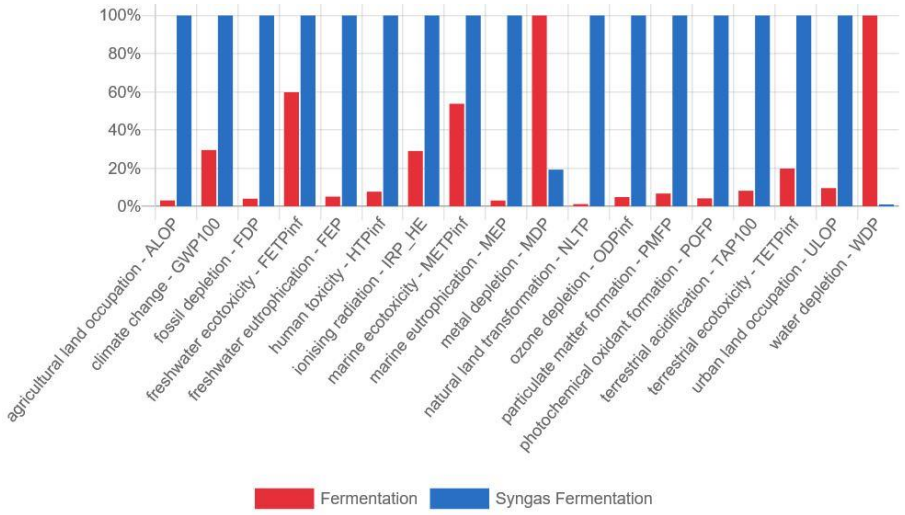

Figure 1 Relative Results for Syngas Fermentation and Direct Fermentation

CONCLUSION

To promote circular economy in the banana value chain, this study evaluated the environmental impacts of bioethanol production from direct fermentation and syngas fermentation of banana peels. It is found that direct fermentation is more environmentally benign than syngas fermentation in 15 categories. Following the contribution analysis of the cradle-to-gate scope of the studied banana peel utilization options, it is recommended that fermentation be used to produce bioethanol from banana peel waste. Syngas fermentation could be used for lignocellulosic banana waste with improvement on bioethanol purification. Use of heat integration schemes and renewable energy may be considered. Ongoing work that builds on this study will further investigate other pathways to utilize residues from banana production and consumption. Further research on the economic and social sustainability of banana waste utilization will be beneficial to create a circular banana industry.

ACKNOWLEDGEMENT

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Built from Rubble: A Review of Disaster Waste for Post-Disaster House

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Keywords: disaster waste, post-disaster housing, recycle material, building waste, reconstruction

INTRODUCTION

In the last 5 decades, natural disaster cases number have been escalating rapidly and more frequent (Ministry of Environment Government of Japan, 2018) (United States Environmental Protection Agency, 2022). Along with the disaster trend, the concern towards the natural environment impact caused by disaster waste is also increasing. In densely populated urban areas, the largest disaster waste is construction and demolition (C&D) waste (Brown et al., 2011). From a single event of disaster, it can result in building and infrastructure collapse which turned into thousands of tons of debris disaster waste (Karunasena et al., 2012).

After the disaster, most of debris end up as landfill material or deposited not processed into high-quality recycling. Meanwhile, in some affected areas material for housing reconstruction is very limited. Alternative sources of material, such as disaster waste, are essential. Therefore, this paper seeks to discuss, through a literature review, the alternative application of disaster waste as material in post-disaster houses.

MATERIALS AND METHODS

To elaborate the utilization of disaster waste for post-disaster housing, the discussion will be categorized into a basic house element namely, roof, wall, structure, and foundation. Addressing the purpose of this article, a literature review was conducted by collecting material utilizing a search engine. The collection of data is accomplished by selecting appropriate scientific papers and journal using keywords such as 'disaster waste recycling,' 'building materials for post-disaster house,' ‘disaster waste for post-disaster housing,’ ‘building waste reconstruction,’ and ‘reuse material reconstruction.’

RESULTS AND DISCUSSION

Identifying Disaster Waste

The collected data is presented in Table 1. The list is ordered based on the category of disaster waste.

Table 1 Types of debris disaster waste

Debris Disaster Waste	Description
Dredging Materials	Dredging materials are those objects or materials which are evacuated during the disaster. Trees, tree stumps, dirt, rocks, and stumps
Insulation And Asbestos Materials	Asbestos is a mineral which provides resistance to corrosion and heat and is used in several building materials. Few examples of asbestos-containing materials are floor backing, gaskets, resilient floor tile, asphalt roofing, pipe insulation, ceiling and wall insulation, sprayed-on fireproofing, thermal pipe insulation and boiler coverings, ceiling tiles and damaged material which were originally non-friable. Materials which contain asbestos are highly hazardous and pose a health risk to humans
Concrete, Bricks, Tiles, And Ceramics	Concrete and bricks form most of the disaster waste and dump it in landfills. But these can be recycled by crushing it into rubble.
Wood, Glass, And Plastic	These non-inert materials can be recycled or reused and as a last resort disposed of to the landfill. Most of these materials when untreated or uncontaminated are non-

	hazardous but may sometimes contain hazardous substances.
Metallic Waste	Metallic waste in construction includes copper, bronze, brass, aluminum, lead, iron and steel, tin, mixed metals; all of these are non-hazardous and can be easily recycled. However, metals containing hazardous substances, cables containing oil, coal tar, are highly hazardous substances and demand careful handling.
Drywall	A disaster site can contain huge amounts of masonry and drywall waste.

Source: (Redling, 2018) (Endo, 2012)

Disaster waste utilization in building

The collected data is presented in Table 2. The list is ordered based on building element category.

Table 2 Disaster waste for post-disaster house references.

Building Elements	Treatment	Disaster	Countries	References
Roof	No treatment	Earthquake	Indonesia	(Sunoko et al., 2016)
Wall	Strengthened	Earthquake	Nepal, Indonesia	(Joshi et al., 2020); (Sunoko et al., 2016)
Structure	Strengthened	Earthquake	Indonesia	(Sunoko et al., 2016)
Foundation	Crushed as aggregate	Generic disaster	Japan	(Japan for Sustainability, 2006)

Concrete and bricks are majorly found in disaster waste from demolished buildings. Those materials are commonly used as the wall and foundation of post-disaster houses. Alternatively, wood is dominantly used as roof and structural elements. Some of the material unavoidably combined with new material or further treated to be strengthened as building element.

CONCLUSION

This study aimed to discuss the alternative application of disaster waste as material in post-disaster houses. Most of the literature revolves around wood, brick, and concrete for building elements. Due to the similar topic literature is still limited, further research is needed to explore the alternative use of disaster waste.

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Development of Long term and cost-effective monitoring method for riverine plastic debris in the Lower Mekong River Basin

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Keywords: Riverine plastic debris monitoring, Standardized method, Riverine Macroplastic, Riverine Microplastic, Microplastic in fish

INTRODUCTION

Rivers are known as main contributors transporting most of the plastic debris into the sea. It is estimated that the world's 10 largest contributing rivers, including the Mekong River, accounts for 88-95 % of transportation of the global load (Schmidt et al., 2017).

Mekong River Commission (MRC) is implementing a series of activities in "MRC Riverine Plastic Debris Pollution Monitoring Programme" to build a mechanism to understand the status of plastic pollution across the region.

Under this programme, MRC is now developing 3 protocols that states standardized sampling/analysis procedures that enables long-term and cost-effective monitoring across 4 member countries, that are Cambodia, Lao PDR, Thailand, and Viet Nam.

Long-term and cost-effective monitoring of riverine plastic debris over such a wide area across borders is a pioneering effort and will sure serve as a good practice for other regions.

PROGRESS SO FAR

3 protocols have different subjects of analysis, namely: Riverine Macroplastic (larger than 5mm in diameter), Riverine Microplastic (smaller than 5mm in diameter), and Microplastic in digestive tracts of fish that are commonly consumed in the Lower Mekong River Basin.

Currently, there are 3 proposed options for sampling method. First option is towing a neuston net on a boat, second option is to collect debris from fishermen that they accidentally catch during their daily fishing activity, and third option is visual observation at artificial barriers such as port and pier. These sampling methods take into consideration MRC's existing monitoring programme of water quality, fisheries and existing resources or equipment such as fishing gear so as to enable long term and cost-effective monitoring. Once the feasibility and data accuracy are confirmed through series of discussion and pilot projects conducted by the member countries, these methodologies are finalized for the actual implementation of the monitoring programme.

Analysis method is made as easy and simple as possible, while securing the accuracy of the result. For example, oxidation of organic matter in the pretreatment of microplastic analysis is a relatively slow and gentle process by adding the 30% hydrogen peroxide and leaving it for 7 days at the room temperature, instead of

Wet Peroxide Oxidation (WPO) that may cause intensive reaction.

In order to assess impacts on freshwater ecosystem, 12 common target species for the four member countries are temporarily selected with reference to the catch of fish considering their eating and swimming habitats.

These protocols were then piloted during both dry and wet seasons, as well as hands-on training session targeting the implementing agencies in each country.

Pilot project in dry/wet season

To check the feasibility of drafted monitoring methods, pilot projects were conducted in Dec 2021 (dry season) and Sep 2022 (wet season). 3 protocols were tested in each member country, and the knowledge and insight gained at the field was gathered at regional workshops.

Examples of the main issues specific in this region are the clogging of the neuston net while towing, and the high flow rate of the river. Frequent clogging of the net was caused by floating water hyacinth. Such large matter can be carefully washed in the sampler and excluded from the sample. High flow rate of the river can cause the net to rotate, and that makes it difficult to sample the plastics floating in the surface water. In this case, appropriate amount of sinker and floats has to be installed so that the net is fixed in the right position.

These region-specific issues were carefully solved through communication in the hands-on training session.

Training session

To resolve any questions regarding implementation and to ensure that data is acquired through the appropriate process by the implementing agency, a week of hands-on training was conducted in each member country.

The training consisted of three parts: (1) classroom lecture, (2) sampling practice, and (3) analysis practice, and was attended by personnel from each country who will be responsible for monitoring in the future. The practical training programme helped to resolve many questions through the process of actually conducting the sampling and analysis while interacting with the person in charge in the designated facility.

CONCLUSION

To gather the region-wide comparable data on riverine plastic debris, the standardized method as well as the robust implementational/reporting mechanism is necessary. Furthermore, it is also important to closely monitor bottlenecks in the implementation process, such as human capacity and equipment of the implementing agencies.

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Comparing Different Type of Marble Processing Wastewater Treatment Sludge in Thermochemical Upcycling of Polypropylene (PP) type Plastic Wastes

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Keywords: polypropylene, pyrolysis, recovery, travertine, white marble

INTRODUCTION

Turkey has the 40% of the world's marble reserves and yearly processes about 27000 tons. During cutting and final polishing stages, approximately 2000 tons of marble powder comes as 2-10% colloids in the effluent which is treated via coagulation-flocculation (Onen et al, 2018). Instead of disposal, it would be better to evaluate these sludges in another process to convert them economical values. Plastics become waste quickly since they are mostly used as packages. They are available materials for second- or third- generation recycled products. Pyrolysis (thermal degradation in inert environment) results in the fractionation of the material into gas, oil and coke (char) products, each are valuable for recovery of raw materials or fuel for industry (Mangesh et al., 2020; Das et al., 2020; Miskolczi and Ates, 2016).

Instead of produce-use-dispose, more sustainable approaches are getting popular in terms of circular economy. The concept of upcycling, the conversion of waste materials into materials of higher value or quality than the original, has begun to be adopted (Fuji et al., 2019). Making waste management with upcycling as a more creative approach than recycling provides better quality products. The main purpose of this study was to examine the symbiotic recovery approaches for waste PP and marble processing wastewater treatment sludge.

MATERIALS AND METHODS

Waste samples

Travertine and white marble processing wastewater sludges were collected from a local plant. Six different physicochemical treatment sludge samples were produced by applying the coagulation-flocculation (K1: Travertine+Alum; K2: Travertine+$FeCl_3$; K3: Travertine+PEL; K4: White marble+Alum; K5: White marble $FeCl_3$; K6: White marble+PEL). PP wastes (90.5% C and 3.9% O) were collected as food packages.

Pyrolysis process

Fixed-bed pyrolysis reactor (D=11 cm, h=24cm) was used in heat-insulated ceramics oven (can heat up to 900°C) operated at 5°C/min. All pyrolysis runs were performed with PP+MS(40%) mixtures at 500°C target pyrolysis temperature, without retention at target temperature. Gas, oil and solid (char) fractions were collected at the end of each run. The fractions were characterized, and upcycled products potentials were evaluated.

Analyses

GC-MS for pyrolysis gas and oil compositions; FTIR for oil and char chemical structures; TGA for thermal strengths; SEM imaging, heat values, ash contents and acidities of chars were all analyzed.

RESULTS AND DISCUSSION

The char, oil and gas fractions in Figure 1 differ such that the sharp increase in char is simply due to MS samples which help pyrolytic reactions but do not degrade until 600-700°C. MS samples increased oil fraction and gas product, which means they improved pyrolytic degradation of PP into organic structures. The MS type in the pyrolysed mixture affects the numbers and types of components in which the main components are alkane, alkene and alcohol structures, some benzene and esters in oils and ketones in gases (Figure 2) which indicated the potential of number of compounds recovery. The chemical and thermal properties were also compared as both TGA (of chars and oils), heat values (of chars and oils) and ash content (of chars).

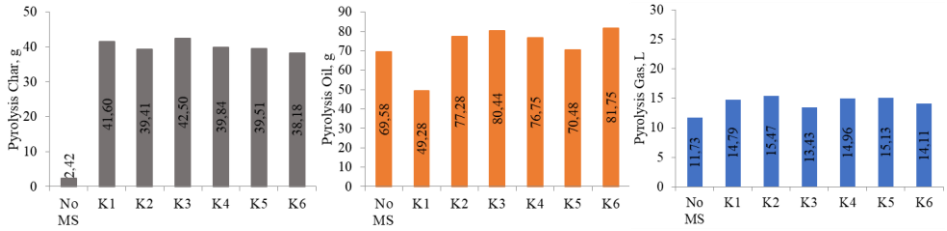

Figure 1 Distribution of pyrolysis fractions

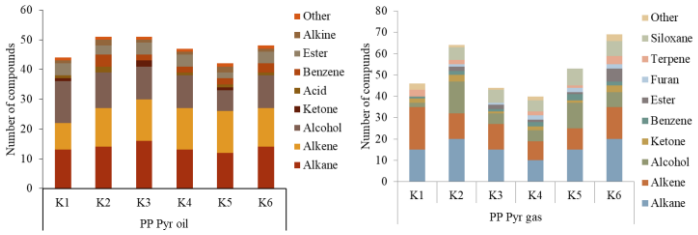

Figure 2 Pyrolysis oil and gas product organic component distributions

CONCLUSION

The study investigated the valuable products recovery potential from the products of pyrolysis of MS and PP wastes, therefore developed a symbiotic solution to two major types of wastes.

ACKNOWLEDGEMENT

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Co-pyrolysis characteristics of polylactic acid and petroleum plastics

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Keywords: pyrolysis, chemical recycling, polylactic acid, petroleum plastics

INTRODUCTION

The generation of waste plastic is annually increasing, and the demand for waste plastic recycling is rapidly and globally growing to allow sustainable plastic use. Resource Circulation Strategy for Plastics has established several milestones; one of them aims to introduce ~2 Mt of bio-based plastics by 2030. Therefore, we will have opportunities to co-treat petroleum- and bio-based plastics at the recycling stage. Pyrolysis is a promising chemical recycling method to recover chemical feedstock from polymeric materials by thermally decomposing polymeric materials in an inert atmosphere. In this work, co-pyrolysis behavior of polylactic acid (PLA) as a biodegradable plastic and high-density polyethylene (HDPE), polypropylene (PP), and polystyrene (PS) as common petroleum plastics was investigated.

MATERIALS AND METHODS

Samples

Reagent grade PLA, HDPE, PP, and PS were pulverized by using a cryomill and were mixed to obtain the desired blending ratio of samples (PLA:HDPE = 100:0, 50:50 (PLA50HDPE50), 20:80 (PLA20HDPE80), 10:90 (PLA10HDPE90), and 0:100).

Analysis

Thermogravimetric analysis (TGA)

The samples (10 mg) were heated from 50 °C to 700 °C with heating rates of 5, 10, 20, 30, and 40 °C/min to investigate weight loss behavior during pyrolysis.

Pyorolysis-gas chromatography/mass spectrometry (Py-GC/MS)

The samples (1 mg) were pyrolyzed from 50 °C to 700 °C with a heating rate of 10 °C/min by using a pyrolyzer. The pyrolysis products were directly analyzed by GC/MS.

Evolved gas analysis-mass spectrometry (EGA-MS)

The evolved gases during pyrolysis under the same pyrolysis conditions with Py-GC/MS analysis were directly introduced into MS through a deactivated metal capillary tube.

RESULTS AND DISCUSSION

TGA revealed that the pyrolysis temperature ranges of PLA and HDPE were 298-386 °C and 435-510 °C, respectively. It suggests that each plastic independently decomposes under slow heating conditions. In fact, the co-pyrolysis of PLA50HDPE50 showed two-step weight loss (Figure 1). The experimental curve almost overlaps with the calculated curve, which suggests there is no interaction during co-pyrolysis of them under this condition. Figure 2 shows the pyrograms obtained from PLA, HDPE, and PLA50HDPE50. The main PLA pyrolyzates were acetaldehyde, lactides, and PLA oligomers. Acetaldehyde and lactide have a main fragment ion of m/z = 29 and 56, respectively. HDPE mainly produced alkenes with various carbon numbers. We selected m/z = 71 as a fragment ion of aliphatic hydrocarbons. The pyrogram of PLA50HDPE50 (Figure 2(c)) included both PLA and HDPE pyrolyzates. Figure 3 shows the total ion chromatogram (TIC). The TIC of the mixed samples showed two independent peaks at 364 °C and 478 °C, which are comparable temperatures of the DTG peaks of PLA and HDPE, respectively. The peak top temperatures of the selected ions of m/z=29, 56, and 71 were consistent with those of the TIC.

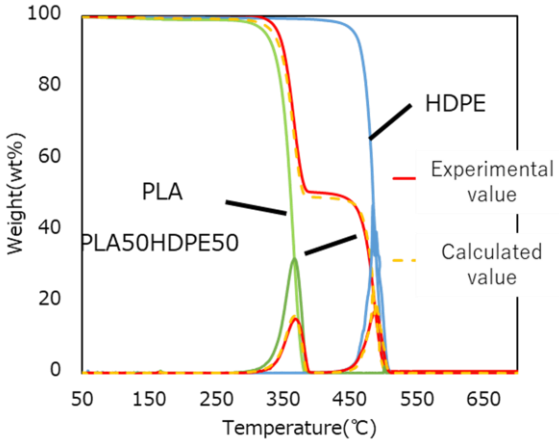

Figure 1 TG/DTG curve of PLA50HDPE50

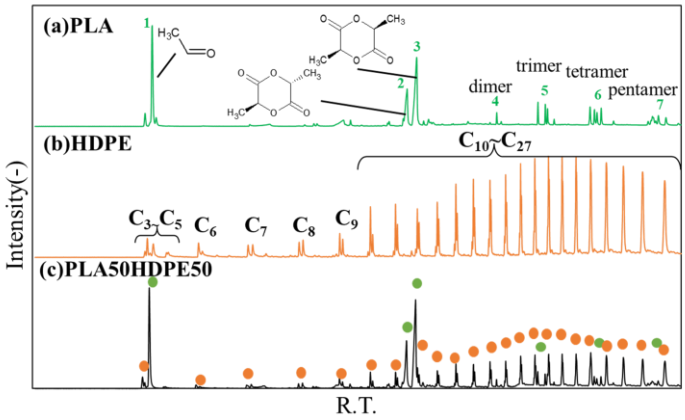

Figure 2 Pyrogram of PLA, HDPE and mixture

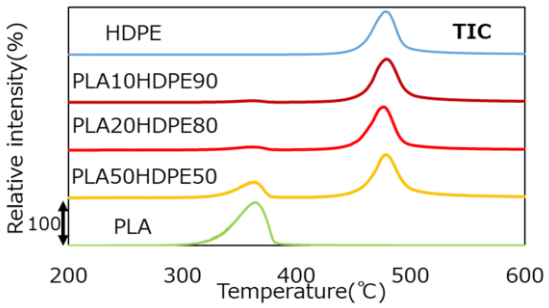

Figure 3 TIC curve of PLA+HDPE

CONCLUSION

This work investigated the co-pyrolysis behavior of PLA and petroleum plastics such as HDPE, PP, and PS. This comprehensive analysis revealed that there is no pyrolytic interaction between PLA and HDPE, PP, and PS during co-pyrolysis under slow heating rates. Each plastic decomposed independently in the mixture due to its different decomposition temperatures. Thus, the incorporation of PLA into HDPE, PP, and PS does not alter the pyrolysis reactions of them under this condition, which will be a beneficial finding for considering the treatment of PLA-containing plastic wastes in the future.

ACKNOWLEDGEMENT

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Wet Process Debromination of Waste Printed Circuit Boards

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Keywords: Waste Printed Circuit Board, Debromination in Wet Process, Iron Powder

INTRODUCTION

A waste printed circuit board (WPCB) consists of insulating resins and conducting metals. Whereas copper composes the majority of metal content, WPCBs also contain valuable metals, such as gold and silver. Accordingly, WPCB recycling offers considerable economic value. However, WPCB resins often contain brominated flame retardants (BFRs), which may endanger the human body and the environment. WPCB debromination could minimize the risks of WPCB recycling. In this study, we focused on improving "wet method" BFR debromination efficiency, which has a lower environmental impact than the dry method, using iron powder as a catalyst[1)].

MATERIALS AND METHODS

To maximize surface area, WPCB was crushed (diameter < 2 mm; 1.0 g). Ethylene glycol (EG; 50 mL) was added to a three-necked flask (100 mL), followed by NaOH pellets to reach the desired concentration (0.5 M). The temperature was slowly increased, and after the solution reached the desired temperature (100–190 °C), the crushed WPCB and reduced iron powder (0–0.8 g) were added, and the mixture was stirred (200 rpm; 1–5 h). The samples were then analyzed using ion chromatography (IC) to determine the debromination rate. In addition, solid residues were separated using vacuum filtration, and the solid residues were subjected to Fourier-transform infrared (FT-IR) spectroscopy.

RESULTS AND DISCUSSION

Effect of reduced iron powder on debromination ratio

Figure 1 shows the progress of WPCB debromination for various loadings of iron powder (0–0.8 g) was added. The debromination rate increased with increasing amount of added Fe powder. WPCB debromination after 5 h increased with increasing iron loading (0–0.8 g; maximum 50.2%). Further increased (0.8–1 g) iron loading did not substantially improve debromination. Accordingly, the following experiments used 0.8 g of iron powder.

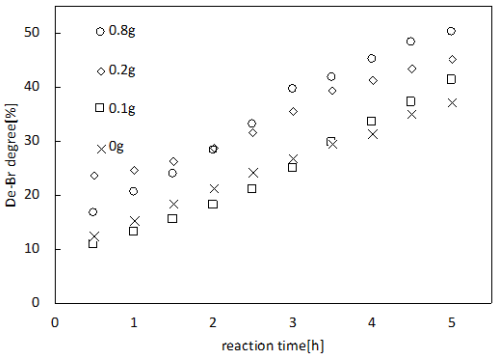

Figure 1 Effect of iron powder addition on debromination rate[2)]

Effect of temperature on debromination rate and reaction rate analysis.

Figure 2 shows the progress of WPCB debromination for various reaction temperatures. Debromination was limited at temperatures of 160 °C or lower, but improves at 190 °C, near the boiling point of EG (197 °C). In addition, an Arrhenius plot was obtained, assuming that the debromination proceeded under pseudo-first-order conditions; this plot was analyzed to obtain the apparent debromination activation energy (58.06 kJ/mol).

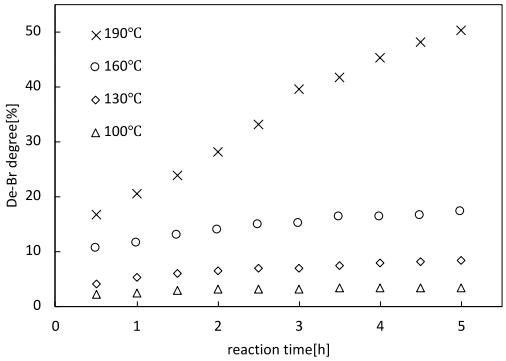

Figure 2 Effect of temperature on debromination rate[2)]

Investigation of debromination reaction mechanism

FT-IR spectroscopy was performed on the solid residue after debromination. FT-IR spectra showed signals attributable to O–H stretches (3000–3600 cm^{-1}) and C–O stretches (1000 cm^{-1}), consistent with the presence of OH groups. WPCB often contain tetrabromobisphenol A (TBBPA) BFRs. Because the bromines in TBBPA are directly bonded to the aromatic ring, elimination reactions, such as E2 elimination, do not occur. Therefore, Figure 3 shows a plausible debrominative substitution step where the OH^- from the base reacts with TBBPA .

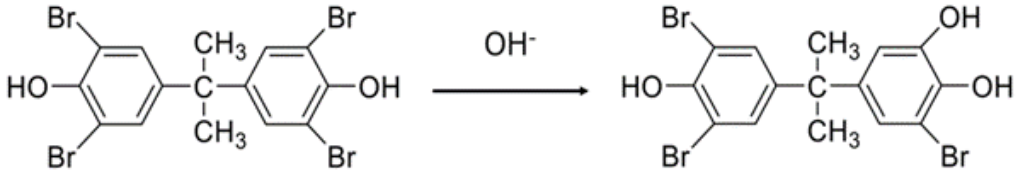

Figure 3 Debromination of TBBPA[2)]

CONCLUSION

In this study, we focused on the wet method, which can remove bromine with a lower environmental impact than the dry method. The addition of iron powder to the NaOH/EG solution increased debromination yields up to 15%, and optimal debromination was observed at 190 °C. The apparent pseudo-first-order activation energy was calculated to be 58.06 kJ/mol. The results of the FT-IR spectra suggest that the solid residue has OH^- groups, suggesting that debromination may proceeds via a substitution reaction involving OH^- of the base.

ACKNOWLEDGEMENT

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Recovery of NaCl by Electrodialysis to Establish Chlorine Circulation

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Keywords: Electrodialysis, Dechlorination, Chlorine Circulation

INTRODUCTION

Polyvinyl chloride (PVC) resin is used in a variety of products and has the third highest production amount among resins in Japan [1]. However, the chlorine content of PVC hinders recycling efforts, raising concerns regarding the corrosion of recycling equipment and adverse effects on human health and the environment. To reduce these risks, we optimized and scaled up a dechlorination protocol for PVC by wet process pretreatment using a NaOH/ethylene glycol (EG) solution [2]. The chlorine desorbed from PVC after the treatment is present in the form of sodium chloride in effluent, so the recovery of sodium chloride leads to the establishment of the chlorine circulation. In our laboratory, we conducted electrodialysis experiments with a lab-scale apparatus [3]. In this study, to achieve more energy-efficient NaCl recovery, electrodialysis parameters were optimized using a bench-scale electrodialysis apparatus.

EXPERIMENTAL

Figure 1 shows a schematic of the electrodialysis apparatus used in this experiment [4]. Sixty pairs of alkali-resistant ion-exchange membranes were used. Aqueous $NaNO_3$ (3 L; 0.5 M) was used as the electrode. The dilute solution contained EG (4 L), NaCl (8 g/L), and NaOH (32 g/L), whereas the concentrated solution contained aqueous NaCl (4 L; of 40 g/L). Each solution was circulated through the apparatus using a pump, and a voltage was applied after they were arranged at the specified flow rate. The experiment was conducted for 1 h and sampling was performed every 15 min. Each sample was analyzed using ion chromatography (IC) and total organic carbon (TOC) analysis, which were used to calculate NaCl recovery yields and solvent penetration.

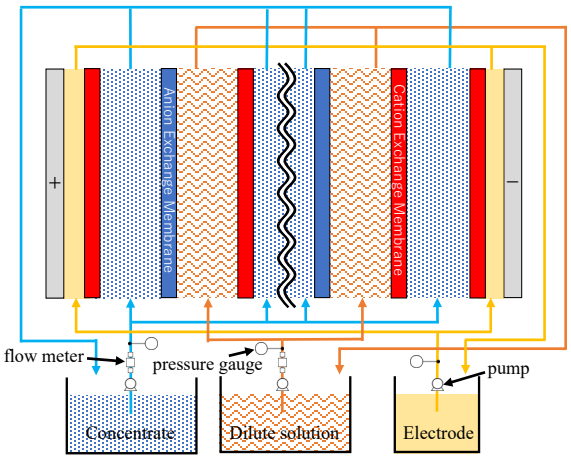

Figure 1. The schematic diagram of the electrodialysis apparatus [4]

RESULTS AND DISCUSSION

Effect of flow rate on processing

Figure 2 shows the NaCl recovery yield and penetration of each solvent over time at different flow rates (2.5–7.0 L/min) [4]. All experiments were conducted at a voltage of 30 V. Variations in flow rate did not induce any significant difference in either the NaCl recovery yield or solvent penetration. However, unlike previous

studies, herein we demonstrated bench-scale chlorine recovery using EG solutions containing both NaOH and NaCl.

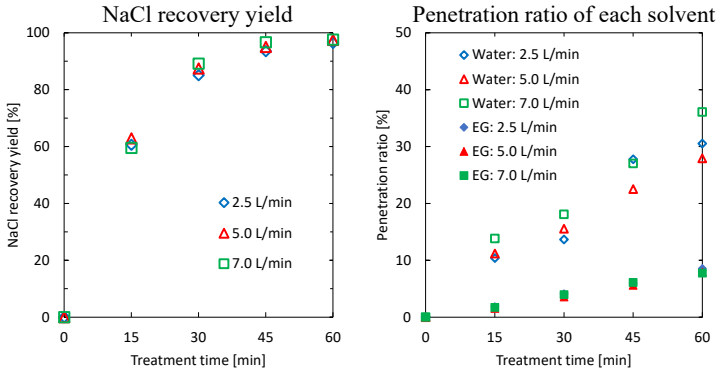

Figure 2. Results for varying Flow rate (Voltage: 30 V) [4)]

Effect of voltage on processing

Figure 3 shows the NaCl recovery yield and solvent penetration over time at different voltages (10–40 V) [4)]. All experiments were conducted at a flow rate of 5.0 L/min. Increased NaCl recovery yields were obtained at increased voltages. At or above 20 V, excellent NaCl recovery yields (>90%) were obtained with similar recovery rates. Accordingly, 20 V was determined to be the voltage for optimal power efficiency and yield. Water penetration decreased, whereas EG penetration increased, with increasing voltage. It was suggested that the mass transfer in the direction of NaCl recovery was promoted.

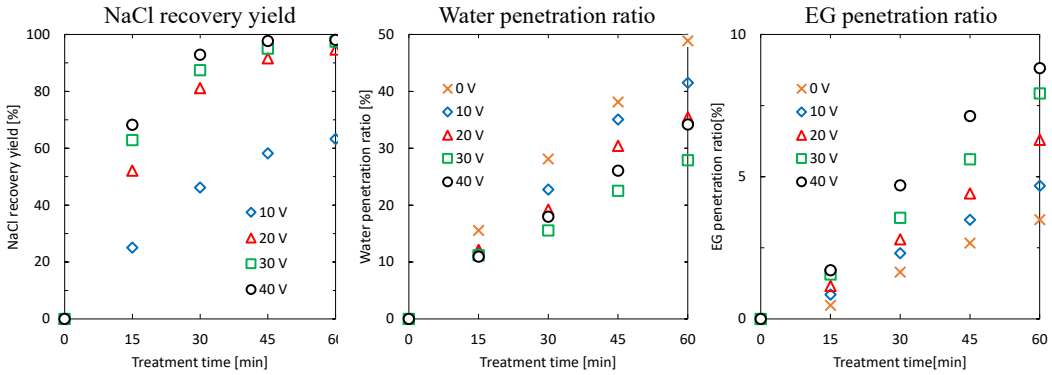

Figure 3. Results for varying Voltage (Flow rate: 5.0 L/min) [4)]

CONCLUSION

In this study, a bench-scale electrodialysis apparatus was optimized for recovery of sodium chloride effluent from the dechlorination of PVC using an NaOH/EG solution. Whereas flow rates did not meaningfully effect NaCl recovery, power-efficient NaCl recovery was optimal at 20 V. Evaluating the impact of other factors in future studies will lead to energy-efficient NaCl recovery.

ACKNOWLEDGEMENT

This work was supported by JSPS KAKENHI (grant number JP20H05708).

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Gasification characteristics of biochar from mushroom waste media of three kinds of carbonization reactors

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Keywords: Biochar, Gasification, Carbonization, Mushroom Waste Medium, Agricultural by-products

INTRODUCTION

Biomass energy is attracting attention as a next-generation energy source because it is less likely to be depleted than fossil fuels and has high renewable potential. Agricultural by-products are by-products generated from agricultural activities and are mainly used as feed or soil conditioners. Recently, as the incineration of agricultural by-products is prohibited, there is a limit to the treatment method. Agricultural by-products have a relatively high energy potential and can be used as fuel, so they are valuable as resources. Gasification is a technology that converts biomass into energy. During the gasification process, syngas containing CO, H2, CH4, etc. can be obtained. Agricultural by-products have low energy density and are vulnerable to moisture, so they must go through a pretreatment process such as a carbonization process. Through the carbonization process, bulk density and heating value can be improved, tar generated during gasification can be reduced, and yield can be improved. In this study, biochar gasification experiments were conducted after various carbonization reactions using mushroom waste, and the characteristics of the generated syngas were identified and compared.

MATERIALS AND METHODS

Materials

King oyster mushroom waste medium was used as the experimental material and was collected in Hadong-gun, Gyeongsangnam-do, Korea.

Table 1 Characteristics of Mushroom waste medium used in this study

Sample	Elemental Analysis (wt. %)				Proximate Analysis (wt. %)			HHV
	C	H	O	N	FC	VM	Ash	[kcal/kg]
MWM	41.02	5.33	43.08	2.66	20.77	71.60	7.63	3870.97

Carbonization and Gasification

The carbonization reaction was carried out using three reactors: hydrothermal carbonization, carbonization and microwave hydrothermal carbonization. The reaction temperature was carried out for 30 minutes at 200~250°C. The gasification reaction of biochar proceeded at 800°C and 1000°C for 30 minutes, and then the composition was compared using GC-TCD to compare the composition of the generated gas. Hydrothermal carbonization and microwave reaction were performed by mixing raw materials and water in a 1:1 ratio, and the resulting liquid-solid mixture was separated and used for gasification. The carbonization reaction was used after drying the raw material at 105°C. for 24 hours.

RESULTS AND DISCUSSION

Figure 1 shows the results of the basic analysis after carbonization. As the carbonization reaction temperature increased, C increased and the ratio of O to H decreased in all three reactions. As O and H decreased, the volatile matter also decreased and the fixed carbon content increased. It was confirmed that the calorific value also increased with the increase of C and fixed carbon. Hydrothermal carbonization showed the highest C and fixed carbon content and the highest calorific value. In the case of Product Yield, carbonization showed the highest yield and hydrothermal carbonization showed the lowest yield when compared at 250°C.

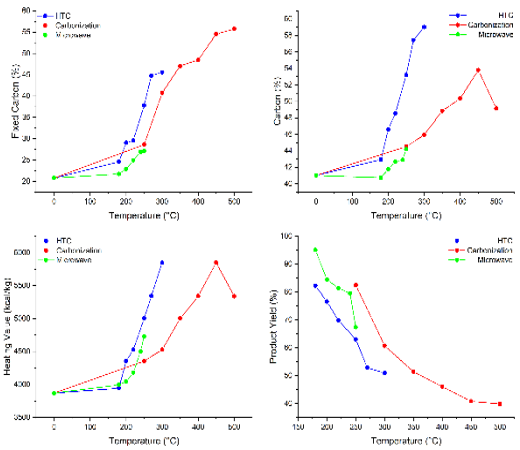

Figure 1 Biochar properties

Figure 2 below shows the result of syngas components. The H2 content increased as the carbonization reaction temperature increased at both 800 and 1000°C, and hydrothermal carbonization showed the highest H2 content when compared at the reaction temperature of 250°C. As the reaction temperature increased, it was confirmed that the value of H2+CO increased as the H2 content increased. At a reaction temperature of 250°C, gasification at 1000°C also showed the highest value in carbonization when comparing H2+CO.

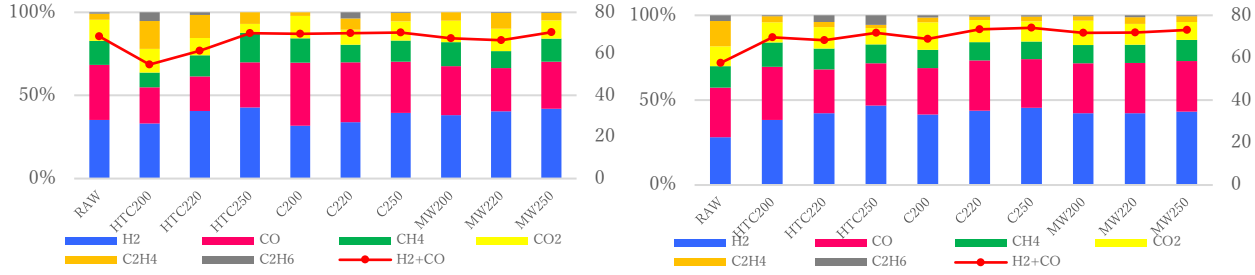

Figure 2 Gasification results after the carbonization

CONCLUSION

This study was conducted to compare the gasification characteristics of biochar according to the carbonization reaction. In the three carbonization reactions, it was confirmed that the higher the reaction temperature, the higher the content of C and fixed carbon, and accordingly the calorific value. As a result of gasification, it was confirmed that the H2 content increased as the reaction temperature increased, and it was confirmed that the biochar produced by hydrothermal carbonization at a reaction temperature of 250°C had the highest hydrogen content during gasification. The H2+CO result increased after carbonization, but considering the yield, Microwave is considered to be the most effective.

ACKNOWLEDGEMENT

This work was supported by Korea Institute of Planning and Evaluation for Technology in Food, Agriculture and Forestry(IPET) and Korea Smart Farm R&D Foundation (KosFarm) through Smart Farm Innovation Technology Development Program, funded by Ministry of Agriculture, Food and Rural Affairs(MAFRA) and Ministry of Science and ICT(MSIT), Rural Development Administration (RDA)(421000-00) and the Korea Ministry of Environment as Waste to Energy-Recycling Human Resource Development Project (YL-WE-22-001)

The unutilized biomass grouping in Korea for alternative fuel by Principal component analysis (PCA) and cluster analysis

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Keywords: unutilized biomass, agricultural by-products, Principal component analysis, cluster analysis

INTRODUCTION

Recently, attention has been paid to sustainable energy production using biomass as an alternative energy source for fossil fuels. The climatic conditions of South Korea are different from those of Southeast Asia; hence, production of the same kind of biomass for a year is difficult. Conversely, various waste biomass has been developed for a year. Differences in agricultural production during the four seasons results in different types of biomass waste being produced in different seasons. As a result of investigating domestic biomass, the typical agricultural by-products can be classified for supply stability as rice husk, mushroom waste medium, field crops and various fruit pruning products that are mass-produced.

In this study, the chemical analysis of unutilized biomass with different occurrence frequencies depending on seasons. The results were conducted to classify through principal component analysis and cluster analysis, it was confirmed whether the stable fuel security was possible.

MATERIALS AND METHODS

A more than 35 kinds of biomass were collected by collecting 30 types of agricultural by-products including 5 types of waste mushroom media, pruned branches of fruits (apple, grape, pear) and field crops (corn) in each region.

PCA method

- Find the correlation matrix R.
- Find the eigenvalues and eigenvectors of R.
- Among the generated principal components, the first k factors with a large proportion in the sum of all eigenvalues are selected.
- Find the component matrix L1.

Cluster analysis

It is used when objects are grouped into homogeneous clusters based on the similarity of various rights and the rights belonging to the same cluster are investigated. The most used Euclidean distance equation was used.

$$d(A,B) = \sqrt{\sum_{i=1}^{n}(X_n - X_{Bi})\,2}$$

RESULTS AND DISCUSSION

Woody biomass such as branches, was found to be high in carbon, was found to be high in carbon, while mushroom waste medium exhibited a high Ash content. Figure 1 shows PCA results. The average calorific value of wood was 4000kcal/kg, while that of ground mushroom waste medium was 3000kcal/kg. Mushroom waste medium with high Ash content is drawn with a negative value. In the case of fruit pruning branches, persimmon, shine muscat, and apple cherry show similar values, indicating that they are close. When I tried PCA grouping, similar ingredients were grouped together.

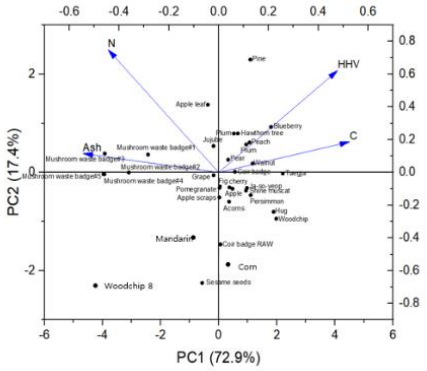

Figure 1 PCA results.

Figure 2 shows PCA grouping using cluster analysis results. As a result of cluster analysis, the group was divied into four groups A, B, C and D. It was found that similar components of mushroom waste medium fruit trees and pruned branches were grouped together.

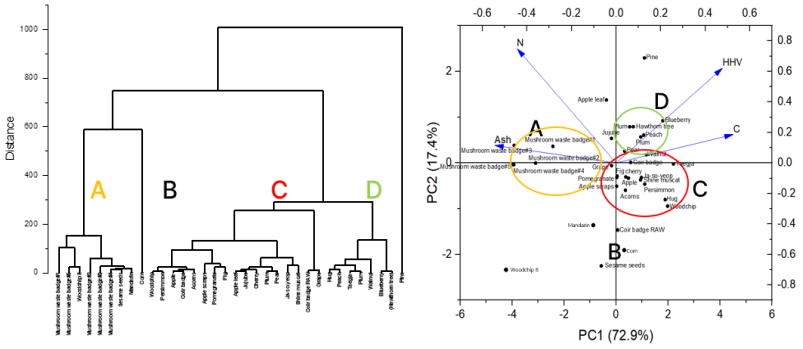

Figure 2 Cluster analysis using PCA grouping

CONCLUSION

This study, the chemical analysis of unused biomass with different occurrence frequencies by season and crop was classified through Principal component analysis and it was confirmed whether stable fuel security was possible. In this sense, when looking at the samples grouped into A, C, and D, samples with similar values of high calorific value, Ash, Nitrogen, and Carbon are grouped together, so it is expected that stable fuel will be secured if the unused biomass grouped through PCA analysis grouping is used.

ACKNOWLEDGEMENT

This work was supported by the Korea Institute of Planning and Evaluation for Technology in Food, Agriculture and Forestry (IPET) through Agricultural Energy Self-Sufficient Industrial Model Development Program, funded by Ministry of Agriculture, Food and Rural Affairs (MAFRA) (No. 321002-02) and the Korea Ministry of Environment as Waste to Energy-Recycling Human Resource Development Project. (YL-WE-22-001)

Phosphorus Removal Performance in a One-stage Partial Nitritation/Anammox Process with HAP-Based Granules

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Keywords: Anammox, HAP granules, nitrogen, phosphorus

INTRODUCTION

The autotrophic anaerobic ammonium oxidation (anammox) process that converts NH_4^+ and NO_2^- to nitrogen gas is attracting increasing interest because of the high efficiency and low cost compared with conventional nitrification and denitrification. Furthermore, the application of PN/A process can simplify the nitrogen removal procedure through the synergy between nitritation by AOB and anammox by AnAOB in the same reactor as the eq. (1).

$$NH_4^+ + 0.85O_2 \rightarrow 0.11NO_3^- + 0.445N_2 + 1.13H^+ + 1.43H_2O \quad (1)$$

Recently, studies of the granulation with hydroxyapatite (HAP), expressed by $Ca_{10}(PO_4)_6(OH)_2$, is rising. HAP-based anammox process can achieve the simultaneous nitrogen removal and phosphorus recovery due to the formation of HAP, according to the following eq. (2). Besides, a higher biomass content also can be achieved due to the denser and well-settling HAP granules.

$$10Ca^{2+} + 6PO_4^{3-} + 2OH^- \rightarrow Ca_{10}(PO_4)_6(OH)_2 \quad (2)$$

This study focused on the nitrogen and phosphorus removal performance of one-stage PN/A process with HAP-based syntrophic granules for treating the high loading ammonium wastewater.

MATERIALS AND METHODS

Reactor set-up

A lab-scale integrated reactor was developed to concurrently achieve PN/A and sludge sedimentation. As shown in Figure 1, an air-lift completely mixed zone with 5 L effective volume was used. In the reactor, the temperature was maintained at 25 °C with a heater, pH was 7.6-8.1 and dissolved oxygen (DO) was bellow 0.2 mg/L during the entire operation.

As Table 1 shows, the experiment was divided into 18 phases with different hydraulic retention time (HRT) and calcium addition. The influent ammonium nitrogen and phosphorus concentration were 500 mg/L and 18 mg P/L, respectively.

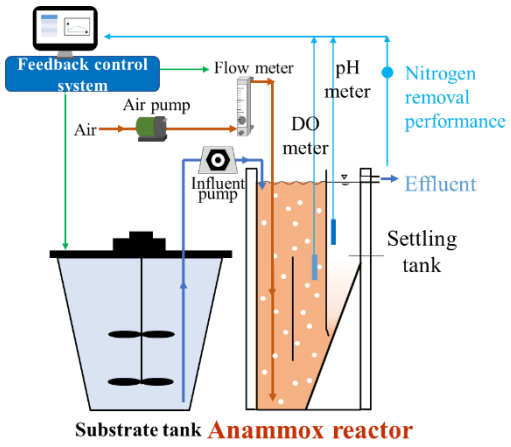

Figure 1 Diagram of PN/A process

Table 1 Operational conditions

Phase	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
HRT (h)	12	8	6	6	12	8	6	8	8	7	6	5	4	3.5	3	2.5	2.2	2
PLR ($g\ P/m^3/d$)	36	54	72	72	36	54	72	54	54	62	72	86	108	123	144	173	196	216
Influent Ca^{2+} (mg/L)	35	35	35	45	45	45	55	65	100	90	90	90	75	75	75-145	100-150	120	90-115

RESULTS AND DISCUSSION

Nitrogen and phosphorus removal performance

As shown in Figure 2, the phosphorus removal efficiency (PRE) was no more than 10% when the influent calcium concentration was 35 mg/L at the beginning. With the influent calcium concentration increasing, the PRE increased. The PRE increased to 90% when the influent calcium concentration was 150 mg/L. The Ca/P ratio of the inorganic granules was around 2.4, close to the theoretical value 2.2 of the HAP.

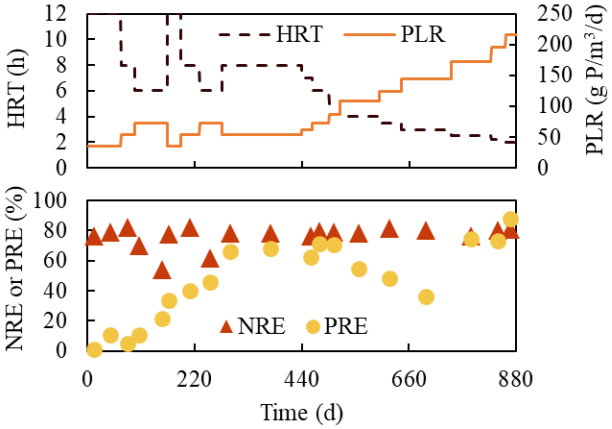

Figure 2 Operational performance

In addition, approximately 80% of the inorganic part was calculated to be HAP. The removed phosphorus deposited at the bottom, which can be recycled as phosphorus resource.

Nitrogen removal efficiency (NRE) of 81% was achieved stably, and no inhibition occurred due to the calcium addition and HAP formation.

CONCLUSION

In this study, the phosphorus removal ability was improved with HAP formation in a one-stage HAP-enhanced PN/A process, and a high PRE of 90% was achieved when the influent calcium concentration was 150 mg/L. Simultaneously, a stable NRE of 81% was achieved at 25 °C.

ACKNOWLEDGEMENT

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Interventions to Prevent Household Food Waste with Supporting Tools: Evaluation by Cloud-Based Weighing System

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Keywords: *household food waste, intervention, ICT, nudge, cloud-based measuring*

INTRODUCTION

Food waste is a global issue. In Japan, 5.7 million tons of food waste is generated in 2018, and about a half is generated by households [1]. It has been pointed out that informational interventions are not very effective [2] and new types of interventions utilizing ICT and other methods are being considered. For example, ICT-based mobile apps are expected to be effective as reviewed by Farr-Wharton et al.[3] In this research, we selected 5 supporting tools for interventions shown in the Table 1 to prevent food waste at home especially targeting foods in the refrigerator. The objective of this research was to quantitatively analyze and clarify the effects of the interventions on changes in the amount of food waste, as well as their impact on awareness and behavior.

Table 1 Five Interventions

Apps	Manage food inventory and expiration dates by mobile apps.
Photo	Take photo of foods inside of the fridge and use it to remind inventory.
Magnet	Put magnets on the fridge door to manage food inventory and expiration dates.
FridgeOrg	Organize fridge by using cases and tape to divide the refrigerator into areas.
Sticker	The message on sticker makes people aware of food items in the back of the fridge.

MATERIALS AND METHODS

The research was conducted among 44 households of college students in Japan for 5 weeks in May-July 2022 with a 2-week baseline, 2-week intervention and 1-week follow-up period. Food waste was measured using a cloud-based weighing system (called "SmartMat Cloud"), which consisted of a mat-type weighing device with a waste bin and a Wi-Fi router. Participants were asked to separate food waste and put it into the bin at home. For students live with family, we asked family member who mainly manage food at home to participate as well. All students were asked to make entries in Food Waste Diary starting the second baseline week. Questionnaires were taken 4 times: before the start of the project, before and after the intervention period, and at the end of the follow-up period. Measurements were taken 24 times a day and were automatically transmitted to the cloud system. With the food waste measurement data and first 3 surveys, two-way mixed ANOVA and other statistical methods were used to evaluate the effectiveness of the interventions.

RESULTS AND DISCUSSION

Food waste measurement data through SmartMat: The mat used in this study was with load capacity

of 5 kg, a measurement unit of 1 g, and a max. error of ±0.15% (2.5 g/1 kg). Since many data caused by error variation were generally less than 5 g, only the rising values were treated as food waste weight with the threshold value of 5 g. After checking the data against the data graph and the number of entries in Food Waste Diary, data from 5 mats with significantly more measurements than the others were excluded from the analysis.

Participants and food waste reduction trend: The attributes of 44 participants are shown in Table 2. There was no control group; participants were surveyed their intervention preferences and assigned. Food waste measurement data showed an average reduction of 206 g / (2-week *household) pre and post intervention, and a reduction of about a half of that in the 2-week period average. For the trends of 5 interventions, all showed a decreasing trend showed in Figure 1.

Table 2 The Attributes of Participants

Participants	All	Male	Female
Student	44	26	18
Live with Family	27	13	14
Live Alone	17	13	4

(N=44, person)

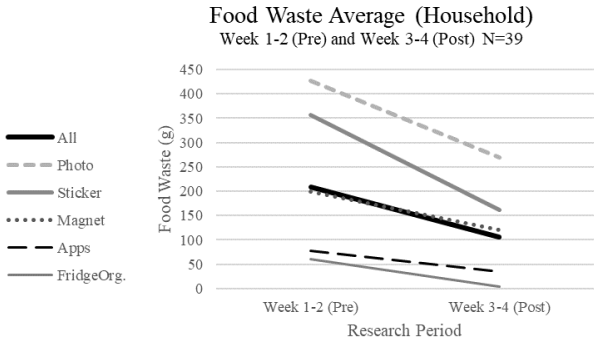

Figure 1 Food Waste Average by Interventions

The effects of interventions on food waste: A two-way mixed ANOVA was conducted on the pre and post intervention food waste 2-week average per household, with the effect and type of intervention as factors and the number of family member as a covariate. The number of family member ($F(1,31)=5.35, p=.028$) and the intervention effect ($F(1, 32)=13.49, p=.001$) were significant, indicating that the intervention was effective in reducing the amount of food waste. However, this effect includes the effects of food waste separation and use of dedicated trash bins, and Food Waste Diaries.

CONCLUSION

This research was to evaluate the effects of interventions using 5 supporting tools to prevent household food waste. The effect of the interventions was significant as the food waste amount was reduced before and after the interventions. This is the first research using the cloud-based weighing system, and after further study and improvement, research with an increased number of participants and a control group is planned for FY2023.

ACKNOWLEDGEMENT

This research has been supported by the Environment Research and Technology Development Fund (JPMEERF20223M03) by the Ministry of the Environment, Japan.

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Evaluation of Air Pollution Emission during Recycling Process of Carbonization Disposable Chopsticks Waste into Charcoal

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Keywords: recycling, carbonization, disposable chopstick waste, charcoal making, air pollution

INTRODUCTION

Charcoal is a kind of renewable energy source that could be used in the open area to reduce air pollution compared to using wood as energy sources. Our previous report proposed the recycling disposable chopsticks (DC) into charcoal at 650°C by carbonization process for using as a renewable energy source (Jodnok et al, 2022). This recycling DC charcoal has calorific value of 32.8 MJ kg^{-1} with high fixed carbon at 80% wt. However, charcoal making process is doubtful with the air pollution emission during the carbonization process. In order to proclaim the recycling DC charcoal process with environmentally friendly point of view, the evaluation of air pollution emission during our charcoal making process at 650°C was elucidated.

MATERIALS AND METHODS

DC waste was collected and used as raw materials for making DC charcoal at 650°C. The size of DC wastes is 200 – 220 mm in length and the diameter is 4.8-5.0 mm. The weight of DC wastes is 3.25 g/piece (6.50 g/pair). The physical and chemical characteristics of DC waste and charcoal are in Jodnok et al. 2022.

The laboratory scale kiln used in this study is a stainless-steel pot with lid (28 cm in diameter) setting with a thermocouple thermometer type K for measuring kiln temperature as shown in Figure 1. LPG gas stove burner was used as heating source for kiln. The kiln temperature was controlled at 650°C for 1 hour during carbonization process for recycling DC waste to charcoal.

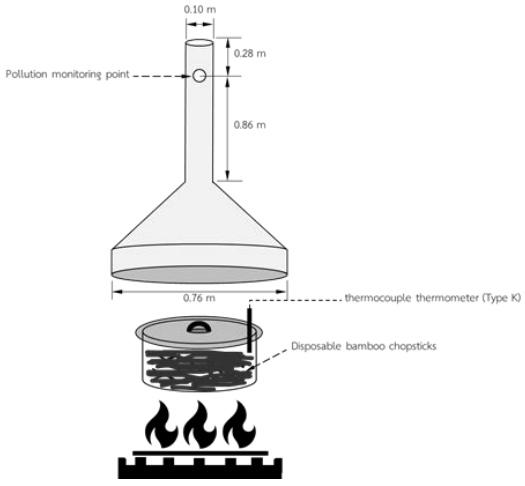

Figure 1 Experimental set up

The experimental set up of air pollution detection, followed USEPA, 1995 method no.1 and 2, is shown in figure 1. The hood was placed above the kiln and LPG gas stove burner. KIGAZ 310 Analyzer combustion used for detection of CO, CO_2, SO_2, NO and NO_x was set at the pollution monitoring point. The detected air pollutions were recorded every 5 minutes for 145 minutes duration after ignition for starting carbonization process to kiln.

RESULTS AND DISCUSSION

The duration time of 145 minutes along the experiment was separated into 60 minutes of charcoal making at 650°C and 85 minutes after stop the process until the smoke disappeared. The detected air pollutions concentration was recorded every 5 minutes of CO and CO_2 as shown in figure 2 (a), and of SO_2, NO and NO_x as shown in figure 2 (b). The highest emission pollution of CO showed at 5 minutes after ignition as much as $10.767x10^3$ ppm, and gradually decreased until 40 minutes, after that constantly emission around $0.1x10^3$ ppm until the end of experimental time. The highest emission pollution was CO_2, gradually increased and constantly emitted around $50x10^3$ ppm after 100 minutes until the end of experimental time. NO, NO_x and SO_2 were emitted in a small fraction compared to CO and CO_2.

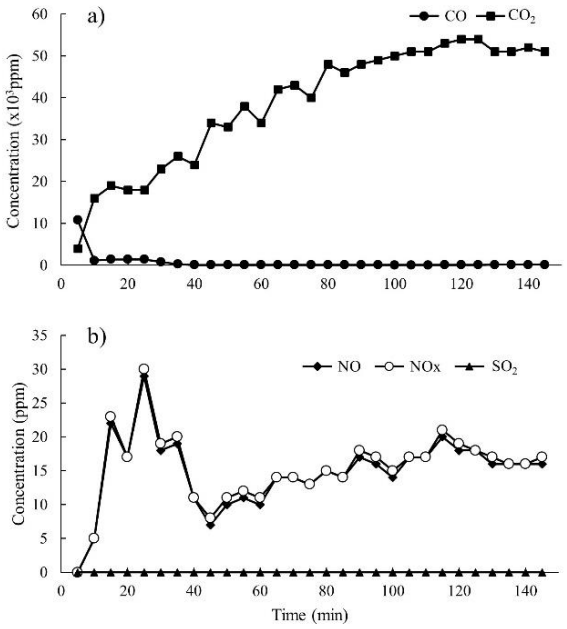

Figure 2 Concentration of air pollution

The integration of the pollution concentration and time were calculated and summarized into air pollution in kgs per kg DC wastes and into air pollution in kgs per kg charcoal product as shown in Table 1. The CO and CO_2 emission were around 1 and 8 kg/kg DC charcoal product, CO/CO_2 emission ratios were 0.125. These values are in the similar range as making charcoal from wood in Thailand (US EPA 1999).

Table 1 Air pollution emission during the experiments for 145 minutes

Parameters	CO	CO_2	SO_2	NO	NO_x
Pollution in kgs/kg DC wastes	4.037	32.157	0.00	0.008	0.012
Pollution in kgs/kg DC charcoal product	1.009	8.039	0.00	0.002	0.003

CONCLUSION

The emission air pollution during DC charcoal making at 650°C was mainly found with CO and CO_2 at 1.009 and 8.039 kg/kg DC charcoal product, respectively. The emission of SO_2 was not detected. The emission of NO and NO_x were slightly found at 0.002 and 0.003 kg/kg DC charcoal product, respectively.

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Recycling Disposable Diaper Waste to Building Material: Urban Society Insight

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Keywords: disposable diaper waste, urban area, waste management, building material, waste recycling

INTRODUCTION

It has been substantially agreed that the environmental impact of disposable diaper waste is necessary. Every year, over 20 billion disposable diapers are discarded into landfills, amounting to more than 3.5 million tons of garbage, and this figure is increasing year after year (Environment Agency, 2008). Previous study surveyed people's preferences for disposable diaper waste treatment and found 5-40% of this waste is disposed of in landfills without additional processing. The majority of respondents said they threw trash in the open or in any place (Wambui, 2015), this habit causes contamination to water, which is most likely to cause diarrhea, exacerbated by waste conditions that are difficult to degrade, although burning will also produce unfavorableresults because the gas produced will have an adverse impact on the environment. Furthermore, individuals commonly dispose of diaper trash by wrapping it in plastic, which promotes slow biological degradation in landfills (Valdemar, et.al, 2011; Valdemar, et.al, 2014). In line with population increasing annually in Indonesia, diapers as non-biodegradable waste is one of the serious environmental issues especially in urban areas. In construction sector, one of attempts to tackle the issue is by recycling it into building materials. However, the method is still uncommon for public. The aim ofthis article is to understand public perception towards recycling diapers waste especially in urban area.

MATERIALS AND METHODS

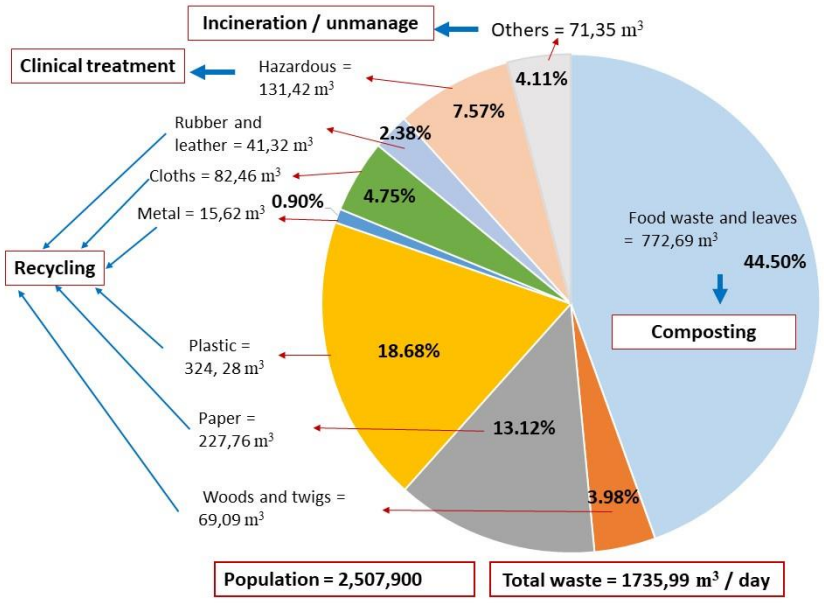

Figure 1. Bandung Municipal population, Waste Capacity, and Waste Treatment in 2021

Bandung as capital city of West Java is one of metropolitan cities in Indonesia which has a population of 2,507,900 (2021) with the capacity of waste is nearly reach to 1.736 m3 per day (BPS-Bandung, 2021). In waste management, the garbage is divided to some criteria that is considered by its recycling treatment as it shown in figure 1. Due to the consideration, target group for questionnaire is population of Bandung and the sample ofwaste treatment was household with existing experiment of caring children at age 0 to 4 years. The populationis 182.116 which the sample for questionnaire is determined 315 respondents by Slovin formula with significant value of 0.05.

RESULTS AND DISCUSSION

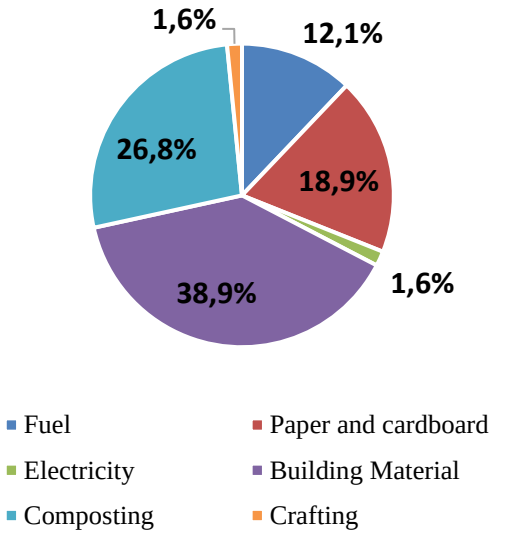

Figure 2. Distribution of Society Knowledge on Recycling Disposable Diapers

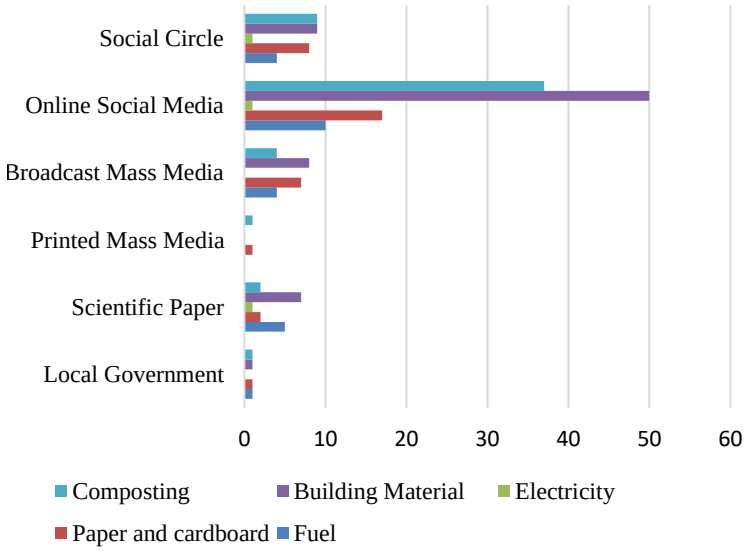

Figure 3. Source of Information on RecyclingDisposable Diapers

CONCLUSION

The study reveals that the respondents received information about the waste being recyclable and two thirds of the respondents did not know or were unsure. Furthermore, more than half of those who know information about waste recycling get it from social media, and nearly a quarter of that information is about recycling for building materials. This article will include additional quantitative research findings. In general, the results of this study provide an overview of the potential for recycling non-biodegradable waste to be used as building materials. Furthermore, with the help of social media, which is currently popular, it can be used to educate the public about waste management,particularly non-biodegradable waste.

ACKNOWLEDGEMENT

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Production and Mechanical Properties of Recycled Aggregate Concrete from Construction and Demolition Waste in Hanoi, Vietnam

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Keywords: construction and demolition waste, recycled aggregate concrete, mechanical property

INTRODUCTION

Circular economy is a trending concept being repeatedly stressed in Vietnam in recent years, especially since the strong commitment of "a carbon neutral Vietnam by 2050" of Prime Minister Pham Minh Chinh in the United Nations Climate Change Conference COP26 in 2021. Within this context, innovative solutions are much desirable in every aspect of the economy as an effective strategy to reduce – reuse – recycle goods, minimize the use of natural resources that are already depleting, and eliminate waste. This study summarizes the practice of one of the solutions to the management of construction and demolition waste (CDW), which is recycling this type of waste into materials for mixing recycled aggregate concrete (RAC). With careful considerations and design, RAC can be adequate for various structural applications.

MATERIALS AND METHODS

Collection of CDW in Hanoi as source material for experiment

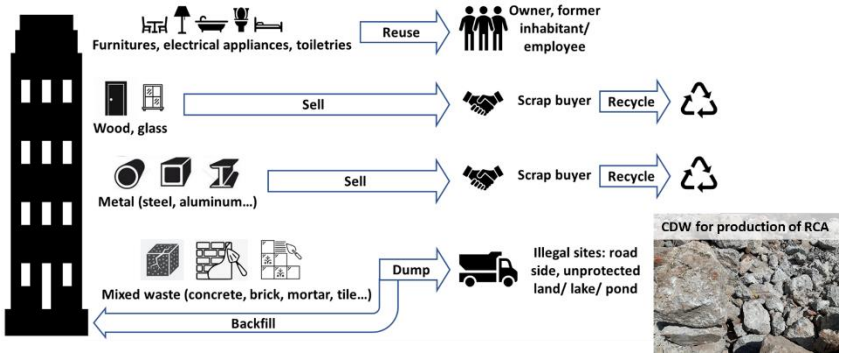

Figure 1 CDW flow from demolished buildings (Source: Nghiem et al., 2020)

According to MONRE (2018), Hanoi is generating approximately 2,500-3,000 tons of CDW per day, which makes up 25-30% the total amount of solid waste. Together with a low recycling rate of only 1-2% (Nghiem et al., 2020), this is exerting heavy pressure on the urban environment.

Production of recycled aggregates from CDW

Table 1 Properties of RCA from CC in comparison with NCA

S/N	Property	Unit	RCA	NCA
1	Porous volumetric mass	kg/m^3	1420	1460
2	Water absorption	%	4.8	6.3
3	Los Angeles abrasion	%	43.4	37.1

In this study, crushed concrete (CC) is collected from a demolition site in Hanoi. This source material is then crushed and sieved to produce recycled coarse aggregates (RCA) for mixing concrete. Properties of RCA are equivalent to natural coarse aggregates (NCA) as shown in Table 1.

RESULTS AND DISCUSSION

Basic properties of concrete mix

Table 2 shows the basic properties of concrete mixes with various replacement rates of RCA.

Table 2 Basic properties of concrete mixes

S/N	Property (unit)	CP0	CP30	CP50	CP70	CP100
1	Replacement rate (%)	0	30	50	70	100
2	Specific weight (g/cm^3)	2.43	2.37	2.34	2.30	2.31
3	Slump (mm)	12.1	11.3	11.5	11.8	12.3

Compressive strength

RAC strength reduces by 10-20% in comparison with reference concrete sample, this result agrees with previous studies. There is one unusual point with 70% replacement rate, the cylindrical strength at which is greater than that with 30% and 50% replacement rates. However, with 5% error range, this result is acceptable.

Figure 2 Concrete cylindrical specimen and results of compressive strength at 28 days

CONCLUSION

This paper presents a case study of RAC in Hanoi, Vietnam. Recycled aggregates from CC are shown to be adequate in mixing concrete of good compressive strength, and applicable to making structural components.

ACKNOWLEDGEMENT

This research was supported by JST–JICA Science and Technology Research Partnership for Sustainable Development Program (SATREPS) project (No. JPMJSA1701).

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Development of a Model to Describe Life Extension of Solid Waste Final Disposal Site

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Keywords: Incineration, Waste to Energy, Final Disposal Site, Lifetime Extension

INTRODUCTION

The introduction of waste incineration and power generation (WtE) facilities is considered in Asian countries such as Malaysia, Thailand, the Philippines, Indonesia, Vietnam, and Bangladesh. There are cases where the construction has not yet been realized due to various reasons, such as economic and political backgrounds. And in some other cases, the facilities have not been functioning because the operation maintenance is not satisfactory.

This paper created a model for the calculation of cumulative landfill amount and remaining years of final disposal sites. It aims to calculate the extension time of final disposal sites by introducing measures such as incineration facilities or using excavated waste as cover material. In this paper, the concept of the created model formula is explained, and case studies will be described at the conference.

DEVELOPMENT OF MODEL EQUATIONS

The following model equations were developed to calculate the filled volume and residual capacity of operating landfill sites. The model equations were developed based on the following aspects. The parameters used in the equations are shown in Table 1.

(1) Volume of waste decomposes in landfill sites when disposed of without incineration, which is common in developing countries.

(2) Excavated waste from operating landfill sites can be used as cover soil to extend its lifetime because sanitary landfills with cover soil shorten the useful time.

(3) Lifetime extension effect by incineration was incorporated into model equations.

Table 1: List of Parameters

Parameters and suffix		Unit
V_0	Remaining landfill capacity of the repository at the start of landfill	(㎥)
V_n	Remaining landfill capacity of disposal site in the n^{th} month	(㎥)
L_n	Cumulative amount of landfill from base i^{th} month to n^{th} month	(㎥)
W_i	Monthly landfill volume in i^{th} month	(㎥/mon)
N_i	Amount incombustible waste in i^{th} month	(t/mon)
C_i	Amount of combustible waste in i^{th} month	(t/mon)
S_i	Amount of cover soil in i^{th} month	(t/mon)
ρ_N	Bulk density of incombustible waste in disposal site	(t/㎥)
ρ_C	Bulk density of combustible waste in disposal site	(t/㎥)
ρ_A	Bulk density of ash materials in disposal site	(t/㎥)
ρ_S	Bulk density of cover soil	(t/㎥)
r_i	Incineration rate	(-)
q	Coefficient of decomposition of unburned combustible waste	(-)
α	Decrease rate of capacity due to incineration	(-)
a	Ash content of combustible waste	(-)
u	Month to start using excavated waste as cover soil	(-)

Residual capacity at the n^{th} month from the start of operation is expressed by equation (1).

$$V_n = V_0 - L_n \quad \ldots (1)$$

The volume of waste filled in the i^{th} month is expressed by equation (2).

$$W_i = \frac{N_i}{\rho_N} + \frac{C_i\,(1 - r_i\,)}{\rho_C} + \frac{C_i r_i (1-\alpha)}{\rho_A} + \frac{S_i}{\rho_S} \quad \ldots (2)$$

Unburned combustible waste filled between 1^{st} to n^{th} month decomposes in accordance with time, thus cumulative volume can be expressed in equation (3). Although there are plural theories for the mechanism of volume reduction, this paper assumed that the first-order decay model is applicable to the decomposition.

$$L_n = \sum_{i=1}^{n} \left(\frac{N_i}{\rho_N} + \frac{C_i((1-a)e^{-q(n-i)} + a)(1-r_i)}{\rho_C} + \frac{C_i r_i (1-\alpha)}{\rho_A} + \frac{S_i}{\rho_S} \right) \quad \ldots (3)$$

Based on equations (1) and (3), the residual remaining of the disposal site in the n^{th} month is as equation (4).

$$V_n = V_0 - \sum_{i=1}^{n} \left(\frac{N_i}{\rho_N} + \frac{C_i \left((1-a)e^{-q(n-i)} + a\right)(1-r_i)}{\rho_C} + \frac{C_i r_i (1-\alpha)}{\rho_A} + \frac{S_i}{\rho_S} \right) \quad \ldots (4)$$

If the excavated waste from a disposal site is used as the replacement of cover soil from the u^{th} month, the sanitary landfill can be implemented without cover soil. Hence the remaining capacity of the disposal site in the n^{th} month (V_n) can be expressed by equation (5) when cover soil is replaced with excavated waste from the u^{th} month.

$$V_n = V_0 - \sum_{i=1}^{n} \left(\frac{N_i}{\rho_N} + \frac{C_i \left((1-a)e^{-q(n-i)} + a\right)(1-r_i)}{\rho_C} + \frac{C_i r_i (1-\alpha)}{\rho_A} \right) - \sum_{i=1}^{u-1} \left(\frac{S_i}{\rho_S} \right) \quad \ldots (5)$$

RESULTS AND DISCUSSION

Model equations developed above mean that lifetime of the landfill site is longer than the substruction of filled volume at each month from initial capacity. This is because organic materials are decomposing in the landfill site. The model also shows that the use of excavated waste can also extend the useful time when a sanitary landfill is to be implemented. Of course, the introduction of incineration has a life-extension effect on the life of the final disposal site.

CONCLUSION

In this study, a model was developed to describe the remaining capacity of landfill sites. With this model, it became possible to have sensitivity analysis of the introduction timing of life extension measures such as incineration or use of excavated waste as cover soil. At the conference, the results of some case studies will be presented, and the influence of such measures on the extension of useful time will be discussed. As incineration is an expensive measure, it is important to have other alternatives in developing countries to extend useful time. The authors wish that the developed formula may help developing countries make appropriate decisions through the utilization of the model.

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Glycolysis Process for Chemical Recycling of PET derivatives

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Keywords: polyethylene terephthalate, glycolysis, polyester polyols, polyurethane

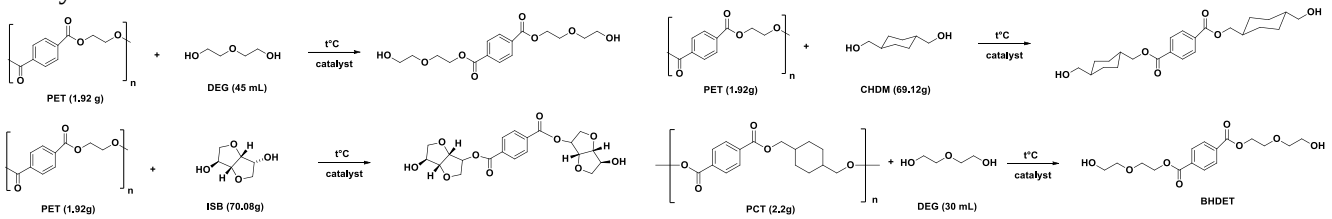
INTRODUCTION

Polyethylene terephthalate (PET) and its derivative, poly (1,4-cyclohexylenedimethylene terephthalate) (PCT), have been widely used in the production of fibers, films, and food packaging, owing to their chemical resistance, durability, and good transparency. Among chemical recycling processes, glycolysis appears to be an effective method for converting waste plastics into valuable products. Various diols such as diethylene glycol (DEG), cyclohexanedimethanol (CHDM), and d-isosorbide (ISB) have been utilized to expand the application of post-glycolysis products. In our research, we systematically investigated the effect of different diols on the glycolysis rate of PET and PCT, where steric hindrance caused by the rigid structure of diols was clarified. An enhanced catalytic glycolysis process was proposed and tested to overcome this low reactivity. The optimal conditions were then applied to directly convert PET to low-molecular-weight liquid polyols, which can be used in rigid polyurethane production.

MATERIALS AND METHODS

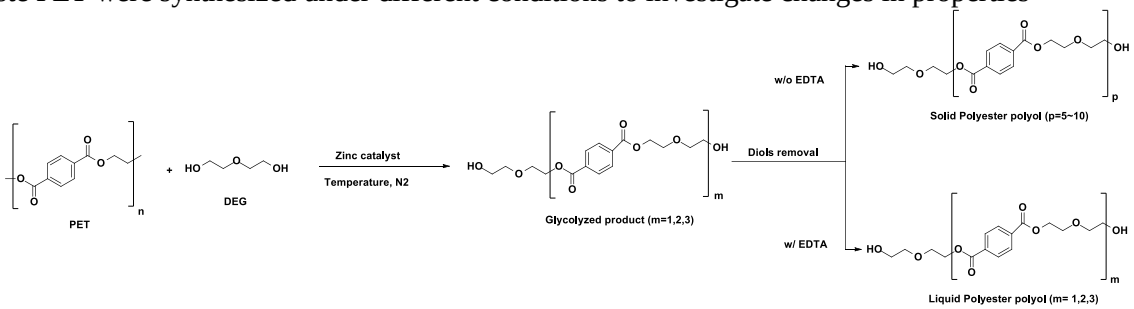
Glycolysis of PET and PCT

We conducted an investigation on the reactivity of PET and PCT toward glycolysis with different diols under catalytic conditions.



Liquid polyol from PET

Polyols from waste PET were synthesized under different conditions to investigate changes in properties



RESULTS AND DISCUSSION

Glycolysis of PET and PCT

Table 1. The summarized results of glycolysis of PET

Glycol	Catalyst	Catalyst amount (mmol)	Reaction rate ($mmol.min^{-1}$)	TOF (mmol/(min.(cat) mmol)
DEG	$Zn(OAc)_2$	6.00×10^{-3}	5.28×10^{-2}	8.8
CHDM	$Zn(OAc)_2$	6.00×10^{-3}	3.07×10^{-2}	5.08
ISB[d]	$Zn(OAc)_2$	0.5	7.19×10^{-3}	0.014

	$Zn(OAc)_2$/NaOEt	0.5	1.90×10^{-2}	0.038

The relative reaction rate was estimated during the initial reaction period (<30% conversion) when product formation can be expressed as a first-order reaction. The reaction rate of PET glycolysis involving ISB was 0.17% and 0.28% of that observed with DEG and CHDM, respectively. The low reactivity caused by the bicyclic structure and the secondary hydroxyl groups of ISB was confirmed. The zinc catalyst and alkoxide combination was applied to promote the glycolysis involving ISB, and the reaction rate increased by 2.7 times (Table 1). The presence of the alkoxy species was expected to enhance the nucleophilicity of ISB.

Table 2. The summarized results of glycolysis of PCT

Catalyst	Reaction rate (mmol/min)	Relative rate	TOF (mol/(min · Cat mol))	Yield of BHDET (%)
$Zn(OAc)_2$	1.44×10^{-2}	1	2.4	12
$Zn(OAc)_2$/NaOEt	4.13×10^{-2}	2.87	6.88	31
$Zn(OMe)_2$	4.65×10^{-2}	3.23	8.08	35

The glycolysis reactivity of PCT with DEG was compared with that of PET and summarized in Table 2. PCT exhibits a reactivity one third of that of PET, which is considered to arise from the effects of the chemical structure of the backbone on glycolysis. The combination of $Zn(OAc)_2$ and NaOEt catalysts was applied to PCT; a reaction rate 2.9 times higher was obtained. The catalytic effects of $Zn(OMe)_2$ were similar to $Zn(OAc)_2$/NaOEt catalytic system and showed a 3.2 times higher rate over $Zn(OAc)_2$.

Liquid polyol from PET

Table 3. Characteristics of glycolyzed product and rPOLs

Samples	M_n (g/mol)	M_w (g/mol)	M_w/M_n (PDI)	Viscosity (cP, RT)	>=Trimer/Dimer/Monomer Ratio
Glycolyzed PET	354	361	1.02	44.4	0/8/92
SrPOL[a] (w/o EDTA)	700	788	1.13	>3000	62/20/18
LrPOL[b] (with EDTA)	357	364	1.02	402.0	1/9/90

We conducted an optimal one-step process to produce a recycled polyol from waste plastic, beginning with glycolysis of PET at high temperatures in a large excess of DEG. Degradation converts PET into DEG-terminated monomer and oligomers. After the glycolysis, excess DEG and formed (EG) must be removed to obtain a purified polyol. During the removal of diols at high temperatures, polymerization occurs because of the deficiency of diols and the presence of an active Zn^{2+} catalyst that can significantly increase the viscosity of the obtained polyol. The solid polyol possesses high molecular weights and viscosity in the absence of EDTA. In the presence of EDTA, the obtained liquid rPOL stably retained its predominant compounds as monomers in high proportions (>90 wt%), dimers, and trimers due to the deactivation ability of EDTA by chelating on the Zn^{2+} catalysts of EDTA.

CONCLUSION

The reactivity of PET toward glycolysis with DEG, CHDM, and ISB was investigated in this study. The rate of PET glycolysis with ISB was 0.17% and 0.28% of that observed with DEG and CHDM, respectively. The co-catalyst $Zn(OAc)_2$/NaOEt was applied to promote the reaction rate up to 3 times. In the glycolysis of PCT, the reaction rate was improved 3 times than that of the conventional zinc acetate, and the catalytic efficiency of the zinc ion – alkoxy species combination was as good as that of zinc methoxide. From the effective glycolysis of PET with DEG, a low-molecular-weight polyol was synthesized in the presence of EDTA as a chelating agent to prevent catalytic polymerization during the removal of diols. The obtained liquid polyol with desired characteristics can be directly used in rigid polyurethane production.

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Removal of Cesium Using *Rhodococcus Erythropolis* and Identification of the Cesium Accumulation Location

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Keywords: Acidocalcisomes, Cesium, Radioactive

INTRODUCTION

Nuclear power is an environmentally friendly and economic means to generate massive energy with a small amount of fuel compared to fossil fuel power. Owing to its stable generation of electricity with low carbon dioxide emission, nuclear power is continued to be developed as a sustainable energy source. However, nuclear power plants have released radioactive substances such as cesium (Cs) from nuclear waste. Leaked radioactive substances can easily be accumulated in animals and plants that inhabit regions close to the plants, and they are ultimately accumulated in humans at the top of the food chain (B. J. Howard et al., 1991). The hazardous repercussions of radioactive substances released into the environment highlight the need for research on environmental restoration.

MATERIALS AND METHODS

Cell viability and Cs elimination

Rhodococcus erythropolis was cultured on BS media. Various Cs concentrations were used for cell viability experiment and three Cs concentrations (0.1, 1.0, 5.0 mM) were used for Cs elimination experiment. In Cs elimination experiments, the collected samples were measured using ICP-MS (N. Tomioka et al., 1992).

Location of Cs accumulation inside the bacteria

FE-TEM analysis was performed to determine the location of Cs accumulation inside the bacteria. The bacteria were cultured under the same conditions and method as that used in the Cs elimination experiment.

Morphological changes of bacteria

Bacteria were cultured under the same conditions for the experiment to examine the morphological changes after Cs treatment. They were observed under an FE-SEM at 15 kV.

RESULTS AND DISCUSSION

Cell viability and cesium removal efficiency

It was confirmed that bacterial growth was completely inhibited in an environment in which the concentration of cesium was 30.0 mM or more. Cs removal efficiency increased steadily as the bacterial biomass growth passed the exponential phase and peaked at 24 hours after culture.

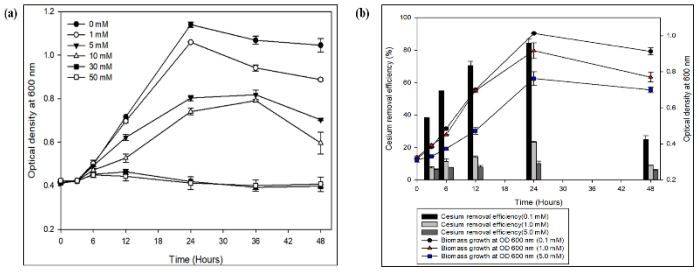

Figure 1 R. erythropolis growth curves (a) and Cs removal efficiency with bacterial biomass growth curves (b).

Location of Cs accumulation inside the bacteria

As shown in Figure 2, black spots were observed in *R. erythropolis*. These round organs are referred to as acidocalcisomes, and metachromatic are known to be involved in diverse cell functions, such as phosphorus storage, pH regulation, osmotic regulation, and stress responses (R. Docampo et al., 2011). Cations are transported via various pumps and mechanisms of these cellular organelles, and Cs ions dissolved in aqueous solutions are also believed to be absorbed by bacteria via a similar mechanism.

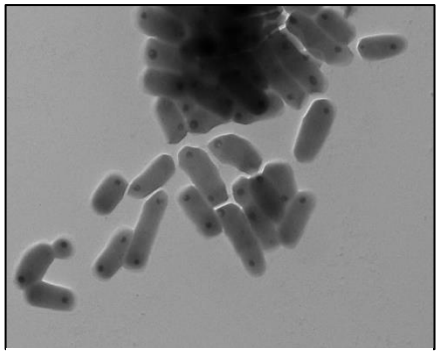

Figure 2 FE-TEM image of *R. erythropolis* after removing Cs

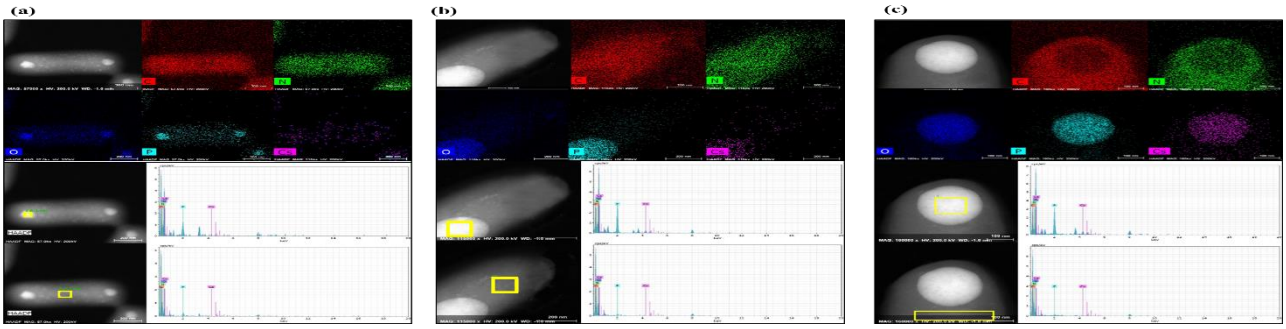

Figure 3 EDS images of five elements of Cs treated *R. erythropolis* (a: 0.0 mM, b: 1.0 mM, and c: 5.0 mM)

TEM-EDS analysis was conducted to compare the part of the bacterial cell that has acidocalcisomes and parts that do not. In the part of the cell containing acidocalcisomes, there were much higher concentrations of oxygen, phosphorus, and Cs compared to the part not containing acidocalcisomes. This shows that acidocalcisomes not only store phosphorus and regulate pH and osmosis but also accumulate Cs.

CONCLUSION

In this study, we tested the Cs removal capacity of bacteria in aqueous solutions with varying concentrations of Cs and identified the location of Cs accumulation inside the bacteria. When inoculated in aqueous solutions with four different Cs concentrations, the bacteria showed a peak removal rate at 24 hours at all concentrations: 84 ± 1.97% at 0.1 mM, 23 ± 0.4% at 1.0 mM, and 10 ± 1.05% at 5.0 mM. Cs was predominantly accumulated in round organelles known as acidocalcisomes.

ACKNOWLEDGEMENT

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Can a higher restriction on plastic waste import lead to a more sustainable plastic waste trade globally?

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Keywords: plastic waste trade, plastic waste ban, environmentally extended input-output (EEIO) model, carbon emission

INTRODUCTION

High income countries generate much more plastic waste per capita than developing countries (Law et al., 2020). Many countries that cannot manage plastic waste domestically choose to export it with the justification that waste should be treated in a place with better treatment facilities. However, the main importers of plastic waste are low-income countries that have limited treatment infrastructure (C. Wang et al., 2020), such as China, India, Indonesia, Vietnam. In 2018, China banned the import of plastic waste, and following this, India, Vietnam, and Indonesia also suspended plastic waste import (W. Wang et al., 2019). With higher restrictions on plastic waste trade worldwide, plastic waste can indeed be treated by countries with better treatment capacities. Moreover, because plastic is produced from fossil fuels, less carbon emissions will be released into the atmosphere if plastic waste is properly treated. In this study, we evaluated the sustainability of the global plastic waste trade after the ban on plastic waste import by China and many other countries by comparing the carbon emissions based on the final plastic consumption by 48 countries and regions before and after the ban.

MATERIALS AND METHODS

Data

We used the Exiobase hybrid multiregional input–output table (MR-HIOT), which covers 48 countries and regions (28 EU member plus 15 major economies and 5 regions) (Merciai, 2021; Merciai & Schmidt, 2016; Stadler et al., 2018). Exiobase MR-HIOT has detailed information on the plastic waste treatment and trade among countries; however, the data are only available till 2011. Therefore, to model the change in the plastic waste trade after China's ban, we used bilateral trade data from the United Nations Commodity Trade (UN Comtrade) database (publicly available at http://comtrade.un.org/).

Methodology

We applied the environmentally extended input–output (EEIO) model, which is a popular method to quantify the carbon emissions embodied in international trade. We used the original data from Exiobase MR-HIOT to calculate household carbon emissions before China's ban. We modified the proportion of waste imports and exports between countries in Exiobase MR-HIOT using UN Comtrade data and then applied the EEIO model again to compute the carbon emissions embodied in final consumption after China's ban. The total amount of plastic waste and treatment technology remained same in our calculations before and after the ban.

RESULTS AND DISCUSSION

Plastic waste restriction has marginal impact on global carbon emission

Our calculations showed that if there is no change in plastic product consumption or plastic waste treatment technology, the reorganization of the plastic waste trade can only reduce global carbon emissions by 0.5%.

Impact of plastic waste restriction varied significantly by countries

Carbon emissions induced by final consumption decreased in most EU countries by approximately 0.3–2.0%. This was also supported by the goals of the European Commission to solve the EU plastic waste problem within EU countries (W. Wang et al., 2019). In contrast, US plastic waste was sent to alternative places, such as Mexico and Malaysia, which may not have high-quality treatment facilities (W. Wang et al., 2019). Countries with increased restrictions on plastic waste imports experienced a reduction in carbon emissions. For example, emissions in China were reduced by 0.9%, whereas emissions in new plastic waste importers such as Mexico and Turkey increased by approximately 0.3–0.4%.

CONCLUSION

This study estimated the impact of plastic waste ban on the international trade of plastic waste and global emissions. We found that this restriction helps reduce carbon emissions in the countries that have imposed bans and globally. However, because this restriction was not universally applied, many waste exporters have redirected their plastic waste flow to alternative places with less restrictions, resulting in unchanged or increasing emissions.

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Future Effects of the Indonesia's National Capital City Relocation in the Municipal Solid Waste Management System: exploring the Lessons Learned from Brazil and Australia

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Keywords: Jakarta, national capital city, Nusantara, relocation, solid waste management

INTRODUCTION

Relocation of the national capital city in a nation has been caried out by several countries in the last century. Two of the examples were Brazil and Australia. Brazil relocated its capital city from Rio de Janeiro to Brasilia in 1960 and Australia relocated its capital city from Melbourne to Canberra gradually from 1927 to 1989 (Ni, P., Kamiya, M. et al., 2017). The latest country that planned to relocate its national capital city is Indonesia. Indonesia has planned and currently proceeding step by step on the relocation of its national capital city from Jakarta to the planned city of Nusantara, located in Borneo Island (Presidential Decree of Indonesia, 2022). The national capital city relocation has brought up different point of views towards many aspects, including the municipal solid waste management. This research will investigate the possible effects of the national capital city relocation in Indonesia, especially for Jakarta, and what Nusantara should prepare in term of municipal solid waste management by reflecting on the Brazil and Australia's capital city relocation.

MATERIALS AND METHODS

Brazil and Australia were selected as the main comparison and source of reflection because these countries were used as the exemplary in the background part of official pocket book of Indonesia's Capital City Relocation. Data related to Brazil and Australia's capital city relocation were collected from previous studies while data for Nusantara referred to the master plan of Nusantara. Analyses were carried out descriptively.

RESULTS AND DISCUSSION

Municipal solid waste management in Jakarta post-relocation

Bureaucrats are expected to relocate to Nusantara. Some citizens with a relatively higher income level may also move to the new capital city if the capital would become attractive to live. This relocation will decrease the collective purchasing ability and product demands in Jakarta which ultimately will lead to the fewer solid waste generation. In the perspective of waste management, this situation is favorable. However, less generated waste means fewer recyclable materials available to be collected by informal sectors which lead to the unemployment. Brazil managed to prevent the economic loss in Rio de Janeiro post relocation by increasing public spending for Rio de Janeiro and facilitation of labor reallocation (Quistorff, 2015), the latest one is the employment of several waste scavengers from the closed landfill to work in waste sorting facilities (Bonini-Rocha, A.C., de Oliveira, R.A.C. et al., 2021). This strategy can be implemented in Jakarta as a measure for scavengers' unemployment, solid waste management improvement and possibly contributing to safer and more

stable employment for some proportion of people in informal sector.

Preparation on Municipal solid waste management in Nusantara

In the masterplan, Nusantara city will have material recovery facilities and sanitary landfill to manage its generated solid waste. Brazil failed to include the waste management facilities in Brasilia's masterplan hence open-dumping was still carried out from 1960 to 2017, until the landfill was closed and the new sanitary landfill was opened (Zolnikov, T.R., da Silva, R.C., et al., 2018). Nusantara must ensure that the waste management plan will be executed accordingly to prevent the reoccurrence of similar cases. Nusantara must adapt with the current and future trend of waste management to set up an appropriate municipal solid waste management system. During the period of gradual relocation of Australia's capital city, Australia was in a situation of raising environmental concern and incinerator implementation is limited (Nicholls, 2002). This situation leads to the enhancement of 3R (reduce, reuse, recycle) practice in Canberra until the usage of thermal-based waste to energy treatment facilities in banned now (ACT, 2020). Learning from this, Nusantara must be also able to respond the current concerns on solid waste management, especially with the plastic waste and safe handling of municipality-generated infectious waste due to COVID-19 pandemic.

CONCLUSION

Post relocation, Jakarta is predicted to experience waste generation reduction which lead to an opportunity for a more manageable waste management system but contrary will reduce the recyclable materials for informal sectors. Recruitment of informal sectors as workers in formal waste separation facility as implemented by Brasilia could be an option to address the issue. For the new capital city of Nusantara, a proper final waste collection and disposal management should be carried out as planned in the official document and prepare it to be adaptable with the current waste-related concerns and disease outbreak.

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Effect of microbes on food waste compost using horse dung as an independent variable

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Keywords: microbial population, bacteria, food waste, horse dung, composting

INTRODUCTION

Horse dung is a potential C/N source for composting. Besides having larger fibres and lignocellulolytic material, it is also colonized by various organisms such as bacteria, protozoa, and fungi (Radoslaw M, Karol K. et al., 2014). Horse manure can be added into food waste compost to increase the quality of final compost product. It can build soil organic reserves, resulting in improved water-holding capacity, increased water infiltration rates, and improved structural stability. It can decrease the energy needed for tillage, increase root penetration and the ability of a seedling to sprout, stimulate growth of beneficial soil microbial populations, and increase the number of beneficial organisms such as earthworms (Buchanan, 2003), (Rebecca C, Elizabeth A. et al, 2015). The effect of microorganisms in food waste compost as well as horse dung mixture can be analyzed by assessing the bacterial and fungal population, enzyme activity and total organic matter (Lee, Park. et al, 2004). This study aims to analyze the complex microbial communities in food waste/horse dung mixture compost.

MATERIALS AND METHODS

Food waste consists around 80% of the total compost material. 10% of old compost and 10% of fallen leaves were used to serve as a buffer and balance out the C/N ratio of the compost, respectively.

Table 1. Methods and analysis used in food waste composting

Methods / analysis	Devices	Amount	Period
Air supply	GEX e-AIR 6000 WB (Air pump)	0.7 L/min (42 L/hour)	24 hrs
Air supply adjustment	Mass flow meter	-	Once
CHN analysis	PerkinElmer CHNS/O analyzer	-	-
O2 consumption rate	Oxygen monitor	-	Daily
Material moisture analysis	Gravimetric analysis (Oven drying)	105 °C	48 hrs
Volatile Solid analysis	Ignition method (Muffle furnace)	850 °C	5 hrs
Mixing	Manually	-	Once / Week
Air diffuser	Hand-made	-	Built – in

RESULTS AND DISCUSSION

The material temperature of independent compost has been consistently higher than the controlled compost with its peak at 39.8 °C on the 10th day. The independent compost consists of horse manure in addition to the food waste material while the controlled one only consists of food waste. The Oxygen concentration rate (OCR%) of independent compost was lower than the controlled one as well indicating better microbial activity and higher organic matter decomposition. Overall, Independent compost has shown better composting quality compared to controlled compost.

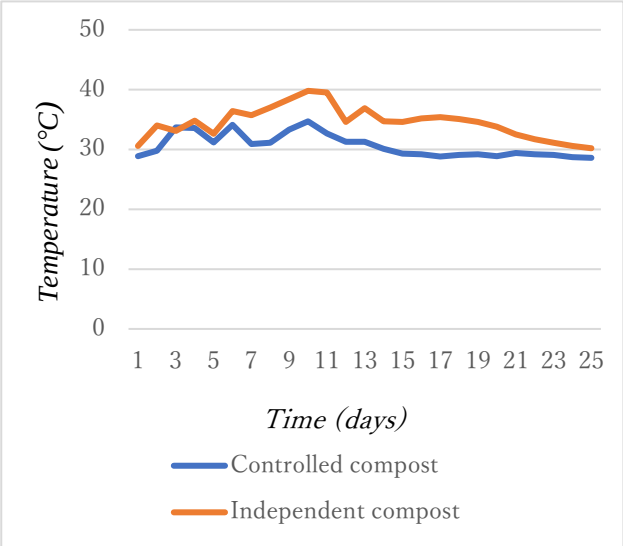

Figure 1. Material Temperature of both composts

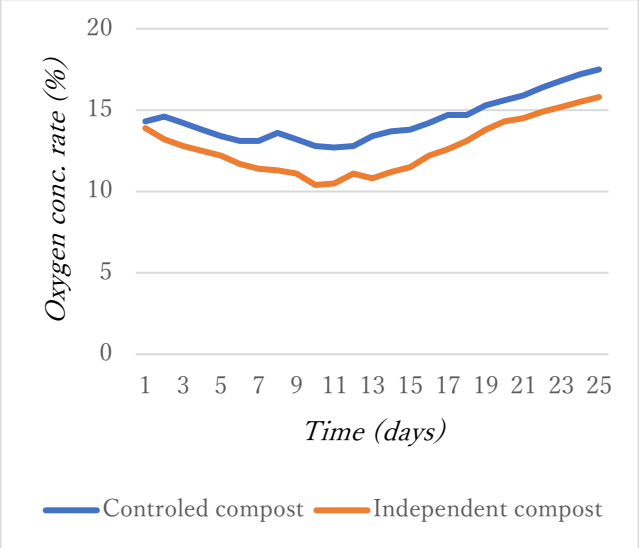

Figure 2. Oxygen concentration rate of both composts

CONCLUSION

This study compared the difference in quality of controlled and independent compost end products and the effect of microbes on the composting process. Given what has been said, the complex microbial communities had better effect on the oxygen consumption rate (OCR%) and OM decomposition in independent compost.

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Barriers and Policy Implications for 2R behaviors in South Korea Based on the Survey Targeting Eco-Friendly Citizens

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Keywords: waste reduction and reuse (2R), citizen behavior, sustainable consumption, circular economy, green transition

INTRODUCTION

Many environmental problems are caused by human behavior, and behavioral change is a necessary issue for environmental sustainability (Steg and Vlek, 2009). Circular economy principles go beyond traditional waste management to improve design and production practices so that end-of-life products can be used as raw materials to create new products (Romero-Hernández and Romero, 2018). In other words, the circular economy is one that directly contributes to clean production in the upper stages of waste prevention, reuse, and recycling (Luttenberger, 2020). Circular strategies to increase the resources efficiency in interaction with daily life are difficult to succeed without public acceptance and adaptation, but research on the role of consumer behavior, an important factor in the circular economy, is still insufficient (Parajuly K., Fitzpatrick C. et al., 2020). This study focuses on 2R behaviors in consumers' daily life. The purposes of this study are to identify the barriers on 2R behaviors and to derive policy implications to improve them.

MATERIALS AND METHODS

Online survey

This survey was conducted for about two weeks from June 13 to 24, 2022. In total, 278 eco-friendly citizens who had experience participating in environmental activities responded. The questionnaire can be divided into items about refraining from reducing single-use products, packaging food in reusable containers, using un-/less packaging products, repairing broken goods, using rental/shared products, and sharing/selling/donating used goods.

RESULTS AND DISCUSSION

Experience and barriers on 2R behaviors

Regarding the difficulties of 2R behaviors, "Reducing single-use products" was the highest, and "Buying used goods" was the lowest. The frequency of use was investigated for 9 types of single-use products, and how often they use single-use products varied depending on the items. The products with the lowest frequency of use were single-use tableware and single-use cutlery. This means that other alternatives are needed to induce action to reduce the use of each single-use product.

The reasons for experiencing difficulties in the 2R behaviors were investigated with short answer questions. The short answers responded were classified into social, infrastructural, and individual factors. Social factors included concerns about hygiene and lack of awareness of 2R behavior, and infrastructural

factors included answers to the lack of facilities and the provision of only packaged products. Individual factors included answers such as discomfort felt during the 2R behaviors and contact with strangers. Infrastructural factors were relatively high in 2R behaviors related to packaged products, and 2R behaviors such as used goods were highly answered to have barriers due to individual factors.

Deriving policy implications to improve 2R behaviors

To reduce the use of single-use products, the regulatory policy seems to be effective for the products that are used relatively low frequency. For the products with a relatively high frequency of use, it will be more effective if consumers' choices are expanded. In the case of 2R behaviors with relatively high infrastructure factors, it is necessary to install infrastructure (such as related facilities). For 2R behaviors with a relatively high social factor (such as reducing single-use plastic products), the spread of 2R cultures will be required. In the case of 2R behaviors with high individual factors, an institutional capacity to resolve conflicts between individuals seems to be needed.

CONCLUSION

This study investigated the practical experiences and barriers that eco-friendly citizens have had during the waste reduction and reuse (2R) behaviors through an online survey. And, we grouped the responses and derived policy implications to improve waste reduction and reuse behaviors. In the future, more surveys targeting the general public should be carried out to investigate the status of waste reduction and reuse behaviors.

ACKNOWLEDGEMENT

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Life Cycle Assessment Research and Development in Africa: A Bibliometric Review

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Keywords: Life Cycle Assessment, Africa, Environment

INTRODUCTION

Since the dawn of the industrial revolutions in the 18th and 19th century, mankind has seen an advancement in technology, food production and processing, improved medicines and healthcare, automation of manufacturing, new innovations in research and development, a higher material standard of living etc. (Black et al., 2021). Despite these breakthroughs, it has come at a cost to the environment. We have witnessed increased level of waste disposal problems, habitat destruction and deforestation, marine pollution, biodiversity loss, transboundary transportation of pollutants, climate change and global warming phenomena etc

Worried by these happenings, different tools, and theories for assessing the environmental impacts of human activities have been developed by academics, research institutes, think tanks, governments and businesses- one of such tools is Life Cycle Impact Assessment (LCA). LCA is a tool that has been used to evaluate the environmental aspects and potential impacts of a product, system, or service. It evaluates the entire life cycle from raw material extraction, transportation, processing, manufacturing, distribution, use, reuse, and disposal (cradle-to- grave) (Udo de Haes and Heijungs, 2007).

The LCA tool has undergone different stages of development and use in Japan, Europe, the United States of America (USA) and other parts of the world. The same thing cannot be said of the tool in Africa – the tool has been used albeit, slowly and not so much compared to other parts of the world.

According to the United Nations (UN) Human Population prospects of 2022, "Countries of sub-Saharan Africa are expected to continue growing through 2100 and to contribute more than half of the global population increase anticipated through 2050". However, this rapid population increase may result in widespread environmental problems except the right policies, tools and guidelines are applied (Bradshaw and Di Minin, 2019). Considering LCA is gaining traction in Africa and the likely role it will play to improve economic development and growth, create jobs and lead to sustainable development, this study aims to map the state of the art regarding LCA tool through a bibliometric analysis. The objectives of this research are:

1. Establish the publication trends according to authorship aspects, period of publication, geographic focus of the case studies, and research impact.
2. Describe the type of research and thematic focus being conducted.

MATERIALS AND METHODS

The bibliometric analysis was carried out by adopting the reviewed Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Framework (Page et al, 2021). The SCOPUS database website was used for the search and the following systems boundaries were applied; 1. Language: English, 2, Search criterion keyword: Life Cycle Assessment, 3. Document type: articles, review articles, book chapters and books, 4. Time period: No limitation, 5. Subject areas: Limited to Environmental Sciences, Engineering, Energy, Material Science, Agriculture and Biological Sciences, Material Science, Earth, and Planetary Boundaries 6. Countries: Limited to African countries recognized by the African Union. The returned search results were analyzed using a combination of VOSviewer 1.6.15 and Microsoft excel tool.

RESULTS AND DISCUSSION

Distribution of LCA publications across Africa

There was a total of 231 publications during this 22-year research period in all. In the initial years from 1992-2011, the annual publications did not change significantly with the with the output numbers of 1-5 per year as shown in figure 1. The lack of publications may be due to a lack of understanding and expertise on the field. However, the figures jumped abruptly from 2012 onward. These publications have been predominantly in the field of Environmental Science, Energy and Engineering (Figure 2). The thematic area or focus of LCA research have varied over the years, however, studies on climate change and greenhouse gases, waste

management, agriculture, carbon footprint etc. rank highly (Figure 3). South Africa ranked number 1 in collaboration and LCA research output in Africa.

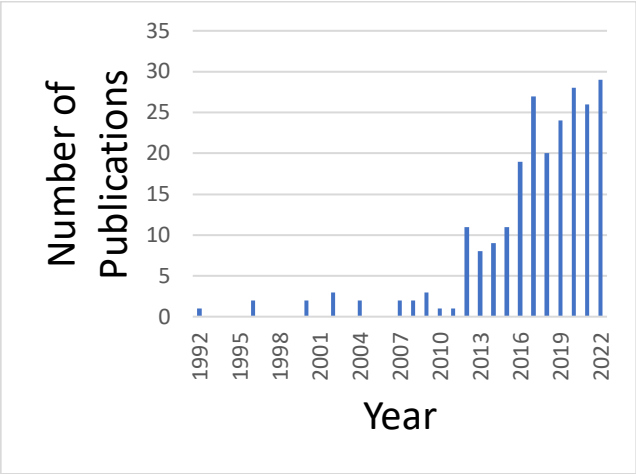

Figure 1: Number of LCA publications Per Year

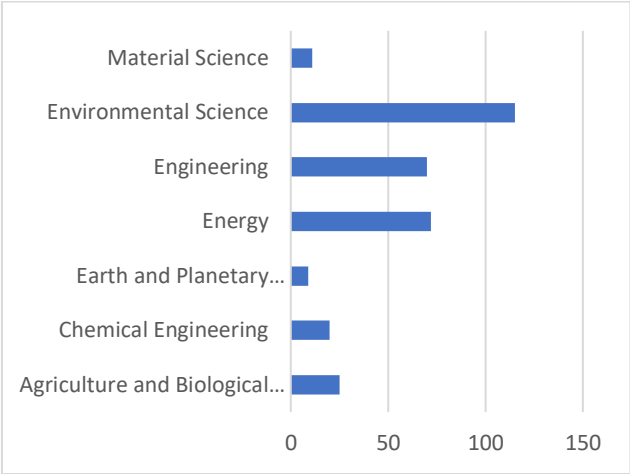

Figure 2: Number of Publications in the Selected Fields

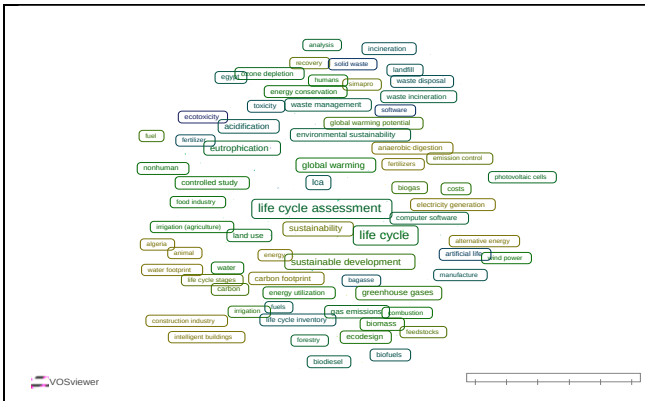

Figure 3: Key Words co-occurrence

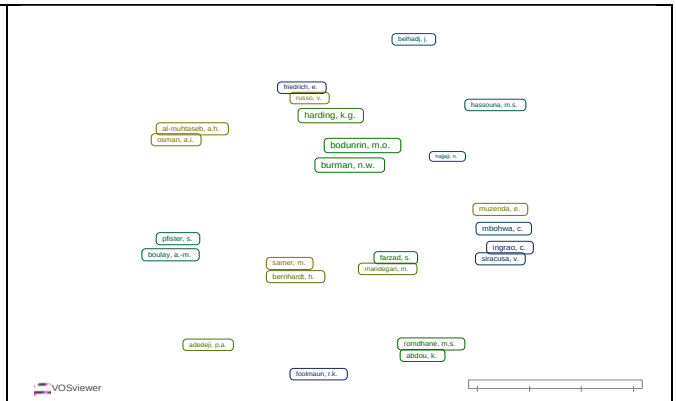

Figure 4: The Level of Research Collaboration Amongst Authors

CONCLUSION

For the period under review, research institutions in South Africa, Egypt, Tunisia, Nigeria, and Algeria are at the forefront of LCA research in Africa. The focus has varied over the years, however, research that focus on climate change, waste management, energy, water and carbon footprint, and biofuels feature prominently. Most of the research focus on carrying out LCA using software tools such as SimaPro, GaBi etc., using global average data. No attention has been paid to LCA methods development to suit the context of African countries. There is therefore a need to train researchers in LCA use and development to meet up with countries such as the USA and Italy who had 3,852 and 2,389 publications for the same period under review. Further collaboration is also required amongst scholars and universities within and outside the continent.

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Assessment of Indonesian Nitrogen Footprint of Agriculture Sector using Nutrient Extended Input-Output (NutrIO) Approach

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Keywords: nutrient management, input-output analysis, agriculture sector, nitrogen emission, Indonesia

INTRODUCTION

Nitrogen (N), in its reactive form (Nr, N-based compounds and molecules other than N_2), is crucial for providing protein to living things (Guo et al., 2017). However, excessive Nr loss in the environment can cause damage to human health, ecosystems, and the climate. Technical creation of Nr is required to meet the target of global food production. Nevertheless, effective ways for ensuring less Nr loss to minimize the detrimental effects of Nr are one of the major concerns now.

Indonesia is one of the critical countries for producing agricultural products. Chemical fertilizers are the primary sources of N input for Indonesia's agriculture sector (Indonesian Central Bureau Statistics, 2015). In this study, the Indonesian N footprint of agriculture was estimated using a nutrient-extended input-output (NutrIO) approach (Oita et al., 2021), a nutrient-based material flow analysis linked to national economic transactions.

MATERIALS AND METHODS

N footprint calculation

The Indonesian N footprint of agriculture using NutrIO is defined as the relationship between the physical N input and the economic sectors from four sources: chemical fertilizer, manure fertilizer, organic fertilizer (agriculture residue), and feed. Using the Indonesian input-output table of 2010, the calculation was done as follows (Eq. 1):

$$E_j^k = \sum_{i=1}^{\mathrm{p}} N_i^k (I - A)_{ij}^{-1} F_j \text{.....(1)}$$

where E^k_j is the nutrient footprint of industrial j for nutrient input source k, N is the nutrient demand factor (Gg-N per million IDR), $(I\text{-}A)^{-1}$ is the Leontief inverse, I is the identity matrix, A is the input coefficient matrix, i is the sector of primary production, p is the number of sectors, and F_j is the final demand of the sector production j.

RESULTS AND DISCUSSION

The study revealed that cereal group (rice and maize) contributes the highest to the Indonesian N footprint of agriculture (Figure 1). The total Indonesian N footprint of agriculture was estimated at 27.3 Gg-N year^{-1}. Chemical fertilizer was observed as the dominant source of N emission, whereas the other sources are manure fertilizer, organic fertilizer (agriculture residue), and feed for animals.

There is also some highlight from sugar as the source of N for several sectors. A residue from sugar

production is used as an input for organic fertilizer. In addition, residue from non-alcohol drinks and cigarette making was also considered the N source of organic fertilizer for the industries. As for the animal production sectors, maize is the main feed contributor. The residue of maize is usually reused as feed by Indonesian farmers.

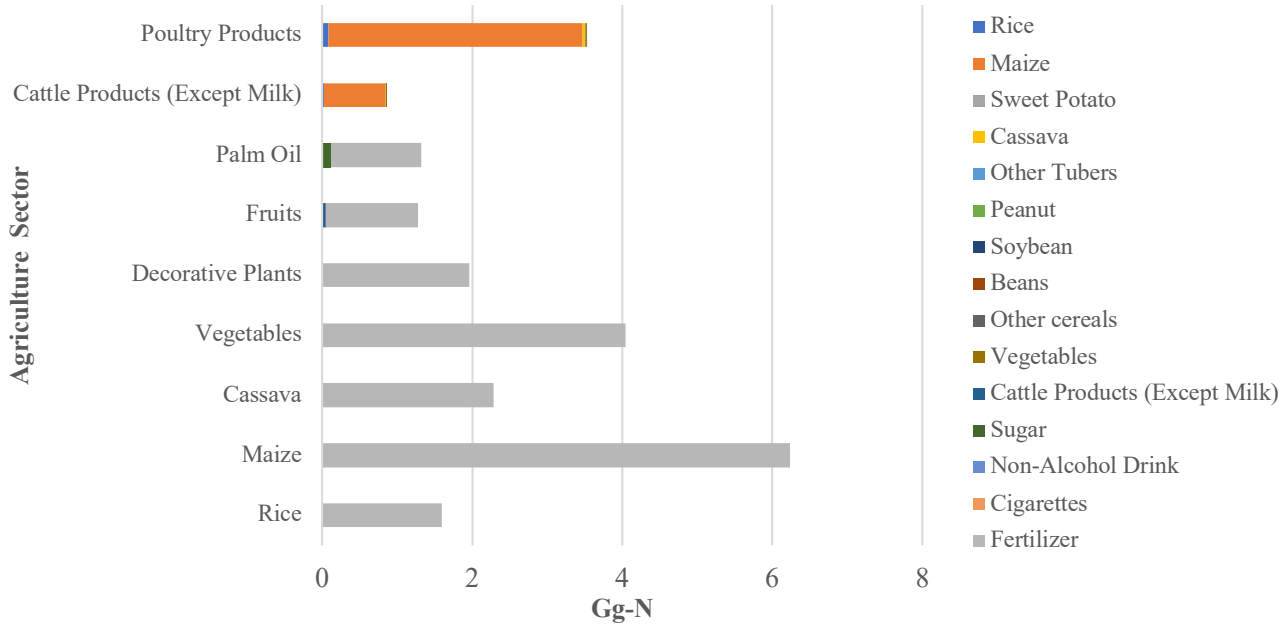

Figure 1 Indonesian NutrIO N footprint of agriculture sector (Ver 20221220)

CONCLUSION

This study aimed to quantify the quantitative N emission of the agriculture sector through the interconnection of Indonesian economic sectors. This evaluation can help improve nitrogen use efficiency from the supply chain view of whole economic sectors in Indonesia. In addition, the policy recommendation to have a more efficient fertilizer for Indonesian farmers should be considered to achieve more sustainable nutrient management. In this work, the non-energy sector of N input was mainly considered. However, for further work, the energy sector of N source should be included to get a complete result.

ACKNOWLEDGEMENT

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Municipal Policies for preventing Single-Use Plastics in Japan

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Keywords: SUP, waste prevention, reuse, the Plastic Resource Circulation Act, advanced initiatives

INTRODUCTION

Recently many policies are introducing for preventing single-use plastics(hereafter referred to as 'SUP'). The author proposed a policy framework for promoting SUP prevention, examing existing single-use plastics policies mainly in Japan and EU countories (Yamakawa, H., Watanabe, K. et al., 2022). This study aimed to reveal the present situation of municipal policies for preventing single-use plastics in Japan, based on the above policy framework.

MATERIALS AND METHODS

Mail survey was conducted in February to March 2022 (some responses were received by e-mail), targeting cities(815) and characteristic towns and villages (66: introducing characteristic policies, collecting large amount of plastic recyclables, implementing active 3R initiatives, with large fish catches or with catches near the median) throughout Japan. A total of 465 were collected (of which 437 were from cities and 28 from towns and villages), with a collection rate of 52.7%. The dispatch, collection and data entry were outsourced to ResearchWorks Corporation. The main survey contents were waste prevention and recycling policies for plastics, waste collection systems and anti-scattering measures, mobile apps related to waste policies, etc.

RESULTS AND DISCUSSION

Table 1 shows one of the results. Number of valid responses is 437. Among them, more than half of municipalities have implemented awareness-raising campaign in plastic problem, while 10% of municipalities set the numerical targets and only around 10 municipalities have seeked advanced cases through initiatives and contests. Among various SUP, plastic bags are most common policy target and about 40% municipalities conducted awareness-raising campaign for its prevention and about 20% even introduced economic incentive policies through voluntary local agreements.

The next most common target is beverage bottle. About 70 municipalities collect or assist to collect reuable glass bottles and about 50 municipalities install or subsidize free water machines. About 30 municipalities also conduct campaigns to promote bringing personal bottle or cup and support reusalbe tablewares use in events. On the other hand, few municipalities took regulatory initiatives, such as banning the installation of vending machines for plastic bottled drinks in their buildings or requiring reusable tableware in their events.

We have found some advanced initiatives such as a reuse program of large plastic items in Fujisawa city of Kanagawa Pref. and elimination of straws from school milk in Nasushiobara city of Tochigi Pref. through examination of the survey results. Further studies are need to explore factors on the introduction of advanced policies.

Table 1 Situation of municipal policies for preventing SUP in Japan

	1.Intro-duced	2.Used to introduce	3.Plan to introduce	4.No plan to introduce	N.A.
1. Numerical target for plastic reduction	42	5	33	356	1
2. Initiatives for SUP reduction	8	4	11	411	3
3. Awards/contests on reducing SUP	13	4	5	414	1
4. Awareness-raising campaign on plastic problems	165	2	47	219	4
5. Installation or subsidization for water machines	52	3	26	353	3
6. Introduction/support for introduction of vending	10	2	3	420	2
7. Non-installation of vending machines for plastic	19	3	9	405	1
8. Registration system for shops which accept	19	0	8	409	1
9. Campaign to bring your own bottle and cup	30	4	19	382	2
10. Support for introduction of sharing containers and	5	1	13	417	1
11. Support for reusable tableware at events	35	14	9	378	1
12. Requirement of reusable tableware at public	1	1	4	429	2
13. Voluntary local agreements to charge for plastic	84	26	1	321	5
14. Plastic bag reduction / bring your own bag	187	90	5	153	2
15. Promotion of SUP reduction in restaurants in	16	0	14	405	2
16. Campaign to reduce the specific plastic products	11	3	39	382	2
17. Voluntary local agreements to charge the specific	1	1	2	432	1
18. Voluntary local agreements to charge disposable plastic tableware and containers	1	0	0	435	1
19.Provision of map of shops where people can buy	4	1	4	426	2
20. Registration system for shops where people can	14	1	5	416	1
21. Collection and support of reusable glass bottles	71	3	1	361	1
22. Utilisation of the requirement of the waste	11	0	5	419	2
23. Disclosure of SUP use by high volume waste	1	0	1	434	1
24. Municipal initiatives for non-use of SUP	61	3	15	357	1

N=437

CONCLUSION

This study showed the present situation of municipal policies for SUP in Japan. Awareness-raising campaign in plastic problem are popular policies, while setting numerical targets were limited. Among various SUP, major policy targets are plastic bags and beverage bottles. About 20% municipalities introduced economic incentive policies through voluntary local agreements for plastic bags.

ACKNOWLEDGEMENT

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The effect of age and income on waste separation behavior of Hanoi citizens

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Keywords: waste separation, behavior, age, income, Hanoi

INTRODUCTION

In the waste management system, households contribute greatly to the growth of municipal solid waste (MSW), causing landfill sites to become overloaded, resulting in environmental degradation. It is admittedly better to separate solid wastes at the source rather than recover materials from mixed wastes. The separation of waste at a source, however, requires an adequate management system where regulations are strictly followed and infrastructure supports waste handling at all stages. As a result, in Vietnam and other developing countries where infrastructure development is not keeping up with the rate of urbanization, another approach should be taken in light of the lack of landfill space and pollution from unsanitary treatment.

Understanding what motivates households to separate their waste is crucial to effectively boosting source separation. As the first step to do that, the main objective of this paper is to discuss the effect of age and income on waste separation behavior of Hanoi citizens.

STUDY AREA AND SURVEY DESIGN

Hanoi, with a population of 8.093 million and a land area of 3,358.59km2, with a high population density in the 12 urban districts. An online survey was conducted in February 2022. The survey used a structured questionnaire with multiple choice methods and Likert rating scales. A set of questions is asked to collect basic household information, such as years of residence in the community, types of homes, and home ownership status. This survey measures waste separation behavior based on organic and recyclable waste separation. The questionnaire asked the respondents to answer the statements "I always separate organic waste" and "I always separate recyclable waste" on a Likert scale ranging from 1 to 4. The online questionnaire survey was conducted by Macromill research company and collected a total of 750 samples.

RESULTS

The number of male respondents and female respondents are approximately equal, with the female ratio slightly higher at 57.2% and male ratio at 42.8%. 150 samples were equally collected from each of the five age groups: 20 to 29, 30 to 39, 40 to 49, 50 to 59 and 60 to 69. The majority of the survey respondents are earning 11 to 15 million VND a month (30.9%) while the group of lowest income (less than 5 million VND) only takes 8.1% of the survey population. People who earn from 6 to 10 million VND account for 17.9%, people who earn from 16 to 20 million VND account for 27.3%, and those who earn more than 21 million VND account for 15.7% of the collected samples. (1 million VND roughly equals to 5000 JPY).

The latest legislation in waste management in Hanoi categorizes waste into 3 groups (biodegradable organic, reusable and recycled, and others). However, this is not strictly abided as the survey result shows that up to

49% of households are not sorting out kitchen waste. 32% of the household are using kitchen leftovers to make compost, and 19% are feeding kitchen leftovers to pet or livestock. The rate of no separation for recyclable waste such as PET bottles, etc., is lower at 40%. Separated materials are provided to informal junk buyers with or without monetary compensation.

Table 1 Crosstabulation for age and recyclable waste

AGE	No separation	Selling	Giving away	Total
20-29	39.33%	50.00%	10.67%	100%
30-39	34.67%	43.33%	22.00%	100%
40-49	38.67%	42.00%	19.33%	100%
50-59	39.33%	26.67%	34.00%	100%
>60	48.67%	22.00%	29.33%	100%
Total	40.13%	36.80%	23.07%	100%

Table 2 Crosstabulation for age and organic waste

AGE	No separation	Animal feed	Compost	Total
20-29	47.33%	27.33%	25.33%	100%
30-39	40.67%	20.00%	39.33%	100%
40-49	42.67%	21.33%	36.00%	100%
50-59	48.67%	16.00%	35.33%	100%
>60	62.67%	11.33%	26.00%	100%
Total	48.40%	19.20%	32.40%	100%

For both recyclable and organic waste separation, the rate of no separation is the highest in the two oldest group (including people above 50 years old), followed by the youngest group of 20-29 years old at 39.33% and 47.33% respectively, with a bigger difference between the ratio observed in organic waste separation.

Table 3 Crosstabulation for income and recyclable waste separation

INCOME (VND)	No separation	Selling	Giving away	Total
<5 mil	45.90%	44.26%	9.84%	100%
6-10 mil	38.81%	46.27%	14.93%	100%
11-15 mil	33.19%	41.81%	25.00%	100%
16-20 mil	47.32%	32.20%	20.49%	100%
>20 mil	39.83%	20.34%	39.83%	100%
Total	40.13%	36.80%	23.07%	100%

People who separate cardboard, glass, plastic and so on can trade these materials with informal junk buyers for monetary compensation, hence the rate of selling recyclable waste is the highest among the two groups with lowest income.

CONCLUSION

This survey examined 750 samples collected from Hanoi city. It is observed that despite the regulation for waste separation, the number of households that do not separate organic and recyclable waste still rise to 49% and 40%, respectively. Those who do sort out kitchen waste use it to make compost or feed livestock. The survey results indicate that the elder generation of more than 60 years old is least likely to separate waste at home. It can also be implied that there is a correlation between the income level and the decision to separate recyclable waste and sell for an extra source of income.

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Physicochemical Characteristics of Deep Eutectic Solvents Based on Monoethanolamines with Quaternization of Triethylenetetramine

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Keywords: Deep eutectic solvent (DES), CO_2 capture, quaternization, functionalization, solution architect

INTRODUCTION

Complementing the shortcomings of the alkanolamine absorbents, a study using deep eutectic solvents (DESs) that can be used as a CO_2 absorbent has got an attention of lots of researchers. DES is the 3rd generation absorbent, which is formed by arrangement of intermolecular interaction by substances which are called hydrogen bond acceptor (HBA) and a hydrogen bond donor (HBD). In this research, the authors tried using acid to quaternize nitrogen in triethylenetetramine (TETA) so as to be act as HBA in the form of [Amine$^+$][Cl$^-$]. Also, if hydrochloric acid is used, Cl^- ion can activate amine groups and can help increase CO_2 absorption capacity. To maximize CO_2 absorption capacity and to investigate effect of amine orders in CO_2 capture, alkanolamines with different orders were used as HBD. With this study, new types of DES whose absorption capacity and physicochemical properties including viscosity, free volume for efficient diffusion and physical absorption can be improved.

MATERIALS AND METHODS

Materials for DES Synthesis

In this study, TETA (Sigma-Aldrich)and 5 mol/L aqueous HCl (Sigma-Aldrich) were used to prepare [TETA]Cl_n which will be used as HBA. MEA (Sigma-Aldrich, monoethanolamine) was used as HBD.

Procedures

The [TETA]Cl was prepared by stirring the same mol of TETA and HCl, using rotary evaporator under reduced pressure at 353.15 K for 24 hours. To maintain low viscosity, 10 wt% of distilled water was added. Using a double jacket reactor and stirred at 200 rpm using a magnetic stirrer under the temperature of 353. 15 K, DES was synthesized. By using Fourier transform infrared spectroscopy, existence and properties of functional groups of each reactant and final products can be analyzed. Also, Differential scanning calorimeter analysis was performed to confirm their thermal stability in a room temperature.

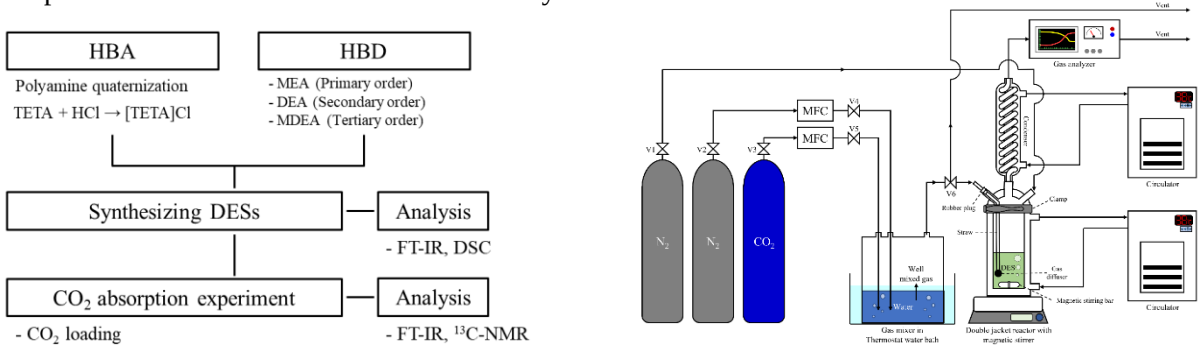

Figure 1 Schematics of the study (left) and apparatus for CO2 absorption measurement (right)

RESULTS AND DISCUSSION

Characteristics of DES Synthesis and CO_2 absorption

Results of FT-IR analysis and the expected molecular structures of DES formulated based on the FT-IR spectra were shown in the Fig. 1. FT-IR spectra for DES seemed to follow the spectra of HBD due to high ratio of HBD compared to HBA. The peaks indicating hydrogen-containing functional groups are broadened after forming DES. By these results, hydrogen bond formation among HBA and HBD can be predicted. Also, it was in thermal stable phase at room temperature.

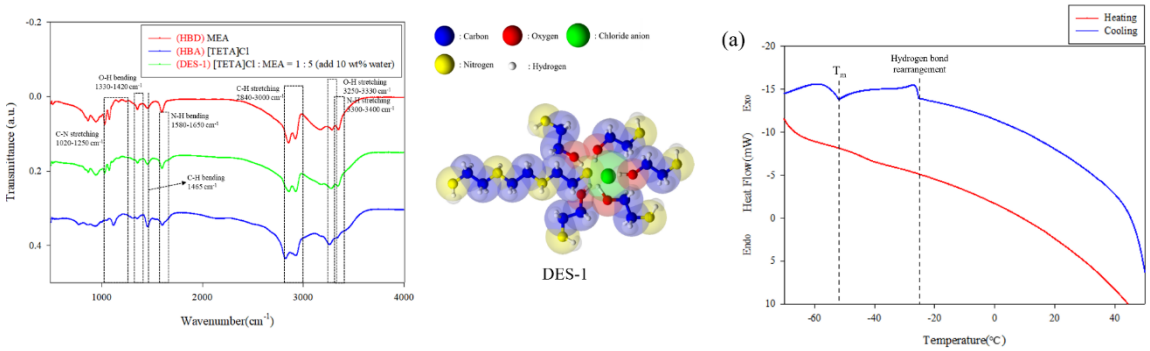

Figure 1 FT-IR spectra (left) and DSC measurement (right) for raw DES

The carbon dioxide absorption performance of the synthesized DES and 30 wt% aqueous MEA are shown in Fig. 2. For the case of 30 wt% MEA, the absorption performance was reported to be 0.5547 mol CO_2/mol absorbent. Meanwhile, synthesized DES showed higher CO_2 absorption performance. Reaction rate was also higher for DES compared to raw MEA. For the last, carbon dioxide can be thought to be chemically captured based on FT-IR after CO_2 uptake.

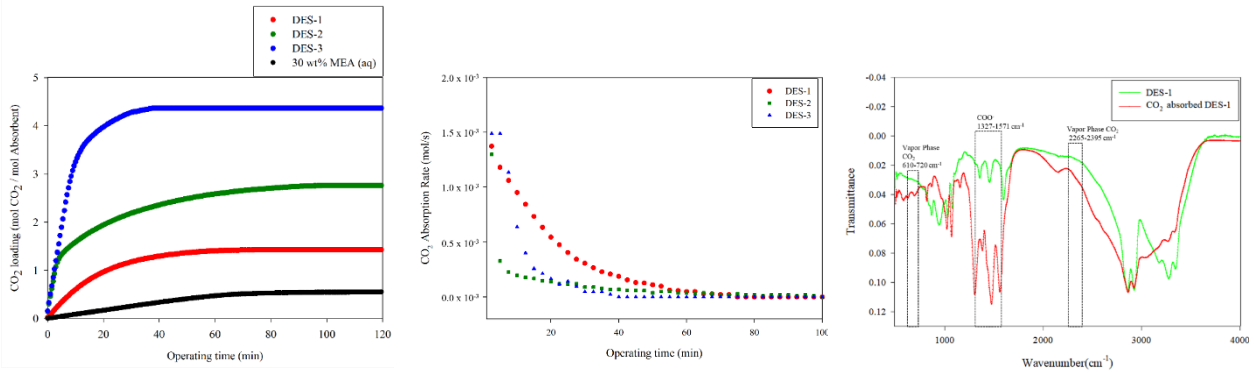

Figure 2 CO_2 loading (left), Reaction rates (mid), and FT-IR spectra (right) for DES with CO_2 uptake

CONCLUSION

Tertiary amine based DES with high absorption rate, low viscosity, high diffusivity, and high absorption capacity can be thought to have potential and applicability to be efficient absorbent in industrial CO_2 removal as proven in this work.

ACKNOWLEDGEMENT

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Preventing Mangroves from Plastic Pollution: Some Good Practices

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Keywords: plastic pollution, mangroves, prevention

INTRODUCTION

Coastal habitats are considered as the destination for mismanaged marine debris derived from anthropogenic activities (Cundell, 1973). From many kinds of debris, plastic dominates the composition (Derraik, 2002). Unfortunately, the marine plastics can bring detrimental impacts to the coastal habitats, including mangroves. A study in the north coast of Java showed that the impacts of plastic entanglement in mangroves can be varied, ranging from the root-growth response to the death of the plant, depending on how much the plastic covers the part of the flora (van Bijsterveldt et al., 2021). At the same time, in the ecosystem, mangroves play some fundamental roles, such as raw materials and food provision, coastal protection, erosion control, carbon sequestration, and recreational and educational platform. From all of them, coastal protection has the highest value (Barbier et al., 2011). Recognizing the impacts of plastic pollution to mangroves and the fundamental roles of the mangroves to the ecosystem, this research aims to provide some suggestions of good practices that can be adopted to prevent the mangroves from plastic pollution.

METHODS

This research employs literature review to collect data. In the collection process, the keyword 'mangrove' is combined with the keywords 'plastic pollution', 'plastic pollution', 'protection' to find related articles about the topic. Furthermore, this research focuses on macro plastics, hence, the findings about microplastics will not be considered. Since Southeast Asia owns the largest mangrove coverage (Bunting et al., 2018) and it is also considered as one of the biggest contributors of marine plastics (Jambeck et al., 2015), the study cases used in this research will mainly focus on the region.

RESULTS AND DISCUSSION

The entanglement of plastic in the mangroves is affected by several factors, such as UV radiation, humidity, and wave movement (Luo, Not, Cannicci, 2021). Furthermore, mangrove is the closest habitats for the river-borne plastic pollution. A study showed that around 54% of mangrove habitats are located within 20 km of a river that disposes tons of plastic annually (Harris et al., 2021). This finding indicates that plastics going to the river will likely end up in the mangroves. From this reason, some approaches can be conducted to prevent the occurrence. For on-site activity, preventing the plastic waste going from rivers to oceans is the key. The activity can be performed through installing the floating nets or interceptor that can extract the plastic debris from the water. An interceptor installed in Cengkareng Drain, Indonesia can reduce up to 8 tons debris per month. Besides that, clean-up activities can also help to reduce the plastic pollution flowing to the marine environment. Performing mangrove restoration projects, including planting and habitat rehabilitation as well as plastic

management is also important to remove and prevent the plastic trapped in the mangroves. The financial support from international carbon finance is a potential donor for the activity, realizing that the mangrove itself serve as a carbon sink.

Looking from a bigger picture, the plastic pollution in the mangrove can be prevented by implementing proper waste management, changing lifestyle to reduce single-use plastics, and preventing littering.

CONCLUSION

Plastic pollution can negatively affect the mangroves, which have many fundamental functions in the ecosystem. With the growing amount of plastic waste end up in the marine environment, some efforts can be performed to protect the mangroves from plastic pollution. For in-site efforts, the actions include installing floating net or interceptor to extract the debris from the rivers and performing clean-up activities. Meanwhile, to reduce the plastic waste in general, the actions include implementing proper waste management, changing lifestyle to reduce single-use plastics, and preventing littering.

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Metal assessment in the vehicle sector to establish recycling as a proposal for circularity strategy in Latin America

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Keywords: Circularity, Metal recovery, Latin America, ELV, metal recycling

INTRODUCTION

In Latin America, Mexico has been positioned as the fifth largest exporter of light vehicles and the 7th producer in the world, as well as the 4th exporter of auto parts overpassing countries such as Brazil and Argentina.

Mexico and Brazil are Latin American countries that have significant participation in automobile production in the region, Argentina, Colombia, and Ecuador represents a small fraction. Mexico and Argentina are presented as countries whose most of their production is exported, nevertheless, the registered vehicles in each country are rapidly rising and the automotive fleet in the region is being increased annually. Such figures represent a rapid growth in the demands of materials and metals, as well as the rise in the number of end-of-life vehicles (ELVs) looking for proper recycling and waste treatment (INEGI, 2022; Inghels et al., 2016).

Several research studies have pointed out that one strategy to accomplish metal resource security and waste management is procuring a recycling system encouraging circularity (Andersson et al., 2017; Sato et al., 2019).

Many developed countries have established systems for ELVs and the Extended Producer's Responsibility (EPR) principle to reuse and recover and recycle materials. Yet, this goal is not easy to achieve (D'Adamo et al., 2020; Inghels et al., 2016) To this point, limited attention has been performed to assessing the recycling management of materials from the automobile sector in emerging economies from Latin America. Hence, the main of this study is to perform an overview of if and how recycling initiatives, remanufacturing, and circularity in the automotive sector are performed in Latin America.

MATERIALS AND METHODS

The methodology includes sample collection and statistical analysis. The data obtained about domestic production, imports, exports, and annual registration of vehicles is extracted from National Automotive Associations in Mexico, Brazil, Argentina, Colombia, and Ecuador considering 10 years, since 2012. For the lifespan of cars, it was considered 12 years. Additionally, a literature review of scientific articles was carried out considering the same period. The review was conducted using searching academic databases such as SCOPUS as well as Web of Science and Google Scholar.

RESULTS AND DISCUSSION

The scope considers Latin American countries that are currently producing vehicles. In this stage, production and export of automobiles and light trucks information from National Automotive sources is collected and analyzed. Figure 1 shows the Production and Exports Vehicle of Mexico and Brazil from 2012 to 2022. As can be seen, the vehicle production leadership has changed since 2014 to Mexico. In 2021 around 70% of its products are exported to the USA. Brazil, on the other side, reports 16% of exports for the same

period mainly to Argentina. Other Latin American countries are also considered, however as they have minor participation, there are not presented in this abstract.

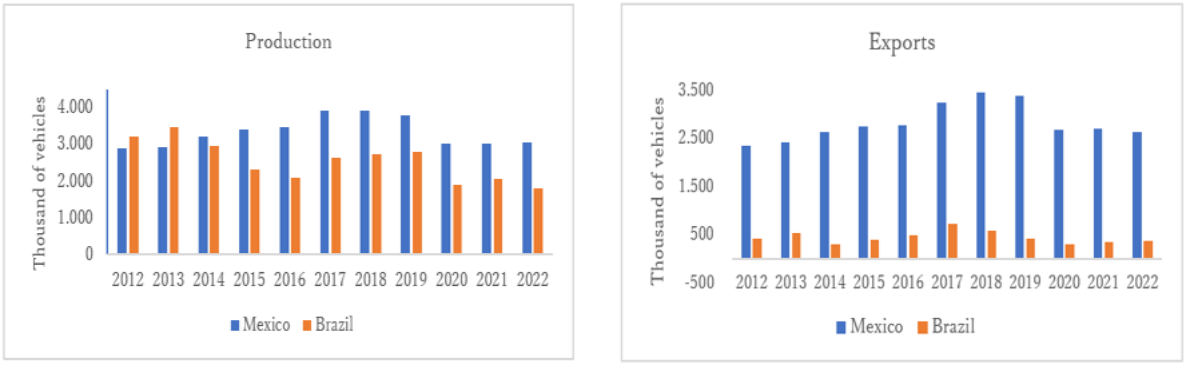

Figure 1. Production and Exports of Vehicles

There is a lack of information related to the statistical deregistering vehicles in these countries, as a result, it can be inferred that even though there are exports there are also imports and an accumulation of vehicles in Latin America.

CONCLUSION

As the total fleet in Latin America is seemed to increase, there will be an accumulation of vehicles in the region, it is imperative properly management of the resources, especially metallic components from vehicles and ELVs. In that sense, recycling is proposed as a strategy to support circularity, which is already used in many developed countries. In the case of Latin America, it can be inferred that there is an important potential to recover reusable and recyclable resources and metals. One of the main challenges is to establish the proper treatment of the recovered resources and procure environmental management in the region. This study procures to point out the present and future efforts needed to establish recycling and management of ELVs in Latin America.

ACKNOWLEDGEMENT

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CFD Study on Decomposition Characteristics of Nitrous Oxide inside Reaction Chamber of Semiconductor Scrubber System

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Keywords: Scrubber System, Reaction Chamber, Semiconductor Fabrication Process, Greenhouse Gas (GHG), Computational Fluid Dynamics (CFD)

INTRODUCTION

With the continuous development of the semiconductor industry, interest in the technology for purifying various greenhouse gases (GHGs) in the semiconductor fabrication process has increased recently. Various gas scrubbers are being used to remove the GHG from the processes. An efficient design of the reaction chamber is crucial in a scrubber system due to the effective removal of GHGs and the overall operation stability. In the present study, a computational fluid dynamics (CFD) analysis was conducted to figure out flow-thermal characteristics inside the reaction chamber of the scrubber system. In order to verify the numerical method, the temperature at several monitoring points was compared to that of experimental results and a good agreement between the CFD and experimental results was achieved.

NUMERICAL ANALYSIS

Computational domain and meshes

Figure 1(a) shows the geometric model, which is 0.414 m in diameter and 1.212 m in height. The top of the pyrolysis reactor (Part A) has 4 inlets, and the semiconductor waste gases enter two of these inlets diagonally. Fig. 8b shows meshes used for the numerical analysis of the pyrolysis reactor. Tetrahedral and hexahedral meshes were used (2,126,855 altogether), and they were placed as shown in Figure 1(b).

Properties and boundary conditions

The boundary conditions of the chamber were set based on the experimental results as follows:

- Inlet Ⅰ: xN2=0.997, xN2O=0.002, x SiH4=0.001, Q= 200 L/min, T= 110 ℃
- Inlet Ⅱ: xair=1.0, Q= 20 L/min, T= 25 ℃
- Outlet: P= 1 atm (atmospheric pressure)
- Wall (heater): q= 3.4 kW/Aheater
- Porous media: ε= 0.3, K= 1.0×10-7 m2

To predict the waste gas behaviors in the chamber, the present study set the properties of the nitrogen gases, which accounted for most of the waste gases, in a way that changed in accordance with the changing temperature

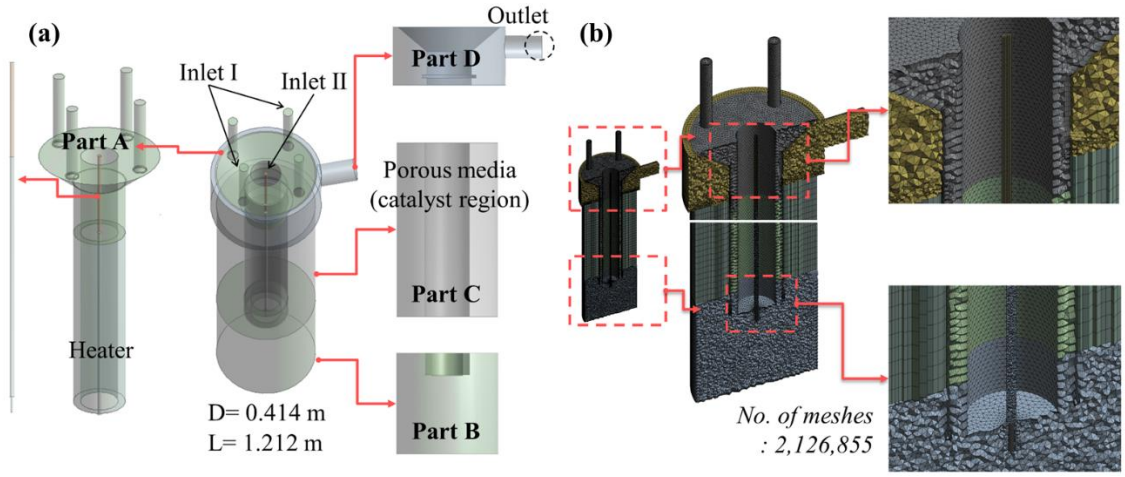

Figure 1 Computational domain and meshes: (a) geometry feature and (b) mesh configuration.

Numerical result and validation

Fig. 2 illustrates temperatures measured at 8 monitoring points (TC#1-8) at every 45° at a constant height to compare numerical and experimental results. The maximum and minimum temperatures of the numerical analysis were higher than those of the experiment were. In the experiment, the average temperature of discharged gases would have declined due to slight heat release or solid materials' heat transfer. A comparison of the temperatures between experiment and numerical analysis to confirm the validity of the numerical method revealed that the temperature trend at each 45° was overall similar between the two, and the temperature error at each 45° ranged from 1.27 to 2.07%, which was lower than the error of small-scale model, which was in the range 2.5–9.8%. Arranging the waste gas inlets at 45° would have made the flow more even.

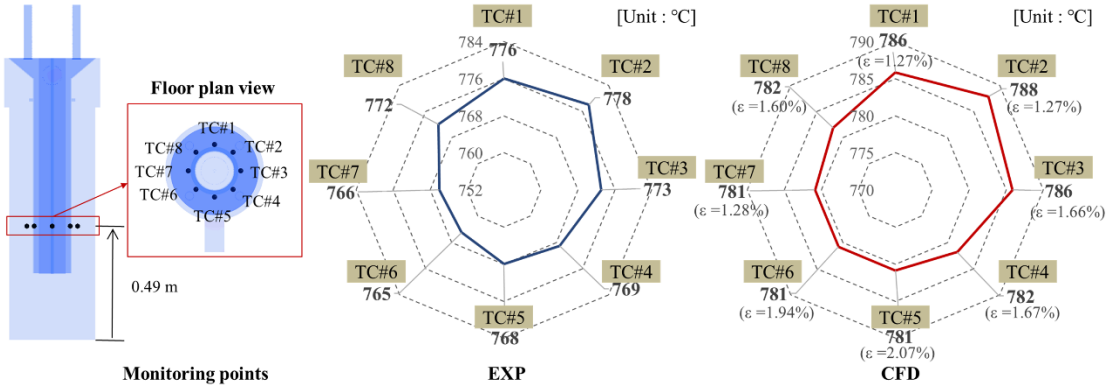

Figure 2 Comparison of temperature distribution between experiment and numerical results

ACKNOWLEDGEMENT

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Indoor and Outdoor Airborne Levels of Per and Polyfluoroalkyl Substances at a Waste Recycling Facility

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Keywords: Per- and polyfluoroalkyl substances (PFAS), Waste recycling facilities, active and passive air sampler

Introduction

Per- and polyfluoroalkyl substances (PFAS) are a group of man-made synthetic fluorinated chemicals that are widely used in industrial and consumer products, such as water-repellent textiles, non-stick cookware, and firefighting foam. Due to the high persistence, bioaccumulation potential and toxicity, for example, perfluorooctanoic acid (PFOA), its salts and precursors have been listed as persistent organic pollutants (POPs) under the Stockholm Convention and are banned for production, export, and usage. Nevertheless, there is a lack of studies on emissions of PFAS into the environment, especially from waste treatment and recycling facilities. This study aims to identify PFAS emitted into the air in indoor and outdoor environments at a waste recycling facility and clarify their levels in both environments using two types of air sampling techniques.

Materials and Methods

We investigated the indoor and outdoor air concentrations of 23 neutral and 53 ionic PFAS in a waste recycling facility that produces RPF (refuse derived paper and plastics densified fuel). In this investigation, 5 indoor and 2 outdoor air samples were collected by an active low-volume air sampler (LVAS) (Wu R, Lin H et al., 2021) and a passive air sampler (PAS) within XAD-2 resin (Wania F, Shen L et al, 2003) in the facility from May 20 to June 20, 2022. Using the LVAS method, air was sampled continuously for 5 hours with a flow rate of 20 L/min while the PAS method was used for one month to capture gaseous PFAS. The PFAS collected by the LVAS method were extracted with organic solvents using the methods of an earlier work (Wu R, Lin H et al., 2021). In the case of the PAS method, PFAS were extracted with acetone. The neutral and ionic PFAS concentrations in the extracts were analyzed using GC-MS/MS and LC-MS/MS, respectively.

Results and Discussion

Concentration levels of neutral PFAS in the air

The air concentrations of neutral PFAS determined by the LVAS method at two locations are shown in Fig. 1. The highest concentration was observed near a RPF molding machine, while PFAS was hardly detected in the northern part of the facility. Therefore, we conclude that the molding machine was the main emission source. In fact, vaporization of PFAS can be promoted by heating plastic and paper wastes over 120 ºC during RPF molding. Although the main PFAS were 6:2 fluorotelomer alcohol (FTOH) and its methacrylate (6:2 FTMAcr), their composition in the first measurement (May 20) differed from that in the second (June 20). This indicates daily variations of treated waste might affect their emissions into the air. In the results from the PAS

method, which were similar to the LVAS method, the largest amount of captured neutral PFAS was observed near the RPF molding machine. As shown in Fig. 2, however, more PFAS components were identified compared to the LVAS method, and also the total amount of PFAS emitted during the month of sampling might have been more representative. From the results, we suggest that predominantly alternative neutral PFAS rather than regulated neutral PFAS were emitted into the air inside this facility.

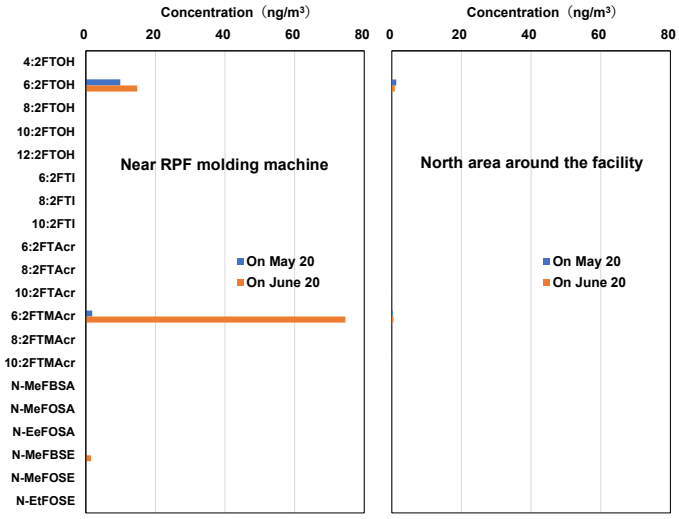

Fig. 1. Concentration of neutral PFAS by LVAS method

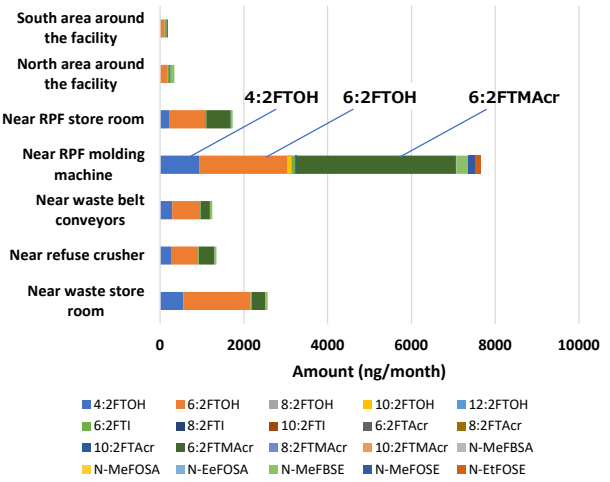

Fig. 2. Amount of neutral PFAS by PAS method

Concentration levels of ionic PFAS in the air

In the results of the air concentrations of ionic PFAS using the LVAS method, only perfluorohexanoic acid (PFHxA) was detected at a trace level of < 1 ng/m^3. Contrary to the results for neutral PFAS, the outdoor concentration levels of PFHxA were higher than the indoor ones. This suggests that there may be a source outside the facility. Finally, no ionic PFAS were detected with the PAS method. Since it is designed for gaseous PFAS, ionic PFAS are considered to exist mainly in particulate form.

Conclusion

At a waste recycling facility, neutral PFAS concentration levels in the indoor air were higher than those in the outdoor air, indicating that the waste recycling facility could be a potential source of PFAS to the surrounding atmosphere. However, most of the detected PFAS were unregulated PFAS, such as 6:2FTOH and 6:2FTMAcr, suggesting that the use of alternative PFAS rather than regulated PFAS is in progress. In contrast to neutral PFAS, ionic PFAS concentration levels were very low.

Acknowledgment

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Physico-chemical properties and pyrolysis study of Indian sludge

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Keywords: pyrolysis, characterization, thermogravimetric analysis, mixed sludge, oily sludge.

INTRODUCTION

A huge amount of oily sludge is produced during the distillation of petroleum products at the refinery. Approximately 60 million tons of oily sludge are produced globally, and over 1 billion tons are believed to have accumulated. [1] The recovery of hydrocarbons from oily sludge will have significant economic and environmental benefits. [2] The pyrolytic breakdown may yield around 80% of the weight as liquid aromatics, paraffin, and olefins. The thermogravimetric analysis, or TGA, is used to investigate the thermal degradation process and the pyrolytic mechanism for solid-state breakdown processes.

The present study is aimed to find the activation energy variation during sludge pyrolysis and the possible change in carbon structure in char at different conversions.

MATERIALS AND METHODS

Physical and chemical characteristics of the sludge

Proximate examination of the sludge was performed in accordance with American Society for Testing and Materials (ASTM) standards. The elemental analysis was done to know the sample's Carbon, Hydrogen, Nitrogen, Sulphur, and Oxygen elemental composition. The sample's higher heating values were also evaluated. A thermogravimetric analyzer (TGA) was used to investigate the temperature-dependent mass loss. The TGA was used to conduct pyrolysis experiments at temperatures ranging from 30-600 °C in a nitrogen atmosphere. Four heating rates of 10, 15, 30, and 40 °C min^{-1} were employed in the TGA experiment. The results have been used to find out the activation energy.

Activation energy calculation:

The activation energy was calculated from the TGA data using Kissinger–Akahira–Sunose method (KAS) method, Ozawa– Flynn –Wall (OFW) method and Starink method.

Raman of Sludge char:

The Char was prepared at temperatures to the corresponding α= 0.2,0.5,0.8, and the same was analysed by Raman spectroscopy.

RESULTS AND DISCUSSION

Characteristics of sludge:

The results of the proximate analysis and the elemental analysis are given in Table 1. The mixed sludge had high volatile content (VM) of above 68% and fixed carbon (FC) percentage of 14%. The higher heating value (HHV) of this sludge was 30.56 MJ/kg which is like that of coal. The oily sludge had VM of 50% and FC of 12%. The oily sludge had HHV of 23.49 MJ/kg.

Table1: Proximate, Elemental Analysis and HHV

Sludge	Elemental Analysis (wt % dry basis)					Proximate Analysis (wt % dry basis)				HHV
Sample	C	H	N	S	O*	M	VM	Ash	FC	MJ/kg
MS	60.67	6.99	5.56	0.72	9.86	0.76	68.68	16.20	14.36	30.56
OS	52.92	4.28	0.66	3.14	2.26	0.86	50.44	36.74	11.96	23.49

*calculated by the difference

Figure 1 shows the TGA plot of the mixed sludge and the oily sludge. The first stage showed drying up to 150°C followed by devolatilization which continued till 500°C. The last stage was the charring of the sludge which began at 500°C. The mixed sludge degraded more as compared to the oily sludge. This is due to the presence of more volatiles in the mixed sludge. The activation energy plots of the sludge pyrolysis are shown

in figure 2. The activation energy of the mixed sludge was in the range of 64–131 kJ/mol. It is observed from the calculation that the mixed sludge has an increasing trend of activation energy as the pyrolysis proceeds. This is probably due to the degradation of lighter hydrocarbons at lower conversion, and at the higher conversion, the heavier molecules had to break into lighter molecules which needed more energy.

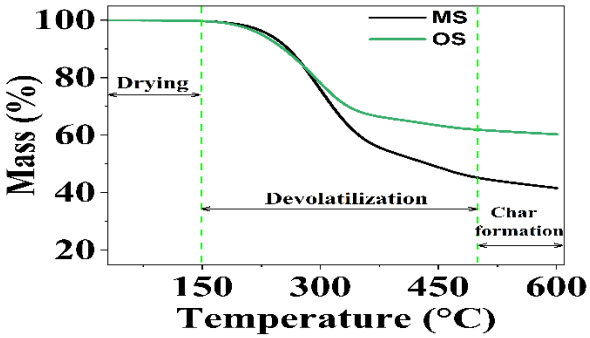

Figure 1: TGA plot of mixed sludge & oily sludge

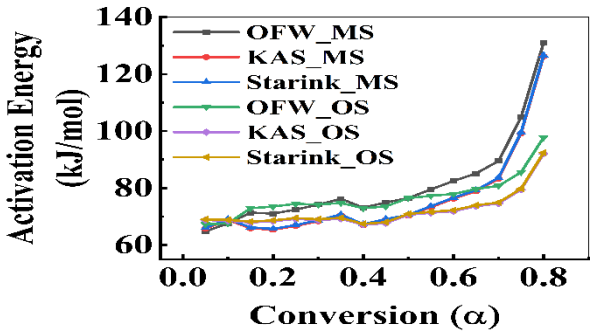

Figure 2: Activation energy plot of mixed sludge & oily sludge

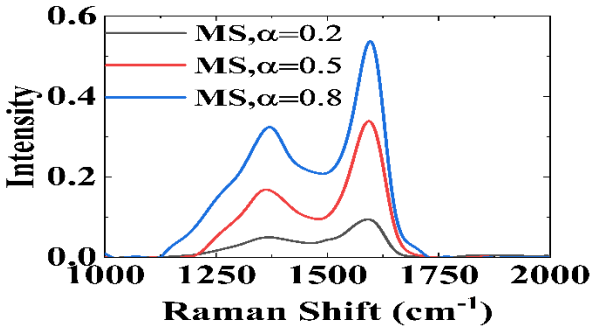

Figure 3: Raman plot of mixed sludge

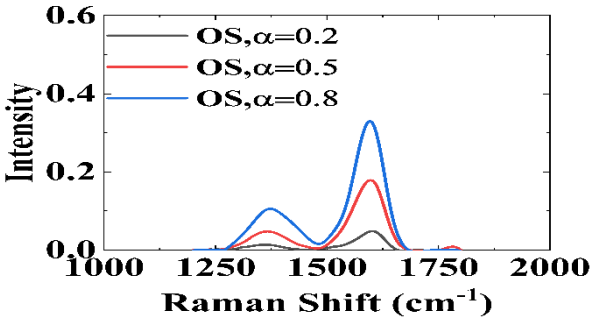

Figure 4: Raman plot of oily sludge

The activation energy of the oily sludge was in the range of 67–98 kJ/mol. The oily sludge also showed an increasing trend, but the increase was lower as compared to mixed sludge. This is due to the presence of fewer volatiles in the oily sludge as compared to the mixed sludge.

The Raman of the sludge was conducted at a conversion(α) of 0.2,0.5,0.8 to study the change in the Carbon structure of the sludge during the pyrolysis. From figure 3 it can be observed that the G peak of α is increasing indicating the formation of graphitic carbons as conversion proceeds. The increase in activation energy can also be justified by the formation of graphitic carbons with an increase in conversion. Similarly, from figure 4 it is observed that the graphitic band increased, but it was much less as compared to the mixed sludge. This justifies the higher values of activation energy in the mixed sludge as compared to the oily sludge.

CONCLUSION

The physicochemical study of the two sludges was conducted. The two sludges had high heating values in the range of 23–31 MJ/kg. Characterization showed that the sludges were a suitable candidate for pyrolysis due to the presence of high volatile matter. A wide variation of activation energy with conversion levels was observed. The increase in activation energy is due to the increase in the graphitic band of the sludge chars at higher conversion.

ACKNOWLEDGEMENT

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Circular economy in plastic, textile, steel, food processing, beer and beverage sectors in Vietnam – current conditions and influential factors

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Keywords: circular economy, enterprises, plastic, remanufacturing, Vietnam

INTRODUCTION

Circular economy (CE), which is based on the principles of designing out waste and pollution, keeping products and materials in use as long as possible, and regeneration of natural systems, holds the promise of tackling several challenges facing our production and consumption systems (Ellen MacArthur Foundation, 2021). The CE is gaining traction in Vietnam both in the political agenda and in practice, in which several CE solutions have been widely adopted by enterprises. This study aims to assess the current situation, drivers, and barriers for the transition towards a circular economy of enterprises in five selected sectors (plastic, textile, steel, food processing, beer and beverage) in Vietnam.

MATERIALS AND METHODS

The analysis is based on interviews with 45 enterprises from five selected sectors applying semi-structured questionnaires.

RESULTS AND DISCUSSION

Current status of circular economy application in five sectors in Vietnam

The interviews reveal that the circular economy principles have been well adopted by enterprises in Vietnam, with 56-88% of interviewed companies applying solutions for optimizing input, keeping resources and materials in use, or regenerating natural systems (Table 1).

Table 1. Degree of circular economy application in five researched sectors

	Very little	Little	Average	Much	Very much

Degree of circular economy application in your sector (%)	5.6	25.0	44.4	22.2	2.8

Input optimization is the most frequently applied solution by enterprises, with nearly 88% of interviewed companies answering that they have applied these measures. Solutions to extend the product life cycle and regenerate the natural ecosystem are also applied at a relatively high rate, at 70.3% and 55.6% respectively.

Types of circular economy solutions applied in five sectors

When asked about each specific solution based on the 9R framework (Recover, Recycle, Reuse for Other Purposes, Re-Manufacturer, Reproduction, Repair, Reuse, Reduce, Rethinking, Refuse), solutions related to recycling, reuse, and recover were the most frequently mentioned measures (Figure 1). In contrast, solutions related to reproduction, repair, and rethinking are little applied.

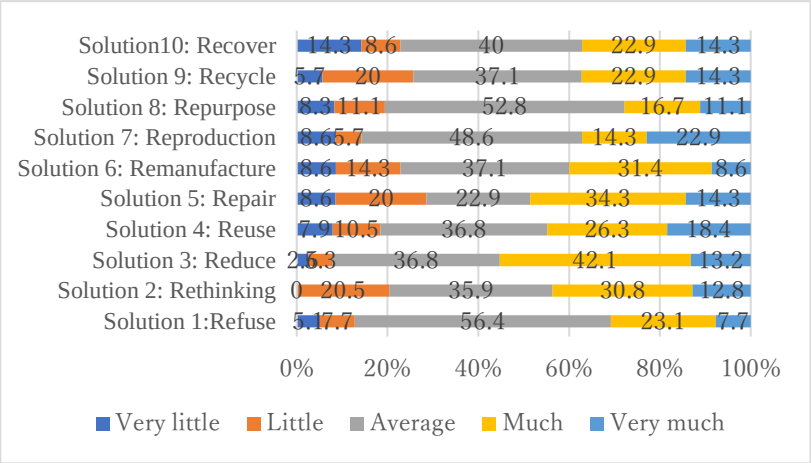

Figure 1. Types of circular economy solutions applied in five sectors

CONCLUSION

Circular economy solutions have been widely adopted by enterprises in Vietnam. Recycling and reuse are the most frequently listed solutions, while refuse and remanufacturing are less practiced. Initiatives to facilitate the adoption of refuse and remanufacturing solutions are therefore recommended to increase the uptake level of CE practices.

ACKNOWLEDGEMENT

This research was supported by the project “Survey, evaluate and propose policies to promote the application of the circular economy models in the industry and trade sector, contributing to promoting sustainable production and consumption” from the Ministry of Industry and Trade of Vietnam

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Flood Waste Governance towards Community Resilience in Jakarta, Indonesia: A Preliminary Study

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Keywords: flood waste governance, disaster governance, river waste, riverside community

INTRODUCTION

Indonesia is one of the most disaster-prone countries with floods as the most frequent disaster at over 12,000 cases in the past 14 years (National Agency for Disaster Countermeasure of the Republic of Indonesia, 2022). The capital, Jakarta, where the Ciliwung River and the other twelve rivers disembogue, is especially vulnerable to floods and flood waste for lacking flood waste governance and resilience strategies. In its determination, understanding the roles and responsibilities of related stakeholders is an important first step. This preliminary study was conducted to provide basic information to understand waste management in Ciliwung riverside communities, Ciliwung River, and Jakarta flood events.

MATERIALS AND METHODS

Sixteen semi-structured in-depth interviews and a focus group discussion were conducted in Jakarta, Indonesia, in November 2022 with different segments of stakeholders from policy to practice, situated at the national to the local level. The topics were linked to waste management in riverside communities, river, and flood events. Site visits were also conducted to see the waste management activities in Kampung Melayu riverside communities, Kampung Melayu Bridge, and Manggarai Water Gate.

RESULTS AND DISCUSSION

State of River waste and Flood Waste in Jakarta

In normal conditions, based on the data provided by DLH and KLHK, river waste accounts for 3-4% of total landfilled waste (Figure 1). Yet in disaster times, such as the 2020 Jakarta floods, the total of landfilled flood waste reached over nine times the average landfilled waste amount.

Figure 1 River and landfilled waste in Jakarta

Organizations related to Ciliwung River and flood waste management in Jakarta

Ciliwung River is managed by different stakeholders (Table 1) for flowing through multiple provinces and cities. On the national scale, the General Director of Water Resources of the Ministry of Public Works and Housing of Jakarta (PUPR) acts as the plan and policy maker on water resources in general while Ciliwung-Cisadane Watershed Management Unit (BBWSCC) acts as the executor of water resource management. On the other hand, flood and disaster-related

policy is made by the National Agency for Disaster Countermeasure (BNPB) and the solid waste one is by the Ministry of Environment and Forestry of The Republic of Indonesia (KLHK). On the provincial scale, in this case, Jakarta, the Department of Water Resources of Jakarta (DSDA) is focusing on flood and drainage management, while river and flood waste is managed by the Department of Environment of Jakarta (DLH) and the special task force of the Waterbodies Management Unit of Jakarta (UPKBA).

In times of high surface water reading at the first water gate, the Regional Disaster Management Agency of Jakarta (BPBD) will give the initial command to related stakeholders and send an early warning to the public and communities in flood risk areas. Flood waste clean-up at the community level is led by Subdistrict Public Infrastructure Management (PPSU). DLH and UPKBA coordinate to remove flood waste from waterbodies and residential areas and transport them all together to Bantar Gebang Landfill.

Ciliwung riverside community: Kampung Melayu Subdistrict

Kampung Melayu Subdistrict is one of the areas with the worst floods impact in Jakarta, especially at community unit No.8 (RW8) with a record of over two meters high flood. In the event of a flood, it is uncommon to have river waste surging the community; instead, most of the flood waste is mud which must be dealt with using a pressure washer back to the river. Other than acts of reuse, prevention of flood waste generation is done by moving valuable furniture and electronics to the second floor or roof, and by replacing the furniture with plastic made to withstand reoccurring floods. As for the damaged furniture and electronics, it is easier to send them into the river, to be managed at the next water gate, than to transport them up to the collection point because they live remarkably far from the main road where flood waste collection trucks are.

Table 1 Roles and responsibilities of Ciliwung River and flood waste related stakeholders

Segment	General Management		Waste Management			
	River	Flood	Household	Public Facility	River	Flood
National	PUPR[1], BBWSCC	PUPR[1], BBWSCC, BNPB[1]	KLHK[1]	KLHK[1]	KLHK[1]	KLHK[1]
Provincial	DSDA	DSDA, BPBD	DLH[2]	DLH[3]	UPKBA[4]	DLH[3], UPKBA[4]
Subdistrict		PPSU		PPSU		PPSU
Community			RW[5]			

[1]Policy making, enactment; [2]Transport waste (transfer station to landfill); [3]Clean-up, collect, transport on land waste; [4]Remove waste on waterbodies; [5]Officers collect waste (household to transfer station).

CONCLUSIONS

This preliminary study covered rudimentary information on the current waste management in Ciliwung riverside communities, Ciliwung River, and Jakarta flood events with the roles and responsibilities of related stakeholders. Further surveys on household-river waste flow, improvement of waste reduction, and impact of flood waste governance on landfill are deemed essential to be conducted.

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Research on Quality of Life (QOL) of Road Sweepers in Chattogram City, Bangladesh

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Keywords: road sweepers, Harijan, Shebok, municipal waste management, QOL

INTRODUCTION

In Chattogram City Corporation (CCC), around 3,500 cleaners, called "Shebok", are engaged in conservancy work such as road sweeping and door to door waste collection (primary collection). Majority of cleaners (71%) is Hindu, and Muslim is 29% among them (CCC, 2022). In caste hierarchy of Hindu, some castes, including sweeper community called "Dalit" or "Harijan"[1], were regarded as impure or untouchable. Due to their hereditary occupation, sweepers had been experienced discrimination and subordination in Bangladeshi society (Habiba & Subedi, 2016). In CCC, 1,913 cleaners (55%) is Harijan (as of December 2022). In this paper, we are focusing on the Quality of Life (QOL) of Harijan and confirm whether or not the negative perception against Harijan is remaining and affects their QOL.

METHODOROGY

Questionnaire Survey

The World Health Organization (WHO) defines QOL as "an individual's perception of their position in life in the context of the culture and value systems" in which they live and in relation to their goals, expectations, standards and concerns. We follow the guideline of WHO and apply WHOQOL-BREF to assess the QOL of cleaners. WHOQOL-BREF is composed of 26 questions with 5 scales (1-5). WHO officially provides questionnaire in Bengali and its validity has been proved (Atsuro Tsutsumi, Takashi Izutsu et al., 2006). Therefore, WHOQOL-BREF in Bengal was distributed to cleaners, and cleaners marked their answers on it by themselves[2]. Data was collected by Conservancy Inspectors of each ward in CCC and data entry and analysis was done in accordance with the WHO guideline.

Target group

Target groups are Harijan and others. There are five colonies of Harijan in CCC (Jhautola Colony-Ward 21, Bandel Colony-Ward 29, Motherbari Colony-Ward 32, Firingi Bazar Colony-Ward 33, Ananda Bazar Shebok Colony-Ward 37). In this survey, 10 cleaners are randomly selected from each colony and 10 cleaners other than Harijan also selected as a comparison group. As a result, 60 cleaners are selected in total.

RESULTS AND DISCUSSION

[1] Gandhi used the term "Harijan" (People of God) at the first time to refer to the untouchables. A. B. M. Mohiuddin Chowdhury, the former Mayor of Chattogram City (Chittagong City), initiated to use "Shebok" (a servant in Bengali), and currently "Shebok" is popular as a common name of road sweepers/cleaners in Chattogram City.

[2] Literacy rate of cleaners is estimated at 90 % (CCC, 2022).

Table 1 shows the results of overall QOL index per each target group. The results are converted into 0-100 scale. Based on the result, it can be said that self-satisfaction of life of Harijan indicated by the overall QOL is slightly lower than others (non-colonial shebok). Especially, satisfaction of health in Firingi Bazar Colony (Ward 33) is considerably lower than others. Table 2 shows the detailed analysis in four domains, namely physical, psychological, social relationships and environment. Average scores of adult population (men and women) in Bangladesh are quoted as a reference (Atsuro Tsutsumi, Takashi Izutsu et al., 2006). The results revealed that the tendency of three domains (physical, psychological, and social relationships) of Harijan are almost same as average adult population while one domain (environment) is considerably lower while the same tendency can be observed for non-colonial shebok. It suggests that the issues related to environment could be common among clears job and CCC required to take countermeasure on it.

Table 1 Results of overall QOL (0-100 scale)

Target Group	Hindu colony (Harijan)					Non-colonial shebok
Ward No.	Ward 21	Ward 29	Ward 32	Ward 33	Ward 37	
Overall QOL Index	48.75	48.75	51.25	25.00	40.00	57.50

Table 2 Domain scores (Mean of answers)

Domain scores ()*	Survey Results			Comparison group**	
	Hindu colony (Harijan)	Non-colonial shebok	Total	Adult population (Men)	Adult population (Women)
Physical (7)	13.96	15.71	14.25	14.14	11.43
Psychological (6)	14.64	15.40	14.76	13.79	11.86
Social Relationships (3)	15.01	16.93	15.33	14.58	13.85
Environment (8)	9.01	8.65	8.95	12.00	12.53

* Note: Numbers described in () are numbers of questions categorized in each domain.
** Source: Atsuro Tsutsumi, Takashi Izutsu et al. (2006)

CONCLUSION

Although the common needs among cleaners, nevertheless their religion or living areas, for improving work/living environment of cleaners were pointed out, significant difference of QOL among Harijan, other cleaners and average adult population was not determined through the survey.

ACKNOWLEDGEMENT

This research was supported by the Chattogram City Corporation, Bangladesh.

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Supplying risk of critical metals in photovoltaic industry in China

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Keywords: photovoltaic module, critical metal, carbon neutrality, sustainability

Introduction

In the past decade, the global installed capacity of photovoltaic (PV) power generation has increased nearly 20 times due to the decline in costs and strong policy support in key regions such as the EU and China [1]. Globally, the proportion of PV power generation installed capacity in all power generation will rise rapidly by 2050. China's PV market has experienced a fast expansion in recent years, making it the global largest market (one-third of global installation in 2018) [2]. The PV module mainly comprises cells and other parts, including the frame, inverter, and transmission cable.

With many PV systems retiring in the oncoming future, end-of-life management for PV systems will become a crucial environmental and social issue regarding resource depletion, ecotoxicity, and climate change. Copper, silver, gallium, indium, germanium, and cadmium are essential materials used by current PV technology. Excepting copper, most of the world's primary supply of silver, gallium, indium, germanium, and cadmium commodities are lack of rich ores and are recovered as byproducts from other metals' ores. Thus, effective management of end-of-life PV components is critical to sustainable renewable energy development.

Methods

Critical metals in industrialized PV panels

Different PV modules require different types and quantities of key metals. Crystalline silicon (c-Si) module is the main PV module at present. The remaining market is mainly "thin film" components, including cadmium telluride (CdTe), copper indium gallium selenide (CIGS), and amorphous silicon (a-Si) types. Therefore, we considered four types of technologies in this study.

Metal intensity

The metal intensity data is collected from literatures [3]. There are three scenarios for metal intensity, that is low development scenario (LDS), middle development scenario (MDS) and high development scenario (HDS), metal intensity varies from lowest to highest. In the years earlier than 2010, the metal intensity data is not available. It was set to be constant, equal to the intensity in the earliest year that have available data, which is 2010.

Weibull lifetime distribution

This research uses the Weibull distribution model to map the retirement of PV modules. The Weibull distribution model is recognized as the best model for PV retirement in the existing research. However, mass retirement of PV modules has not come yet in China, so researchers can only determine the parameter through an accelerated life test experiment. The average lifetime is set as 30 years [4].

PV installation growth scenarios

The below 2℃ scenario (Carbon Neutral Scenario in this research) path of the Energy Research Institute of the national development and Reform Commission is between the 2 ℃ scenario path and the 1.5 ℃ scenario path, which is also representative of the new path under the new carbon emission reduction commitment. In the future, it is uncertain which PV technologies can win the market, so the research sets five technology scenarios for PV market in China. In different

scenarios, market shares occupied by technologies are different.

Results and discussion

Supplying potential of end-of-life photovoltaic panels

The result shows that PV modules in China starts mass retirement around 2025 (1.1GW annual retirement in 2025 for Carbon Neutral scenario, about 10 kt in weight), takes off after 2030 (12.0 GW annual retirement in 2030 for Carbon Neutral scenario, about 100 kt in weight) and keeps fast increasing. In the year 2050, the annual retirement scale of PV modules in China is estimated to be 66 GW (about 600 kt) for BAU scenario and 89 GW (about 810 kt) for Carbon Neutral scenario. The result of Carbon Neutral and Technology Base scenarios shows that in 2030 the amount of critical metals in waste PV modules reaches copper 800−850 kt, silver 100−280 t, gallium 1.5−3.4 t, and indium 6.0−12.7 t, germanium 16−23 t and cadmium 21−64 t.

Supplying risk of critical metals for PV installation growth

Based on the predicted cumulated consumption of critical metals for PV penal installation, the research estimated annual net consumption and cumulated net consumption of PV panels under different recycling rates in the Carbon Neutral scenario. Due to the ratio of consumption scale and retirement scale, the influence of different recycling rates is remarkable after 2035 for annual net consumption and after 2040 for cumulated net consumption. Cumulated net consumption will not peak before 2050 under any recycling rate, although under 90% recycling. Assume that the recycling rate reaches 90%, which means the lowest net consumption in all the scenarios. Fig.1 shows the ratio of the highest cumulated net consumption-to-current reserve (of China). It can be found that the critical metals under potential supplying risk in at least one scenario are silver, indium, germanium, and cadmium.

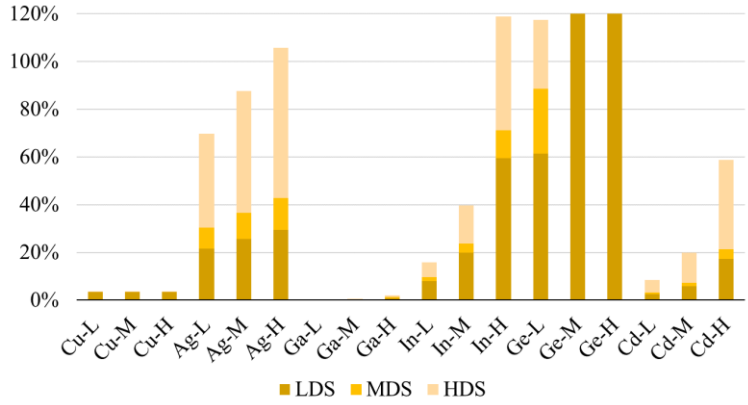

Fig.1 China PV: Highest cumulated net consumption-to-current reserve (of China) ratio under 90% recycling rate

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The intergenerational learning effects of a home study program for elementary and junior high school students on knowledge and awareness of plastic consumption

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Keywords: plastic consumption behavior, environmental education, awareness, intergenerational learning

BACKGROUND AND OBJECTIVES

Measures to manage plastic waste based on the 3Rs (Reduce, Reuse, Recycle) at the household level can reduce the household waste and ensure proper circulation of plastics. It is important to engage children in environmental issues as they will experience first-hand the dire consequences of looming environmental issues, including plastic issues. Children can influence their family through intergenerational learning (IGL) which is the transfer of knowledge, attitudes, and behavior between generations. This research aims to develop an educational program fostering IGL to see its effects on the child's knowledge, attitude, perceived behavior control and intention to reduce plastic waste and the effect of IGL on parent and child's behavior.

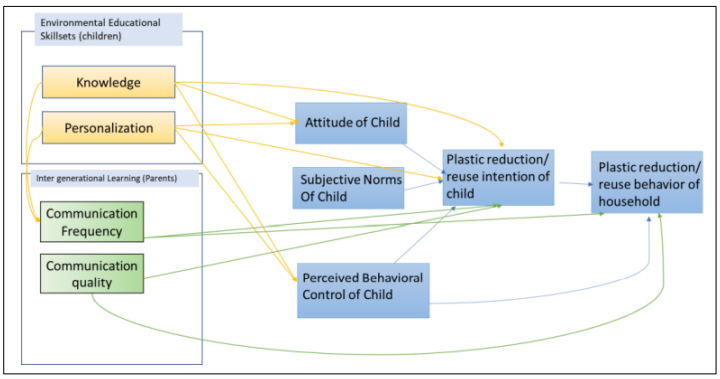

Fig.1 Extended Theory of Planned Behavior

MATERIALS AND METHODS

A home study program, spanning over two weeks, was designed targeting elementary and middle school students. Recruitment was conducted through Bikkuri eco newspaper distributed to schools across Kyoto city. The program required for the participants to engage in 6 "missions" related to plastic consumption. The program was carried out from 9th May to 30th May 2022. Missions 1 to 4 were designed for children to observe plastics in their surroundings and in the shopping contents of the household. In the 5th mission they thought of 3 actions to reduce plastics and in the 6th mission, they monitored the implementation of the actions of the entire family. Pre and post questionnaires were administered to children as well as parents. The prequestionnaire for children was based on the extended theory of planned behavior model (Figure 1). The parents' questionnaires looked at current interest and consumption behavior of the parents and detailed reflection of the home study program. A thematic qualitative analysis of the questionnaire answers and workbook contents was carried out.

RESULTS AND DISCUSSION

25 participants successfully completed all the missions. Of the 25 participants, 11 participants and their parents showed positive pro-environmental behavior. In terms of intergenerational learning, children and parents who communicated more frequently about plastic issues showed more tendency to engage in pro-

environmental behavior. Figure 2 shows that parents whose frequency of conversing about social issues with their children increased exhibited positive behavior. Thus, increasing opportunities for discussing social issues can enable intergenerational learning.

However, several children showed a negative change in attitude toward plastic reduction. The change was especially visible in the 11 children who displayed positive behavior. As can be seen in figure 3, 6 children strongly agreed that reducing plastic is hard compared to 3 in the pre scenario. 3 children strongly agreed that reducing plastics is bothersome compared to 0 in the pre scenario. A thematic analysis of the workbook and the questionnaires revealed 2 major themes for the negative change in attitude of the children. Lack of options is a major difficulty faced by the children and their families. The lack of products without plastic packaging, cashiers automatically putting unpackaged vegetables in plastic covers, and so on seemed to create barriers in the reduction behavior. Habitual barriers pose another difficulty. Reliance on the convenience of plastics and not being used to the available plastic free alternatives posed barriers in plastic reduction. Thus, it is important to improve access of options for consumers. Furthermore, improving educational content to provide hints to change habits is also important.

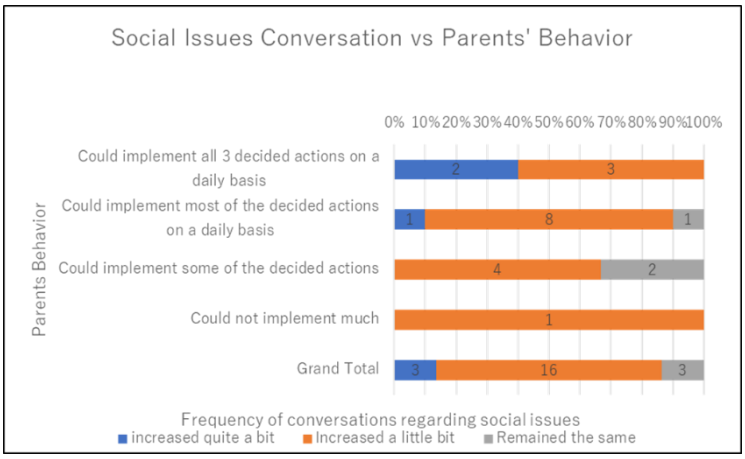

Fig.2 Increase in parents' pro environmental behavior with increase in frequency of social issues-based communication

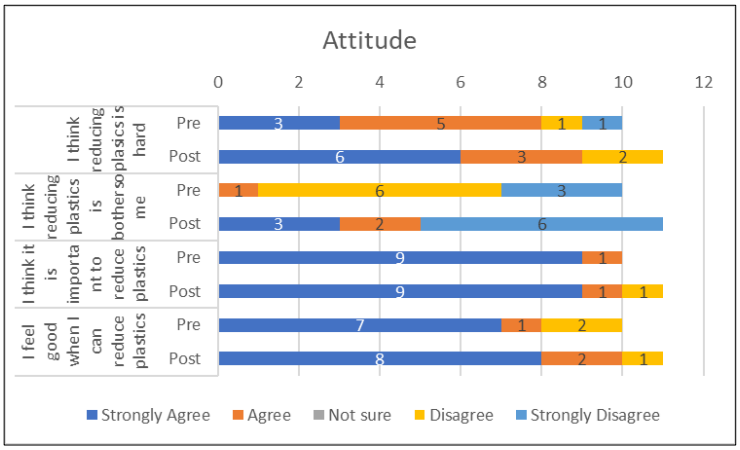

Fig.3 Change in attitude of children with high pro-environmental behavior

CONCLUSION

This study aimed to develop a home study program about plastic consumption that fosters intergenerational learning. The program could successfully allow children to interact with their parents and influence parents' behavior through communication about social issues. However, children felt difficulty in reducing plastics due to lack of options and habitual barriers. Thus, it is important to increase access to plastic free options and improve educational content to help remove habitual barriers.

ACKNOWLEDGEMENT

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Potential of Greenhouse Gas Emission Mitigation of Municipal Solid Waste Management in Bangkok Metropolitan

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Keywords: greenhouse gas emission, IPCC methodology, mitigation, solid waste management, waste disposal

INTRODUCTION

Municipal solid waste (MSW) generation in Bangkok Metropolitan, capital city of Thailand, has steadily increasing from its urbanization, economic growth and people life-style changes. In 2021, there was 12,214 tons of MSW generated daily in Bangkok in which 3,564 tons was recycled and 8,650 tons was disposed [1]. The disposed MSW was managed in composting plant at 1,600 tons/day, incineration plant at 500 tons/day, mechanical biological treatment (MBT) facility at 800 tons/day, and the remaining wastes at 2 sanitary landfill sites [2]. The MSW management by these combined methods results in significant greenhouse gas (GHG) emissions. In 2015, Thailand has submitted its national determined contribution aiming to reduce its GHG emissions by 20-25% [3]. Meanwhile, Bangkok Metropolitan Administration (BMA) has issued its development plan (20 years: 2013-2032) in 2014 targeting reduction of MSW amount to be disposed by 20% and increase waste utilization by 40% from the base year (2013) to achieve sustainable MSW management while reducing impacts to the environment and climate change [4]. Nevertheless, the extent of GHG mitigation to be achieved from the implementation of MSW management following BMA development plan has not been evaluated. Therefore, this research determined GHG emission from MSW management in Bangkok Metropolitan by comparing 3 different scenarios, i.e., business as usual (BAU), Bangkok solid waste management plan, and National GHG mitigation policy which include increased methane gas recovery from solid waste disposal sites, increased waste treatment by composting and incineration.

METHODOLOGY

The estimation of GHG emission was carried out following 2006 IPCC Guidelines for National GHG Inventories [5] and 2019 Refinement to the 2006 IPCC Guidelines [6]. The MSW management activities resulting in GHG emissions were 1) Solid waste disposal on land 2) Biological treatment of solid waste 3) Incineration of waste. Information on the quantity and most recent physical composition of MSW from BMA statistics was used. Default parameters recommended in the guidelines were applied for the estimation of GHG emissions.

RESULTS

In this study, GHG emission from waste sector in Bangkok Metropolitan under BAU was estimated at 1,216.31 $GgCO_2eq$ in 2032 but will reduce to 714.23 $GgCO_2eq$ under Bangkok solid waste management plan. Adoption of National GHG mitigation policy in terms of increase in methane recovery from landfill disposal will emit 771.65 $GgCO_2eq$ whereas increasing waste treatment through composting and incineration will yield

1,163.18 and 930.64 $GgCO_2eq$ emissions. Implementation of all 3 measures will emit 633 $GgCO_2eq$. This lowest emission scenario can reduce the emissions by 47.69% from the BAU scenario in 2032. To achieve this maximum GHG emission reduction scheme, 2400 tons/day of composting, 3,500 tons/day of incineration, and 43% of methane gas recovery from landfills needs to be implemented in 2032.

ACKNOWLEDGMENT

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Value Chain Assessment of Lithium Mineral Concentrates Production for FEB Applications

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Keywords: lithium mining exploitation, lithium concentrates production, ferroelectric electrolyte batteries, life cycle assessment, circular economy

INTRODUCTION / ABSTRACT

This case study is part of a co-promotion project between the industry (proponent) and the academia whose main objectives is the sustainable production of Lithium mineral concentrates, from the reserves that exist in concessions of the proponent, to be use on Ferroelectric Electrolyte Batteries (FEB) for electric vehicles. It foresees the full recovery of the minerals that exist in the ore (quartz, feldspar and eventually heavy metallic minerals), thus driving to a process that does not generate solid wastes (tailings). This way, it becomes possible to attain the two main objectives assigned in the guiding principles of sustainable management of mineral resources: full utilization and absence of wastes.

As second objective, the project intends to develop, up to the maximum limit considered as possible and feasible, the value chain of the production cycle of lithium based batteries for electric vehicles, thus enhancing the maximization of the added value resulting from the exploitation of the national resources of this metal. Portugal is currently the country with higher proven Li reserves on the European continent.

Under the project scope, the present study is specifically focused on the Life Cycle Assessment (LCA) of the production of lithium hydroxide monohydrate ($LiOH.H_2O$), with battery grade (99%), using a cradle to gate approach. The structure of the integrated production system comprises the following production stages: a) mining, which leads to the extraction of the ore; b) ore processing, which leads to the production of mineral concentrates; c) metallurgy, which leads to the production of a marketable lithium compound; and d) distribution or outflow of the final product.

RESEARCH METHODS

SimaPro software and Ecoinvent databases were used to support the analysis. System boundaries, inputs and outputs are schematic represented on Fig. 1. All relevant environmental, human health and socio-economic impacts of each production stage were considered and a contribution analysis was run allowing identifying the critical product cycle phases that can be further improved. For the main impact categories, the following indicators were evaluated: 1- Climate Change; 2 - Ozone depletion; 3 - Terrestrial acidification; 4 - Freshwater eutrophication; 5 - Human toxicity; 6 - Inhalable particle formation; 7 - Water depletion; 8 - Depletion of abiotic resources (minerals and metals).

Initial results seem to indicate that the mining extraction and ore processing product cycle phases are associate to the higher environmental load. Alternative procedures/proceedings, within these product stages, are being analyzed towards possible and economic viable mitigations of environmental effects.

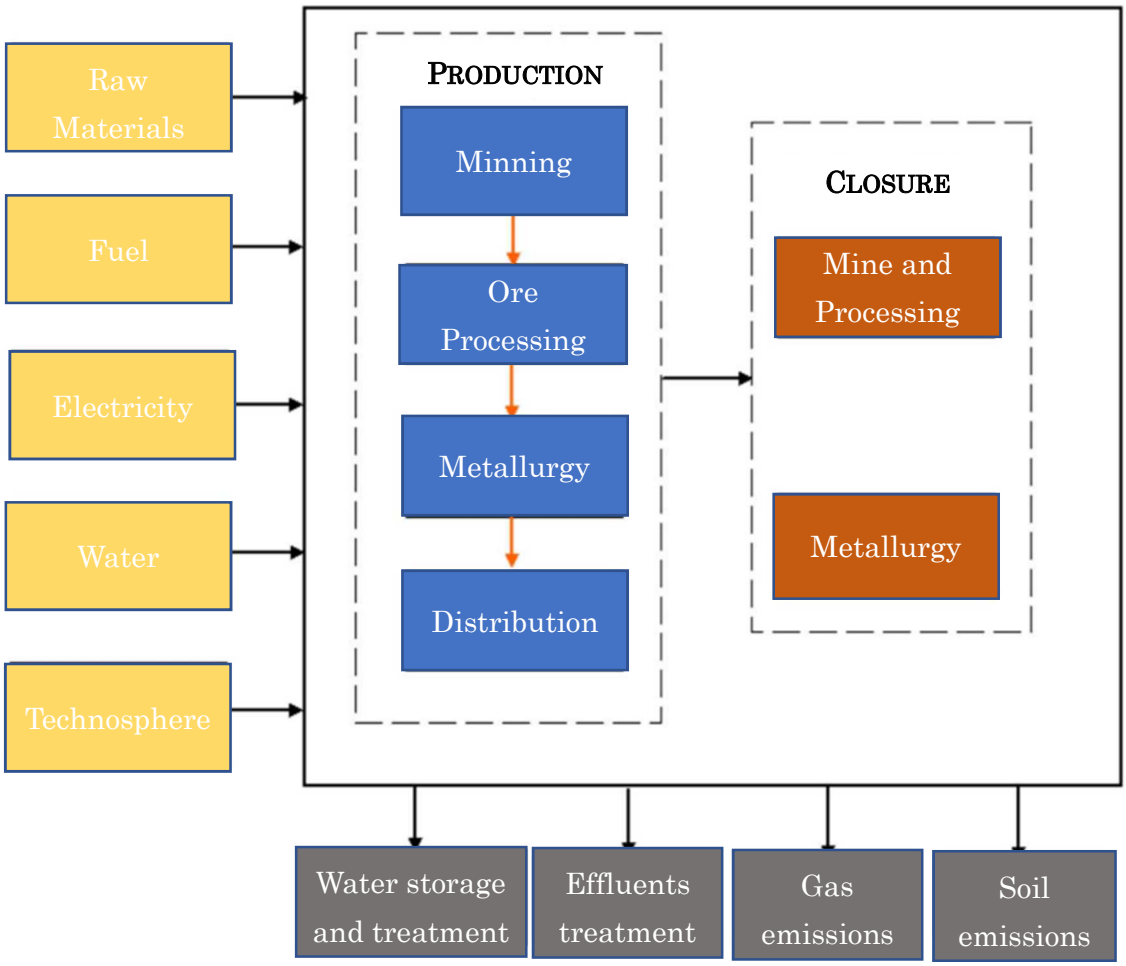

Figure 1 – Flow diagram and boundaries of product system

ACKNOWLEDGEMENT

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Development Stage of waste management in ASEAN cities

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Keywords: Waste management system, development stage, ASEAN

INTRODUCTION

With strong population growth and increasing urbanization, the Association of Southeast Asian Nations (ASEAN) is one of the fastest-growing regions in the world. Although production and efficiency are rising, ASEAN countries still have major challenges in improving their waste management. Only 57% of the waste produced in ASEAN is estimated to be collected, and only one-fourth of that amount is recycled. Illegal waste dumping such as open burning and open dumping, which accounts for 34% is still a serious issue (Ferronato N, Torretta V., 2019) that causes negative impacts on environmental contamination of air, water, soil and poses a potential risk to human health. The study aims to establish baseline data on the current state of waste management and comparison of the status quo in ASEAN cities, the results will be used to determine the next steps in developing waste management using the LCA approach, and the most effective measures shall be identified.

MATERIALS AND METHODS

When analyzing the development of WMS through the years, some typical development stages become visible, leading from the absence of essential elements of waste management to a Circular Economy model, where waste is seen as a resource. In this paper, the development of the WMS of nine capital cities in the Association of Southeast Asian Nations (ASEAN) region is analyzed. This region has very dynamic characteristics, with similar cultures and lifestyles but distinct geographic constraints and economic development, leading to the diverse development of WMS. To describe and analyze the development stages of these cities, a recently developed model, the Waste Management System - Development Stage Concept (WMS-DSC) was used.

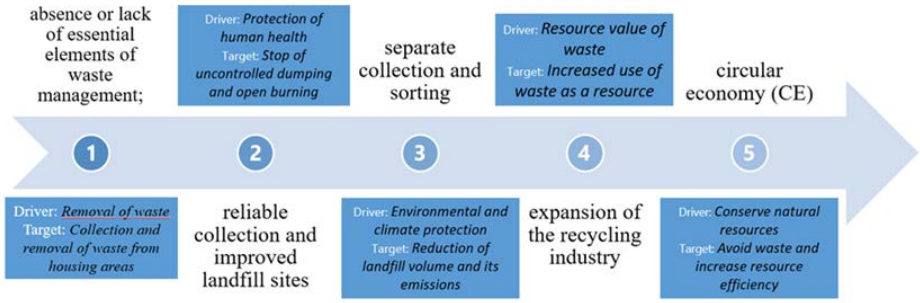

Figure 1 Five development stages of WMS-DSC (Campitelli et al., 2022)

RESULTS AND DISCUSSION

Waste Collection and Transport

The 9 ASEAN countries have a similar path of development in terms of waste collection whereas Singapore (Stage 2 to 5) has a more advanced system and facilities. Vientiane, Hanoi, Phnom Penh, Banda Seri Begawan (stage 1 to 4) still struggle with inadequate facilities and service coverage for municipal waste collection.

Bangkok, Kuala Lumpur and Manila are in a better development stage where the coverage is higher with better waste management infrastructure. However, the collection rate of recyclable materials for all cities is not documented and the majority of the collection service depends on informal recyclers. The waste banks initiative is also widespread among ASEAN cities and contributes to the collection of recyclable materials. There are about 5,500 waste banks in Thailand (Fang, E. 2020) and a total of 1443 waste banks were established in 56 cities spread over 19 provinces in Indonesia back in 2013 (Fatmawati et al., 2022).

Waste Disposal

While some sanitary landfills have recently been created, many ASEAN cities (varying from stages 1 to 4) still rely on the controlled landfill where open burning still occurs in many parts of the metropolis. Food waste and recyclable waste are still primarily disposed of in landfills. Only Singapore has reached the highest state of the art of their only landfill (Stage 5) where only bottom ash from incineration plants and non-incinerate waste are allowed to dispose of at the landfill.

Energy Recovery (ER)

Having operated the first incinerator plant in ASEAN back in 1979 and at least 50 years of expertise, Singapore (Stages 2 to 5) plays a leading role in ER. In large cities with significant waste production, such as Bangkok, Jakarta, Hanoi, Manila, and Kuala Lumpur (Stage 1 to 4), ER has also gained popularity and some pilot plants are introduced technology from Japan, Korea and Europe. In the coming years, Thailand plans to construct 79 WtE plants with a combined capacity of 619.28 MW, whereas Indonesia has 17 projects with a total proposed capacity of 134.9 MW.

Waste Recycling

All the cities (stages 1 to 4) are still working to raise their waste recycling rates, particularly for food waste, plastic, glass, paper, and metal. Singapore has the highest rate of construction and demolition, as well as metal a nearly 100%. Despite this, formal and informal waste recycling activities can be found in multiple places in Thailand, Vietnam, Malaysia, and Indonesia. Composting and fermentation are commonly implemented on small scales such as home composting, vermicompost and Bokashi in the 9 cities.

Prevention and Reuse

The Circular Economy concept is being implemented in Singapore, Jakarta, Bangkok, Kuala Lumpur, Manila, and Hanoi (Stages 1-4), and numerous forums that aim to close the gap between businesses, the government, and academia have been developed in recent years. The top three priority waste streams in each of the nine cities are food waste, packaging, and e-waste.

CONCLUSION

ASEAN cities' WMS development stage averagely evolving in stages 2 to 4 where the majority has established reliable waste collection, improved landfills site, and introduced of separate collection and sorting while the recycling industry is rapidly expanding. However, Landfills continue to be the predominant method of disposal in many ASEAN nations, despite the rise in popularity of waste-to-energy and the 3Rs (Reduce, Reuse, Recycle) strategy.

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Evaluating the Key Success Factors for Waste Management of Local Level: Observational Cases of RDF Utilization and Semi-Aerobic Landfill in Thailand

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Keywords: low carbon waste management; key success factors; RDF production; semi-aerobic landfill

INTRODUCTION

Thailand Voluntary Emission Reduction Program (T-VER) was developed by Thailand Greenhouse Gas Management Organization (TGO) to promote and support all sectors to participate in the greenhouse gas (GHG) emission reduction program voluntarily. This reduction unit or carbon credit, called "TVER" under this T-VER program, can be sold under a voluntary domestic market (T-VER, 2020). However, the development still has limitations in expanding the results of greenhouse gas reduction projects; both the readiness of operators and technical and other factors that affect GHG reduction activities at the local level. In addition, the key success factors have never been extracted from a successful project, including extracting additional concerns. Therefore, this study aims to extract key success factors for GHG reduction activities in the waste sector at the local level from the success cases. Then, local governments can use these key success factors to create methods for promoting and developing GHG reduction projects and implementing them suitable for their local context.

MATERIALS AND METHODS

Selected site

The selected technologies were (1) refuse-derived fuel (RDF) production from municipal solid waste (MSW) and (2) semi-aerobic landfill. Two sites were studied per type of activity, totaling four areas.

System boundary

The scope of the study is the promotion and expansion of the GHG reduction project at the local level through the investigation and analysis of factors that could affect and benefit the implementation of greenhouse gas reduction projects, such as the preparedness of local administrative organizations, technical factors, and economic factors. Two methods were used to collect data: (1) a field visit and (2) an in-depth interview.

Financial analysis

The calculations are separated into two cases: (1) the case in which the local site invests 100% of its operational expenses (Base Case; BC), and (2) the case in which the initiative receives government funding of 90% and 10% of the local site's operating costs (Low Case; LC) at a discount rate of 4.08 %.

RESULTS AND DISCUSSION

RDF utilization

It was found that the system's sustainability depends on the fuel used, and a reasonable haul distance

between the plant and the fuel user helps increase the cost-effective investment. The economic cost-benefit analysis of technology found that the project was not economically appropriate for both case studies. However, the economic feasibility data also depends on various factors affecting RDF production. Therefore, the outcomes of project-based investments differ from those of commercial investments.

Semi-aerobic landfill

It was found that this technology is simply implemented, does not incur a disproportionately higher cost, and requires only the installation of pipelines for collecting leachate and a ventilation system. However, in the first stage of construction, the experienced company should be used to transfer knowledge in design and construction. The economic cost-benefit analysis of technology found that the project was not economically appropriate for both case studies. However, both case studies are small projects that operate within the community, which might be affected by the economies of scale. Moreover, the case studies are also operated within the migrant zone and municipality with no tipping fee as operations income. Therefore, the outcomes of project-based investments differ from those of commercial investments.

Recommendations for the local administrative organizations

The data collection must be separated during holidays and business days, which could affect the efficiency of project operations. The funders should have a Key Performance Indicator (KPI) to monitor and measure the system. For knowledge and understanding of the operational details, it should have a mentoring approach to oversee projects. It may consist of mentors provided by the funders or cooperation from the education sector because problems with equipment and technology may necessitate the use of the expertise of outside experts and the provision of knowledge, training, or study visits to increase understanding. These are extremely important to develop, modify and improve their systems for maximum efficiency and effectiveness. In addition, the pre-project agreement is needed in a concise verification to create the full benefits for the municipality.

CONCLUSION

This research aims to examine the feasibility study for the promotion and expansion of GHG reduction projects at the regional level. It was discovered that the executives who gave the operation top attention were responsible for its initial success. During the operation phase, people's preparedness is still a factor determining the operation's success, but operational procedures have the most significant impact. The selection of appropriate technology varies by circumstance, impacting the total system. Concern should be given to the knowledge and comprehension of waste management in the context of other features specific to the location. In addition, it is necessary to specify various benefits that will be received in operation in the form of a document or TOR for the country's advantage in developing various GHG reduction technologies to be consistent with various national and international development plans.

ACKNOWLEDGEMENT

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CO_2 Utilization Processes to Produce Nano-Sized $CaCO_3$ Based on Oyster-Shell Waste

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Keywords: Carbon capture and utilization, CO_2 Mineralization, Resource recovery, Oyster-shell waste

INTRODUCTION

Every year, approximately 6 million to 8 million ton of various mariculture waste are produced globally of which about 1.5 million ton is produced in Southeast Asia alone. In developing countries, mariculture waste is often just dumped in landfill or the sea. In developed countries, disposal can be costly—up to 150 $ per ton in Australia, for example. However, mariculture waste such as oyster-shell waste is a valuable natural material that is rich in $CaCO_3$ and can be directly used as limestone or as a suitable feedstock for CO_2 mineralization, in carbon capture and utilization (CCU) technologies, due to its enough generation, high reactivity, and low cost.

EXPERIMENTS

Materials

In these processes, the samples of the oyster-shell waste were obtained from the south coast, of Taean, Chungcheongnam-do, the Republic of Korea. The recovered oyster-shell waste was washed with distilled water to remove impurities remaining on the surface of oyster-shell waste. The extraction agent was HCl (purity ≥ 37%, CAS No. 7647-01-0). NaOH (purity ≥ 98%, CAS No. 1310-73-2) was used to control the pH. All chemicals used during this process were of analytical reagent grade and used without further purification and deionized water was used throughout the process. Actual flue gas was simulated using 15 vol.% CO_2 mixed with 85 vol.% N_2 gas. All gases used in the experiments were purchased from Union Gas Inc.

Methods

To utilize the oyster-shell waste as feedstock for CO_2 mineralization, we proposed an advanced calcination process and a novel extraction process based on oyster-shell waste. In the case of calcination, the multi-calcination process which is consist of 1st Calcination (Impurity Removal) and 2nd Calcination (Transition of $CaCO_3$) was proposed because the organic compound can generate hazardous gases such as SOx and NOx due to the organic impurities in the oyster-shell waste. And then, the calcinated oyster-shell waste was hydrated to convert into $Ca(OH)_2$ before CO_2 mineralization and it was used as an absorbent for CO_2 mineralization. In the case of extraction, a strong acid-mediated extraction–mineralization process was proposed. In the extraction process, the pH swing method, which is known for the selective precipitation of metal ions, was used. Following that, the recovered high-purity Ca_{2+} was used as an absorbent for CO_2 mineralization, and the generated alkaline wastewater, which has the advantage of reacting with CO_2 due to high pH conditions, was intended to be used as a solvent.

RESULTS AND DISCUSSION

This study investigated the utilization process employing oyster-shell waste for CO_2 mineralization via the calcination and extraction process. To compare utilization methods, we proposed two advanced

utilization processes; calcination and extraction. In the calcination process consisting of 1st and 2nd calcination, oyster-shell waste was calcined for 1h at 900 °C in a muffle oven and it was converted into CaO. In response to calcination, we proposed a novel extraction-mineralization process using an in-situ recyclable strong acid. The process included the extraction of $Ca(OH)_2$ from oyster-shell waste using strong acids and mineralization for CO_2 absorption employing extracted $Ca(OH)_2$ as absorbents and alkaline wastewater as solvents. Through this process, we achieved both low pH conditions in which alkaline earth metals are leached using acid from alkali waste and high pH conditions in which the reactivity of CO_2 is enhanced using alkaline wastewater in CO_2 mineralization. Therefore, we solved the acidic or alkaline wastewater generation problem, which is the main problem when using chemical extraction methods. The calcination showed a significant CaO conversion yield of 95.2 %, whereas the extraction process showed Ca^{2+} extraction efficiency of 99.07%. As a result of the mineralization of CO_2, when the $Ca(OH)_2$ was used with deionized water as a solvent, they have shown similar CO_2 loading values (1.07 and 1.13 mol CO2/mol Ca(OH)2 with calcination and extraction, respectively). When the solvent was replaced with alkaline wastewater, the CO2 loading values were increased from 1.13 to 1.96 mol CO_2/mol $Ca(OH)_2$ with the extraction. In the proposed process, $CaCO_3$ yield was achieved at 0.98 and 0.86 kg CaCO3/kg oyster-shell waste with calcination and extraction, respectively. However, the obtained $CaCO_3$ via the calcination process has a relatively low purity due to not removing impurities. In addition, the average particle size of $CaCO_3$ via extraction process was different depending on solvent types and it is observed that nanosized $CaCO_3$ with 53.49 and 62.81 nm of average particle size was formed with deionized water and alkaline wastewater as a solvent, respectively. As a result, it seems that the high pH of alkaline wastewater affected the increase of particle size because the nucleation and the growth of $CaCO_3$ are highly dependent on the pH of the system [1]. The proposed extraction-mineralization process takes advantage of no additional energy and no generation of acidic or alkaline wastewater in the overall process, and high-purity nano-sized $CaCO_3$ products.

CONCLUSION

This study proposed two processes for oyster-shell waste utilization based on calcination and extraction. First, the calcination process was advanced according to the characteristics of oyster-shell waste. It has the advantage of obtaining high-purity CO_2 gas via the pretreatment process by removing organic compounds. Second, the novel extraction process consisting of three phases was proposed. This can simultaneously achieve low pH conditions where alkaline earth metals are leached and high pH conditions in which the reactivity of CO_2 is enhanced using alkaline wastewater. In addition, it does not produce acidic or basic wastewater which is the main problem in the chemical extraction process. Via substituting conventional products of $CaCO_3$, this process could reduce more than the original CO_{2e} emissions. Therefore, the results of this study can be applied to CO_2 utilization processes to produce nano-sized $CaCO_3$ based on industrial alkaline waste

ACKNOWLEDGEMENT

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A Comparative Study on Creating a Sustainable Municipal Solid Waste Management System in Gampaha city, Sri Lanka towards an Eco friendly City with Special reference to Misato city, Japan

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Keywords: Sustainable municipal solid waste management. Eco-friendly city. Legislation. Administrative framework. "Top-down" and "Bottom-up" approaches

INTRODUCTION

Sri Lanka can be identified as one of the countries where the unbalanced (1) urbanization, and (2) spatial planning have increased the pressure on natural resources and the environment through inefficient and wasteful utilization (Vitharana, 2016).

Local Authorities (LAs), the obligatory institutions for Municipal Solid Waste Management (MSWM) in Sri Lanka, are struggling with an overwhelming burden on waste management. Gampaha city is a semi-urban city that has undergone a massive development program in recent years under the national government's master development plan and with the biggest challenge in MSWM in all its five phases. Households are the major waste generators nevertheless, the threshold city capacity for waste collection is only 50% of household waste. And the rest 50% is mismanaged and disposed of in environmentally sensitive areas aggravating related health, social, environmental, and economic conditions. Misato city manages MSW successfully despite the challenge of a higher population and high waste generation than that of Gampaha city even though they have approximately the same city area (Gampaha city – 37km^2, Misato city – 30.13km^2) and per capita per day waste generation rate (Gampaha city-588.95g, Misato city-628.68g). There have been no published studies with the scope of comparing the effect of legal/policy and administrative framework toward a sustainable MSWM system in Sri Lanka and Japan. This research examines the emergence of new MSWM governance initiatives toward new "policy windows" on MSWM for Gampaha city. This study aimed to explore current MSW management problems, challenges, and underlying reasons in Gampaha city and to compare it with Misato city.

MATERIALS AND METHODS

The study was purely qualitative, and the comparative case study approach is applied. The established comparative analytical criteria encompass the four main pillars (1) Legislation, (2) Administrative framework, (3) Stakeholder collaboration, and (4) Institutional in-house capacity. A preliminary investigation was conducted in Gampaha city for the households. Data was gathered and tabulated from 304 respondents at a 95% significance level using 5 points Likert scale. The secondary survey and follow-up interview were conducted with six households in case cities, selected via purposive sampling together with the authorized officers on MSWM in case cities.

RESULTS AND DISCUSSION

The identified causes for the issue are (1) poor administrative framework (79%), (2) deficient community involvement and awareness (66%), (3) poor collaboration with other government and non-governmental institutions (65%), (4) poor legislation (71%), (5) lack of in-house capacity (56%), and (6) lack of political commitment (50%).

CONCLUSION

The author(s) conclude and recommend the identified issues in Gampaha city could be overcome with the city-specific policy and administrative framework with an institutional coherence to achieve community awareness and commitment. Further, the policymakers should be considerate of both “top-down” and “bottom-up” approaches to bound all the stakeholders into the system to fulfil a sustainable MSWM system in the city.

ACKNOWLEDGEMENTS

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Material Flow Analysis of a Large-Scale Landfill Mining: Case Study Thailand

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Keywords: material flow analysis, landfill mining, refuse-derived fuel, municipal solid waste

INTRODUCTION

In 2021, Thailand generated 24.98 million tons of municipal solid waste (MSW). According to the Pollution Control Department (PCD), only 31.6% of the waste is utilized, while the remaining 17.08 million tons are buried in either sanitary or non-sanitary landfill. Approximately 30% of the MSW expect to be reusable, meaning that around 5.12 million tons of resources will be buried and not utilized in 2021. The number of resources buried in landfills may be equal to the remaining natural resources, according to Krook et al. (2012). However, Thailand had not considered landfill mining a strategic tool for a sustainable future. Therefore, this research focuses on the recovery of plastic material from a large-scale landfill in Thailand, aiming to find the flow of the plastic and the efficiency of the refuse-derived fuel (RDF) production process for the future implementation of landfill mining as a sustainable tool for Thailand.

MATERIALS AND METHODS

Study Site

The study site is located in Samut Prakan province, Thailand, receiving approximately 1.2 million tons of waste yearly. The site has been operating as an open dump landfill since the 1990s. In 2017 the operator commissioned an RDF fuel incineration waste-to-energy (WtE) power plant, incinerating 220 tons of RDF daily, exporting 7.9 MW of electricity. The RDF is produced using a landfill mining technique, processing 800 tons of landfill waste and producing 220 tons of RDF.

Material flow analysis

A material flow analysis was conducted to monitor the flow of landfill waste in and out of each sorting process. The characteristic of the material was analyzed following the ASTM standards. The operating site installed three sorting lines, and each line is installed with a different machine, and the RDF produced from each line has a different standard. This research analyzed each sorting line separately, and the result displayed the material flow data and the plastic flow of the sorting process. The recommendation for improvement has been presented to the operator for future implementation.

RESULTS AND DISCUSSION

Material flow data

Figure 1 shows an example of the material flow data (left) and the plastic flow data (right) of the sorting line set one. Each product characteristic was also analyzed to find the cause of the varied RDF quality, and a suggestion was made concerning the efficiency of the sorting system.

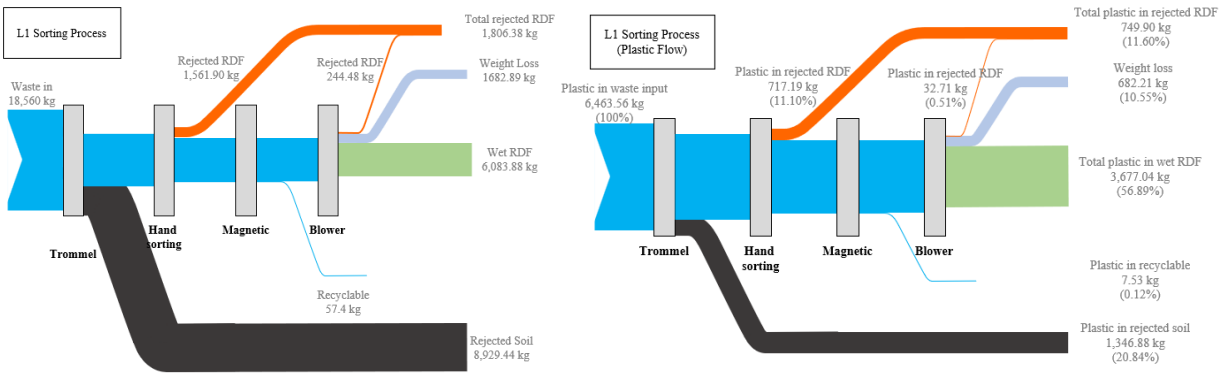

Figure 1 Material flow (left) and plastic flow (right) of the sorting line set one.

Point of concerns

The three points of concern and the suggestion presented to the operator, the point of concerns are as follows: 1) the actual production quantity is 33% lower than the result due to the high machine downtime, as some processes have a higher production impact than others. 2) the plastic recovery rate is low; only 51.66% - 56.89% of plastic is recovered, while the rest remains in the rejected RDF and rejected soil.

CONCLUSION

This study investigated the MFA of a large-scale landfill mining business. The MFA shows that the flow of plastic to produce RDF could be more efficient and improved. Two scenarios of the new setup are presented to the operators. MFA of other scales of landfill mining business should be further investigated, and the plastic flow of different processes should be conducted to compare the machine efficiency.

ACKNOWLEDGEMENT

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Preliminary Evaluation of Greenhouse Gas Emission Reduction from Waste Treatment and Disposal Systems in Nonthaburi, Thailand

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Keywords: GHG emissions, MSW, landfill gas to energy, SWM-GHG calculator

INTRODUCTION

The province is the second-largest local administrative unit in the country. It plays a role that can regulate and direct development at the local level to control greenhouse gas emissions. In addition, the province can significantly set measures and develop projects to reduce greenhouse gas (GHG) emissions. In order to support Thailand in achieving GHG reduction goals, conducting a provincial GHG assessment and developing an appropriate GHG Reduction Plan are necessary. Nonthaburi is a province with rapid urbanization and economic growth, resulting in increased municipal solid waste (MSW). In the past, Nonthaburi has not assessed the effectiveness of the GHG reduction actions that have been undertaken. The main objective of this study was to assess GHG emissions from the existing MSW system in Nonthaburi based on the IPCC methodology using the SWM-GHG calculator.

MATERIALS AND METHODS

Study area

Nonthaburi Province is located in Bangkok's metropolitan area. The Nonthaburi Provincial Administrative Organization (PAO) manages the downstream waste management. In 2021, Nonthaburi had a total of 571,993 tons of MSW to be disposed of in the landfill, consisting of food waste 34.04%; plastics, rubbers, and leathers 31.57%; papers and textiles 21.72%. ; woods, bamboo, and straws 8.46%; and incombustible 4.21%. Currently, Nonthaburi PAO operates a landfill gas-to-energy (LFTGE) project with a capacity of 6.24 MW. In the year 2025, the incinerator project with a capacity of 1,000 tonnes per day will be implemented.

GHG calculation

The SWM-GHG Calculator of ifeu-Institut was used to quantify the GHG balance of waste management for the Nonthaburi Province. It complies with the life cycle assessment (LCA) approach; hence it can be regarded as an LCA-based analysis. Some necessary information was required to use the SWM-GHG Calculator and simulate a waste management system. It had to do with the amount of waste generated and managed during a reference year (2021) as a baseline scenario; the waste composition; the rates of recycling

for both dry and wet recyclables; and the method of final disposal for any leftover residual waste. When feasible, the information was gathered from the Nonthaburi PAO. According to the use of the new incinerators in 2025, the remaining MSW will be disposed of at landfills while the project LFGTE still operates. Therefore, GHG emissions in 2025 (scenario 1) were performed to quantify GHG reduction from the baseline scenario. In addition, the Nonthaburi PAO plans to build another MSW incinerator (600 tonnes per day). Therefore, to review the overall GHG reduction, total waste treatment by all incinerators is set as scenario 2.

RESULTS AND DISCUSSION

Results of GHG emissions analysis

It is also interesting to be informed about the waste properties of the original waste stream for future waste management planning. The lower calorific value represents the ability of the waste to be used for waste-to-energy options since self-sustaining burning is associated with a calorific value higher than 6 MJ/kg. The estimated lower heat value of 13.8 MJ/kg is connected to a relatively high plastic content. All emissions calculated by SWM-GHG Calculator are accounted for the amount of household waste managed over a defined period and region. Then the methodology of LCA implies that the emissions are quantified for this waste management service of a reference year and municipality independent of when and where the emissions occur.

The results showed a comparison of the amount of GHG generated by solid waste management between the baseline and scenarios 1 – 2. It indicates opportunities to reduce greenhouse gas emissions in the order of difficulty and budget. Net GHG emissions were 569,641 tonnes of CO_2 equivalent per year from the baseline. If Nonthaburi PAO take measures following scenario 1, their net greenhouse gas emissions will be 444,691 tonnes of CO_2 equivalent per year. On the other hand, if implemented according to scenario 2, net greenhouse gas emissions remain at 315,925 tonnes of CO_2 equivalent per year.

CONCLUSION

The preliminary assessment of GHG emissions from the activities that Nonthaburi is conducting can only reduce GHG emissions by about 4%. Nevertheless, if the waste treatment is converted to incineration entirely, it can reduce GHG emissions by 38%. However, reducing GHG emissions from the waste sector, waste management at the source is considered an essential part of reducing GHG emissions, especially the sorting activity for recycling, which is in line with the circular economy concept. Therefore, there is further research on waste management at sources suitable for the Nonthaburi context. There should also be a cost analysis of various upstream waste management measures that will be implemented in the future.

ACKNOWLEDGEMENT

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Analysis of WEEE Plastics for Secondary Raw Materials

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Keywords: WEEE, Plastics, Secondary raw materials, Additives, Flame retardant

INTRODUCTION

Japan's Plastic Resource Circulation Act came into effect in April 2022. The act promotes resource recycling throughout the product life cycle, with the goals of advancing the resource recycling of plastics and shifting to a circular economy[1)]. However, while the recycling of WEEE is being promoted in Japan under the Small Home Appliance Recycling Law, effective reutilization of the plastics used in WEEE remains insufficient. One reason for this insufficiency is that determining each type and additive of plastic actually used in society is difficult. In this study, we conducted a screening analysis of plastics used in small household-appliances to explore the issues in their conversion into secondary raw materials. In addition, we analyzed the contents of brominated flame retardants, which are governed by international regulations such as the Persistent Organic Pollutants (POPs) Convention.

MATERIALS AND METHODS

Plastic parts of used in Japan, small household-appliances (N = 114), including mobile batteries (N = 14), laptop computers (N = 10), e-cigarettes (N = 9), game consoles (N = 9), and routers (N = 9) were sampled.

The plastic types in the samples were identified using a Plastic Analyzer (TSI, PolyMax) that used Raman spectroscopy. Those with a match rate of more than 50% were identified as possible specific resins and classified. In addition, products containing specific elements including halogens and metals were identified by X-ray fluorescence (XRF) and scanning electron microscopy-energy dispersive X-ray analyses.

Furthermore, the samples were analyzed quantitatively using elemental analysis and inductively coupled plasma mass spectrometry. Some samples contained bromine, thought to be included as a flame retardant. Therefore, we conducted gas chromatography–mass spectrometry (GC-MS) analysis to investigate the presence of polybrominated diphenyl ethers (PBDEs) and polybrominated biphenyls (PBBs), which are specified as target substances in the international regulations for POPs and Directive on the Restriction of the use of certain RoHS.

RESULTS AND DISCUSSION

The Plastic Analyzer revealed a percentage match with more than 200 existing libraries. Approximately one third (30.7%) of the 114 samples showed a match rate of more than 90%, while 85 (74.6%) samples showed a match rate of more than 75%. Fourteen resins (12.3%) had a match rate of less than 50% and were classified as "Unknown." Acrylonitrile butadiene styrene copolymerization resin (ABS resin) (N = 39, 34%), polycarbonate (PC) (N = 17, 15%), and PC/ABS (N = 14, 12%) were the common resin types (Figure 1).

Figure 2 shows the number of samples that contained 0.1 mass% or more of the elements specified using XRF analysis. Titanium was the most commonly included element (N = 70, 61.4%), followed by phosphorus, silica, and aluminum. Halogens, such as chlorine and bromine, were also present. Titanium dioxide is added as a white pigment and a UV-shielding filler[2], while phosphorus and bromine may be added as flame retardants[3].

The samples with high bromine content were analyzed by GC-MS, and PBDEs or PBBs were not detected in the samples.

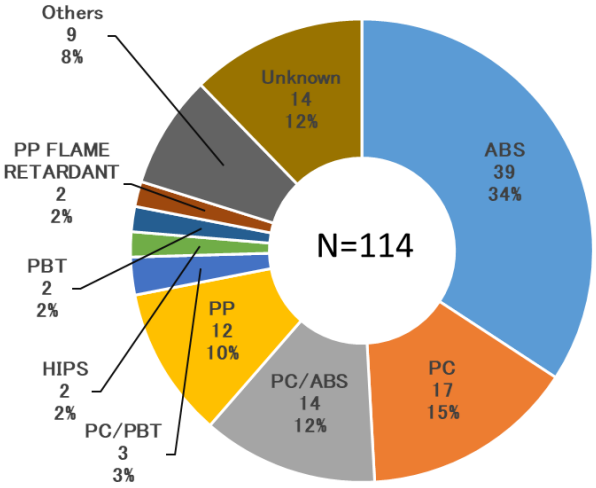

Figure1 Types of plastics in WEEE

CONCLUSION

In this study, we analyzed plastics used in WEEE to understand the actual situation in order to consider issues in the conversion of plastics into secondary raw materials.

ABS resin and polycarbonate were the most common types of plastics found in the samples collected in this study. Additives such as titanium, phosphorus, and halogens need to be considered as a challenge in the conversion of these plastics into secondary raw materials.

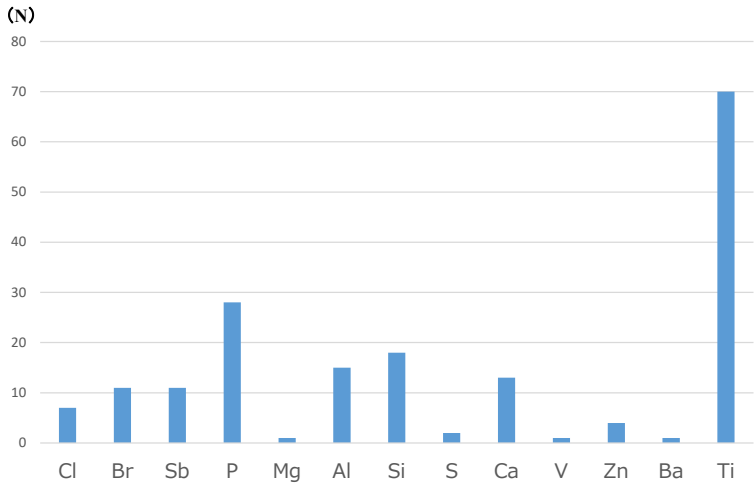

Figure 2 Number of samples containing of each specific element

ACKNOWLEDGMENTS

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A Perception Survey of Plastic Waste Recycling in Households of Tonle Sap Lake, Cambodia

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Keywords: Questionnaire, principal component analysis, floating village, Cambodia

INTRODUCTION

Plastic pollution is present in most bodies of water on the planet, this has become one of our most serious global environmental problems (Shahul Hamid et al. 2018). Tonle Sap Lake in Cambodia has tributary rivers with rich biodiversity. Until now, the floating village residents in the Tonle Sap Lake have been dumping household waste directly into the lake, with the large amount of plastic waste seriously affecting the water quality of the watershed and the quality of the surrounding soil. While calling on residents to reduce the use of non-essential plastic products, the proper post-use recycling of plastic products has become an urgent issue. The aim of this study is to investigate the willingness of the residents to recycle plastic waste and the influencing factors to provide theoretical support for the establishment of a plastic waste recycling system.

MATERIALS AND METHODS

The perception survey including questionnaire was divided into three sections: personal attributes, awareness survey, and preference of the plastic recycle system. The study conducted a perception survey by face-to-face interview questionnaires at households in the 4 floating villages (Table 1) in Tonle Sap Lake, and eventually received 25 valid responses. For awareness, the Likert scale questions mainly examined the residents' attitude (ATT), perceived behavioral control (PBC), subjective norms (SN), behavioral intentions(I) which based on the Theory of Planned Behavior (Ajzen ,1991). In addition, environmental cognition (EC) makes use of the brain's ability to process real environmental situations and assess environmental quality and tolerance of environmental problems (Henry, A. D.et al., 2012.). The factor of ECs also examined.

Table 1 Target villages and residents

Village name	Number of households
Kampong Chamlorng	6
Koh Ta Pov	4
Phat Sanday	7
Neang Sav	8

RESULTS AND DISCUSSION

Firstly, a frequency analysis showed that 56% of the respondents were male, the age was concentrated between 41-60 years old, the family size was concentrated between 5-6 people, the main house type was

permanent floating house, and the main occupation was fisherman. The average monthly income of Cambodian households in the second quarter of 2022 was US$372, and 64% of the respondents did not reach the average income. The average monthly expenditure of the respondents was US$300. For the establishment of a plastic waste recycling system ,88% of households are most concerned about whether recycling system have incentives. If the recycling system requires payment, 24% of households choose not to participate. If they can get reward compensation through the recycling system, only 4% of households choose not to participate.

The study conducted a principal component analysis on the scale questions, and the divided components met the expected design. After Friedman test on each principal component, it is found that each factor has medium difference. The correlation results of nonparametric tests between each principal component, personal attributes and paid services are shown in Table 2. The correlation shown that men had stronger subjective norms (SN). The occupation order in accordance with the strength relationship of perceived behavioral control (PBC) was seller>self-employee>fisher>wage labor>Gov. official>other. People with strong intention(I) and subjective norms (SN) of participate in plastic waste recycling prefer to choose the subscribe recycling service.

Table 2 Result of Nonparametric tests

	I	EC	SN	PBC	ATT
Gender	0.24	0.931	0.008**	0.2	0.106
Age	0.504	0.259	0.597	0.519	0.558
Household Number	0.851	0.147	0.993	0.798	0.713
House Type	0.055	0.551	0.123	0.215	0.633
Occupation	0.217	0.759	0.144	0.048*	0.188
Education	0.459	0.733	0.177	0.457	0.178
Income	0.975	0.242	0.772	0.85	0.227
Expenditure	0.927	0.703	0.178	0.117	0.503
Subscribe Service	0.022*	0.615	0.007**	0.347	0.546
Exchange Service	0.18	0.422	0.476	0.18	0.342

* $p<0.05$ ** $p<0.01$

CONCLUSION

The research results show that the surveyed households in the Tonle Sap Lake have a high desire to participate in the plastic waste recycling if there will be any incentive. The environmental cognition and the attitude, perceptual behavior control, subjective norms, and intention to recycling plastic waste are at a high level. All these shows that the establishment of plastic recycling service is urgent and necessary.

ACKNOWLEDGEMENT

This research was supported by “Promotion of community participation for plastic pollution control at floating village in Tonle Sap Lake, Cambodia (TONLESAP project)”, promoted by Japanese International Cooperation Agency (JICA) Partnership Program.

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Managerial Implication of Mercury Release: A Case Study in Waste Treatment Sector in China

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Keywords: anthropogenic activities, mercury release, waste treatment, China

INTRODUCTION

China is the largest anthropogenic mercury emitter, and it caused a great negative impact on both human health and ecosystem diversity. Since the implementation of the Minamata Convention on Mercury (MCM), the Parties who signed it should take several effective actions to reconstruct their mercury management system. All wastes including municipal solid waste (MSW), hazardous waste (HW), industrial waste and sewage sludge in domestic China are increasing rapidly (NBSC, 2016-2021). In addition, waste treatment sector accounted for 15% of total mercury release in China in 2019 (Habuer et al.,2021). It is an urgent need to clarify the contribution of the amount and/or environmental impact by each subcategory of waste treatment. This study aims to evaluate mercury release amount by subcategories from waste treatment sector given the expected scenario/technology transformations (STranfs) in 2020 in China. Government policymakers involved in hazardous waste management, especially those working in the related industry, and engineers and scientists interested in hazardous waste management may benefit from the result.

MATERIALS AND METHODS

The sources can be divided into four categories of waste incineration, including incineration of MSW (C1), and incineration of HW (C2), as well as informal dumping of general waste (C3), waste water treatment (C4). The detailed calculation algorithm for the potential mercury distributions to different sinks can be referred to our previous study (Habuer et al., 2021). Two technology transformation scenarios were defined in this study. One is the scenario of business as usual (BAU), which implies that each category kept the existing technologies. Another is the scenario of accelerated STranf (ACR), which implies that there were accelerated innovation and transformation to the best available technologies responding to MCM. The categories of those given in Table 1 are assumed to transform the scenario/treatment technologies. The categories C3 and C4 kept same treatment technologies.

Table 1 Technology/scenario transformation in two scenario

Category	Treatment technology	
	BAU	ACR
C1 Incineration MSW	Level 3:Acid gas control with limestone (or similar acid gas absorbent) and downstream high efficiency FF or ESP, PM retention	Level 5:Mercury specific absorbents (and downstream FF)
C2 Incineration HW	Level 3:Acid gas control with limestone (or similar acid gas absorbent) and downstream high efficiency FF or ESP, PM retention	Level 5:Mercury specific absorbents (and downstream FF)

Note: ESP-electrostatic precipitator, FF-fabric filter, PM: particulate matter

RESULTS AND DISCUSSION

The total atmospheric emission to air in scenario of BAU and ACR is estimated to be 43,251 and 8,932 kg in 2020, respectively. There are no releases to water and land from categories of C3 and C4. In category C3, the releases to water and land are 353 and 2,821 kg in both scenarios of BAU and ACR. In category C4, the releases to water and land are 80,000 and 32,000 kg in both scenarios of BAU and ACR. There is no atmospheric emission by C4, and the amount of mercury discharged to water remain obviously high level. Mercury emission in waste treatment sector is attributed to the incineration of MSW. Mercury releases to water and land in waste treatment sector are attributed to the waste water treatment. It was reported that the atmospheric emissions are most sensitive to Stranf. (Habuer et al., 2021). Figure 1 shows atmospheric emission by two categories of waste treatment under scenarios BAU and ACR in 2020 in China. In BAU, atmospheric emissions by C1 and C2 are estimated to be 36,519 and 6,379 kg when applying the technology in level 3 (Table 1). However, the atmospheric emission can be reduced to 20% of those in BAU when applying the mercury specific treatment system (level 5). Therefore, it is urgent to reconstruct or modify the air emission control devices applied in incineration of both MSW and HW, especially to that of facilities using outdated devices.

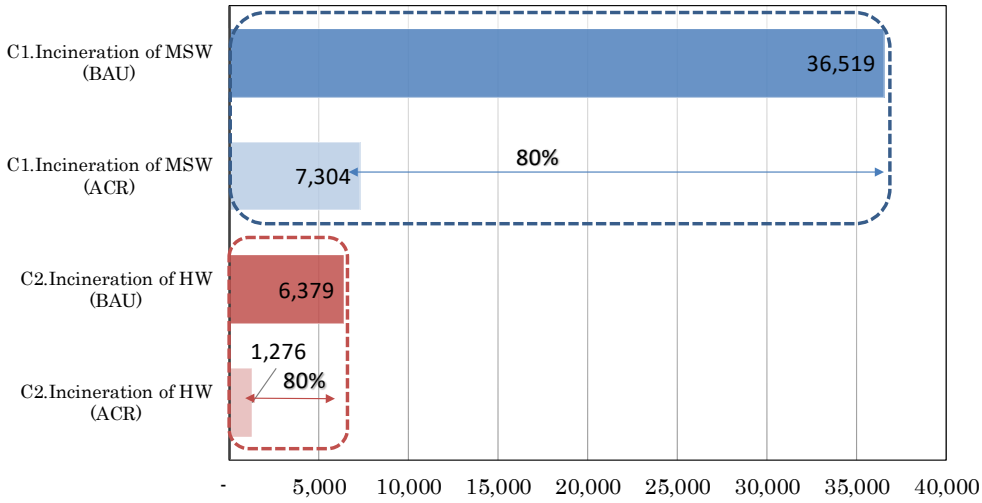

Figure 1 Atmospheric emission by categories under two scenarios (kg Hg/y)

CONCLUSION

This study compared the mercury release amount by categories from waste treatment sector given the expected scenario/technology transformations in 2020 in China. The result can facilitate the creation of strategic management policies for mercury in China.

ACKNOWLEDGEMENT

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Plastic Waste Composition Analysis for Floating Villages in Tonle Sap Lake, Cambodia

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Keywords: plastic waste, marine pollution, waste composition analysis, floating village, Cambodia

INTRODUCTION

Plastic waste has increased globally due to a consistent increase in the use of plastic products (Thompson et. al., 2009). Unlike other waste, once used plastic flows into the ocean, it decomposes very slowly, breaking into tiny pieces known as microplastics, which can enter the marine food chain and become incredibly damaging to marine life. It can also be a problem for the aesthetics and sanitary environment of the region. Therefore, it is necessary to conduct a strategic system for managing used plastics, especially for those rural regions in which the basic public waste collection services haven't reached. This study targeted the floating villages in Phat Sanday Commune which located in Tonle Sap Lake, Cambodia. The objective of the study was capturing the basis information of plastic waste and recycling potential in the targeted area. A composition survey has been conducted, then an analysis for plastic waste composition has been done.

MATERIALS AND METHODS

Composition survey of plastic waste

The aim of this survey is to clarify the discharged amount of plastic waste from houses at present. It collects the waste daily discharged from house and measure the amount of plastic waste in it. The collaborator will separate and store the plastic waste during the survey term (one week), and to provide the stored waste to the team after the survey. In total 11 households participated in this survey as the collaborator. Among the plastic waste categories, it was separated into three categories: PET bottle, easy-to-recycle plastic, and non-recyclable plastic. Containers and packaging that are made from polyethylene (PE), polypropylene (PP), and polystyrene (PS) are called easy-to-recycle plastics

Plastic Waste Composition Analysis (PWCA)

The analysis of the composition of household waste is separated into two main categories: plastic waste (plastic bottles, soft plastic, hard plastic, and foam plastic) and other types of waste (paper, cloth, wood, cans, glass, and degradable). However, for this study, only plastic waste categories were included for waste composition analysis. The collected data were analysed using statistical analysis tool IBM SPSS 22.0.

RESULTS AND DISCUSSION

Characteristic of plastic waste in Phat Sanday Commune

Figure 1(a) shows that of the total plastic waste collected, PET bottle types made up 43%, followed by 39% for soft plastic, 15% for hard plastic, and 3% for foam plastic. Figure 1(b) shows that PET bottle accounts for 31% of the total plastics, and easy-to-recycle plastics account for 44% of the total. In summary, 75% of the plastic waste that has been collected and potentially can be recycled.

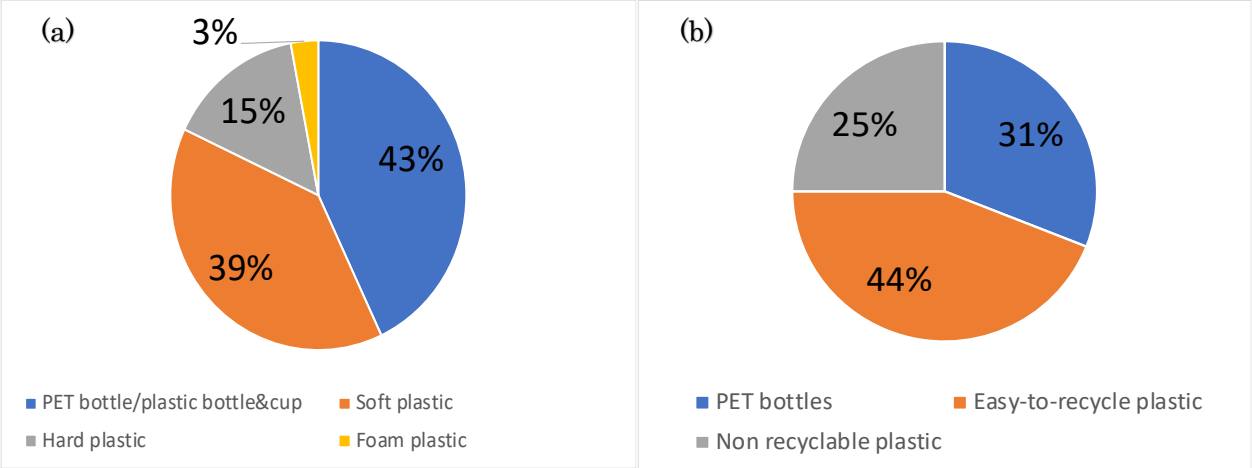

Figure 1 Plastic waste composition (a) plastic waste types (b) percentage of recyclable plastic

Total maximum recyclable plastic waste generated in Phat Sanday Commune

In Phat Sanday Commune, there were 807 families living in four villages there. Based on the overall PWCA result, the maximum amount of recyclable plastic waste generated in these four villages per day is estimated to be 11.5 kg (3.7 kg for PET bottle, and 7.8 kg for easy-to-recycle plastic). Additionally, the ability to distinguish the recyclable plastic waste from other types of waste is on average 66% for the 11 participants.

CONCLUSION

This study aimed to evaluate the recycling potential at Phat Sanday Commune as well as the general state of the current plastic waste. The statistics gathered show that this commune generates enough recyclable plastic waste to begin a recycling system. However, the residents of this village still struggle to distinguish the recyclable plastic waste from other types of waste. In this sense, education regarding it should be conducted first, followed by a theoretical approach to building strategic recycling system. The result of this study will contribute to promotion of plastic waste separation and recycling in the target area.

ACKNOWLEDGEMENT

This research was conducted under “Promotion of community participation for plastic pollution control at floating village in Tonle Sap Lake, Cambodia (TONLESAP project)”, Japanese International Cooperation Agency (JICA) Partnership Program.

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Development of plastic discrimination sensor

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Keywords: Plastic waste, Near-infrared Spectrometer, Recycling

INTRODUCTION

In Japan, the recycling of waste plastics is high at 86%, but thermal recycling (energy recovery) is high at 62%. In addition, 14% of unused waste plastics exist. In order to promote the reuse of materials and chemicals for 76% of these waste plastics, we developed the "RICOH HANDY PLASTIC SENSOR", a plastic discrimination sensor that can easily identify the types of plastics. This paper describes this sensor.

MATERIALS AND METHODS

Figure 1 shows the measurement principle of this sensor. This apparatus is a near-infrared spectrometer using a halogen lamp, which illuminates a measurement sample in contact with the halogen lamp and receives light that is diffusely reflected at the spectroscopy unit. Then, photoelectric conversion is performed in the Electronic Board, and the absorbance spectra of 1000-1600 nm are calculated. Then, the coefficient of correlation with the absorbance spectrum of the reference resin retained in the sensor obtained beforehand is calculated to determine the resin. The time from the start of the measurement to the output of the discrimination result is approximately 2 seconds.

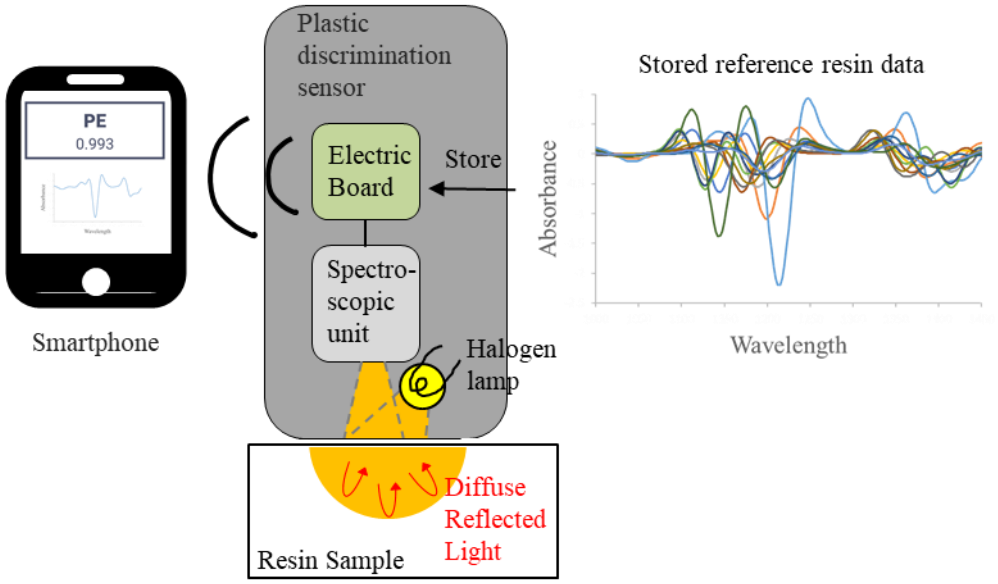

Figure 1 Measuring method of plastic discrimination sensor

RESULTS AND DISCUSSION

Table 1 shows a combination of two correlation coefficients from the absorbance spectra of seven reference resins obtained with developed sensor. Figure 2 is a graph of correlation coefficients with reference ABS and PS when ABS was measured 100 times in succession.

Table 1 correlation coefficient of major seven reference resin data

	ABS	PC	PE	PET	PP	PS	PVC
ABS	1.00	-	-	-	-	-	-
PC	0.27	1.00	-	-	-	-	-
PE	0.49	-0.26	1.00	-	-	-	-
PET	0.04	0.54	-0.13	1.00	-	-	-
PP	0.38	0.21	0.69	-0.04	1.00	-	-
PS	0.96	0.28	0.34	-0.04	0.19	1.00	-
PVC	0.39	0.40	0.50	0.21	0.89	0.16	1.00

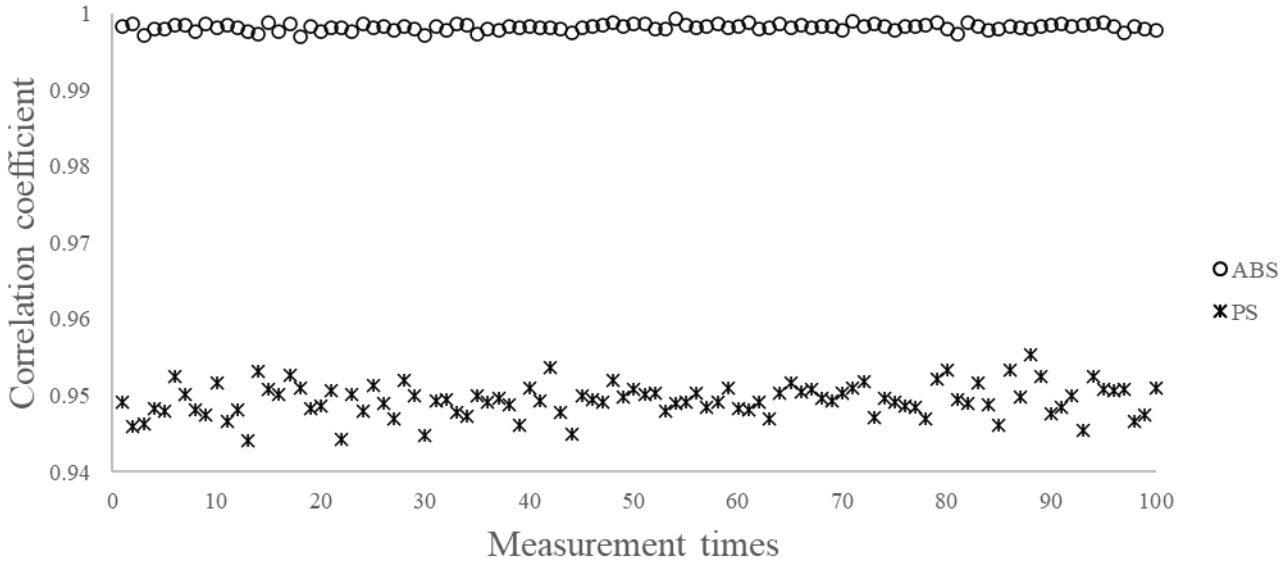

Figure 2 Correlation coefficient between reference ABS and reference PS when measuring ABS

In Table 1, the correlation coefficient between ABS and PS appears to be high and difficult to distinguish. However, as shown in Figure 2, the variation in the correlation coefficient between ABS and PS when measuring ABS is about 0.002 even when including factors such as temperature increase by continuous measurement, and the probability of erroneous discrimination is extremely low.

Since ABS and PS, which have the highest correlation coefficients in Table 1, can be sufficiently discriminated, it is easy to discriminate other combinations of the above seven types.

CONCLUSION

We have developed sensors that can be easily measured in a short period of time and have shown that the sensors can be used to distinguish resin. For those generating plastic waste, no special knowledge is needed to sort the waste. This makes sorting and collection easy, and improves the plastic recycling rate, contributing to the efficient circulation of resources.

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Assessment of Challenges for Plastic Waste Management at the National Level

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Keywords: Plastic waste management, Plastic pollution, Comparative analysis, Circular Economy

Almost every facet of our lives uses plastic, from water bottles and sandwich wrap to grocery store bags and cutlery. However, because we do not use plastics effectively, we are wasting essential resources and endangering the ecosystem. Plastic overuse and inadequate waste management are growing issues that threaten marine environments, cause landfills to overflow, and cause rivers to get choked. In addition, this overuse of plastic and lack of proper waste management has a detrimental effect on many nations' crucial businesses, including tourism, shipping, and fishing.

The simplicity and adaptability of plastic goods and packaging have resulted in the wide usage of plastic consumption. Especially, in Southeast Asia has developed into a hotspot for plastic pollution. Plastic consumption has ramped up due to fast urbanization and a burgeoning middle class. However, the infrastructure for local waste management has yet to keep up, leading to a significant amount of improperly treated waste. Furthermore, the COVID-19 problem has worsened the situation by increasing the usage of masks, sanitizer bottles, and online delivery packaging.

Mainly, single-use plastic is one of the biggest challenges in marine plastic pollution. Most of the single-use or disposal plastics in marine plastic pollution, which is 80 percent land-based, have a relatively limited useful life and are difficult to decompose in the environment. Studies have proved that single-use plastic that is not recovered and repurposed is dumped.

With this background, the nations are evaluating their stances following the discussions to create a global instrument to address plastic pollution, notably in the marine environment. Evaluating the difficulties in the current waste management system for controlling plastic waste in every nation is crucial to address plastic waste management effectively. Therefore, five nations (Japan, Thailand, India, Sri Lanka, and Pakistan) in the study are analyzed to figure out the difficulties in managing plastic waste. The results imply that the plastic value chain, regulations, technology, business models, and awareness-raising strategies exhibit differences and commonalities across countries in plastic waste management. Therefore, these nations can advance through sharing knowledge. Furthermore, the result based on the focal five countries can be applied to contribute to mitigating plastic pollution in Southeast Asia.

Influences of thermal dechlorination treatment on polychlorinated naphthalenes in municipal solid waste incineration fly ash

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Keywords: PCNs, MSWI fly ash, thermal dechlorination, chlorination ratio, dioxin-like toxicity

INTRODUCTION

Polychlorinated naphthalenes (PCNs) are hazardous compounds regulated by Stockholm Convention on Persistent Organic Pollutants (POPs), and are contained in municipal solid waste incineration (MSWI) fly ash. For reduction of PCDD/DFs in MSWI fly ash, thermal dechlorination treatment, the process of heating fly ash to 300 – 400 oC under reducing condition are often reported (Hagenmaier et al., 1987). In this study, the influences of thermal dechlorination process onto PCNs in MSWI fly ash were evaluated.

MATERIALS AND METHODS

From five MSW incinerators (four stoker type and one fluidized bed type), fly ash before and after thermal dechlorination treatment were sampled respectively. PCNs were extracted from 1 g of fly ash by Soxhlet extraction, and their contents were determined by GC-HRMS. The analysis conditions were as follows: automated sample preparation system, SPD-600GC (Seeds Tec); GC, 7890 B (Agilent Technologies); HRMS, JMS-800D (JEOL); column, RH-12ms, 0.25 mm i.d. × 60 m, (InventX), and selected ion monitoring mode (SIM).

RESULTS AND DISCUSSION

Change of PCNs contents and that of congener distribution are shown in Figure 1 and Figure 2 respectively. While the PCNs content decreased significantly in some ash, some ash increased in PCNs content. Regarding congener distribution, however, the treatment decreased the proportion of highly chlorinated PCNs and increased the proportion of low chlorinated PCNs. To discuss this phenomenon quantitatively, a chlorination ratio was calculated for each ash of before/after treatment. The chlorination ratio indicates the average number of chlorine atoms attached to naphthalene instead of hydrogen. Furthermore, dioxin-like toxicity before and after thermal dechlorination treatment was calculated based on mass-based REP-ECS_{TCDD} with toxicity equivalent factors (Suzuki et al., 2020). The change of total PCNs contents, total PCNs contents except for monochloride, chlorination ratio and dioxin-like toxicity are shown in Table 1. The chlorination ratio of all ash decreased significantly, indicating that PCNs in the fly ash changed from highly chlorinated compounds to low chlorinated compounds due to thermal dechlorination. The dioxin-like toxicity was also reduced accordingly. Thermal dechlorination of MSWI fly ash, which aims to reduce the concentration of dioxins, is effective for PCNs.

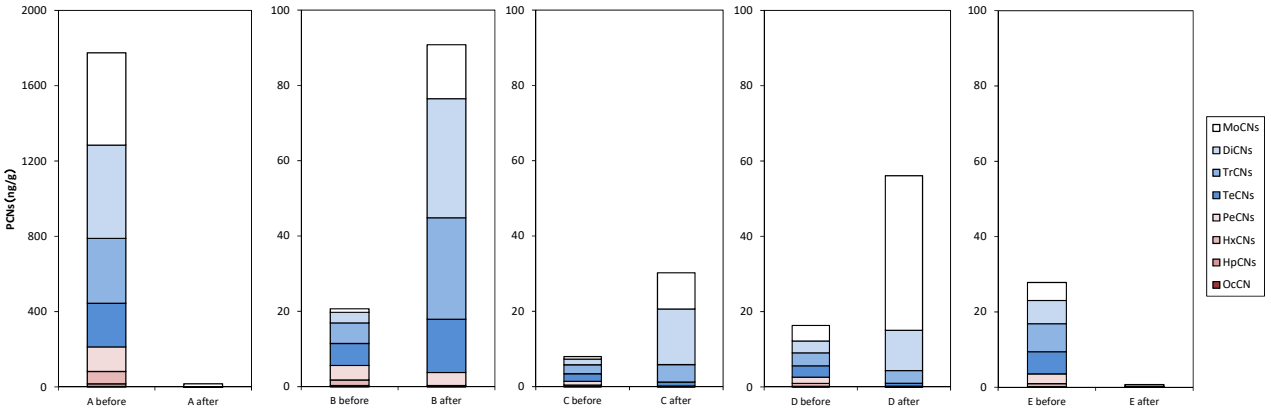

Figure 1 Change of PCNs contents before/after thermal dechlorination

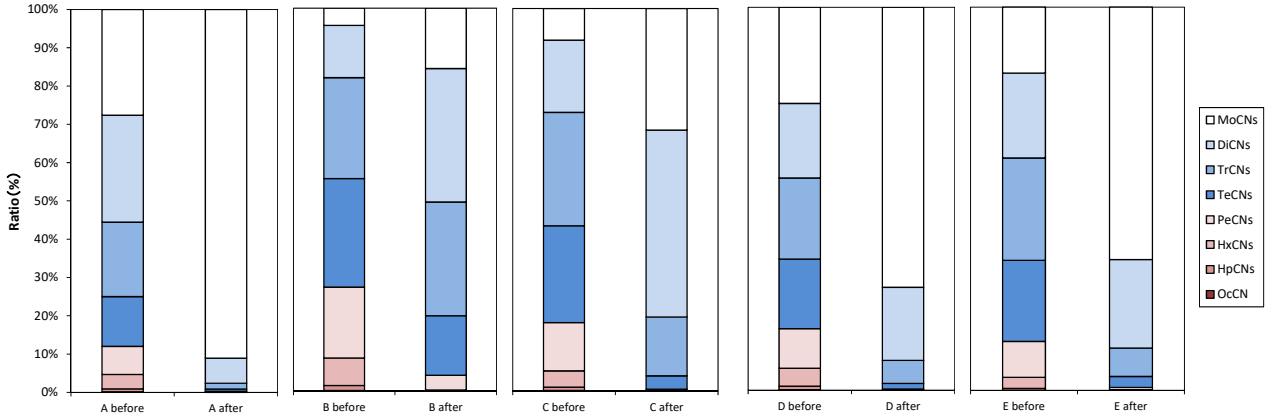

Figure 2 Change of congener distribution of PCNs before/after thermal dechlorination

Table 1 Changes of before and after thermal treatment

Ash	A		B		C		D		E	
Dechlorination process	before	after	before	after	before	after	before	after	before	after
Total PCNs (ng g^{-1})	1774.7	16.8	20.7	90.8	7.99	30.2	16.3	56.1	27.8	0.698
Total PCNs except monochloride (ng g^{-1})	1284.7	1.50	19.7	76.5	7.33	20.6	12.2	15.1	23.0	0.238
Chlorination ratio * (-)	2.30	1.09	3.46	2.40	3.07	1.81	2.53	1.29	2.67	1.39
Dioxin-like toxicity (pgTEQ g^{-1})	61.0	0.014	1.89	0.91	0.46	0.044	0.98	0.054	1.05	0.0016

* Chlorination ratio: Σ((PCNs molarity for a given chlorine number)/(Total PCNs molarity)) x (chlorination number)

ACKNOWLEDGEMENT

This research was performed by the Environment Research and Technology Development Fund (JPMEERF20193004) of the Environmental Restoration and Conservation Agency of Japan.

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Plastic accumulation during the pandemic: bioplastic a step towards this challenge?

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Keywords: plastic waste; bioplastics; pandemic; biogas; methane oxidizing bacteria

INTRODUCTION

Plastic products have played significant roles in protecting people during the pandemic. At the same time, the widespread use of plastic products, including single-use containers and personal protection equipment (PPE) created a disruption in the supply chain and waste disposal system. This generated an enormous amount of plastic waste from both healthcare and household units, and will continue to do so for the foreseeable future. The use of single-use PPE is inevitable to protect human health, but at the same time, is resulting in concerning issue of plastic pollution. Here, we demonstrate production of sustainable PPE from waste-derived substrate to protect both human health and environment. Single-use masks were fabricated using biodegradable polymers to minimize negative environmental impacts resulting from the mask waste. The biodegradable polymer was selected based on the "true" biodegradation level quantitively measured using laboratory-scale biodegradation test device. We also show that these polymers can be synthesized from waste-derived substrates and can be readily recycled without deterioration in polymer quality.

MATERIALS AND METHODS

We collected the results of studies that quantitatively measured biodegradability via weight loss and/or produced gaseous end products Despite some variations among studies, we analyzed the biodegradability data to obtain critical insights into biodegradable plastics.

The bio-based and biodegradable poly(hydroxyalkanoates) (PHA) and polylactic acid (PLA) are most widely studied. PHA-based bioplastics are biodegradable in all indicated environments (industrial composting, anaerobic digestion, marine, soil, and aerobic aqueous). PLA-based bioplastics, on the other hand, are biodegradable only in terrestrial environments such as under industrial composting conditions and in soil environments, but are hardly biodegradable in aquatic environments

Therefore, we selected PHA as our finalist for the main ingredient to fabricate truly biodegradable face mask**.**

RESULTS AND DISCUSSION

Fabrication of waste-derived, biodegradable single-use masks

We collected the results of studies that quantitatively measured biodegradability via weight loss and/or produced gaseous end products Despite some variations among studies, we analyzed the biodegradability data to obtain critical insights into biodegradable plastics.

Figure 1. "MACSK" fabricated using truly biodegradable, waste-derived biopolymer

CONCLUSION

This study aimed to replace massively used non-biodegradable, fossil fuel-based, single-use face masks with environmentally-friendly alternatives. We selected PHA as a candidate material as it is biodegradable in all tested environments (including (industrial composting, anaerobic digestion, marine, soil, and aerobic aqueous). The biodegradation test further demonstrated its distinct "true" biodegradability under these conditions. The fabricated face mask is a promising first step in overcoming the future pandemic challenges.

ACKNOWLEDGEMENT

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Use of Modern Technology for the Improvement of Solid Waste Management in Developing Countries: Case Study of a Database System in the Western Province of Sri Lanka

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Keywords: municipal solid waste management, waste stream, database system, Sri Lanka

INTRODUCTION

The use of modern technologies can become a very important asset for the field of solid waste management in the near future (Istudor et al., 2014). In Sri Lanka, just like in many developing countries, daily data on municipal solid waste collection, intermediate treatment, and final disposal volumes is not easily accessed for many reasons (Vidanaarachchi et al., 2006). Even though the Local Authorities have the necessary equipment at their disposal, the recording of data remains forsaken in many cases, making it difficult to estimate the amount of waste intake.

It is for this purpose that EX Research Institute Ltd, in collaboration with its local counterparts, opted for the development of a database system for 49 Local Authorities in the Western Province of Sri Lanka under the Project for Formulation of the Solid Waste Management Master Plan funded by Japan International Cooperation Agency (JICA). The said Database was designed with the purpose of allowing to record relevant data on waste collection, treatment and final disposal. Such data will significantly contribute to waste management on all the decision making process stages including the formulation of policies and plans, setting goals and monitor their progress (Zurbrügg, 2014).

MATERIALS AND METHODS

Purpose of Database and target waste

The purpose of developing the database system is to support the Western Province's Waste Management Authority, which supports 49 Local Authorities, in the collection, management, and analysis of data related to waste management. The database is designed to assist the formulation of the waste management master plan, and through its use, Local Authorities can make their action plans by utilizing the accumulated data. In addition, the database system enables them to monitor the progress of waste management in accordance with the plans. In order to achieve these purposes, the current database targets mainly the municipal solid waste in the Western Province of Sri Lanka as a pilot for potential future consideration of other types of waste (industrial, medical or construction and demolition waste).

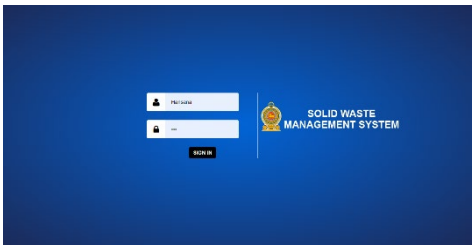
Database System Structure

The database system consists of three levels: National Level, Provincial level, and Local Authority Level. The National Level organization has the highest privileges in the management of the system. The Provincial Level organization has the privileges to create and manage the accounts of Local Authority Level counterparts,

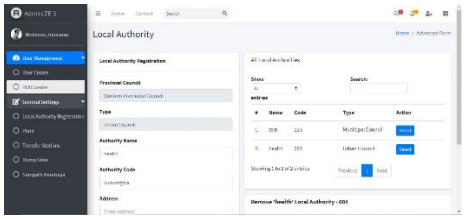
preview and manipulate the data with report generation. The Local Authority Level organizations can introduce data entry operators, enter their data, data visualization, and report generation with the database system.

Database modules and operational testing

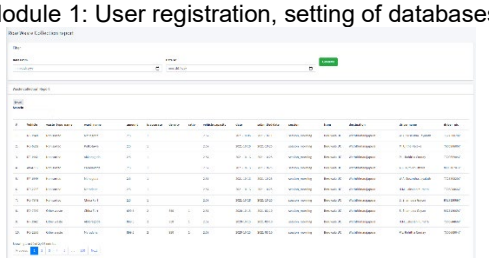
The database is composed of five different modules related to the different aspects of data entry and visualization (Figure1). The operational testing of the database was conducted from April 2021 to April 2022 and a series of training sessions to teach Local Authorities on how to input the data into the database, manipulate data, and report were held in the first two months.



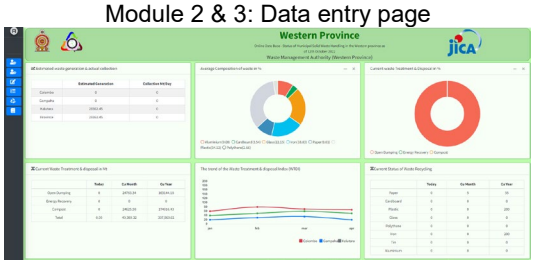
Module 1: User registration, setting of databases



Module 2 & 3: Data entry page



Module 4 & 5: Report generation



Dashboard

Figure 1 Modules of database system

RESULTS AND DISCUSSION

As a result of operational testing, two Local Authorities kept entering the data for one year, and the others submitted intermittently. As the trips of waste collection increase, the data volume to be input by Local Authority also increases. And since the data input is done manually by the staff in Local Authority, it takes time and cost for Local Authorities to input the data into the database daily given that the data volume is large.

CONCLUSION

The introduction of the database has proven that data availability can help the Local Authorities in understanding the current situation and thus contribute to the decision-making process in the future. However, some Local Authority have found the daily data input method rather challenging from a time and cost consumption perspective. Therefore, the system should be improved in full-scale operation in which 49 Local Authorities enter the data, these improvements are scheduled to start in early 2023.

ACKNOWLEDGEMENT

This database development and operational testing were conducted under the Project for Formulation of Western Province Solid Waste Management Master Plan funded by JICA

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A Comparative Study on Green-Branded Toothbrushes and Consumers Attitudes in Bulgaria and Japan

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Keywords: sustainable consumption, green marketing, eco labels, toothbrush, Japan, Bulgaria

INTRODUCTION

As the problem of transitioning to a model of cirlcular economy and resource efficiency is gaining popularity among researchers, policy makers, scientists and consumers alike, the issue of finding ways to involve all stakeholders related to the plastic market becomes more and more important as the whole chain from manucature through use and disposal of the product needs to be reinvented. This puts green marketting and sustainable consumption in a key position to trigger and fuel the change.

As of yet, the multitude of consumer targetting policy and behavioural research focuses on single use plastics as a first step toward the goal of phasing out fossil-fuel based plastics and replacing them with more sustainable alternatives. Fewer studies look into household items, which are used multiple times but still require regular replacement and are predominantly made of virgin plastic, such as the manual toothbrush. This research focuses on the availability and attitudes of consumers in regards to purchasing green-branded toothbrushes with the aim to verify whether green marketting and availability of alternatives is driven by consumer demand.

MATERIALS AND METHODS

The research reviews the plastic policies implemented in Bulgaria (EU member state) and Japan, so as to compare two areas of the world where previous research has found a high regard for environmental issues within consumers. Observations in drugstores and supermarkets (most common places for shopping for toothbrushes) has allowed for this study to analyze who are the biggest manufacturers offering their products on the market as well as review the types of products sold, their packaging, green-marketting and the price range.

RESULTS AND DISCUSSION

The review of literature found that since the adoption of stircter measures in regards to the EU plastic strategy in 2019, all big manufacturers started putting more emphasis on green marketting and development of sustainable alternatives. In the sphere of dental hygene, leading brands who sell on the EU market started introducing not only toothbrushes in plastic-free or recyclable packaging, but also a multitude of alternative handle types to the standard virgin plastic toothbrush which was the dominating type until then. The establishment of the Sustainability in Dentistry Project (May 2021) by key toothbrush manufacturers the commitment to creating a more sustainable market serves as an indicator of how the market priorities were changing.

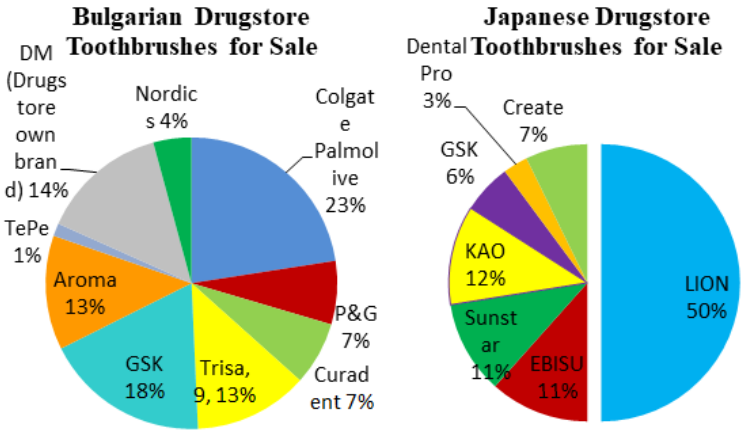

Figure 1 Key manufacturers of toothbrushes in Bulgaria and Japan

With Japan having introduced the Act on Promotion of Resource Circulation for Plastics (2022) we could expect a similar change in the availability of toothbrushes for sale there to follow a similar pattern and for consumers to start noticing a variety of green marketted toothbrushes in the near future.

The observations in store genarally identified four types of innovative "green toothbrushes" : wooden handle, bio-plastic handle, recycled plastic handle, replaceable head. We also discovered that even the traditional virgin plastic's packaging was being made sustaionable and ultimately almost all brands on the market were providen green branded toothbrushes as shown in Table1.

Table 1 Green Branded toothbrushes in Bulgarian Drugstore by Brand

Brand	Number of items	GB total items	GB Percentage	*Wooden handle*	*Bio-plastic handle*	*Recycled plastic handle*	*Replaceable haed*	*Packaging*
Colgate Palmolive (Colgate+ Elmex)	16	5	31%	*1*	-	*3*	-	*1*
P&G (Oral B)	5	1	20%		-	*1*	-	-
Curadent (Curapox)	5	-	0%	-	-	-	-	-
Trisa	9	6	67%	*2*	*2*	*1*	*1*	-
GSK (Sensodyne+Parodontax+aquafresh)	13	5	38%	*1*	-	-	-	*4*
Astera	9	-	0%	-	-	-	-	-
TePe	1	1	100%	-	-	-	-	*1*
DM (Drugstore own brand)	10	4	40%	*1*	*1*	-	-	*2*
Nordics	3	3	100%	-	*2*	*1*	-	-
Total :	71	25	35%	*5*	*5*	*6*	*1*	*8*

As for Japan, the key manufacturers on the market do seem to be interested in sustainability, but seem to be focusing more on decarbonizing or offsetting their manufacturing process rather than providing green marketted alternatives to the consumer. This is likely to change as key importers of toothbrushes from the EU, such as GSK have already started sales of toothbrushes with a "plastic-free packaging" branding on them in Japan, which will potentially start to attract more attention from environmentally conscious consumers.

CONCLUSION

With the above mentioned findings in mind we can conclude that the innitiating factor of the innovation of the toothbrush market is circular economy policy, but the real driver would be sustainable consumption and demand from the consumer for such items to be sold.

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Japanese consumers' necessity of plastic products and awareness of plastic issues revealed from questionnaire survey

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INTRODUCTION

In the lifecycle of plastic products where diverse stakeholders across arterial and venous industries are involved, the consumers as the main actors who purchase and consume plastic products can trigger sustainable plastic management through their changes in awareness and behavior (Heidbreder, 2019; Marazzi, 2020). Thus, based on the possibilities of changes in consumer awareness and behavior, it is necessary to draw a roadmap of the further measures for various plastic products which are widely used in current society, in addition to the products for which measures have been taken. Generally, many previous researches on consumer awareness of plastic products have mainly focused on investigating the environmental awareness and awareness and behavior towards only single-use plastic products including containers and packaging. However, only a few studies have focused on the differences between the individual plastic products. Thus, for each of a wide range of plastic products, the consumer awareness and behavior have not been sufficiently clarified and the investigation of actual consumption and scenario design have been hardly implemented. In this study, we aimed to understand what factors determined consumer awareness of a wide range of plastic products, not limited to plastic containers and packaging, based on the results of questionnaire survey on necessity of 50 plastic products in Japan.

MATERIALS AND METHODS

To reveal consumer necessity and substitutability of the targeted 50 plastic products, we conducted the online questionnaire survey by Neo Marketing Inc., Japan on March 14th to 18th 2022. The questionnaire survey was conducted on 10,000 respondents aged 15-69 living in Japan. The questionnaire contained three sections consisting of demographic information, awareness of plastic issues (interest in the issues caused by plastics, opinion about mandatory charging for plastic shopping bags, number of plastic bags in the last week, most important issue related to plastic) and consumer necessity and substitutability of the targeted 50 plastic products.

RESULTS AND DISCUSSION

The obtained results from the questions about consumer necessity and substitutability of the targeted 50 plastic products were already analyzed in different studies. In this study, to investigate the correlation between the awareness of plastic issues and the necessity and substitutability of plastic products, we performed cross tabulation for targeted 50 plastic products (not shown in this manuscript). For visualization of the results of cross tabulation, adjusted residuals were used for a heatmap display with upper and lower limits of ±15, for 13

products and 2 questions as an example (Table 1).

As a result, interest in the issues caused by plastics was strongly associated with the responses, especially in single-use plastic products such as shopping bags and straws. In other words, the respondents interested in the issues chose "I do not need this plastic product because I know the alternatives" more. The respondents choosing “agree” for mandatory charging for plastic shopping bags showed the high response rate of "I do not need this plastic product because I know the alternatives" and "I do not need this product itself” for many products. The similar trend was observed in the number of plastic bags in the last week. On the other hand, for the products such as synthetic clothing, non-woven face masks, stationery and disposable diapers, which consumers may recognize the value or function of being made of plastics, the limited correlation had been shown.

Table 1 Correlation between necessity and awareness of plastic issues

Adjusted residual d_{ij}: 15, 10, 5, 0, −5, −10, −15

Product	Option	Demographic information N	Interest in the issues caused by plastics: Very interested	Interested	Partially interested	Partially not interested	Not interested	Not interested at all	Opinion about mandatory charging for plastic shopping bags: Agree	Partially agree	Partially disagree	Disagree
			660	1589	3347	2386	949	1069	2836	3581	1984	1599
Plastic packagings for mails (e.g. advertising mail)		1098	2.903	-2.491	-5.05	1.727	1.615	4.412	-6.131	-2.215	0.494	9.899
		2975	-4.348	-5.309	-4.206	6.424	2.812	4.67	-10.08	2.357	5.966	2.823
		2306	1.894	7.051	5.241	-4.245	-2.903	-9.259	6.216	2.437	-1.519	-9.18
		3621	0.588	0.491	2.692	-3.513	-1.181	0.802	8.128	-2.937	-4.665	-1.079
Single-use non-woven refreshment towels		1929	1.091	-1.977	-2.397	1.352	2.416	0.967	-6.413	-3.001	3.196	8.336
		3654	-4.949	-6	-0.704	5.27	2.001	2.983	-10.66	3.487	5.106	2.987
		1732	2.095	5.478	3.097	-3.426	-1.566	-6.684	4.62	4.452	-3.554	-7.639
		2685	2.616	3.602	0.255	-4.004	-2.988	1.605	13.34	-4.918	-5.358	-4.145
Single-use plastic shopping bags		2434	-2.876	-7.698	-1.909	4.442	4.295	4.133	-18.26	-8.244	11.46	20.78
		1908	-2.863	-5.93	-6.289	5.956	4.509	6.427	-13.33	0.783	8.134	6.521
		3113	-0.214	8.527	8.15	-4.7	-4.747	-11.38	10.17	11	-8.157	-18.02
		2545	5.643	3.868	-1.11	-4.753	-3.252	2.225	19.21	-4.279	-9.955	-7.2
Single-use plastic straws		2677	-2.063	-8.425	-3.063	5.101	4.62	4.885	-12.84	-3.375	6.167	13.49
		1639	-5.894	-6.683	-6.902	6.587	8.061	6.451	-11.68	1.694	8.252	3.164
		2955	1.675	13.46	11.01	-7.819	-9.903	-13.89	13.81	6.026	-8.863	-15.22
		2729	5.234	0.145	-2.493	-2.535	-1.148	4.016	8.32	-4.226	-3.909	-0.451
Single-use plastic takeout containers		1776	1.558	-5.24	-3.683	2.164	2.987	4.755	-9.037	-2.619	3.782	10.42
		3219	-7.539	-4.362	2.386	4.567	1.644	-0.285	-6.121	2.289	4.259	-0.1
		2885	5.031	10.42	4.976	-5.56	-5.331	-11.24	11.65	2.573	-6.054	-11.1
		2120	1.585	-1.664	-4.799	-1.081	1.237	8.344	2.539	-3.02	-1.694	2.671
Plastic cushioning materials		1510	2.176	-1.37	-2.746	-0.281	1.782	2.764	-5.529	-2.78	1.64	8.653
		4455	-7.944	-6.324	2.682	6.28	1.8	-0.602	-5.956	2.546	2.529	1.243
		2298	3.67	9.418	4.325	-5.649	-3.818	-9.282	8.505	2.037	-2.558	-10.34
		1737	4.291	-0.867	-5.726	-1.7	0.194	8.484	3.595	-2.974	-2.027	1.675
Plastic egg cartons		1583	0.94	-3.787	-2.835	0.533	2.97	4.502	-5.466	-4.164	1.163	10.9
		3933	-7.304	-5.037	0.591	6.32	1.729	0.567	-7.33	2.758	4.04	1.012
		3008	4.169	10.26	6.11	-5.664	-5.391	-11.89	11.07	2.949	-4.855	-12.19
		1476	3.7	-2.432	-5.796	-1.93	1.532	9.965	1.401	-3.326	-0.483	3.153
Plastic bottles for water and tea		2260	-0.401	-3.016	-1.035	1.333	2.49	1.27	-8.537	-0.065	2.315	8.065
		4643	-6.415	-2.511	5.481	2.361	-0.727	-2.812	-2.569	2.356	1.651	-1.719
		1710	4.508	7.867	-0.357	-2.804	-2.382	-6.258	10.02	1.421	-3.814	-10.03
		1387	4.831	-1.297	-6.268	-1.964	0.629	9.338	3.123	-4.869	-1.029	3.648
Synthetic clothing		2515	1.579	1.158	2.551	-2.113	-0.132	-3.495	-1.547	-3.635	1.157	5.399
		4394	-6.168	-5.688	1.295	5.322	2.338	0.149	-4.208	4.56	0.972	-1.847
		1621	3.062	7.973	1.521	-3.55	-3.688	-5.821	5.375	1.671	-2.15	-6.455
		1470	3.524	-1.744	-6.524	-1.176	0.722	10.13	2.2	-3.676	-0.542	2.693
Single-use non-woven face masks		3261	-0.535	0.107	2.466	-0.504	0.403	-3.148	-0.37	-2.081	1.071	2.012
		4352	-4.893	-1.409	3.222	3.2	-1.377	-2.43	-1.979	2.463	1.445	-2.36
		1307	4.748	4.327	-1.16	-2.287	-0.408	-3.622	3.971	3.339	-3.147	-5.827
		1080	3.467	-2.61	-7.611	-1.866	2.035	12.57	-0.592	-4.418	-0.507	7.06
Plastic stationery		1637	1.846	-0.6	-0.739	-0.354	0.705	0.175	-3.253	-4.127	1.438	7.834
		5669	-6.759	-0.872	7.894	1.296	-1.17	-6.271	-1.6	3.996	0.317	-3.605
		1390	4.687	4.517	-2.648	-1.265	-1.372	-2.02	4.797	1.582	-1.796	-6.015
		1304	3.102	-2.697	-8.083	-0.218	2.356	11.11	1	-2.971	-0.202	2.876
Plastic containers for shampoo, conditioner, shower gel, etc.		1555	3.931	-3.403	-3.711	0.97	2.206	3.105	-5.449	-2.178	2.11	7.255
		5727	-8.873	-1.439	5.277	3.535	0.38	-4.463	-2.34	2.115	1.357	-1.365
		1624	5.549	7.264	1.692	-3.975	-3.064	-7.249	7.726	2.796	-3.481	-9.371
		1094	2.941	-2.352	-6.053	-2.032	0.457	12.03	0.906	-4.127	-0.486	4.814
Disposable diapers		1780	4.372	1.871	0.013	-2.067	-1.063	-1.885	0.475	-1.659	-0.469	2.095
		2759	-2.441	-0.82	0.88	1.717	0.624	-1.371	-1.015	4.527	-0.919	-3.673
		649	1.172	2.984	-2.083	0.014	0.888	-2.152	0.535	1.659	0.024	-2.855
		266	3.115	1.314	-3.296	1.39	-0.9	-0.088	-0.06	-0.292	1.594	-1.277
		4546	-2.753	-2.602	1.296	-0.409	0.109	3.772	0.301	-3.515	0.658	3.512

I need this plastic product although I know the alternatives / I do not need this plastic product because I know the alternatives
I need this plastic product because I do not know the alternatives / I do not need this product itself
I am not the target of using this product (only for “disposal diapers” and “disposal sanitary pads and tampons”)

CONCLUSION

This study investigated the correlation between the consumer necessity of plastic products and the awareness of plastic issues. To propose effective measures which lead to changes in consumer awareness, the detailed sociopsychological analysis is required in our future studies.

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Estimation of Future Copper Demand and Scrap in Vietnam

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Keywords: dynamic material flow analysis, in use stock, Shared Socioeconomic Pathways (SSP)

INTRODUCTION

Copper is one of the human society's earliest and most widely utilized metals. Along with the rapidly increasing population and economic development, the global demand for copper has increased significantly. The increase in demand is particularly important in developing countries like Vietnam raising the issue of dependence on imports. Besides, the scarcity caused by the demand increase may lead to the increased energy consumption due to the exploitation of lower quality ore and an increase in the environmental impacts caused by copper mining and processing activities. The use of secondary copper could reduce copper extraction and associated environmental impacts. The present research aims at assessing the future copper demand and scrap generation in Vietnam.

MATERIALS AND METHODS

Copper flow analysis

The material flow for copper is made of six processes: mining, refining, semi-finished production, finished production, use, and waste management. Copper mining, refined copper production, and refined copper consumption data are taken from the World Bureau of Metal Statistics database whereas import data are extracted from the United Nations Comtrade database. The in-use stock is modelled with lifetime function. Copper content of imported and exported items as well as in-use dissipation rate and lifetime function parameters' value are taken from Maung K.N, Hashimoto S. et al. (2017). Based on this information, we calculated the copper demand, in-use stock, and scrap in Vietnam for the period 1990 – 2020.

Estimation of copper demand and scrap until 2050

The forecasting of the copper stock for the period 2020 – 2050 is based on the logistic function developed by Hatayama H., Daigo I. et al. (2010):

$$S_t = \frac{S_{sat}}{1+ \exp(\alpha - \beta . GDP_t)} \quad (1)$$

The stock in year t (S_t) is modelled as a share of the stock saturation value (S_{sat}). The share is based on a logistic function of parameters α and β using the GDP per capita in year t as a variable (GDP_t). The stock saturation value is derived from Maung et al. (2017) using the 2020 stabilized in-use copper stocks of major nations as proxy. The GDP per capita is derived from the socioeconomic pathway's scenarios (Riahi, K., Van V.D.P. et al., 2017) leading to the establishment of five scenarios (SSP1, SSP2, SSP3, SSP4, and SSP5). The copper demand in year t (It) is calculated as shown in (2) by differentiating stock levels and withdrawing the generated end-of-life scrap (Ot):

$$D_t = S_t - S_{t-1} + O_t \quad (2)$$

RESULTS AND DISCUSSION

Vietnam's copper stock is projected to reach the stock saturation,14-16 Mt, under five SSP scenarios by 2050 (Figure 1). The highest growth in copper demand is for SSP5 and SSP1 with a peak in 2025, 6 times the value of 2020 demand (Figure 2). Though having the lowest growth rate in 2020-2030, SSP3 has the highest demand in 2050. These changes result from the changes of the per capita GDP in SSP scenarios. By 2050, the copper scrap supply reaches the level of the demand (Figure 3), meaning Vietnam should enhance the copper recycling system to increase the secondary copper use in the society.

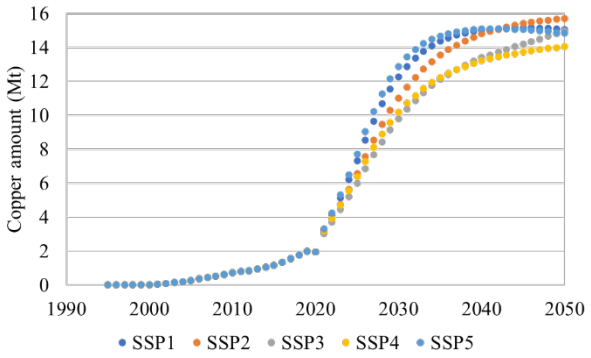

Figure 1 Copper in-use stock

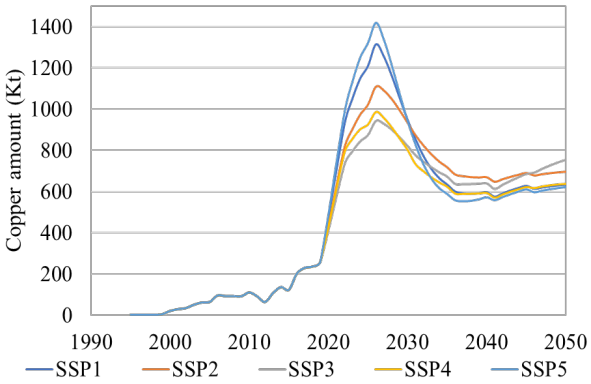

Figure 2 Copper demand

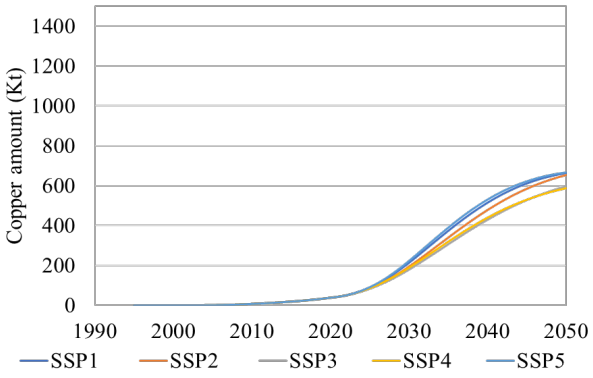

Figure 3 Copper scrap

CONCLUSION

The study estimated the copper stock, demand and scrap in Vietnam until 2050. Demand peak will occur in 2025- 2030 and stock saturation will be reached in 2050. Recycling policies should be enforced because copper scrap supply can reach the demand level in the future.

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Compilation of environmental thermodynamics from material cycles through a field of methanation 2 — consideration of activity between gas and aquatic phase—

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Keywords: methanation, Gibbs energy, enthalpy, Henry's law

INTRODUCTION

Environmental science and technology often requires thermodynamic considerations. Current available data are not only textbooks of physical chemistry[1)] but also free web-based database[2)] and suite software[3-5)]. However, some environmental scientists may face challenges, when they apply thermodynamics to practical materials. The reasons could be listed here :

●The thermodynamics consists of three fields: thermochemistry of pure substances, aqueous solutions, and electrochemistry; which are separately written in textbooks of physical chemistry;

● Two types of Gibbs energy expression are possible: one is absolute Gibbs energy employed in FactSage[4)], and the other is ΔfG named standard Gibbs energy change of formation found in JANAF table[6)]; and

● Aquatic system needs ΔfG in aqueous solution, whose connection to the pure substance system is seldom explained in textbooks.

Any re-construction of the system as "environmental thermodynamics" is desirable. Visual description will be helpful, if it covers G and ΔfG, various activity standard, and chemical potential in different fields. In this article, thermodynamic functions: G, ΔfG, ΔfH, S, and ΔrG are implicitly of standard condition (1 bar (=1/1.013 atm), 298.15 K); namely they are simplified from G^0, $\Delta_f G^0$, $\Delta_f H^0$, S_{298}, and $\Delta_r G^0$.

Methanation, especially biomethanation, brings useful study example. The reaction can be written in two fashion: one is as stable states, the other is as aquatic system:

$CO_2(g) + 4H_2(g) = CH_4(g) + H_2O(l)$ (1a); and

$CO_2(aq) + 4H_2(aq) = CH_4(aq) + H_2O(l)$ (1b).

Standard Gibbs energy change of reaction, ΔrG, of above two formulae varies according to activity standards. The former is 1 bar, while the latter is 1 mol/L. For mass flow analysis, the latter is favored. The purpose of this article is to illustrate the environmental thermodynamics exampling methanation, which is hopefully easy-to-understand, and to obtain ΔrG which is applicable to mass analysis.

MATERIALS AND METHODS

Absolute G and ΔfG

Absolute G and ΔfG at 298.15 K are obtained for gaseous state and aqueous solution from textbooks value with the following equations exampling with CO_2:

$G_{CO2(g)} = \Delta fH_{CO2(g)} - 298.15 \times S_{CO2(g)}$ (2) ; and

$\Delta fG_{CO2(g)} = G_{CO2(g)} - G_{C(s)} - G_{O2(g)}$ (3) ;

where, G, ΔfH, and S are absolute G, standard enthalpy of formation, and mol entropy, respectively.

ΔfG of aqueous system

Applying Henry's law constant to $CO_2(g)$, ΔfG value of $CO_2(aq)$ is obtained ;

$\Delta fG_{CO2(aq)} = \Delta fG_{CO2(g)} + RT \ln (p_{CO2(g)}/[CO_2(aq)])_{eq}$ (4).

Precisely compiled Henry's law by Sander[7)] is applied.

Balance of chemical potential

Balancing of chemical potential of methanation:

$\mu_{CO2(g)} + 4\mu_{H2(g)} = \mu_{CH4(g)} + 2\mu_{H2O(l)}$ (5a) ; and

$\mu_{CO2(aq)} + 4\mu_{H2(aq)} = \mu_{CH4(aq)} + 2\mu_{H2O(l)}$ (5b)

gives Gibbs energy change of reaction, ΔrG, and equilibrium constant, Kp(= exp (- ΔrG/(RT)).

RESULTS AND DISCUSSION

Obtained value for $G_{CO2(g)}$, $\Delta fG_{CO2(g)}$ and $\Delta fG_{CO2(aq)}$ are -457.2, -394.4, and -385.9 kJ/mol respectively. The process is illustrated in Fig 1. $\Delta fG_{CO2(g)}$ is the value frequently found in textbooks, while the others are limited to some literature[8]. Values of H_2 and CH_4 are obtained in the same way.

Balance of μ depicted in Fig 2 brings ΔrG and Kp. They were -131 kJ mol^{-1} and 8×10^{22} for gaseous base (p = 1 bar); and -194 kJ mol^{-1} and 1×10^{34} for aqueous base(mol/L), respectively. Theoretically, gaseous and aqueous system is equivalent through Henry's law constant.

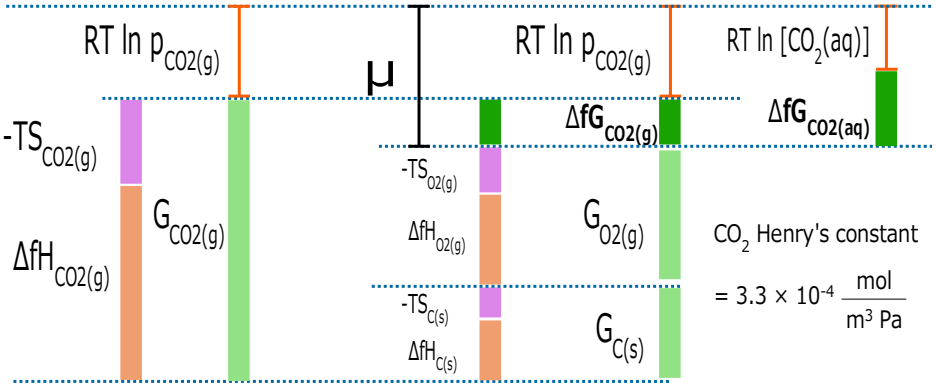

Figure 1 Chemical potential, μ, consists of RTln(activity) and ΔfG, which is derived from absolute G(= ΔfH-TS) of relevant substances.

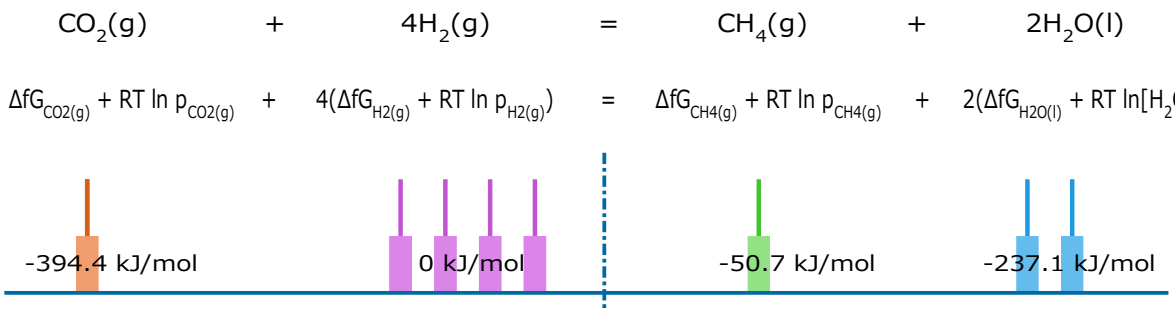

Figure 2 Balance of chemical potential, which gives ΔrG and Kp

CONCLUSION

Environmental thermodynamics uses various field simultaneously; therefore, its handling is sometimes challenging to scientists and engineers. Visualized Gibbs energy calculation covering thermochemistry and aqueous solution could illustrate absolute G and ΔfG all at once. Moreover, aqueous solution's ΔfG for CO_2, H_2, and CH_4 were obtained. Those value gave ΔrG for gaseous and aquatic solutions system: -131 and -194 kJ/mol, respectively; however, they are fundamentally equivalent if Henry's law constant is to be concerned. The advantage of the latter is easy to apply to mass balance considerations.

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Points to be Considered to Implement a Sustainable Material Recovery Facility in Chattogram City, Bangladesh

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Keywords: Material Recovery Facility, Sustainable, Chattogram City

INTRODUCTION

Chattogram City (CC) is the business capital and the second-largest city of Bangladesh. The country's largest coastal seaport is situated in CC, which makes this city the export hub of Bangladesh. It has a population of almost 6 million and area of 155.4 sq.km. Daily Municipal Solid Waste (MSW) generation is about 3,063 t/d while waste collection rate is around 72% (JICA, 2021). The height of existing landfills become around 120 meters from mean sea level with very steep slope over 60^{O}. There are cases of land collapse with deaths people in many countries. In such a situation, Material Recovery Facility (MRF) can be considered as an essential solution to diminish the current crisis in CC. Solid Waste Management (SWM) Rules (2021) specifies the need for MRF with necessary follow-up instructions about new technologies or methods on waste processing, segregation and 3R. Those are mentioned in schedule-4 and rule-8 of MSW Rules, 2021.

Table 1: Estimated Waste Generation (ton per day by waste type) in 2021 (JICA, 2021)

HH (t/d)	Street & construction (t/d)	Business waste (t/d)			Total (t/d)
		Market	Restaurant & Hotel	Office	
1868 (61%)	521(17%)	306(10%)	276(9%)	92(3%)	3063(100%)

This paper identifies the important sustainability factors which need to be considered effectively to plan and implement an MRF in CC. The hindering factors that need to be tackled, and on the other hand, the success factors that need to be nurtured are discussed in this paper based on field observations.

CONCEPT OF MRF

MRF is important for integrated waste management, which can reduce the waste entering landfills. MRF is a facility where recyclable MSW is processed, separated and stored using manual or mechanical methods (ADB, 2013). The MRF outputs are the raw materials for remanufacturing and reprocessing. They include paper, glass, plastics, and metals, which are baled, temporarily stored, and eventually sold. The remaining wastes from MRF are disposed to landfill (Citrasari et al., 2019). It can process either source-separated recyclables or mixed wastes; however, biodegradable components can be processed into compost plant. MRF has great environmental value.

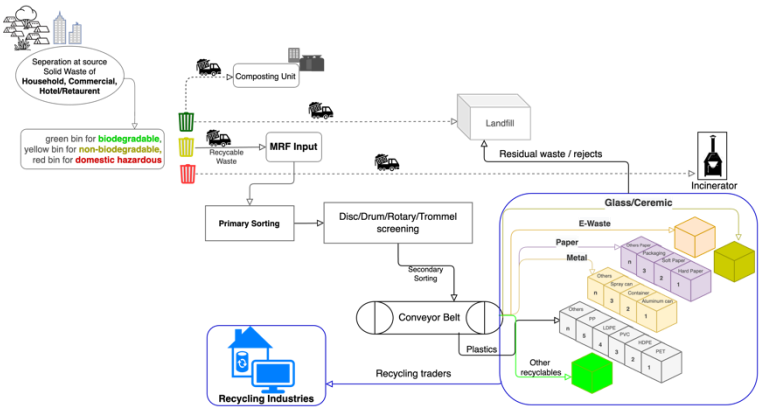

Figure 1: A hypothetical concept of MRF for Chattogram City

Figure 1 shows a hypothetical concept of MRF for CC.

METHODOLOGY

This paper is based on field survey, literature review and consultation with municipal staffs. We have identified the strengths and weakness, opportunity, and threat (SWOT) as internal and external factors within in the domain of Political, Economic, Social, Technological, Legal, and Environmental (PESTLE).

RESULTS AND DISCUSSION

Important strength (internal) for the plan and implementation of MRF are Government's positive intension, SWM Rules (2021), Environmental Conservation Rules (1997), etc. prioritize MRF. The weaknesses (internal) are scarcity of fund, absence of proper organogram/organizational setup, lack of community involvement, insufficient knowledgeable and skillful officials towards technologies and operational procedures, lack of waste collection vehicles, lack of momentum in MRF implementation, etc. The opportunities are emergence of recycling companies, doners' willingness in investment, overall improvement in SWM. Threats are political interfaces, livelihood of waste pickers or junkshop owners, etc.

The composition and selling price of MSW of CC are paper 9.64% (16 tk/kg), food waste 63.28% (10 tk/kg, only bones, and coconut shells are salable), sand/stones 5.83%, plastics 8.84% (34 tk/kg), grass/wood 6.57%, textile 4.22%, rubber/leather 0.36%, metals 0.59% (36 tk/kg) and other materials 0.68%. According to authors survey, total paper and plastic generation are about 295 t/d and 271 t/d respectively and their current market price at grass-roots junk shop are about 47,200 US$/d and 92,140 US$/d respectively (1 US$ = 100 BD tk, 2022). And this price might go up about 12% to 16% in large junk trading shops where more categorizations are done. The recyclable generation of the CC's MSW is estimated more than 36% (1100 t/d). So, CC have a high potentiality to operate MRF system, if the findings of the above SWOT analyses are addressed properly.

CONCLUSION

In this study, based on the field survey potential of MRF is assessed and quantified. The daily generated recyclable waste in Chattogram City is around 1100 t/d. Current rules and regulations emphasize the importance of MRF but weak organization setup, lack of funding and momentum of MRF implementation among different organizations are the found issues to be resolved. MRF can help CC to achieve the objective of extending the lifespan of landfill and contribute to sustainable development goals (SDG). Private investors might take this opportunity to capture this market by employing waste pickers, and provided with better price for recyclables, minimizing the health risks, protecting environment and develop social entrepreneurship. There is high potential to operate and maintain MRF in social business model as felt by some officials.

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Waste generation and characterization by tourism sectors in Jeju Island in Korea

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Keywords: Plastic, tourism waste, MSW, recycling

INTRODUCTION

Jeju Island has shown a trend of rapidly increasing the amount of waste discharged as related industries are activated, centering on the tourism industry. As of 2020, the average daily MSW waste per person in Jeju Island was 1.89 kg/person/day, which is about 1.6 times higher than the national average (1.16 kg/person/day). For the continuous development of the tourism industry, which is a representative industry of Jeju Island, policies for waste reduction and decarplastic society are needed. To this end, it is necessary to investigate the types and amounts of MSW waste in major tourism industries with many visitors from the tourism industry in the province, and establish policies for waste reduction and recycling based on this study.

MATERIALS AND METHODS

Estimation of MSW Gerneration by Residential and Tourist Population

There are a total of seven major tourism sectors surveyed in this study. Detailed industries are divided into airports, ports, tourism and lodging, tourist facilities, amusement facilities, tourism convenience facilities, casino, tourism transportation and rental cars, international conference facilities, and public tourist destinations as follows. Companies subject to the survey by industry were selected first for places with a large size of companies and places with a large number of users in the tourism industry. In the case of airports, ports, casinos, and international conference facilities, the number of samples was less than one or three, so data was secured through a total survey. In addition, in the case of tourism and lodging, tourism transportation and rental cars, tourist facilities, amusement facilities, tourism convenience facilities, and public tourist destinations, data were secured through sample surveys. Based on the number of secured users, workers, and waste generation, the amount of waste generated by each tourism industry and the unit of household waste generation per person were calculated.

RESULTS AND DISCUSSION

Estimation of Waste Generation by Tourism Industry(Jeju)

The estimated total waste generation by tourism sector was estimated at about 2,491 tons/year at the airport, about 238 tons/year at ports, about 57,724 tons/year in tourism and lodging, about 3,611 tons/year in use, amusement, convenience, and casino, about 2,788 tons/year in tourism transportation and rental car, and about 205 tons/year in international conference facilities, and about 613 tons/year. The total amount of waste generated in the tourism sector was estimated from a minimum of 34,994 tons/year to a maximum of 67,670 tons/year. The estimated amount of waste generated in the major tourism sector in this survey did not include food waste and living (home) waste such as small restaurants and cafes.

<Table 1> Estimated 3-year average waste generation and Number of users & workers by tourism industr y in Jeju(period 2019-2021)

Sector	Estimated total waste generation & in major tourism sectors (based on average)	
	Number of tourists & workers (person/year)	Municipal waste generated (ton/year)

Airport	14,844,489	2,491
Harbor	662,663	238
Lodging industry	67,507,165	57,724
Utilization, recreation, convenience, casino business	10,845,669	3,611
Rental car industry	5,095,800	2,788
International Conference Facilities Industry	163,676	205
Public tourist destination	9,100,333	613
Total	**108,219,794**	**67,670**

CONCLUSION

As a result of estimating the number of users and workers in the workplace by tourism sector, the total number of 7 industries was 108,219,794 people, and tourism and lodging accounted for the largest portion with 62.38%. The amount of waste generated was estimated to be 67,670 tons/year, of which 85.30% was accounted for by the tourism and lodging industry. The average original unit, which divided the total waste generation by industry by the total number of users and workers were 0.63 kg/day, and the tourism and lodging industry were 0.86 kg/day, 1.37 times more than the average original unit. The industry with the largest unit was the international conference facility industry, with 1.25 kg/person/day per person, which was analyzed to be 1.98 times larger than the average unit.

ACKNOWLEDGEMENT

This reserch was financially supported by Jeju Tourism Organization, Korea.

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Prediction of Greenhouse Gas Emissions from Municipal Solid Waste Incinerators Considering Utilization of Heat and Captured CO_2 on the Tokyo Waterfront Area

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Keywords: Carbon neutral, Municipal solid waste incinerator (MSWI), Methanation, Waste heat utilization

INTRODUCTION

In 2020, the goal of becoming carbon neutral by 2050 was declared, and carbon neutrality (CN) is being promoted in all sectors. In the waste and resource recycling sector, non-energy-origin CO_2 emissions accounted for about 36.4% of total CO_2 emissions in FY2019. In addition, about 78% of CO_2 emissions from the general waste treatment sector are due to incineration and the use of raw fuel. The objective of this study is to evaluate the municipal solid waste (MSW) incineration system and the surrounding conditions in order to find a desirable MSWI to achieve CN. Specifically, four MSWIs (Chuo, Minato, Shinkoto, and Ariake) located in the Tokyo waterfront area, which is an important area with a large population and where population decline is expected to be relatively slow in the future, were targeted, and nine decarbonization measures were set. The GHG emission reduction benefits of each measure were evaluated with the period from waste delivery to exhaust gas and ash discharge as the evaluation boundary over a time horizon from FY2025 to FY2050.

DECARBONIZATION MEASURES

Details of the nine decarbonization measures are provided in Table 1 below.

Table 1 Decarbonization measures.

Decarbonaization measures	Description.
BaU	The collection population will increase until FY2045 and then decrease. The amount of MSW incinerated per day per person is the average from FY2010 to FY2020 until FY2050.
MSW reduction	The amount of paper and plastic waste incinerated will be reduced by 18.7% and 40% in FY2030 compared to FY17. The amount of other incinerated MSW categories will decrease with a modified exponential curve from the trend from FY2010 to FY2020.
Bioplastic dissemination	In FY2030, 2 million tons of biomass plastic with 35% biogenic carbon content will be introduced. The biogenic carbon content as a percentage of total plastic waste will increase linearly from FY2020 to FY2050.
Improvement of power generation efficiency through renewal of MSWIs	The Chuo, Minato, Shinkoto, and Ariake MSWIs will be rebuilt in FY2040, FY2032, FY2038, and FY2035, respectively. Power generation efficiency will be improved.
Wide area management	In 2035, a new MSWI with a capacity of 2,800 t/day (applying MSW reduction measure) will be built by integrating 4 MSWIs. The collection method is the same as before, with the waste collected at the old MSWIs and then transported to the newMSWI.
Introduction of methane combined system	Methane combined systems will be introduced at each of the four MSWIs starting in FY2035.
Methanation	Emission factors for electricity and city-gas will decrease, and CN will be achieved in FY2050. The emission factor of supplied heat will be reduced by about 30% in FY2050 compared to FY2020.
Expansion of direct use of heat	Methanation will be introduced to incineration facilities from FY2035. The methane produced will replace conventional city-gas.
Lower CO_2 emission factors	From FY2035, power generation will be discontinued and all heat obtained from MSW incineration will be used to supply high-pressure steam to large-scale plants.

RESULTS AND DISCUSSION

Scenarios combining decarbonization measures

Eight scenarios were evaluated, combining the eight decarbonization measures as shown in Table 2, for two cases: one with constant emission factors for electricity, supplied heat, and city-gas, and one with a decrease. It means that 16 patterns were evaluated.

Table 2 eight scenarios.

Decarbonation measures	Scenario							
	I	II	III	IV	V	VI	VII	VIII
BaU	●							
MSW reduction		●	●	●	●	●	●	●
Bioplastic dissemination			●	●	●	●	●	●
Improvement of power generation efficiency through renewal of MSWIs				●				
Wide area management					●	●	●	●
Introduction of methane combined system						●	●	●
Methanation							●	●
Expansion of direct use of heat								●

GHG emissions estimation results

The estimated results of GHG emissions in FY2050 are shown in Figure 1 and 2. Figure 1 is the case with a constant emission factor and Figure 2 is the case with a decreasing emission factor.

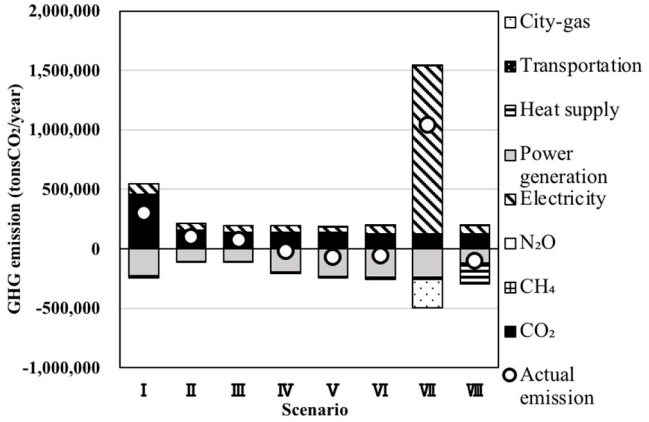

Figure 1 GHG emission in FY2050. (constant CO_2 emission factor)

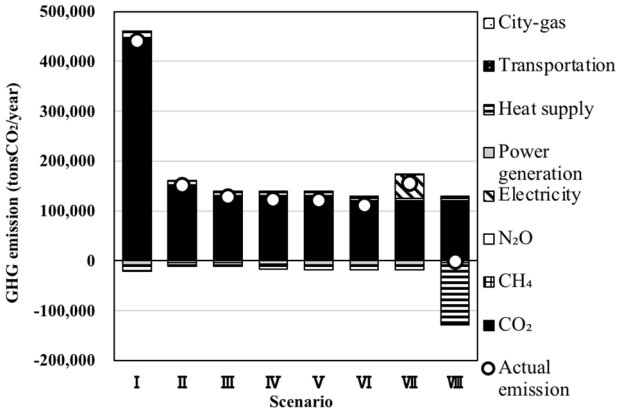

Figure 2 GHG emission in FY2050. (lower CO_2 emission factor)

CONCLUSION

In this study, the desirable MSWI for achieving CN in the Tokyo waterfront area was examined. A large-scale MSWI integrated with existing MSWIs was considered desirable, based on efforts to MSW reduction and introduce biomass plastics. If the emission factors of various energy sources are expected to decrease in the future, a shift to "expansion of direct use of heat" should be considered in addition to "wide area management". In the future, it is necessary to estimate the actual amount of heat supply available from the demand side and to make future projections.

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Assessment of greenhouse gas emissions from municipal solid waste management practice in Phnom Penh, Cambodia

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Keywords: greenhouse gas, municipal solid waste, landfill, Phnom Penh

INTRODUCTION

Greenhous gas (GHG) emissions have drawn the attention of many nations worldwide. The emissions from waste management share about 5% of total GHG (Bogner et al., 2007). The landfill is the most used method for municipal solid waste management (MSWM), emitting the greatest CH_4 gas compared to other management practices. Phnom Penh, Cambodia's capital, generates more than 1 million tons of MSW annually, about 25% of the MSW generation nationwide. The city is facing a challenging issue since the daily waste disposal at the landfill has rapidly increased, coupled with the lack of source segregation and management system. Commingled waste is disposed of at the landfill without proper management, which poses environmental risks, particularly GHG emissions and leachate. The composition of MSW in PPM is commonly organic waste (49.18%), followed by plastic (21%), textile (8%), wood and leave (6.69%), and paper (6.54%) (Seng et al., 2018).

This study aims to assess the GHG emissions from current practices and propose new scenarios that potentially reduce the sector's emissions.

MATERIALS AND METHODS

System boundary and scenario design

The study considered the GHG emissions (CO_2, CH_4, and N_2O) from different sources, including transportation, operation of the treatment plant and final disposal at the landfill, emissions from combustion, emissions saving from the waste-to-energy plant, and emissions avoidance from using recyclables. Four scenarios were developed: scenario 1 is the current management, and scenarios 2-4 are alternative management options, as summarized in Table 1.

Table 1. Waste management scenarios (tons/day)

Scenario	Composting	Open burning	Recycling	AD	Incineration	Landfill	Total
1	60	200	-	-	-	2835	3023
2	100	-	100	500	1000	1450	3150
3	200	-	300	500	1300	850	3150
4	300	-	500	500	1800	50	3150

Estimation methods for emissions

The quantification of GHG emissions from waste treatments followed the IPCC (2006) guideline, and the calculation of total and net GHG emissions aree given in Equations (1) to (3). The calculation of emissions from

transportation follows Equation (4).

$$GHG\ emissions = \sum(Net\ GHG\ emissions \times MSW) \quad (1)$$

$$Net\ GHG\ emission = Gross\ emissions - Emissions\ saving \quad (2)$$

$$Emissions\ saving = ERP_i \times EF_{electricity} \quad (3)$$

$$E_{tran} = \sum(EF_t \times d \times MSW) \quad (4)$$

RESULTS AND DISCUSSION

The gross GHG emissions are highest in scenario 1 and lowest in scenario 4. The current practice under scenario 1 emitted about 3.47 x 10^6 kg CO_2/day, while the best-case scenario (scenario 4) yielded 1.86 x 10^6 kg CO_2/day. The most significant emissions under scenario 1 are mainly from landfill CH_4 gas and open burning. Under scenario 4, waste is sent to the composting plant, recycling, AD, and incineration instead of landfilling. Electricity generated from AD and incineration plants can replace fuel- and coal-based electricity products; hence it helps offset GHG emissions. Furthermore, using recyclables help save the emissions from complex extraction of raw materials and production process. The compost products can replace chemical fertilizers, saving GHG emissions and enabling carbon sequestration, but it is not included in the calculations. The net GHG emissions are positive under scenarios 1-3, while the net negative emission is found in scenario 4. This means that scenario 4 helps save rather than emissions of GHG. Scenario 1 remains the highest emission owing to an absence of recycling, AD, and incineration for electricity generation.

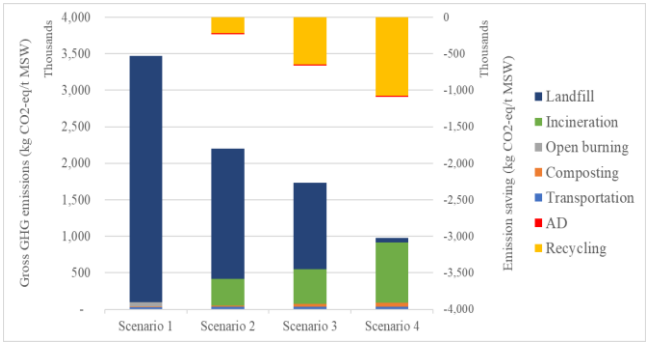

Figure 1 Relationship of methane emission and oxidation

CONCLUSION

Scenario 4 is the best-case scenario, saving about 155 t CO_2-eq/day. The emission saving was mainly from recycling activity and electricity generation from the AD plant. In contrast, scenario 1 has the highest environmental pollution with respect GHGs owing to the open burning of waste and landfill dependency. The most negligible GHG emissions were found in waste transportation. Incineration is the second top emitter. However, incineration is potentially producing electricity, which helps reduce GHG emissions. Hence, sorting out recyclables for recycling practice and separating food waste for AD and composting are vital for mitigating GHG emissions from the MSW management system and enhancing resource recovery via waste recycling and energy recovery. It can be concluded that waste separation at source played a crucial role in GHG mitigation in the MSWM sector.

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Cumulative Energy Demand of Single Use Plastic Bags and their Alternatives

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Keywords: cumulative energy demand, single use plastic bags, reusable packaging

INTRODUCTION

Plastic consumption has various socio-economic and environmental challenges. At 2R level (Reduce & Reuse) policies target usage shifting the burden to regulatorily admissible and accessible alternatives. Life cycle assessment (LCA) is a powerful evaluation tool for adopted policies. The overall study focuses on Kenya's 2017 plastic bag ban on waste management system. This abstract explores the energy burden as an environmental indicator for single use plastic bags (SUPB) and their alternatives (Figure 1) using cumulative energy demand (CED) analysis. CED an output of life cycle inventory analysis (LCI) defined as final primary direct and indirect energy utilized for production, usage and disposal of a product and expressed as an aggregate of fossil and renewable energy.

Figure 1: Carrier bags in the study

MATERIALS AND METHODS

Goal and Scope: The study estimates the energy demand of carrier bags resource extraction and production and, transport flows through retail and disposal in Kenya (Figure 2). The function and functional unit (FU) are defined as a 16.74L carrier bag for carrying commodities from retail to households (1). Kenya is a low middle income economy, hence purchase volumes fit in one bag per shopping trip. Retail, usage and End of Life (open dumping) are assumed not to consume energy.

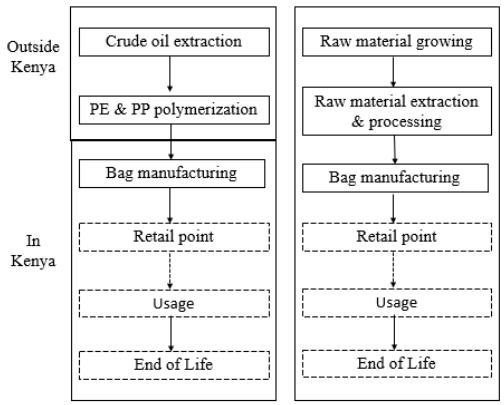

Figure 2: System boundary of bags

Life Cycle Inventory: The ongoing LCI is built on primary data, secondary literature and industry reports using MS Excel. Kenya is a non-oil producing country with Saudi Arabia being the main exporter of polymers from UNComtrade Database. Oil and polymers production was assumed to occur in Saudi Arabia before transportation to Kenya. Shipping relied on heavy oil fuel while road transport diesel fuel moreover, the distances were obtained from Ports.com and Google Map, respectively, Table 1. For non-plastic bags all processes happened in Kenya. Production to fiber processing was assumed to occur in the largest sisal farm from Nairobi. The same was adopted for reeds bags. The CED of oil extraction and polymer production was obtained from industry reports. In most studies, these unit processes are retrieved from commercial databases. Transport was modelled against fuel consumed in kilometers and respective fuel energy value. Fuel consumption for a 26ton truck could not be established, consumption was estimated from the known 46ton

truck. Energy was used in the production of plastic based and paper bags while sisal and reeds bags were hand woven. Data was modelled to 1 ton then calculated to respective carrier weight. Environmental reuse effect adopted the corresponding difference to new SUPB or equivalent single use paper bags usage.

RESULTS AND DISCUSSION

Table 1. shows the energy demand for each process per bag. The bulk of the energy demand is used in raw material extraction and processing for plastic based and paper bags. Energy dominates road transport of sisal and reed fibers to handicraft centers. In comparison to SUPB, reusable non-woven, reusable woven and paper requires 1.4x, 3.8x and 1.3x energy, respectively, for initial production. That is, reusable non-woven and woven bags require approximately 2 and 4 reuses to achieve an equivalent of 2 and 4 new SUPB energy demand. Paper bag, however, progressively increases since it is single use. Reusable sisal and reeds bags show lower energy demand at production thereby achieving negative demand from the first usage to SUPB. The results also show that non-fossil sources are sparingly used with bulk of process and flow energy being fossil.

Table 1: Cumulative energy demand by stage for single use plastic bags and their alternatives

		Plastic based bags			Non-plastic bag		
Bag Type		SUPB	(R).Non-	(R).woven	Paper	(R).Sisal	(R).Reeds
Energy by process		HDPE	woven PP	PP	Single use		
	Bag weight (Kg)	0.0086	0.012	0.033	0.058	0.25	0.25
Raw material extraction; processing	Fossil (MJ)	0.683	0.904	2.485	-	0.005	0.001
	Non-fossil (MJ)	0.007	0.002	0.006	-	-	-
Sea transport Saudi to Kenya *(TEU-4560Km)*	Fossil (MJ)	0.014	0.019	0.054	na	na	na
Road transport: Port to factory[1] *(46ton truck-485Km)*	Fossil (MJ)	0.001	0.002	0.005	0.004	0.016	0.016
Bag production	Electricity (MJ)	0.019	0.065	0.178	0.940[2]	na	na
Road transport to retail point *(26ton truck-20.6Km)*	Fossil (MJ)	5.8E-05	8.1E-05	2.2E-04	3.9E-04	1.7E-03	1.7E-03
Road transport to landfill *(26ton truck-11.9Km)*	Fossil(MJ)	3.3E-05	4.7E-05	1.3E-04	2.3E-04	9.7E-04	9.7E-04
	Total fossil energy used (MJ)	0.717	0.990	2.722	0.945	0.024	0.020
	Total non-fossil energy used (MJ)	0.007	0.002	0.006	0.000	0.000	0.000
	CED (MJ)	0.724	0.992	2.728	0.945	0.024	0.020
	CED ratio (SUPB to other bags)	-	1.370	3.769	1.305	0.033	0.027
	Reuse - 2x	1.448	-0.456	1.281	0.442	-1.424	-1.428
	Reuse - 3x	2.172	-1.180	0.557	0.663	-2.148	-2.152
	Reuse - 4x	2.896	-1.904	-0.167	0.884	-2.872	-2.876

[1] Non-plastic bag Road transport to handicraft centers *(46ton truck-200Km);* (R) means reusable bag

[2]Represents energy consumption from raw material extraction to bag production. Electricity for paper production is 0.007MJ. Electricity is assumed to be fossil based. Energy Values: Heavy Oil – 40MJ/KG; Diesel-38MJ/L

CONCLUSION

CED fossil consumption links to energy emissions such as greenhouse emissions. While energy demand for SUPB is lower than reusable plastic based and paper bags, subsequent reuse shows substitution effect except for paper bags. Since most energy intensive processes occur outside the country, it raises sourcing environmental and policy concerns. Future research on this topic targets more comprehensive LCI and LCA.

ACKNOWLEDGEMENT

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Estimation of greenhouse gas emissions from incineration of municipal solid waste in Seoul, Korea

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Keywords: Incineration, municipal solid waste (MSW), past trend extension method, greenhouse gas, emission prediction

INTRODUCTION

Incineration is one of the common treatment methods used for treating municipal solid waste (MSW). Incineration can reduce the volume of waste by up to 90%, which can conserve landfill space and destroy toxic substances in waste materials by thermal treatment. With an increased amount of incineration, greenhouse gas (GHG) emission have been increasing over the past years. In this study, GHG emissions from incineration of MSW in Seoul, Korea by 2040 were estimated, based on three scenario analyses.

MATERIALS AND METHODS

Data source, incineration and GHG emission

In this study, we used the data of 'National Waste Generation and Treatment Statistics (2000~2020)'. Seven models (linear model, arithmetic series model, geometric series model, exponential function model, least squares method, logistic curve, and Gompertz model) were used to predict MSW incineration amount. To estimate GHG emission by incineration, we used the waste sector GHG emission calculation tool provided by the KECO. The emission factors and parameters for calculating GHG emissions were given by IPCC guideline.

Scenario analysis

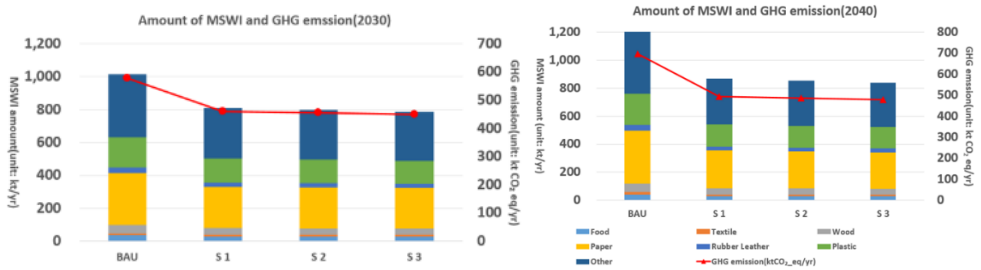
In Korea, there were some policies about reducing amount of MSW. In this study, we have set four scenarios targeted for increasing or decreasing the amount of incineration and recycling due to the decrease in the amount of landfill: Business-as-usual (BAU), scenario 1 (S1), scenario 2 (S2), scenario 3 (S3).

Category	Assumption
Business-as-usual, BAU	No significant change at MSWI amount (Present treatment amount)
Common assumption (S1 ~ S3)	Considering source control policy, assume reduction rate of landfill amount of 5%. In addition, it was assumed that a certain portion of the reduced landfill amount for each scenario was divided into incineration and recycling, respectively.
Scenario 1 (S1)	100% of the reduced landfill amount is treated entirely by incineration.
Scenario 2 (S2)	50% of the reduced landfill amount is treated by incineration and the other 50% is treated by recycling.
Scenario 3 (S3)	100% of the reduced landfill amount is treated by recycling.

RESULTS AND DISCUSSION

Prediction of MSWI amount and GHG emissions in 2030 and 2040

As a result of calculating Scenario 1, which was evaluated based on the weakest assumption among the three scenarios, it is considered necessary to reflect the reduction policy as it does not exceed the Seoul Metropolitan Government's processing capacity of 2.85 kt/day. A scenario-by-scenario comparison of the MSWI's amount and GHG emissions from changes in treatment methods showed that Scenario 3, an assumption that all of the reduced landfill is recycled, treats the least amount of waste as incineration. Comparing BAU and Scenario 3, it was found that as of 2040, there was a difference of 32% in the incinerator sector and 31% in GHG emissions. Although there is a limitation in that waste treated by landfill cannot be treated for 100% recycling, it can be seen that increasing the ratio of recycling rather than incineration is more effective to reduce GHG emissions from waste disposal.



CONCLUSION

The MSW emissions in Seoul are expected to increase over the next few years. In particular, plastic consumption due to COVID-19 increases, making it inevitable to increase greenhouse gas emissions. As a result of analyzing the changes in the disposal method of MSW due to the ban on direct reclamation by scenario, it was found that the 100% recycling method has the effect of reducing the MSWI and reducing GHG emissions. There is a limit to treating all reduced landfills for recycling, but if it is higher than the current recycling rate, GHG emissions in the incineration sector can be reduced. The main characteristics of waste treated by incineration were paper and plastic (48%). The results of this study can be used as basic data for reducing MSW and GHG emissions in the incineration sector of Seoul.

ACKNOWLEDGEMENT

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Microplastic contamination in selected Malaysian mangroves: prevalence, distribution, and characteristics

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Keywords: Microplastics, fragmentation, mangrove ecosystem

INTRODUCTION

Plastic pollution has been a very global issue which continues to threaten the ecosystem due to the inevitable dependency of human civilization to plastics product. As a result, 400 million tonnes of plastic waste is discarded annually, which some were fragmented into microplastics due to weathering and physical abrasion. Its abundance varies from one region to the next that it is crucial to establish a baseline data, including from marine and mangrove areas. Malaysia being the eighth-largest producer of poorly managed plastic garbage with 140–370 million kg entering the ocean annually, faces serious threats from plastic and microplastic pollution. The lush diversity of the tropical ecosystem is being contaminated as the microplastics has been recorded in animals of various trophic levels. Therefore, this study was conducted to establish a baseline data of microplastics prevalence, distribution, and characteristics, in selected mangrove areas in Peninsular Malaysia. It is aimed to investigate microplastic abundance in mangrove sediments, and to identify the most prevalent colour and types.

MATERIALS AND METHODS

Sampling sites

Sediment samples were collected from four mangrove sites (Cherating, Pahang, Sedeli Besar, Johor, Matang, Perak and Kuala Selangor, Selangor) along the coastline of Peninsular of Malaysia during the intermonsoon and Southwest monsoon seasons. The sediments were collected using an auger and a shovel at depths of 1-10, 10-30, and 30-50 cm. Then, collected samples were placed into containers and transported to the laboratory.

Quantification of microplastics

A modified flotation technique was used to extract the microplastics. 300 g sediments were dried at 50 °C for at least 48 hours, followed with the addition of 750 ml NaCl (conc). The mixture was left to stand overnight, then sieved using a series of Tyler Sieves with mesh sizes of 5.0 mm, 1.0 mm, and 0.1 mm. Using steel tweezers, the microplastics retained on the sieves were separated and categorized into three groups which are size, shape, and colour. During the sampling and analysis, the tools used are either made of glass or metal to avoid contamination from tools. Results from the study were subjected to statistical analysis to determine the correlation and others.

RESULTS AND DISCUSSION

Total Abundance of Microplastics

The results obtained from the sampling during inter-monsoon and Southwest monsoon indicated that microplastics contamination is higher on the west coast of Peninsular Malaysia which is highly influenced by the busy shipping routes along Straits of Malacca, than that of the east coast which is exposed to the South China Sea. Figure 1 shows the relationship between the depth of soil and its corresponding microplastic accumulation at selected mangrove sites during the Intermonsoon and Southwest monsoon.

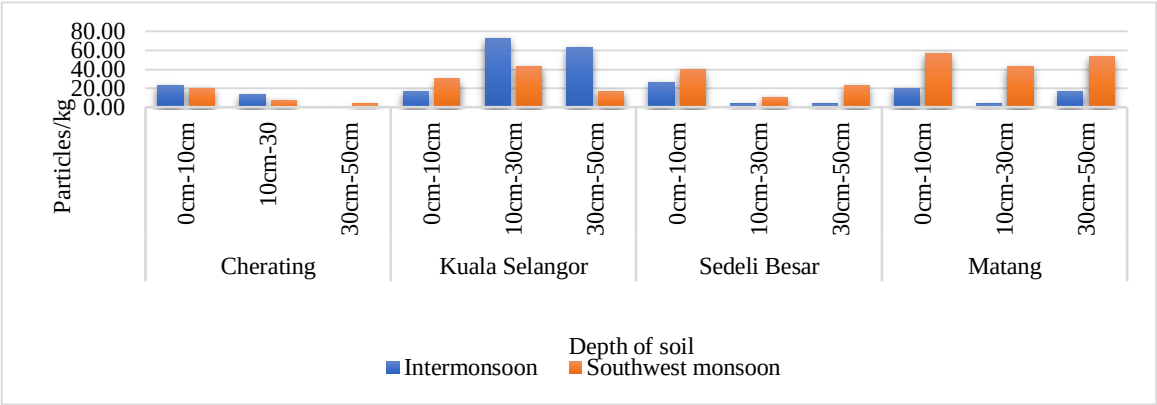

Figure 1 The abundance of microplastics at different soil depths in selected mangroves

The average concentrations of microplastics in sediments during the Intermonsoon and Southwest monsoon seasons were 35 ± 23.42 particles/kg and 25.93 ± 18.28 particles/kg, respectively. The most predominant type of microplastics was film (46.7%), followed by fragments (28.8%), fibers (16.3%), foams (7.1%) and pallet (1.1%). As for the colour, white (30.4%) microplastics was the highest as compared to blue (26.5%), colourless (20.4%) and black (10.50%). In terms of chemical composition, the most abundant are high and low density Polyethelene (HDPE and LDPE), polystyrene (PS) and Polyethelene terephthalate (PET). The findings indicated that the most prevalent human activities dictated the types of microplastic contamination in the areas.

CONCLUSION

The microplastics contamination was the most serious in the west coast of Peninsular Malaysia. In terms of prevalent types and colour, PET and PS, and white was the most abundantly found. The findings from this study is important to provide the baseline data for future research and mitigating measure in managing and preventing future plastics pollution in Malaysia.

ACKNOWLEDGEMENT

This research was supported by NERC, UK.

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Changes in single-use plastic generation by households during COVID-19 in Asian cities

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Keywords: food waste, plastic waste, household, COVID-19, Asian

INTRODUCTION

Asian cities are hotspots for tackling plastic issues for a number of reasons such as extensive coastlines; rapid urbanisation, rapid economic and population growth; fast growth of the urban middle class, as well as increases in consumer goods and services; poor waste management and recycling systems; and tourism. Many reduction targets are set at the global/national level and several countries have issued bans on specific plastic products. For example, the Thai government is aiming to phase out the use of plastic by 2030 and issued a ban on single-use plastics in January 2020. However, the recent COVID-19 pandemic has led to an increased demand for single-use plastic, intensifying pressure on this already out-of-control issue.

Meanwhile, plastic issues are an integral part of consumers' daily lives and cannot be fundamentally solved without a change in consumer behaviour. However, there have been very few studies on consumers in the consumption phase in Asian developing countries. Therefore, this study is an effective way to collect on-the-ground data in countries where officially published data do not exist to decide the baseline for policymaking.

MATERIALS AND METHODS

In order to evaluate policy options to reduce single-use plastics in Asian countries on the path to a circular economy, as well as achieving the SDGs, meeting the goals of the Paris Agreement, and aiming for a green recovery, it is not only important to understand consumers and the reasons behind single-use plastics generation, but it is also vital to bridge the gap between consumer behaviour and local/national as well as global agendas. To do this, (1) firstly we conducted a cross-sectional questionnaire survey to capture people' lifestyle changes before and during the pandemic, and to clarify the "scenes" and reasons for single-use plastics generation by consumers as well as the enabling conditions among stakeholders & the local community: this helps to gain insight into the deciding factors for behaviour change; (2) secondly, we reviewed the relevant policies and action plans that have been put in place, to provide further policy implications based on the local context.

So far, we have selected Bangkok, as a representative city of an upper-middle income country, and Hanoi, as a representative city of a lower-middle income country, as case studies to evaluate the impact of COVID-19 on household single-use plastics. We are planning to expand our case study to Shanghai (China), Manila (the Philippines), Depok (Indonesia), and Phnom Penh (Cambodia) in early 2023 to get an overall picture of Asia. The questionnaire included working days, eating / shopping / cooking habits before and after the COVID-19 outbreak, number of use of single-use plastic products as well as disposal method. Statistical tests (t-test, Kruskal-Wallis test and Dunn's multiple comparisons test) were implemented to detect the differences.

RESULTS AND DISCUSSION

The following points make up the initial stage of our main findings based on the survey in Bangkok and Hanoi:

(1) Plastic shopping bags are the most frequently used type of single-use plastic in Hanoi, at almost 27 bags per person a week, equal to four per person each day. Considering the global average consumption of almost one plastic bag per person per day, it is clear that the plastic bag consumption is at a high level. Also, plastic bags are used more often in rural areas than in urban areas. During the pandemic, in response to questions on their use of plastic bags, half of respondents showed "no change", around 20-30% showed "definitely less" and "less", and around 20-30% showed "definitely more" and "more". When identifying the characteristics of those who have increased use and those who have decreased use, it was found that for people living in a town house, and who use food delivery service often, there was an increased use of plastic bottles and plastic shopping bags. Conversely, those living in detached houses did more teleworking and did not use food delivery service much, so the use of plastic bottles and plastic shopping bags decreased.

(2) The shift from eating out to online food delivery services led to an increase in plastic bags, hot-and-cold food bags, and plastic food containers generated by households in Bangkok. Meanwhile, Hanoi showed the opposite pattern, whereby people preferred and enjoyed cooking at home during the pandemic. Not only "eating out" but "eating ready-made meal" decreased during the pandemic. The use of food delivery services for ingredients increased while food delivery service of ready-made meals did not change much during the pandemic. As a result, household plastic waste generation by food delivery services did not increase much during the pandemic.

(3) Based on the survey carried out in Hanoi, it was found that working patterns in the "new normal" returned to almost "pre-pandemic" levels, and people working out of the home five days or more per week has increased compared to "before COVID-19". Not only "eating out" but "eating ready-made meals" decreased during the pandemic and this has returned to normal levels now. Eating at home increased during the pandemic but this has returned to normal levels now, which might be due to the busy schedules. Under the new normal, there is a decrease in food delivery services for ingredients but an increase in the share of food delivery services for ready-made meals. This might increase the generation of single-use plastics from food delivery services.

CONCLUSION

The impact of the COVID-19 pandemic on single-use plastics varies from country to country. To achieve more effective single-use plastics management in the post-COVID-19 era, key drivers in customs, culture, economy and policy will need to be further identified. However, some timely key policy intervention points might be: (1) to establish green delivery services and online shopping through guidelines, accountability, appropriate incentives or compensation mechanisms etc.; (2) to form a circular economy based on source separation and localised supply chains using an on-line and off-line platform; and (3) to develop behaviour-based solutions/alternatives targeting consumers' daily lives and social practices, including comprehensive and inclusive strategies that can trigger behavioural change among consumers.

ACKNOWLEDGEMENT

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Effect of Recirculation on Starting up Two-Phase Anaerobic Digestion for Biohydrogen and Biomethane Recovery from Organic Solid Waste

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Keywords: anaerobic digestion, organic fraction of municipal solid waste (OFMSW), two-phase, hydrogen, recirculation.

INTRODUCTION

The waste production is growing along with the population. Among all sorts of waste, organic solid waste is feasible for anaerobic treatment to recover its chemical energy into methane gases. Many studies have proved that the process of two-phase anaerobic digestion is efficient for generating biohydrogen and biomethane continuously from organics. By controlling the flow through two cascade reactors, the acidogenic phase, which produces hydrogen, and the methanogenic phase are separated into the two reactors. The key to maintaining the co-production state of biohydrogen and biomethane requires particular manipulation of conditions, including the recirculation ratio. In order to investigate the feasibility to achieve a thermophilic R-TPAD (recirculated two-phase anaerobic digestion), by adjusting R to stabilize the process from an acidified state. The operating performance, shifts of fermentation pathways and microbial structures are discussed.

MATERIALS AND METHODS

Substrate preparation

The organic solid waste was collected from the supermarket (for food waste) and from the office (for paper waste). The food waste and paper waste were mixed with a high-speed blender. Its characteristics are as below.

Table 1 Characteristics of organic solid waste

pH	TS (%)	VS (%)	COD (g/kg)	Carbohydrates (g/kg)	Proteins (g/kg)
5.35 ±0.05	10.03 ±0.03	9.38 ±0.30	141 ±3	74.6 ±3.6	12.1 ±0.9

Process configuration

The process consists of two CSTRs (continuously stirring tank reactors) with working volumes of 3.0 L and 12.0 L. The manual feeding and withdrawing of substrate and sludge were conducted twice a day. The hydraulic retention time (HRT) regardless of recirculation was 15 days. Both tanks were isolated for 55 °C.

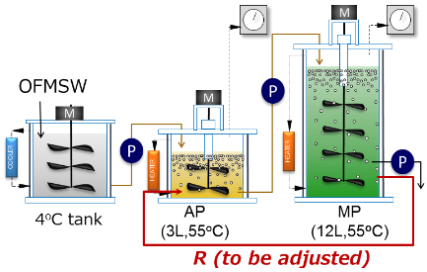

Figure 1 Configuration of recirculated two-phase anaerobic digestion (R-TPAD)

RESULTS AND DISCUSSION

Response to shifting recirculation ratios

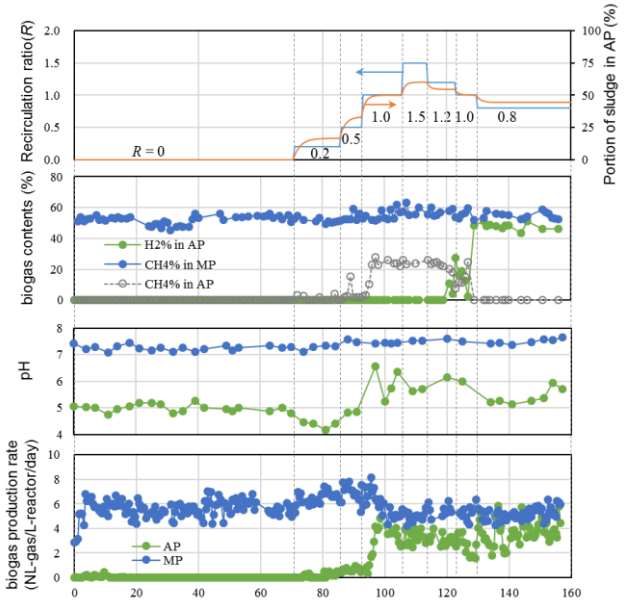

Figure 2 Response of process performance.

When recirculation ratio (R) =0, the pH in AP stayed around 5.0 but no H_2 was produced due to the lack of H_2 producers. Then the R was increased to 1.0, CH_4 contents reached 25% yet no H_2 was produced. The R was increased to 1.5, attempted to wash out methanogens but CH_4 contents remained. Whereas, when the R was decreased to 1.0, H_2 appeared. The R was finally fixed at 0.8 where H_2 was continuously produced and CH_4 did not show up in AP. During those operation, the CH_4 production in MP was always stable, indicating the stable H_2 is the key to start up the R-TPAD process by adjusting recirculation.

Shifts of key microbial communities.

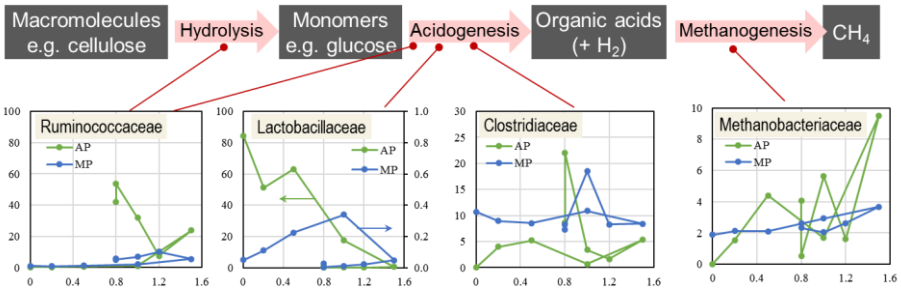

Figure 2 Shifts of key microbial groups.

The most probable cellulose-hydrolyzers and acidogens, *Ruminococcaceae* and *Clostridiaceae*, were enriched in AP. The lactic-acid producer and the initial predominant group, *Lactobacillaceae*, were almost eliminated from AP after manipulation. Although the H_2-consumers, *Methanobacteriaceae*, increased with R, the operating performance indicates they were inhibited by low pH in AP.

CONCLUSIONS

Co-production of H_2 and CH_4 was successfully achieved by adjusting recirculation ratio (R) in a two-phase process. Potential cellulose-hydrolyzers and H_2-producers were enriched. The CH_4 production in MP remained relatively stable when shifting R. The process yielded 57.6 NL-H_2/g-VS_{fed} and 368 NL-CH_4/g-VS_{fed} with a VS removal of 79.4% under an HRT of 15 days.

Factors that improve elderly's access to external help for disaster waste clean-up

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Keywords: Disaster waste, aging society, mutual help, self-help

INTRODUCTION

Disaster waste is larger in volume and weight than the normal waste handled by citizens, and its cleanup and transportation are difficult tasks for the elderly. However, in the event of a large-scale disaster, the human resources of local municipalities can become exhausted, making it highly unlikely that adequate public assistance will be available. In response to the rapid aging of Japan's society, strategies to support elderly households in cleaning up disaster waste are needed. We wanted to understand more about the family help and mutual help from neighbors or volunteers that are available to elderly households for cleaning up disaster waste, and to identify factors that improve access to mutual help. To that end, we conducted a questionnaire survey in a city in Japan that was severely damaged during the 2019 typhoon season.

METHODS

Survey

In 2019, Tateyama City, in Chiba Prefecture, Japan, was severely damaged by Typhoon Faxai in September and Typhoon Hagibis in October. Thirty percent of the 23,000 households in the city suffered damage to their buildings and water damage to their contents. We conducted a survey in three districts in the city that received particularly severe damage and had high percentages of elderly residents. Districts A, B, and C had elderly ratios (residents' age ≥ 65) of 43.1%, 51.5%, and 59.4%, respectively, and the respective percentages of houses damaged were 50.9%, 52.1%, and 79.8%. Our questionnaire was distributed by postal service in mid-April 2021 and collected by mid-May 2021, with 3,297 questionnaires distributed and 1,060 valid responses received (32.2% collection rate). Of the responding households, 17.6% comprised only elderly persons aged 75 or older (**≥75**), 25.8% comprised only elderly persons aged between 65 and 74 years (**65–74**) *, and 56.6% had other compositions (**other**). * Households with 65 years old and a 75 years old living together were classified as 65-74.

Analysis

In this study, cases in which children and relatives who do not live with respondents (hereafter referred to as " relatives ") help clean up disaster waste are defined as family help, and cases in which neighbors or volunteers help are defined as mutual help. We examined how **(1) respondents' participation in local or community activities during non-disaster times** and **(2) the availability of outreach activities or needs assessments performed by related organizations during disasters** affected whether or not a household received mutual help. Binomial logistic regression was used to control for potential confounding by household category (1: ≥75; 2: 65–74; 3: other), degree of housing damage (1, completely destroyed to 5, minor damage), and access to a Volunteer Center** branch (1, 0). All statistical analyses were performed with R version 4.2.1.

** Volunteer Center / Disaster volunteer center: An organization temporarily set up during a disaster to manage disaster volunteers, generally run by the social welfare council***. The main function is to accept and match disaster volunteers in the affected areas.

***Social welfare council: A non-profit private organization with the purpose of promoting private social welfare activities

RESULTS

Family help and Mutual help status

We plotted the percentages of households that were helped by relatives, neighbors, or volunteers to clean up disaster waste, stratified by household group (Fig. 1). Fifty percent of the households in the **≥ 75** group were helped by their relatives, indicating that a large percentage of households had to take care of waste clean-up by family members. Furthermore, 21% of households in the **65–74** group and 13% of the households in the **≥ 75** group indicated that they did not get help, even though they needed it (Fig. 2). Therefore, improved access to mutual help for those who must rely only on themselves to clean up disaster waste is needed.

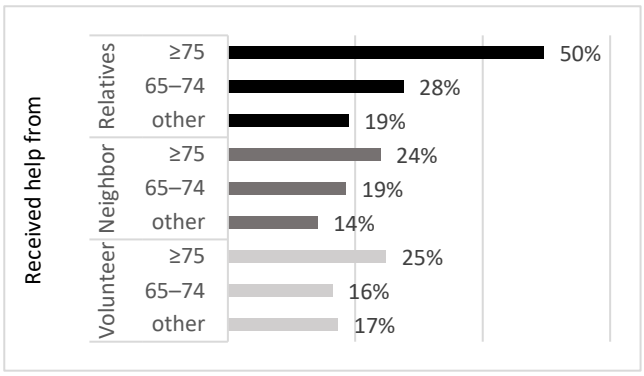

Fig. 1 Percentages of households that received help in cleaning up disaster waste, by household category

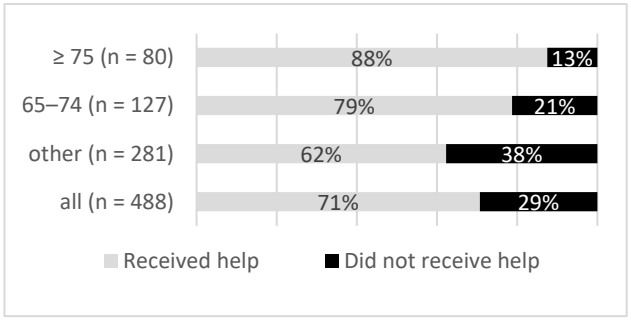

Fig. 2 Percentages of households that received help among those who thought they could not clean up disaster waste on their own.

Factors that improve access to mutual help

We then plotted adjusted odds ratios (ORs) with 95% confidence intervals (CIs) for the associations between receiving mutual help and respondents' levels of participation in community activities during non-disaster times (Fig. 3). Significant interactions were observed between receiving neighborhood support and interaction with the neighborhood (OR = 1.63 [CI: 1.14–2.34, $P = 0.006$]) and sports and hobby activities (OR = 1.29 [CI: 1.04–1.60, $P = 0.018$]). No significant associations were observed for volunteer support.

We also plotted adjusted ORs with 95% CIs for the associations between receiving external help and the availability of outreach activities such as needs assessments performed by related organizations (Fig. 4). Significant interactions were observed between receiving neighborhood support and outreach activities by fire brigade (OR = 2.54 [CI: 1.14–5.65, $P = 0.021$]) and neighborhood associations (OR = 2.20 [CI: 1.15–4.19, $P = 0.016$]). A significant interaction was observed between receiving volunteer support and needs assessment by a volunteer center (OR = 6.28 [CI: 3.88–10.15, $P < 0.001$]).

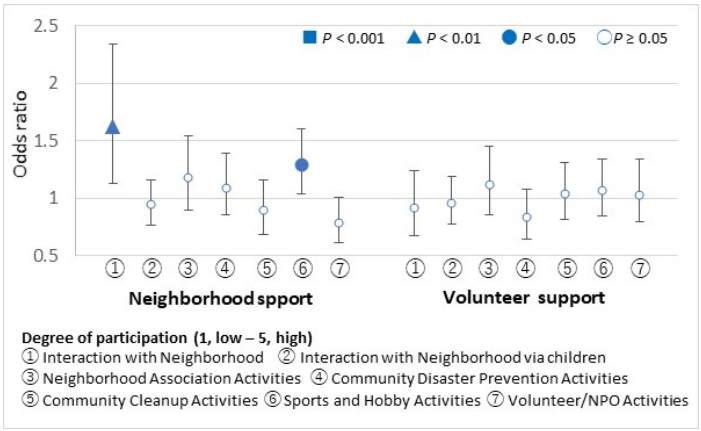

Fig. 3 Associations between receiving mutual help (from neighbors or volunteers) in cleaning up disaster waste and participation in local activities, with 95% confidence intervals. *NPO, non-profit organization

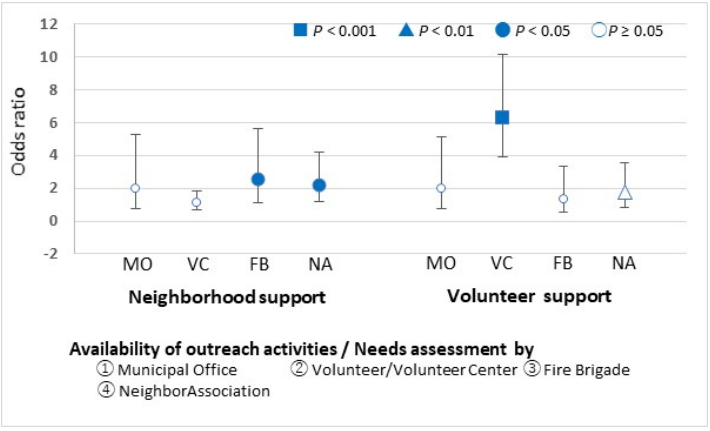

Fig. 4 Associations between receiving mutual help (from neighbors or volunteers) in cleaning up disaster waste and the availability of outreach activities by related organizations, with 95% confidence intervals

DISCUSSION AND CONCLUSION

Our survey revealed that many elderly households in the study area received help for the cleanup from children or other relatives. However, more than 10% of elderly households received no help, despite needing it. Therefore, approaches for connecting such households to mutual help are needed. Our data indicate that improved access to mutual help from neighbors can be achieved by (1) strengthening ties among residents through interaction during non-disaster times, and (2) having fire brigade and neighborhood associations serve as hubs of support in times of disaster. Needs assessments by volunteer centers should also be effective for reducing the number of households that lack help.

Characterization of flame retardants pollution on plastics from WEEE using a chromoproduct approach

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Keywords: WEEE, plastics, chromoproduct, flame retardants

INTRODUCTION

Both Colombian and Japanese legal framework include to a certain extent the management of waste of electric and electronic equipment (WEEE). In Colombia, WEEE licensed facilities usually perform manual disassembly and segregation by plastic, metal, and glass fractions. The plastic fraction is not further sorted out, which translates into a fragile economic scheme and a risk of legacy pollution. Therefore, it is relevant to identify WEEE that contain brominated flame retardants regarded as persistent organic pollutants (POP-BFRs), to carry out their sound treatment according to Stockholm Convention and Basel Convention guidelines. Japan is also a Party on both Conventions, but its role is different as it is one of the top producers and consumers of EEE. For a successful WEEE circular economy, pollutants must be kept out of products and the recyclable waste streams; this challenge is expected to become more relevant in the following years. The objective of this research is to analyze if a novel dismantling-based recycling (Wagner et al., 2019) named "chromoproduct approach" can ease the management of plastics from WEEE, based on XRF analysis of Br and Sb, and diminish waste incineration, sorting POP-BFRs polluted wastes.

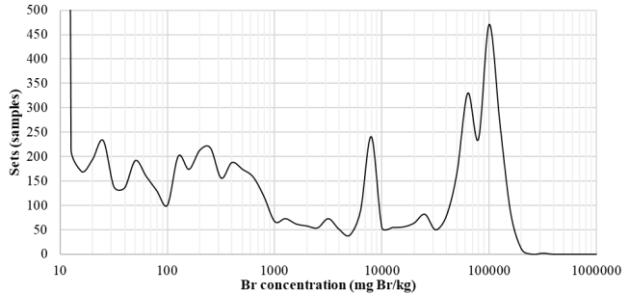
MATERIALS AND METHODS

Chromoproduct is defined as the junction between a product type and its dominant visible color (e.g., black laptop). Hand-held X-ray fluorescence (XRF) device was used to determine concentration on plastics (mg/kg) of Br (as an indicator of POP-BFRs) and Sb (as an indicator of Sb_2O_3 that has been used alongside to increase the flame retardancy feature in a ratio 3:1; Turner, A., Filella, M., 2017) on a sample of sets. Sets are plastic pieces from WEEE for which the following information is known: chromoproduct, polymer type and weight. Representative samples ($n \geq 51$) of selected chromoproducts were prioritized and sent for POP-BFRs GC-MS analysis (IEC 62321-6:2015).

RESULTS AND DISCUSSION

From 2000 tons of plastics from WEEE at six Colombian WEEE managers, a sample of 14 669 sets (16 tons of plastics grouped in 176 chromoproducts) were characterized. Distribution of Br and Sb concentrations of the sets are not normal, meaning that only a few are responsible for the weighted average found (see Figure 1a). Using a threshold based on ROHS limit of 1000 mg ∑PBDE/kg, only 2918 sets had bromine enough to be considered suspicious of POP-BFR pollution (≥ 658 mg Br/kg), meaning that only 20% were polluted, representing 13% w/w (112 chromoproducts). Also, 46 chromoproducts were sent to GC/MS with only 16 being actually polluted with POP-BFRs (6% w/w).

a) Bromine distribution



Note: samples with Br ≤10 mg Br/kg are 8581 sets (~60%), hence are not shown in the figure.

b) Br, Sb and POP-BFR plot

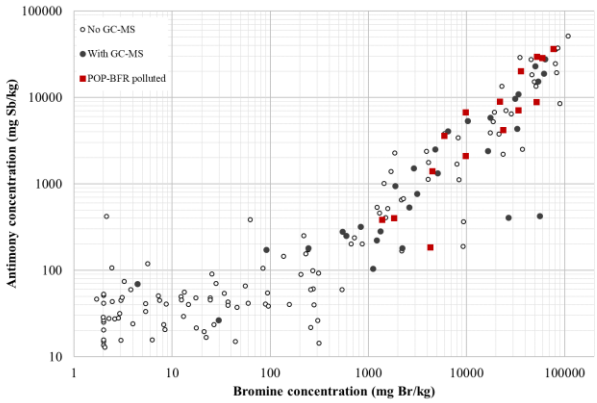


Figure 1. Bromine distribution and correlation with Sb and POP-BFRs

Concentrations of Br and Sb on chromoproducts were plotted and differentiated according to POP-BFR content (Figure 1b). Both Br and Sb occurrences were the highest (> 10 000 mg/kg) in white ballast, black microwave oven, black and white CRT screens, black CPU fan, white fluorescent lamp, black space heater, black and other multiplugs, black fax, and black hair iron. After 500 mg Br/kg, the 3:1 ratio for Br and Sb was found, accordingly to previous reports. Results suggest that it is not possible to establish a prediction of POP-BFR content in plastics solely from Br content, Sb content, or Br/Sb ratio: it is necessary to characterize by GC-MS to discard the suspicion of POP-BFRs pollution. While country of manufacture or brand were data usually not available, it was possible to identify around 707 sets, from Japanese brands, included in black video cameras and radios that are likely to be polluted with POP-BFRs. A further analysis of plastic mining and a comparison of Colombia and Japan standpoint in WEEE management will be done using the obtained results.

CONCLUSION

Occurrence of Br (≥ 658 mg Br/kg) was found on 20% of plastics sets from WEEE (13% w/w, 112 chromoproducts), with a 3:1 Br/Sb ratio. Using chromoproducts approach, waste that needs final treatment may reduce in half, as only 6% w/w plastics are actually polluted (16 chromoproducts) while simultaneously enhancing environmentally sound recycling. There was no need of further XRF or GC-MS of chromoproducts after their characterization, which eased the plastics from WEEE management under the Colombian circumstances studied.

ACKNOWLEDGEMENT

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Pyrolysis of sewage sludge as an alternative to incineration

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Keywords: sewage sludge, organic pollutants, pyrolysis, carbonisation, sludge-char

INTRODUCTION

Sewage sludge, the material resulting from wastewater treatment, contains nutrients, organic matter, and a range of pollutants such as heavy metals, pathogens, microplastics, or organic pollutants (pharmaceuticals, endocrine disruptors including hormones, PAHs, POPs, or PFASs) (Hušek et al., 2022a). The presence of these pollutants limits their direct use on agricultural land or compost production. In 2022 the JRC of the European Commission in the document *Screening risk assessment of organic pollutants and environmental impacts from sewage sludge management* stated that "*Only incineration at high temperatures ensures that all organic priority pollutants are effectively removed*" (Huygens et al., 2022). However, there are other technologies for sludge thermal treatment, such as pyrolysis, which are alternatives to incineration, but a demonstration of the suitability for the removal of organic contaminants is required (Huygens et al., 2019).

MATERIALS AND METHODS

Laboratory pyrolysis of sludge

The sewage sludge was pyrolysed in a stainless steel (or quartz) fixed bed reactor by slow pyrolysis at various temperatures ranging from 200 to 700 °C for 2 hours under a helium atmosphere. For more information on the apparatus, see Moško et al. (2021), and for analyses, see Moško et al. (2021) and Semerád et al. (2020).

Commercial pyrolysis unit

The laboratory results were validated on a commercial pyrolysis unit (PYREG P500 KSF) at the Bohuslavice Trutnov WWTP (CZE). The current annual capacity in operation is 3,700 tonnes of dewatered sludge. The sludge is dried in a low-temperature dryer and pyrolysed at approximately 600 °C (Fuka et al., 2021).

RESULTS AND DISCUSSION

Pyrolysis is an alternative to sludge incineration with low concentrations of heavy metals (most of the HM remains in the final product). The units may find application, especially in remote areas where sludge production is lower. The resulting sludge char is suitable as a soil improver, increases soil permeability and water retention, and serves as a medium-to-long-term source of phosphorus for plants (Hušek et al., 2022a).

Compliance with local legislative limits is essential. The ability of pyrolysis to remove organic pollutants is shown below.

Pharmaceuticals and personal care products and endocrine distributors

- 95 % removed around 400 °C (31 compounds analysed) (Moško et al., 2021).

PCBs, PAHs

- 95% removal rate: PCBs above 600 °C (104 compounds analysed) and PAHs 500 °C (16 compounds analysed – EPA standard) (Moško et al., 2021).

PFASs

- 95% removal rate around 400 °C (37 compounds analysed) (Hušek et al., 2022b)

Flame retardants

- measurements are currently underway, and preliminary results can be expected at the time of the conference.

CONCLUSION

Pyrolysis is an alternative to the incineration of sewage sludge with low heavy metal content in remote areas. The amount of sludge processed is smaller than in conventional incinerators, and sludge with a high content of heavy metals is not suitable due to their ability to concentrate in sludge char. The resulting product, sludge char, can be used (subject to legal limits and laws) as a soil improver. A sufficient operating temperature of at least 500 °C (ideally 600 °C) is necessary to remove organic pollutants.

ACKNOWLEDGEMENT

This work was supported by the Ministry of Agriculture of the Czech Republic – project QK21020022), Czech Academy of Sciences AV 21 – Sustainable energy, and Specific university research grant No. A1_FTOP_2022_001 and No. A2_FTOP_2022_003.

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Purification of polyethylene in waste plastics using solvent extraction method

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Keywords: purification, polyethylene, solvent extraction method

INTRODUCTION

The global recovery of waste plastics has reached about 400 million tons, including about 60% polyethylene (PE) and polypropylene (PP). From the perspective of carbon resource recycling and carbon resource conservation, it is critical to establish methodologies that enable the effective use of recovered waste plastics to be implemented on a wide scale. In many cases, however, the purity of optically sorted PE and PP from recovered waste plastics is about 80% due to waste plastics with different shapes and multilayered food packaging plastics, limiting the purity to high levels. In order to promote effective utilization of recovered plastics, the speaker's laboratory has been researching and developing a rapid and simple purity measurement method using IR measurement for the purity of recovered PE and PP obtained from optical sorting [1]. The sample preparation method used at that time was to prepare uniform film samples by preparing homogeneous solutions of PE and PP in toluene, and the results of screening experiments to search for solvents showed that many aromatic compounds with alkyl chains have the solubility of PE and PP. Among them, only PE and PP were successfully extracted selectively from recovered PE and PP using mesitylene or cumene as good solvents below 200°C [2]. Although there have been many reports on good solvent-poor solvent separation methods, this is the first report on the use of mesitylene or cumene.

METHODS

Experimental Operation of Solvent Extraction

1.0095 g of recovered PE in a cotton bag and 87.0 g of mesitylene were placed in a Nas flask and heated to reflux for 1 hour. After cooling, the cotton bag was removed and acetone, a poor solvent for PE, was added, and the extract was completely precipitated. The precipitate was filtered off as a white solid

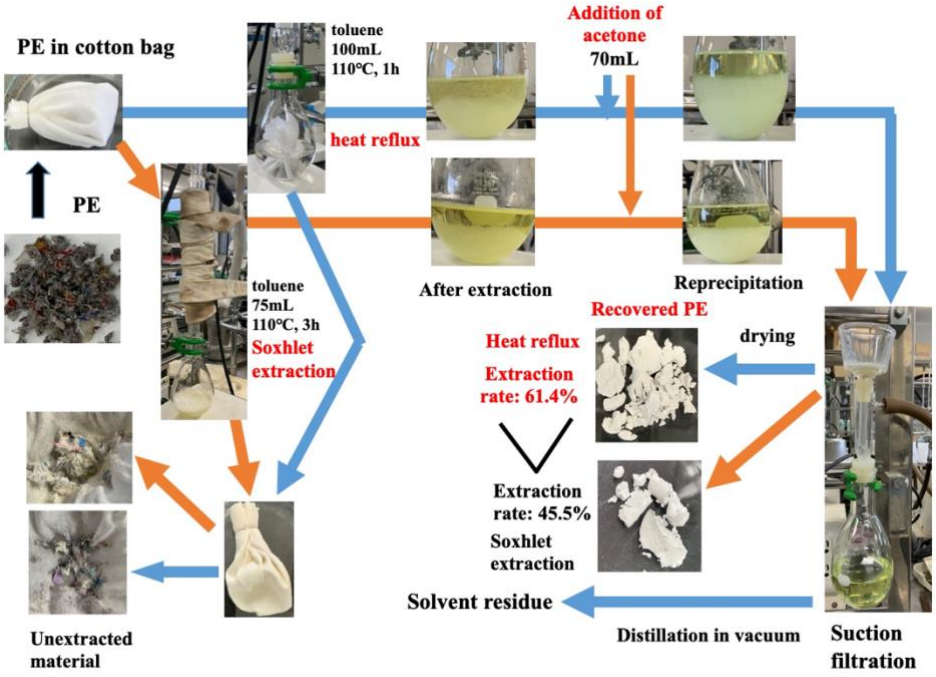

Figure 1. Extraction operation of PE using solvent extraction method

by suction filtration. After drying, 0.8434 g of white solid was obtained, whose IR measurement was PE, indicating a recovery of 84%. Acetone and mesitylene were distillated from the filtrate and 0.0584 g of solvent residue was yielded. In addition, 0.0691 g of unextracted material was recovered in a cotton bag (Figure 1).

Manipulation of purity determination

The purity of the recovered PE was determined using IR measurement with an internal standard, polyvinyl acetate (PVAc). About 30 mg of the recovered PE and about 15 mg of PVAc were heated and dissolved in 4.5 g toluene to prepare a homogeneous solution. The weight of PVAc was used to calculate the weight of PE and PP from the standard PE-PVAc and PP-PVAc calibration curves, respectively, and finally the purity of PE was calculated. The PE purity was calculated by using the weight of PVAc.

RESULTS AND DISCUSSION

Aromatic compounds toluene, cumene, and mesitylene were used as extraction solvents to compare the extraction rates of recovered PE (Figure 2). Soxhlet extraction and in-flask extraction methods were used. In all experiments, the bags were removed after the extraction operation and acetone, a poor solvent for PE, was added to precipitate the extract. In the first experiment, the Soxhlet extraction method was performed using toluene, and the extraction rate was 49.1%. Since the temperature of the solvent receiver portion of the Soxhlet extractor was lower than the reflux temperature of toluene, a ribbon heater was used to maintain the temperature, but the extraction rate was low. On the other hand, the extraction rate increased to 60.5% when toluene was extracted in a cotton bag using the in-flask extraction method, which can receive sufficient heating. However, the extraction rate was still insufficient, so the use of cumene and mesitylene, which have high boiling points, increased the extraction rate to 84.4% and 83.5%, respectively. IR measurements of the recovered extract, the unextracted material remaining in the cotton bag, and the residue in the extraction solvent were performed. From those results, it was found that the recovered extract was mainly PE. However, since it is known that PP is also soluble in cumene and mesitylene, a separate purity measurement was performed, and it was also found to contain about 10% PE. On the other hand, the remaining unextracted material in the cotton bag was found to be PET and nylon; since acetone was used as a poor solvent for PE, the residue in the extraction solvent was found to contain ester compounds that may have been derived from polystyrene and printing inks.

CONCLUSION

It was found that PE could be recovered efficiently from waste plastics by using this solvent extraction method. We plan to study solvent extraction of degraded PE in the future.

ACKNOWLEDGEMENT

The part of this study was supported to carry out by a Grant-in-Aid for Scientific Research (22K12452).

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Microplastic contamination of commercially purchased blood cockles (*Anadara granosa*) from local markets in selected states of Peninsular Malaysia

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Keywords: Blood cockles, Malaysia, microplastic, marine ecosystem

INTRODUCTION

Plastics were introduced as a revolutionary material in the early 1900s due to its low weight, liability, longevity, and durability. Since then, the production of plastics has expanded significantly. The robust properties of plastic, which at the time piqued the interest of many industries and customers, have unfortunately made the situation worse and are extensively disseminated in the environment. Many marine organisms, including coastal species harvested for human food, are known to consume microplastic. Bivalve contamination is a big issue for food safety and human health due to their economic interest and the fact that consumers eat the whole animal. Bivalves are directly exposed to contaminants such as microplastic that are prevalent in their surroundings due to their feeding behaviour. So far, only a few studies have been reported on the abundance and distribution of microplastic in marine organisms in Malaysia. The abundance of microplastic in bivalves especially blood cockles, an important aquaculture species in Malaysia is still largely unknown. Therefore, my research focuses on quantifying the abundance of microplastics in blood cockles commercially purchased from local markets in selected sites of Peninsular Malaysia. The physical characteristics of polymers, such as their size, colour, and shape, were examined. The findings of this study enable the compilation of baseline information on the prevalence of microplastics in blood cockles, which will serve as a foundation for comprehending the destiny and dissemination of polymers.

MATERIALS AND METHODS

Sample collection and Quantification of microplastics

Cockles were purchased at the nearest markets at Cherating, Pahang, Sedeli Besar, Johor, Matang, Perak and Kuala Selangor, Selangor. The purchased cockles were transferred into the cooler box and transported to the laboratory for further analysis. The samples were frozen before analysis. All soft tissues from the cockles were removed from the shell, defrosted at room temperature, and then weighed and crushed in a 250 mL glass Erlenmeyer flask. To allow the tissues to degrade, they were placed in a clean glass container that had been washed with filtered DI water, topped with twice of 10% KOH solution, and incubated at 50°C for 72 hours. A vacuum pump system was used to filter the digests utilising discs with a 70 µm mesh size. The particles were stored in a clean, sealed, and labelled petri dish for microscopic examination and subsequently polymer identification.

RESULTS AND DISCUSSION

Total Abundance of Microplastics

Figure 1 displays the prevalence of microplastics in commercially purchased blood cockles from various locations.

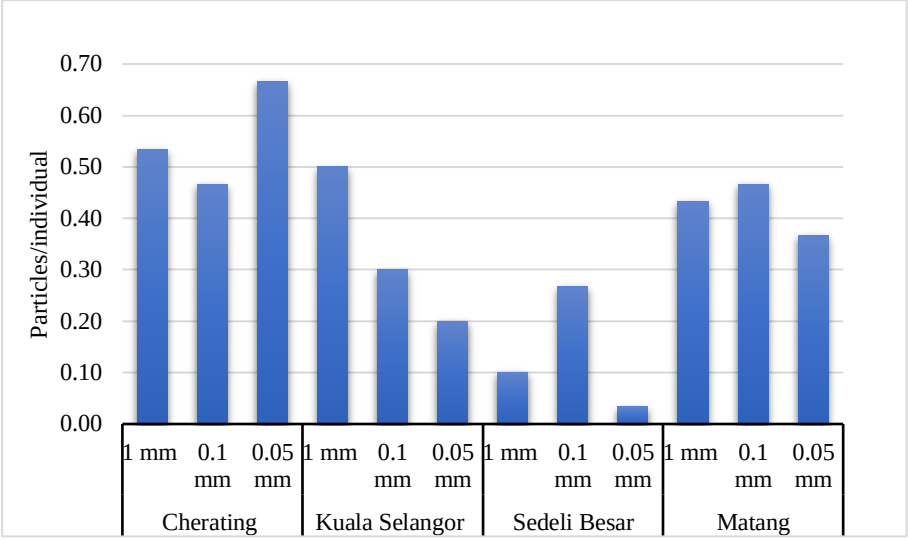

Figure 1 The abundance of microplastics in commercially purchased blood cockles

Microplastics were discovered in all four sites where cockles were purchased. The average number of microplastic recovered from blood cockles was 0.36 ± 0.16 particles/individual. In the samples, fiber-type microplastics comprised the majority (72.8%), followed by films (17.9%) and fragments (9.3%). Blue was the most prevalent colour in the samples, accounting for 29.7% of the total. Black, red, and transparent were the next most frequently detected colours, making up 27%, 12.6%, and 11.7%, respectively.

CONCLUSION

This study provides information on the distribution and prevalence of microplastics in blood cockles in Peninsular Malaysia. The majority of the microplastics discovered were fibers, indicating that local sources (fishing, commercial activities and sewage) may have contributed microfibers to the ocean.

ACKNOWLEDGEMENT

This research was supported by Chuo University, Japan.

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Evaluation of Carbon Fixation during Carbonization of Municipal Solid Waste

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Keywords: carbonization, municipal solid waste, fossil carbon, fixation, negative emission

INTRODUCTION

Carbonization converts organic matter in waste into a stable char through pyrolysis under anoxic or low-oxygen conditions, and is a promising method of carbon fixation. We focused on biomass- and fossil-derived carbon in samples produced at the Saikai City Carbonization Center and evaluated carbon fixation through the MSW carbonization process.

MATERIALS AND METHODS

Carbonization facility information

Carbonized fuels produced at Saikai City Carbonization Center, which produces carbonized fuels from municipal waste, sludge, and other materials. The treatment scale is 30 t/day (15 t/day × 2 trains). The carbonization temperature is controlled at 430–470°C, and reaction time is approximately 1 hour. After carbonization, the processes of desalination, drying, and granulation are performed. Estimation of the CO_2 reduction effects of applying the carbonization system to small-scale facilities were also performed.

Prior to each analysis, the sample (approximately 30 g) was dried at 105°C for 24 h, crushed in a mortar.

Carbon balance calculation

Carbon balance calculation was performed for feedstock waste and carbonized fuels using facility information and literature values. Estimation of the CO_2 reduction effects of applying the carbonization system to small-scale facilities were also performed.

Determining the origin of fossil-derived carbon fixed in carbonized fuels

Elemental analysis was performed with CHN analyzer and SEM-EDS. The fossil- and biomass-derived carbon ratio were measured via accelerator mass spectrometry (AMS). Furthermore, thermogravimetric (TG) curves were obtained under the inert condition. (N_2 flow: 100mL/min, heating ratio: 10°C/min, and samples were heated from room temperature to 900°C). FT-IR measurements and comparisons were performed on samples before and after the weight loss process (approximately 450°C).

Table 1 Elemental analysis

		Char_0703
Element		wt%
C	Total-C	49.9
	Biomass-C	35.5
	Fossil-C	14.4
H		3.3
N		0.0
O		22.0
Mg		0.7
Al		2.0
Si		4.7
P		1.3
Ca		15.9

RESULTS AND DISCUSSION

Table 1 shows the results of elemental analysis of the char. The percentage of C in the char was approximately 50%, and 71.2–81.8% of the C is originated from biomass, while 18.2–28.8% was of fossil origin, indicating that fossil C fixed in the char accounted for 9.1–14.4% of total C in the char.

Figure 1 shows the difference of spectrum before and after the pyrolysis at approximately 450°C. We found that the methylene group -(CH_2)- peaks

at 2935–2915 cm^{-1} and 2865 - 2845 cm^{-1} which were prominent in the raw sample, disappeared after heating to 480°C. The activation energy (Ea) of thermal weight loss was calculated to be 173 kJ/mol, and the fossil-derived carbon fixed in the carbide was estimated to be derived from PE (Ea=175kJ) and PA (Nylon 6-6, Ea=180kJ).

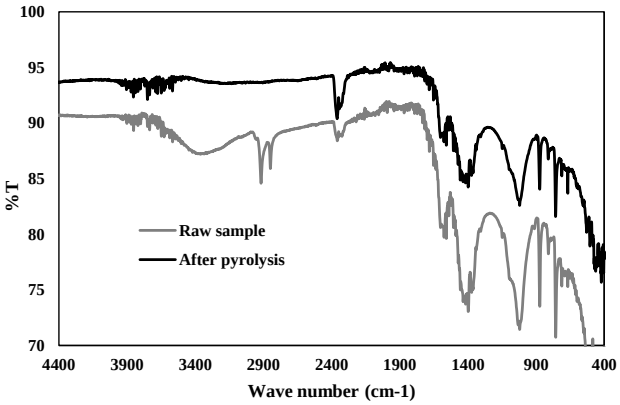

Figure 1 FT-IR spectrum before and after the

Table 2 shows the estimation of the CO_2 reduction effects of applying the carbonization system to small-scale facilities. Coal alternative was the highest CO_2 reduction ratio among fuel alternative uses. When the chars were landfilled, the CO_2 reduction ratio was approximately 80% immediately after landfilling, but over the long term, the carbon fixation ability decreased due to decomposition. Although it is difficult to use all the char as a soil landfill, it is possible to replace some of the charcoal and other soil conditioners with carbide in terms of physical quantity.

Table 2 Comparison of carbonized fuel and incinerated ash amount for landfill disposal

CO_2 emission [t-CO_2/year]						
Incineration	Fuel alternative			Landfilling		
	Heavy oil	Kerosene	Coal	Immediately after landfilling	Net emission 20 years later (Half-time: 50years)	Net emission 20 years later (Half-time: 100years)
5240	2350	2410	1530	1060	2680	2330

CONCLUSION

This study demonstrates that fossil-derived carbon occupies 9.1-14.4% of carbonized fuel, and its origin is estimated to be PE and PA (Nylon 6-6). On the basis of the carbon fixation, carbonization achieves a reduction in C emissions greater than −50%, compared to complete combustion of C in MSW. Carbonization is thought to be an effective C fixation technology for achieving C neutrality.

In addition, CO_2 emissions immediately after landfilling were estimated to be 64.1-78.2% lower than emissions from the incineration on 5 operating days. However, application of char to agricultural lands must be considered carefully, as parameters such as organic pollutants have not yet been measured. Furthermore, as no data or previous studies are available on the decomposition behavior of C during long-term storage in soil and other disposal sites, experimentally measuring this process in future research is essential.

ACKNOWLEDGEMENT

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Assessment of the Wood Waste Potential for Sustainable Development in Mountainous Area: A Case study of Maniwa City, Japan

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Keywords: wood waste recycling, unutilized thinned wood, transportation cost, ArcGIS, LYCS

INTRODUCTION

Maniwa city in Okayama prefecture, Japan, with the support from the Ministry of Environment, the consortium of the city government and local companies constructed an incinerator plant specified for wood tip burning, and the benefit from selling the generated power to the power company is much refunded to the forestry workers who brought the wood waste. Through the reactivation of the forestry, practices of utilizing the wood waste, such as Cross Laminated Timber (CLT) production, wood bark composting, wood tip for fuel, are examined (Ogawa, 2017). Now, the wood waste material is essential for the sustainable development of the city. Therefore, it is required to ensure the availability of the wood waste for future. This study assesses the potential of the private forest in Maniwa city to supply the currently unutilized and the future generation of thinned woods to the power plant.

MATERIALS AND METHODS

Area of private forest and unutilized thinned wood removal

The area of the private forest in Maniwa city was calculated using the help of the digital elevation model (DEM) by aerial laser survey that is a raster data set on the Geographical Information System (ArcGIS pro). The areas of digital elevation in decimal degrees was extracted by using Spatial Analyst Tools and then converted into hectares. Further, local yield table construction system (LYCS) was used to determine the volume of thinned wood per hectare. The program of LYCS had been made compatible with three different thinning styles: lower thinning, upper thinning, and uniform thinning (Matsumoto et.al. 2011).

According to the calculation formula proposed by Watanabe (2012), the total amount of possible value of unutilized thinned wood removal U_t (m^3/ha) could be estimated as follows:

$$U_t = V_t \times D_r \times A_c \div \text{Unit conversion} \qquad (1)$$

where V_t is the volume of thinned wood (m^3/ha), D_r is the road network density (m/ha), A_c is the collection width on the road side (m), and the unit conversion of 10,000 (m^2/ha). The calculation is also categorized into two categories of slope level: Level 1 and Level 2. For steep slope in Level 2, the working system that is used for thinning is only by aerial wiring, hence it is not necessary to multiply the collection area by 2.

RESULTS AND DISCUSSION

Area of private forest and volume of unutilized thinned wood removal

The estimated areas of the private forest in Maniwa city were 11,507 ha and 51,629 ha for Level 1 and

Level 2 respectively, which showed that the majority area of the private forest in the city consisted of the slope area with 15 degrees and above. In addition, Maniwa city carried out thinning for four times since the batch of the tree species had been planted with the total trees of 3000. For example, in this study, a specific tree species called Japanese cedar was chosen to calculate the volume of thinned wood. The thinning process carried out once they became 16, 22, 30 and 40 of age years old. The value of thinned wood calculated by using the LYCS was 228 m^3/ha per year, considering the trees from same species that were planted from other years, with its yield table status was set to 1.5. The transportation cost was also set to 1200 yen/m^3.

Table 1 Volume of unutilized thinned wood removal per hectare for each slope level

Slope level		Thinned wood volume (m^3/ha)	Road network density (m/ha)	Collection area (m)	Unit conversion (m^3/ha)	Volume (m^3/ha)
Level 1	Gentle slope	228	42	15 × 2	10,000	28.72
Level 2	Medium slope	228	32	15 × 2	10,000	21.89
	Steep slope	228	20	15 × 2	10,000	13.67
	Steep slope	228	10	15	10,000	3.42

Table 2 Total volume of unutilized thinned wood removal and its transportation cost per year

Slope level		Total volume (m^3 · year/ha)	Transportation cost (10,000yen)
Level 1	Gentle slope	330,514	39,662
Level 2	Medium slope	1,130,240	135,629
	Steep slope	706,011	84,721
	Steep slope	176,658	21,199
Total		2,343,423	281,211

CONCLUSION

This study aimed to predict the sustainability of the wood biomass resource in Maniwa City to make sure that the stable procurement of fuel is necessary for the stable operation of the power plant in the future. Therefore, sustainable use of forest resources is required through the cyclical use of forests: logging, planting, and nurturing. As the biomass power plant in Maniwa city uses annually 90,000 tons of thinned wood and 58,000 tons of lumber offcut, if all of them are of Japanese cedar, the volume becomes 389,000 m^3. As a result of this calculation, the materials will be supplied for the power plant in every year.

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Resource Use of Household Plastic Waste in Djougou, Benin

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Keywords: Africa, composition, waste management practice, waste stream

INTRODUCTION

In Africa, the amount of plastic waste has seen a rapid increase in recent years. Plastic bags not properly managed block drainage in cities, bringing proliferations of mosquitoes, and runoff into the water body. In low- and middle-income countries, including Africa, while households burn and/or reuse plastic waste as management practices (Nxumalo et al., 2020), they contribute to resource recovery (Nandy et al., 2015). However, quantitative understanding of these practices is limited, hindering the effective designing of plastic waste management strategies that are rooted in local realities. This study aims to estimate plastic waste streams in a West African city, Djougou, Benin, and to explore plastic waste management strategies in the city, as a case study.

MATERIALS AND METHODS

Household plastic waste composition survey

Nine households were selected by convenience sampling, among NGO's waste collection users in the city center. The households were requested to store their plastic waste into a bag, given by the authors, for a week, and the waste was manually sorted into three categories (**Table 1**) and weighed for each category. Non-rigid plastics were further classified into six categories: plastic bags with/without food residues, transparent small bags with/without food residues, water packaging, and other packaging. The households were rewarded for their cooperation.

Table 1 Plastic waste classification

Category	Explanation
Rigid plastic	Plastic containers of pomade or medicine, etc.
Plastic bottle	PET bottles of beverage, medicine, or oil, etc.
Non-rigid plastic	Plastic bags used for shopping, conserving food and materials Packaging of snacks or laundry detergent, etc.

Household waste management practices survey

Ninety-nine residents were selected by a stratified sampling method proportional to the population of the 19 districts that composed of the city center. In each district, random walk was performed. Housewives, often responsible for household chores related to waste, were asked to cooperate in the survey and interviewed on their household plastic waste management practices.

RESULTS AND DISCUSSION

Household plastic waste composition

The generated amount of household plastic waste was 36.4 ± 25.2 g/person/week (avg ± s.d.). Non-rigid plastics accounted for 55.2% by weight. This was mainly composed of plastic bags with/without food residues. Plastic bottles and rigid plastic followed at 32.5% and 12.3%, respectively.

Household plastic waste management practices

Based on the results of waste composition, the total amount of rigid and non-rigid plastic generated in the city center (74,688 inhabitants in 2013) was estimated to be 340 kg/week and 1.33 t/week, respectively. **Table 2** shows management practices of rigid plastic and plastic bags without food residues. Rigid plastic was used as a resource by 64.5% of respondents. Within the 64.5%, 42.9% was sold to the informal sector. Of the total plastic bag generation, 28.1% was used as a resource; 27.1% was used at home, principally as an ignitor for fire wood and charcoal for cooking, while some felt it was a health risk. In addition, plastic bags without food residues were preferred being used as an igniter to ones with food residues.

Comparing the resource use ratios, out of non-rigid plastic, plastic bags after being used were not considered as resources, but they commonly found value in their use as igniters.

Table 2 Management practices of rigid plastics and plastic bags (%)

	Rigid plastic	Plastic bags without food residues
Resource use at home	21.6	27.1
Resource use through the informal sector	42.9	1.0
Waste collection by NGO or individuals	10.8	24.2
Burning in vacant plots or at home	9.7	26.3
Dumping in vacant plot or drainage	15.1	21.4

Note: *n*=93 and 99 for rigid plastic and plastic bags without food residues, respectively.

CONCLUSION

This study aimed to estimate plastic waste streams for exploring plastic waste management strategies in Djougou. In the study area, resource use of various household waste can be observed; recycling was active for rigid plastic, but not for plastic bags. Plastic bags were principally discarded and may have low value for residents. For appropriate management of plastic wastes, it is important to take advantage of the active recycling of rigid plastic in the community and reduce the generation of plastic bags or to establish a system for collection and sanitary disposal.

ACKNOWLEDGEMENT

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Prediction of Emission Potential of Per- and Polyfluoroalkyl Substances during Recycling of Waste Coated by Water Repellents Using Pyro-GC/MS

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Keywords: per- and polyfluoroalkyl substances (PFAS), emission potential, Pyro-GC/MS, water repellent

Introduction

Per- and polyfluoroalkyl substances (PFAS) are widely used as water repellents for various textiles and types of paper. However, the use of specific PFAS, such as perfluorooctanoic acid (PFOA), its salts, and precursors, have been banned because they are listed as persistent organic pollutants (POPs) under the Stockholm Convention of 2019. Therefore, to prevent emissions of POP-PFAS, textiles and paper coated with PFAS must be carefully recycled. Unfortunately, there are no earlier studies on airborne emissions of PFAS during the recycling of such waste. Thus, to better understand the emission potential of PFOA and its precursors during two types of waste recycling that produce RPF (refuse derived paper and plastics densified fuel) from the waste and thermal conversion of it to syngas, we identified and quantified the PFAS emitted during the heating of commercial water repellent products, namely fluorotelomer-based polymers, using a pyrolizer gas chromatograph mass spectrometer (Pyro-GC/MS).

Materials and Methods

The analyzed PFAS were neutral 19 PFAS that included 13 POP-PFAS, such as 8:2 and 10:2 fluorotelomer alcohols (FTOHs), their methacrylate (FTMacr), and so on. The gaseous PFAS discharged during the heating or pyrolyzing of 10 commercial fluorotelomer-based water repellents (seven of the products were produced in 2011 and three in 2021) were identified and quantified by the following three analysis methods using a Pyro-GC/MS (pyrolyzer: PY-2020id [Frontier Lab] and GC/MS: QP2010 Plus [Shimadzu]): 1) Evolved Gas Analysis (EGA): Gas in the heating chamber (pyrolyzer) was heated from 40 ºC to 600 ºC and directly injected into the mass spectrometer. This method can identify gaseous PFAS generated from a sample at elevated temperatures. 2) Desorption-Mode Analysis (DMA): PFAS vaporized while the pyrolyzer temperature was kept at a constant 250 ºC were quantified. 3) Pyrolysis-Mode Analysis (PMA): Gaseous PFAS discharged from the gas while pyrolyzing the sample at 600 ºC were quantified. It was assumed that DMA and PMA would predict the potential of PFAS emissions during the production of RPF from the waste and pyrolyzing it to syngas.

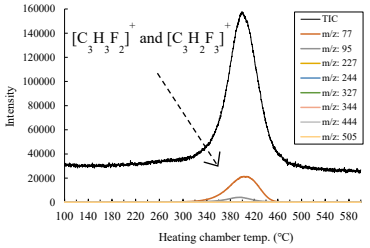

Fig. 1. Mass fragment profiles during evolved gas analysis of a water repellent

Results and Discussion

Identification of PFAS by EGA

In the EGA, the peaks of two fragments with $[C_3H_3F_2]^+$ and $[C_3H_2F_3]^+$ were observed over 320 ºC (Fig. 1).

The peaks indicate fluorotelomer olefins (FTOs) and fluorotelomer alcohols FTOHs, suggesting that such PFAS were emitted by heating the water repellants to over 340 ºC. Therefore, a higher amount of FTOs and FTOHs may have been released during thermal conversion to syngas by pyrolysis of the water repellents.

Quantification of PFAS by DMA

In the DMA of water repellents manufactured in 2011, POP-PFAS, such as 8:2 and 10:2 FTOHs and their iodides (FTIs) and acrylates (FTAcrs) were detected (Fig. 2). Their total emission potentials (mg) from 1 kg of a repellent ranged between 62 and 328 mg/kg (ppmw). On the other hand, for the repellents manufactured in 2021, only the non-regulated 6:2 FTOH was observed. We infer from the difference that 6:2 FTOH was used as an alternative to POP-PFAS. It should be noted that waste recycling facilities for RPF production should pay attention for emissions of the detected POP-PFAS. Since the emission potential is almost the same as the amount of impure PFAS found in the products in our previous work (Matsukami et al., 2022), the impurities may be responsible for the PFAS emissions.

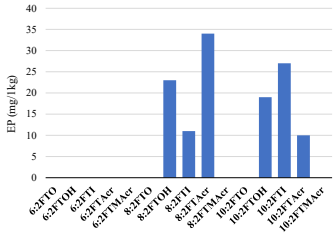

Fig. 2. Emission potential (EP) of PFAS during heating a repellent at 250 ºC

Quantification of PFAS by PMA

The PFAS emission potential determined by PMA was one or two orders of magnitude higher than by DMA, as shown in Fig. 3, with the potential of FTOs the highest. The significant release of FTOs and FTOHs is attributed to the thermal decomposition of ester bonds on the side-chains of fluorotelomer-based repellents. In fact, the amount of FTOHs bonding to the side-chains in the samples was much higher than that of impure PFAS in the samples (Matsukami et al., 2022). Therefore, waste recycling facilities that thermally convert textiles and paper to syngas should pay more attention on the large amount of PFAS emissions caused by the thermal decomposition of fluorotelomer-based polymers.

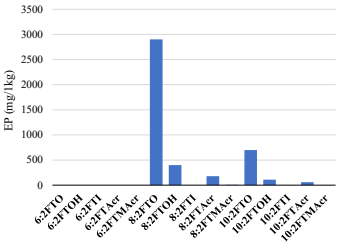

Fig. 3. Emission potential (EP) of PFAS during pyrolysis of a repellent at 600 ºC

Conclusion

From the three methods for predicting PFAS emissions from water repellents (fluorotelomer-based polymers) at elevated temperatures using a Pyro-GC/MS, the following new data were obtained: 1) The evolved gas analysis revealed that the emission potential of PFAS, such as FTOHs, FTArcs, and so on, increased significantly over 320 ºC. 2) The emission potential during pyrolysis of the repellents to convert them to syngas was much higher, by one or two orders of magnitude, than when heating them at temperatures below 250 ºC for RPF production. 3) PFAS emissions during pyrolysis were due to thermal decomposition of the repellents and not from impurities in them.

ACKNOWLEDGEMENT

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GHG Mitigation Potential of Selected Climate-Friendly MSW Treatment Technologies in Thailand

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Keywords: climate change mitigation, waste management, 3R, waste-to-energy, good practice

INTRODUCTION

Greenhouse gas (GHG) emission from solid waste disposal in Thailand was estimated to be 8.14 Mt CO_2eq in 2016. Compared to the national totals of 354.36 Mt CO2eq, the share of GHG emission from solid waste disposal was equivalent to 2.3%. Of this amount, CH_4 emission from landfills and dumpsites contributed to 96%. This value reflects how the country relied primarily on landfilling waste and the organic waste was not sorted out for proper treatment. Thailand's Nationally Determined Contribution set a GHG reduction target for solid waste disposal at 1.3 Mt CO_2eq by 2030. To respond to the target, national action plans include improving municipal solid waste (MSW) management system through waste sorting, 3Rs, waste-to-energy technologies, semi-aerobic landfills, sanitary landfills. Some municipalities have successfully improved their MSW management system and reduce GHG emissions. However, most of the municipalities are still working on their plans. Experience and knowledge sharing from successful cases are required. Therefore, this study aims to investigate existing climate-friendly MSW treatment technologies in Thailand, estimate their GHG mitigation potentials, and disseminate the results in order to encourage more implementation of these technologies.

MATERIALS AND METHODS

The work was carried out between April – December 2021. Step of work included (1) selection of technologies and case studies: projects or municipalities where climate-friendly MSW treatment technologies have been implemented, (2) data collection, (3) selection of GHG estimation and definition of baseline emission, (4) calculation of GHG emission and reduction, (5) result validation and verification by external experts and the Project Management Unit (PMU), (6) analyse case studies for their technical feasibility and socio-economic aspects, (7) conclude lesson learned and dissemination of results.

The GHG mitigation potentials were calculated from the differences between the GHG emissions from selected technologies and the emissions from baseline. In most cases, the baseline was landfilling without gas recovery. The GHG emission estimation were based on the 2006 IPCC Guideline for National GHG Inventories and Thailand's Methodology for Voluntary GHG Emission Reduction (TVER). Depending on the data disclosure policy of each study site, the level of data disaggregation and calculation tiers varied as appropriate.

RESULTS AND DISCUSSION

The results were shown in Table 1. The negative GHG reduction percentage compared with BAU means that technologies had higher greenhouse gas emission than BAU.

Table 1 GHG mitigation of selected climate-friendly MSW treatment technologies in Thailand

Best practices and technologies for climate-friendly MSW management	GHG reduction (%) compared with the BAU			GHG avoidance (%)	GHG reduction (%) from project
	Inside waste sector	Outside waste sector	Total		
Waste sorting and material recovery at the source	19.71	38.87	58.58	0.32	58.90
Composting at home (80% of public participation rate)	21.29	-	21.29	0.28	21.57
Mechanical-biological treatment with bio-drying process and refuse derived fuel production (include coal transport)	93.1	35.4	128.5	-	128.5
Mechanical-biological treatment with bio-drying process and refuse derived fuel production (exclude coal transport)	93.1	-2.0	91.1	-	91.1
Waste-to-energy incineration	53.9	-2.5	51.5	12.2	63.7
Landfill gas to energy	24.4	2.6	30.1	2.6	32.7
Semi-aerobic landfill	50.0	-	50.0	-	50.0
Composting	23.6	-3.3	20.3	-	20.3

CONCLUSION

The selected climate-friendly technologies in Thailand can reduce GHG emissions at least 20.3 – 91.1%. The GHG mitigation potential can increase even more when GHG avoidance from fossil use was estimated. These information could be used to encourage appropriate technology implementation in Thailand and other countries with similar context.

ACKNOWLEDGEMENT

This study was a part of "Compilation of Climate Friendly Practices and Technologies for Municipal Solid Waste and Domestic Wastewater Management" under the Integrated Waste Management for GHG reduction (TGCP-Waste) Project of the Thai-German Climate Programme. The project is jointly implemented by the Pollution Control Department (PCD) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and funded by IKI of the Federal Ministry for Economic Affairs and Climate Action (BMWK). The authors would like to extend their most sincere gratitude to the Project Management Unit (PMU) and all municipalities/project owners involved in this study for sharing their information and giving valuable guidance.

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Extended Producer Responsibility (EPR) for Packaging through Phased Approach in Thailand: Lessons Learned from Korea

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Keywords: extended producer responsibility, plastic recycling, circular economy *(3-5 keywords should be appeared)*

Extended Producer Responsibility (EPR) for packaging aims to reduce the environmental and economic burdens of plastic waste management for municipalities by extending producers' responsibility to the end-of-life stage. EPR has been widely implemented in European countries and some Asian countries like Korea and Japan, and has led to improved waste collection and increased recycling rates. However, in developing countries, EPR implementation varies widely. Some countries have enacted mandatory EPR schemes while others only recently adopted or proposed legislation for voluntary initiatives.

Korea has developed and successfully implemented EPR with a huge achievement in increasing recycling rate since its introduction in 2000. Korea has achieved recycling rates for paper, plastic, metals, construction waste and e-waste with more that 90 percent and resource recovery facilities are in place to handle various separate waste streams, including paper, plastic, metals, construction waste and e-waste. The number of recycling companies has increased from 2,941 in 2001 to 5,972 in 2018. There are 217 public sector recycling facilities, with combined capacity of 4,723 tonnes/day. Private sector recycling facilities number 524, with a combined capacity of 60,291 tonnes/day (Agnes B, Jana B, et al., 2020).

On the other hand, Thailand has opted for the Bio-Circular-Green Economy Model (BCG) that aims to use natural assets more efficiently with as least impact on the environment as possible. Under this new economic model of BCG, the government has initiated Plastic Waste Management Roadmap as a holistic policy approach to prevent and solve plastic waste problem and developed EPR adjusted to its context. In an initial start of EPR, Thailand government has explored existing regulatory solutions to understand situation and country-specific context which would benefit EPR once implemented and industry-driven voluntary initiatives has been established as a pilot EPR in Chonburi province. As many of developed countries which have successfully implemented EPR have developed EPR through phased approach within their context, Thailand government, which is at the initial stage of EPR implementation, needs to gradually develop this according to its own social and political context.

The main objective of this research is to analyze how Korea has established and implemented EPR through phased approach and combine lessons learned from Korean case study to assist the current EPR in

Thailand and outline a recommendation for the journey of accelerating EPR implementation and operationalization in Thailand. Therefore, this research will create a checklist or categories for the next phase of EPR in Thailand as a main outcome. To do this research, literature review has be conducted to identify the relevant methodologies to design EPR in Korea and how data collection has been carried out with some interview of relevant stakeholders and it comes up with some guidelines and recommendations for better implementation of EPR in Thailand

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Production of C5 sugar fatty acid esters (SFAEs) from renewable resources

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Keywords: C_5 Sugar fatty acid esters, renewable resources, biomass.

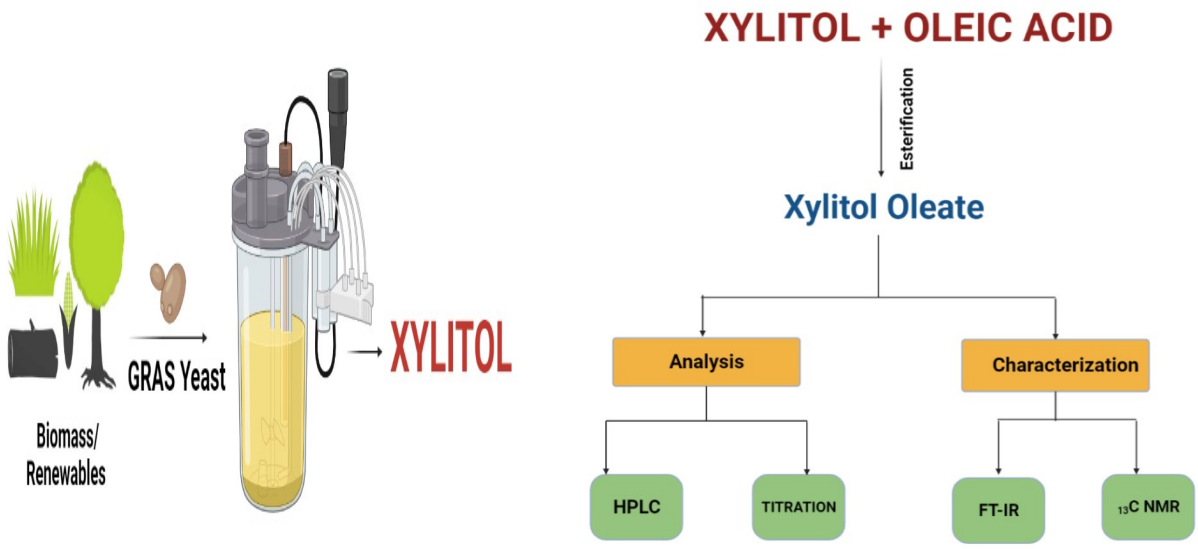
INTRODUCTION

Sugar fatty acid esters (SFAEs), are non-ionic, amphiphilic molecules that present a combination of sugar moieties linked with fatty acid tails derived from various biological origins (Siebenhaller et al., 2018). These are of great interest in chemical industries owing to suitable surface activities and have significant emulsifying, stabilizing, and detergency policies (Koumba et al., 2019).

Due to its widespread application, which has led to its massive global demand, the sugar fatty acid ester market is expected to grow from $76 million (2020) to $120 million within the next decade at a compound annual growth rate (CAGR) of 6% (Pyo et al., 2019). Amongst the SFAEs produced globally, sucrose and glucose esters have been the most studied and used commercially.

Recent research developments have shown that five-carbon sugar esters, which are relatively new in terms of an industrial perspective, are gradually gaining more attention. The polar head of these C5-SFAEs may typically comprise of either xylose/arabinose or the sugar alcohol xylitol, which can be easily derived from natural sources such as wood and other xylan-containing lignocellulosic biomass (Dasgupta et al., 2022). This study proposess a biotechnological route for the production of C_5 Sugar fatty acid esters.

MATERIALS AND METHODS



Scheme of Work

RESULTS AND DISCUSSION

1. Biomass hydrolysis to recover fermentable sugars

Hemicellulose hydrolysis by DASE treatment generated a liquid stream with a D-xylose concentration of 28.82 g/L.

2. Detoxification of Biomass hydrolysate

Furfural and hydroxymethylfurfural, biomass-derived inhibitors, were eliminated from the liquid hydrolysate by detoxifying corncob hydrolysate by activated carbon.

3. Xylitol production from C5 sugar by mesophilic yeast in a bioreactor.

C5 rich biomass was converted into xylitol by microbial fermentation. PC5703 produced a maximum of 80.43 g/L Xylitol.

4. Lipase catalysed esterification of Xylitol

HPLC analysis of the reaction mixture showed a decreasing trend in Xylitol concentration. The results were compared with an enzyme free reaction mixture where no reduction in the xylitol concentration was observed. Similar results were observed in fatty acid conversion analysis by titration. This indicated that the sugar alcohol conversion was taking place. Structural characterization of the product, performed by FT-IR and 13C-NMR, confirmed the formation Xylitol Oleate ester.

CONCLUSION

An activated carbon-based detoxification method could remove the biomass derived inhibitors from the xylose-rich liquid hydrolysate. C5 rich biomass was converted into xylitol by microbial fermentation. An esterification reaction was performed and the analysis of conversion by Titration and HPLC, and structural characterization of the product, performed by FT-IR and 13C-NMR, confirmed the formation Xylitol Oleate ester. Using cheap and inexpensive feedstock such as biomass derived sugars/sugar alcohol and fatty acid sources such as UCO would reduce the cost of raw materials, but may add operational complexity in terms of feed pre-treatment/processing prior to the conversion reaction. The biocatalyst lipase may be improved through the recombinant DNA which may be explored to a greater extent to establish scalable economics for industrial application.

ACKNOWLEDGEMENT

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The Review of Remote Sensing Technology for Plastic Waste Monitoring

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Keywords: plastic litter, remote sensing, monitoring technologies

INTRODUCTION

There are various measures of 3R + Renewable in plastic management that would enhance effective waste minimization (UNCRD, 2020). Above all, for the prevention of environmental pollution, it is important to grasp the actual state of pollution and the effectiveness of preventive measures through monitoring. However, due to lack of systematic review, the potential for monitoring is not fully recognized and applied. We hypothesis: If monitoring technology and characteristics are organized, it will lead to more effective pollution control measures. Remote sensing (RS) is an emerging technology for plastic monitoring as pollution solutions to prevent and collect plastic waste in environment. This study aims to review the type, details, and properties of current RS technology for plastic waste monitoring for implementation for plastic waste management under concept of 3R + Renewable.

MATERIALS AND METHODS

Materials Sources

A systematic search was conducted by using the scientific paper databases for academic papers and internet resources for report, news, press releases, and other non-peer reviewed papers. The following databases were used in the study: Scopus, Web of Science, MDPI and Google Scholar. The articles were searched only by the following keywords: “plastic waste” or “plastic litter” with “remote sensing”. The results of peer-reviewed research articles, review papers and book chapters published during 2019-2022 were considered for analysis. The summary content and essence information of RS technology are categorized by platform as shown in Figure 1. Each category presents a description of the sensor, methods and models, type and monitoring size of plastic waste and accuracy.

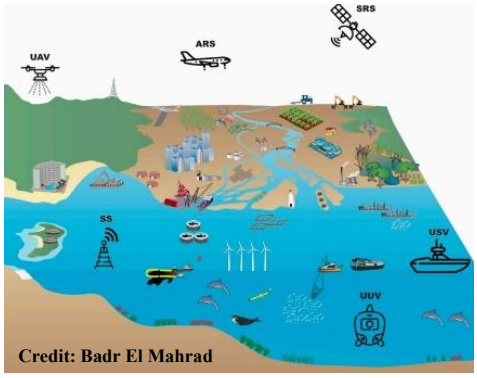

Figure 1 Platform for RS technology

RESULTS AND DISCUSSION

The current RS technology for plastic litter monitoring

From Table 1, the RS technologies can monitor plastic waste in terrestrial, river, marine and coastal environments by applying different methodologies or models for different platform and spectral types (Mahrad, Badr El, et al., 2020). In addition, the technology can also classify plastics types, most of which are water bottles (PET) or plastic bags (LDPE) under the specific conditions (Topouzelis, Konstantinos, et al., 2020). For plastic waste management, this technology can analyze plastic waste hotspot and the frequency of plastic

waste accumulation in term of spatial (area and volume) and temporal dimensions (Di Febbraro, Mirko, et al., 2021). This will be important information for plastic waste monitoring and collection into the waste management system, especially for recycle and disposal processing.

Table 1 shows summary review of current RS technology for plastic litter monitoring

Technology types	Spectral types	Plastic detected band / model or method	Monitoring Area	Plastic type	Sample size	Accuracy
1. Satellite Remote Sensing (SRS):						
Sentinel-2	multispectral	blue band, RS index/ neural network	Land	plastic, tyres, waste site	na	82-86%
		Red, NIR, SWIR, RS index/ matched filtering	beach, ocean	PET, LDPE	1-10 m	na
PRISMA	hyperspectral	na/ machine learning	beach, ocean	HDPE, PET, PS, HDPE + PET + PS	0.6-5.1 m	95%
Sentinel-1	Synthetic Aperture Radar	VH polarization/ backscattering differences	river	plastic accumulation	na	85–95%
2. Aerial Remote Sensing (ARS):						
Aircraft camera	multispectral	NIR, SWIR/ machine learning	ocean	waste, plastic	na	88%
	hyperspectral	na/ deep learning	ocean	PE, LDPE, rope	2.5-10 m	98.71%
3. Unmanned Aerial Vehicles (UAV):						
UAV camera	multispectral	na/ deep learning	river	PET, LDPE, PU	na	86%
	hyperspectral	NIR, SWIR/ linear discriminant	beach, ocean	PE, PET	na	na
4. Static Sensors:						
Radars antenna	Radar signal	X-band/ Radar Cross Section	ocean	mix waste, PET, LDPE, PU, PS	0.3-1m	na

CONCLUSION

The systematic review of remote sensing technology for each platform and sensor that can monitor and classify plastic types, resulting in the spatial and temporal spatial knowledge of leaked plastic inventory from circulation flow. It will be an important basis for developing waste management in terms of policy and raising awareness.

ACKNOWLEDGEMENT

This research was performed by the University of Tokyo FSI-Nippon Foundation Research Project on Marine Plastics.

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A review of the current situation of plastic bag policy in China

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Keywords: Plastic Policy; Policy Timeline; Policy Framework; Terminal Treatment.

INTRODUCTION

The definition of plastic bags is the ultra-thin plastic shopping bag with thickness less than 0.025mm, they were introduced into China as a means of promotion in the 1980s. Because of their light weight, low cost and waterproof properties, they have been continuously consumed mainly by supermarkets, but they are causing devastating environmental and health problems (The World Counts, 2020).

This paper is going to review the development and status of policies on plastic bags in Chinese Mainland through the review and analysis of relevant national and regional policies and regulations on plastic bags to.

MATERIALS AND METHODS

The data source is the policy documents and reports related to plastic bag management officially issued by the Chinese Mainland government. The statistical period of data is from 1980 to 2022. During this period, about 98 related documents were released. Among them, there are 30 national documents and 68 provincial and municipal documents among all documents.

Reviewing and comparative analysis was used to summarize the policy evolution and policy framework on plastic bags in China, as well as the preferential policies involved in the terminal treatment of plastic bags.

RESULTS AND DISCUSSION

1. Policy Evolution and Policy Framework

Policies timeline is shown in Figure 1. First of all, in the 1990s, the policies proposed by local governments did not have the support of the central government and failed. Secondly, the first official policy of the central government appeared in 2008, bringing paid plastic bags to China. Although the policy was investigated three years later, the policy itself did not receive a unanimous response from the local government, and the effect was not obvious. Finally, after the introduction of the policy of "prohibiting the entry of overseas garbage" in 2017, the import of waste plastics was basically stopped. Subsequently, many laws issued by the central

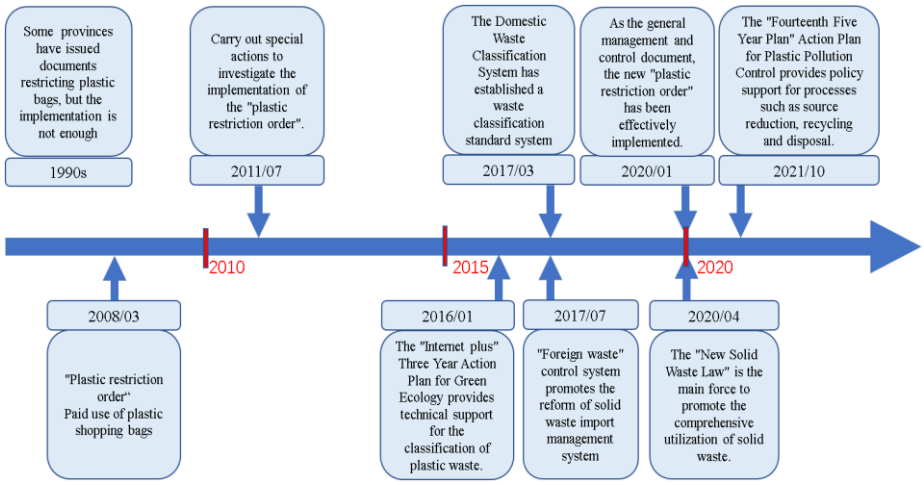

Figure 1: Description of important national plastic bag policies on the timeline

Source: Official websites of Chinese governments

government were responded by local governments, making the relevant policies better implemented.

As shown in Figure 2, after analyzing the policies at the national and local levels, the current policy framework related to plastic bags in China is obtained. The black solid line represents the relationship between the higher-level Law and the lower-level Law, and the black dotted line represents the guiding significance. In the figure, the “Implementation Plan”, the New "Solid Waste Law", the New "plastic restriction order" and the "Fourteenth Five Year Plan" was efficiently followed by local and it has achieved obvious results

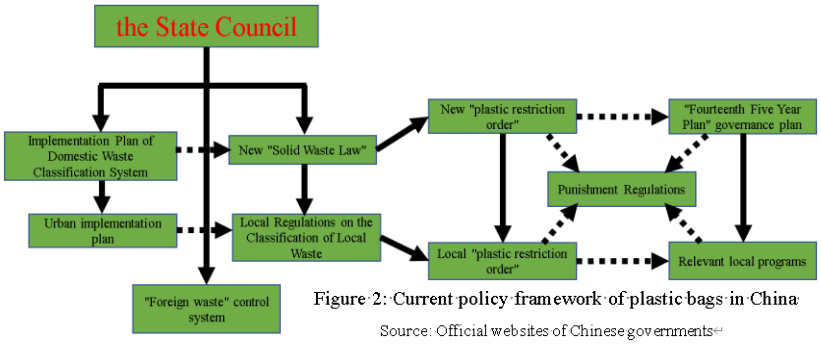

Figure 2: Current policy framework of plastic bags in China

Source: Official websites of Chinese governments

2. Policy Limitations of Plastic Bag Terminal Processing

At present, there are two main methods for the terminal treatment of plastic bags, namely, incineration after mixed with other wastes or recycling after classified as plastic resources. The policy support corresponding to the two processing methods is shown in Table 1.

Table 1: Comparison of preferential policies for terminal treatment of plastic bags

Source: Official websites of Chinese governments

preferential policy	Mixed with other wastes and incinerate	Recycling of plastic resources
Infrastructure	The municipal government is responsible for the construction of infrastructure	Enterprises lease or build infrastructure by themselves
Land	The land dedicated to municipal facilities, and can not be misappropriated	Enterprises lease their own land and face the risk of relocation at any time
Tax preferences	70% tax refund for garbage clearing and transportation fee, and 100% tax refund for garbage incineration power generation income	50% tax refund of waste plastic recycling income
Expense subsidy	The state undertakes the construction and management responsibility of the access system of waste incineration power generation projects	Except for a few plastic recyclables enjoying subsidies, enterprises are generally responsible for their own profits and losses

While enterprises engaged in garbage removal and incineration enjoy multiple preferences in infrastructure, land, tax and expense subsidies, enterprises engaged in plastic recycling are struggling to develop with less policy support. This phenomenon leads to more low value recyclables, such as plastic bags, being burned rather than recycled.

CONCLUSION

After the reviewing and analysis of the policies in China, policy evolution, framework and limitations were summarized and comparatively analyzed. Only the central policies that have been actively responded to by local governments could be better implemented. At present, China's central policies related to plastic bags are being actively followed. After comparing the policy support for plastic bag terminal treatment methods, enterprises that recycle plastic resources may need more policy support to recycle more low value recyclables such as plastic bags.

ACKNOWLEDGEMENT

This research was performed by the Environment Research and Technology Development Fund (JPMEERF21S11900) of the Environmental Restoration and Conservation Agency provided by Ministry of the Environment of Japan.

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A review of existing economic incentive schemes to promote waste separation and collection

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Keywords: economic incentive, waste collection, deposit refund system, rewards points collection system

INTRODUCTION

Economic incentive plays a role in promoting waste separation and collection. Many studies have proved its role in promoting changes in residents' behavior and increasing the amount of recycling. However, different countries/regions have different incentive methods and goals for waste management. Even in the same city, the incentive models are different. Diversified economic incentive systems lead to results and performance that cannot be compared in detail, and the systems cannot be directly replicated in other regions. Therefore, this study aims to summarize and analyze the economic incentive systems in different countries and regions that are still in operation and clarifies their service target, waste types, policies, impact results, etc., to provide data for subsequent performance appraisals.

MATERIALS AND METHODS

The research targets are those economic incentive systems are currently still in use to promote waste separation and collection. The data sources mainly come from two parts: one way is the journal papers from Web of Science, Scopus, and Google Scholar. The search keywords are "economic incentive" and "reward mechanism," combined with "waste separation " and country names. Another way is to obtain relevant legal documents, policies, official data, etc. from the official website.

RESULTS AND DISCUSSION

1. Economic incentives systems in China

Following the release of China's policy to fully enforce the waste separation in 46 key cities in 2017, by the end of 2020, 30 cities had introduced regulations for household waste separation. To promote waste separation behavior, cities have started various incentive mechanisms to explore ways to encourage waste separation. Such as, Beijing, Shanghai and Hangzhou City began an “Bonus point system” to ask citizens to separate waste and throw it in a special box for exchanging points (He, 2020; Zhou, 2020); from 2019, Xi'an city implemented “waste bank” that when household waste is sorted, pasted with a QR code, and put into the recycling bin for points, which can be redeemed at designated supermarkets for household goods, etc. Those incentive systems are almost

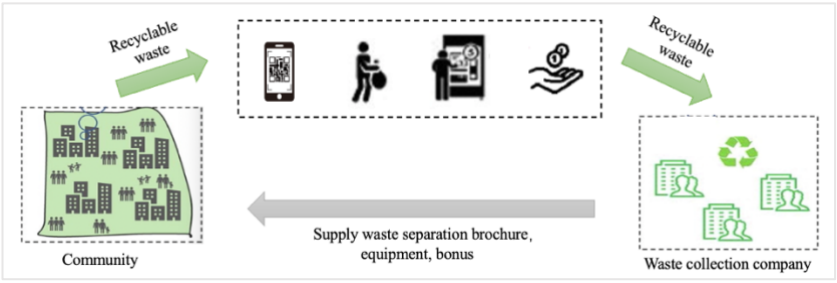

Figure1. Scheme for bonus point system in China

having the same model (Figure 1) with different system names in China.

2. Economic incentives systems in the world

Table 1 shows examples of incentive system names, operation regions, as well as information on the types of collected waste and the organizations.

Table 1 Features of collection systems with economic incentives

Systems	Country/region	Waste types	Incentive	Management institutions
Deposit refund system	Germany	Plastics, Metals, Glass	Deposits	Producer Responsibility Organization
	Sweden	Plastics, Metals, Glass	Deposits	
	South Australia	Plastics, Metals, Glass	Deposits	
iEcoSys	Portugal	Plastics, Metals, Glass	Points	-
Waste bank	Surabaya, Indonesia	Plastics, Metals, Glass , Paper, Textiles	Points	A small-scale entrepreneurship supported by Ministry
	Padang, Indonesia	Plastics, Metals, Glass , Paper, Textiles	Points	
Point system	Dongying, China	Plastics, Metals, Glass , Paper, Textiles	Points	Entrepreneurship. Provide services to government
BP system	Hangzhou, China	Plastics, Metals, Glass , Paper, Textiles	Points	
Green point	Hong Kong, China	Plastics, Metals, Glass , Paper, Textiles	Points	Government department

Note: "iEcoSys" means an Intelligent Waste Management System; "BP system" means Bonus Point system.

From Table 1, we can see that the regions which operate deposit refund systems are developed countries and the management institutions are producer responsibility organizations. The rewards points collection system is operated mainly by developing countries, and regarding management institutions, most are government departments. Even some systems are managed by private enterprises, which are also associated with the government, etc. Regarding the collected waste types, almost all economic incentive systems are focused on recyclable wastes. Deposit refund systems are collected. Plastics, Metals, Glass, and rewards points collection system are added two basic types of garbage, Paper, Textiles. The reason for this is that Paper and Textiles are types of waste that are valuable that can be collected by informal collectors.

CONCLUSION

Through this study, we can understand that there are two main types of economic incentive systems in the field of waste collection, deposit refund systems and reward point collection systems, and the former is primarily used in developed countries, while the latter is mainly used in developing countries, like China and Indonesia. Those economic incentive systems are primarily based on recyclable wastes, and this study will continue to consolidate the recovery rates of various systems.

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Spatio-temporal variation and seasonal dynamics of stranded beach anthropogenic debris on Indonesian beach from the results of nationwide monitoring

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Keywords: Marine debris, plastics, anthropogenic, beach quality index, Indonesia

INTRODUCTION

Human-caused marine litter has become a global issue. Marine litter consists of various materials, although plastics are by far the most prevalent. The growth of plastic litter throughout the world's oceans has resulted in the entanglement, ingestion, and death of vast numbers of marine organisms. Oceanographically and environmentally, Indonesian waters are vital to the global marine ecosystem. This study aims to evaluate the abundance of stranded macro litter along beaches with no-take zones (without routine cleaning) and public access zones and the factors that influence its spatial and temporal distribution.

MATERIALS AND METHODS

Between February 2018 and December 2019, samples were taken every month during the spring tide. We select supratidal areas to sample every month and make debris categories based on the guidelines of NOAA (Lippiatt et al., 2013) and UNEP (Cheshire et al., 2009). We categorized the litter we found on the beach into six groups: plastics and rubber, metal, glass, processed wood, cloth, and others. Each of these groups was based on a previous grouping (Cheshire et al., 2009; Cordova and Nurhati, 2019; Lippiatt et al., 2013). Beach quality was determined using a variety of beach quality indexes. We used the Clean Coast Index (CCI), the Hazardous Items Index (HII), and the Beach Grade Index (BGI) in this study.

RESULTS AND DISCUSSION

The mass and density of debris measured on all 18 beach surfaces were 166.09 ± 75.55 g m^{-2} and 2.69 ± 1.31 items m^{-2}, respectively. The highest peak occurred in January 2019. The lowest stranded debris was found

in July 2019. In terms of quantity of plastic items, plastic sachets/multilayers were the most abundant material, accounting for 12.15 % of all debris collected on Indonesia's 18 beaches, followed by thin plastic wrap/bags (11.96%). Plastic that relatively direct recycling ("Plastic bottles" and "Plastic cups") is more prevalent outside Java. Outside of Java, easily recycled plastic and macro litter connected with fishing activity are more frequent. We consider this is related to the recycling industry's concentration and dominance in Java, with a negligible presence beyond the Java region (Damanhuri and Padmi, 2009; Darus et al., 2020).

The CCI, HII and BGI average scores revealed no sampling location was classified as "very clean" for the entire season. We assume that debris is being generated by local activities and transferred macro litter since the observed debris is typically more recent and littler degraded (55% of the total sample). In Indonesia, local governments are responsible for waste management. However, the average local government expenditure for waste management is 0.07% regional budget. Flexible approaches, rather than reactive efforts, should be employed to improve litter control and, consequently, the environmental quality of this Indonesian coastal region.

CONCLUSION

Stranded debris was discovered along the Indonesian beaches throughout the sampling period. Between October and February (during the rainy season), the average weight and abundance of beach debris were found to be larger than in other months. Plastic was the most prevalent type of debris across all macro litter categories, accounting for 64.64% of total collected macroplastic debris. Outside of Java, easily recycled plastic and macro litter connected with fishing activity are more frequent. As a result, equitable recycling business is necessary, one that is not reliant on Java alone. The source of this anthropogenic macro litter is assumed to be more localized activities than transboundary macro litter. Finally, thorough stranded beach anthropogenic debris monitoring has been strongly advocated in order to gain a better understanding of the role of hydrodynamics in the spread of macro litter in the region.

ACKNOWLEDGEMENT

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USE OF DAM SLUDGE WASTE IN THE MANUFACTURING OF GEOPOLYMER BINDER

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Keywords: geopolymer, waste, binder, sludge

INTRODUCTION

The objective of this work is to use an Algerian natural waste to synthesize a geopolymer binder of high performance as an ecological alternative for conventional cement. The used waste is a dam sludge calcined at 800°C. This geopolymer has a molecular formula ($4SiO_2.Al_2O_3.K_2O$), with molar ratios Si/Al = 2 and Si/K = 2, which gives the binder properties of the synthesized product. The Highlights of this work are the valorization of natural wastes posing an ecological problem in Algeria, the manufacture of high performance geopolymer binder as cement alternative, the obtaining of an ecological geopolymer binder with low CO_2 emission and high mechanical strength (35.38 MPa after 28 days).

MATERIALS AND METHODS

The used sludge waste (SLD) is extracted from the hydraulic dam of Tiaret in the west region of Algeria. The dam sludge was dried to 105°C in oven and then crushed to 80 um. The crushed raw material was burned at 800°C for 24 hours. The mixture of sludge and alumina was attacked by KOH-alkaline solution of 8M and dried in an oven to 40°C. The mixture paste was introduced into silicone cylindrical mold, of 20mm diameter and 20mm height, and then put under vibration on a vibrating plate for 5 minutes to drive out the trapped air bubbles. After 48 hours of heating at 40°C, the obtained geopolymer was demoulded. Fluorescence X analysis, X-ray Diffraction, Thermal Analysis, Infrared analysis, BET technique and Scanning Electronic Microscopy were used to characterize the synthesized geopolymer. Mechanical tests were carried out on mini-eprouvette (2x2x2 cm^3) to evaluate the mechanical performance of this geopolymer.

RESULTS AND DISCUSSION

The evolution of geopolymer hardening was followed by X-Ray Diffraction. The geopolymer is composed from Anorthite, Muscovite, Kilchoanite, Phillipsite, Tobermorite and Xonotlite resulting from the transformation of the raw mixture minerals (Qartz, Calcite, Illite, Gehlenite and Rankinite) contained in the calcined raw mixture. This transformation is due to the presence of high alkalinicity solution (KOH, 8M), which activates the compound crystalline structure and permit an easy chemical reaction between different oxides to form a new products (Kacimi, L., Cyr, M. et al., 2010), (Mazouzi, W., Kacimi, L. et al., 2014). It was also observed the formation of amorphous phase which increases with the hardening time. These crystal and amorphous hydrates consolidate the geopolymer texture and then increase its mechanical strength (Buchwald, A., Dombrowski, K. et al., 2005), (Yip, C.K., Lukey, G.C. et al., 2005). The compressive strength of geopolymer paste increases with the hardening time to achieve an important value (35.38 MPa) at

28 days. This explains the fast hardening of geopolymer at early age. The hardening evolution of geopolymer paste was due to the chemical reactions of aluminosilicates contained in calcined Sludge with alkalis (K_2O) resulted from the used alkaline solution (KOH).

CONCLUSION

Geopolymer with adequate mechanical performance was obtained from a dam sludge waste. The mineralogical characteristics of the synthesized geopolymer in addition to its structural and textural properties, have led to a rapid development of its compressive strength which considered acceptable compared to those found in the literature. The results conduce to classify the obtained geopolymer as binder materials equivalent to cement of class 32.5. A modification in K/Al molar ratio to be near 2 could increase the compressive strength value to achieve its maximum. These mechanical performances permit the geopolymer to be applied in the construction field as ecological binder. The industrial manufacturing of this sludge geopolymer binder will be qualified as an ecological alternative for the conventional cement due to the low CO_2 emissions and the valorization of a natural waste.

ACKNOWLEDGEMENT

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Material flow analysis and management of plastic waste in Korea

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Keywords: Plastic, Plastic waste, Polyethylene Terephthalate (PET), Material flow, Recycling

INTRODUCTION

Plastic production and consumption have soared worldwide. As a result, the amount of plastic waste generated increases and causes social and environmental problems. Korea aims to transform itself into a long-term plastic-free society through the "Measure for plastic-free household waste" in 2020. In this study, plastic material flow in Korea was presented, and the amount of Korea plastic waste generation by 2030 was predicted. Also, we estimated demand for PET recycled material in 2030.

MATERIALS AND METHODS

Plastic material flow

In this study, we used the data of Korea 'National Waste Generation and Treatment Statistics (2020)' in Korea. Also, the material flow and circulation of plastic were analyzed based on various statistical and literature data and interviews with experts.

Estimated plastic waste generation

We used the data of 'National Waste Generation and Treatment Statistics (2010~2020)' in Korea. Seven models (linear model, arithmetic series model, geometric series model, exponential function model, least squares method, logistic curve, and Gompertz model) were used to estimate plastic waste generation.

Estimated demands for PET recycled secondary material

In this study, we used the data of 'Result of recycling obligations' in KORA (Korea Resource Circulation Service Agency). In addition, we predicted demand based on the 'Measure for plastic-free household waste'.

RESULTS AND DISCUSSION

Plastic material flow

As a result of plastic material flow, 6,823 kt of raw material was consumed in Korea in 2020, and a large amount of imported plastic products were consumed. The plastic waste generated 10,796 kt, which generated 4,411 kt of household waste, 5,796 kt of industrial waste, and 589 kt of construction waste. Of these, about 7061 kt was recycled, 2359 kt was incinerated, and 852 kt was landfilled.

Estimated plastic waste generation

Based on the amount of waste plastic generated from household waste from 2010 to 2020, the amount of

waste generated from 2030 was predicted. all 7 models showed an increasing trend. This was predicted to extend from the trend of increasing the amount of plastic waste from 2010 to 2020. The model predicted that the amount of waste generated as of 2030 exceeded the upper limit is excluded. The excluded models were the geometric series model and the exponential function model. As a result of calculating using five models of the past trend extension method, the amount of plastic waste generated in 2030 among living wastes was about 6,291 thousand tons/year.

Estimated recycled material demand

Assuming 5% per year based on the average growth rate for 10 years, the shipment of PET bottles in 2030 was calculated to be about 510 thousand tons. Also, if 30% of PET bottles are obligated to use recycled materials according to 'Measure for plastic-free household waste', high-quality PET recycled materials are expected to require about 153 thousand tons of PET bottles in 2030.

CONCLUSION

Among the domestic wastes in Korea, plastic waste generated about 1,779 thousand tons in 2010, and 4,411 thousand tons in 2020, increasing by about 2.5 times. As a result of calculating the amount of plastic waste generated in 2030 using the regression models, the amount of plastic waste generated in 2030 is expected to be about 43% in about 6,291 thousand tons/year, and the amount of plastic waste generated continues to increase. Therefore, efforts to reduce plastic waste among household waste are very important. Currently, PET recycled secondary materials mainly produce low quality. High quality should be produced to meet 30% goal in 2030, and systematic measures such as development of screening and recycling technologies and certification of investment quality should be prepared to produce PET recycled raw materials.

ACKNOWLEDGEMENT

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Development of Eco-friendly Hydrogen Production Technology based on Waste Floating Ocean Plastics

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Keywords: Floating Ocean Plastic, Hydrogen Production, Waste Recycling, Water Gas Shift, Catalyst

INTRODUCTION

Marine plastic pollution has emerged an urgent issue in accordance with at least fourteen million tons of plastic disposed to the ocean every year (IUCN, 2021). Although there is global efforts to clean the floating waste in the ocean, the cleaning ships are often limited by their operating radius and the size of cargo to store the gathered waste. To overcome such issues, a conceptual design of an eco-friendly onboard pulverization system for marine plastic debris has been recently developed (Lee et al., 2021). In the sequel of the previous work, the present study is devoted to the development of an onboard eco-friendly hydrogen production process using floating ocean plastics, particularly improving the conversion efficiency of hydrogen purification process.

METHODOLOGY

The onboard eco-friendly hydrogen production process can be mainly classified into five sub-processes. Figure 1 displays the major five steps comprising the entire process from the collecting floating waste to use it as a supplementary power supply to the marine engine. The first step is collecting the floating marine plastic debris in the ocean using conveyor. Although this procedure is simply represented as waste collection in the schematics, this process includes the pre-treatment step consisting of multistage sorting and grinding, freezing, desalinization, dehydration and/or compression. The second step is pyrolysis process using the rotary kiln

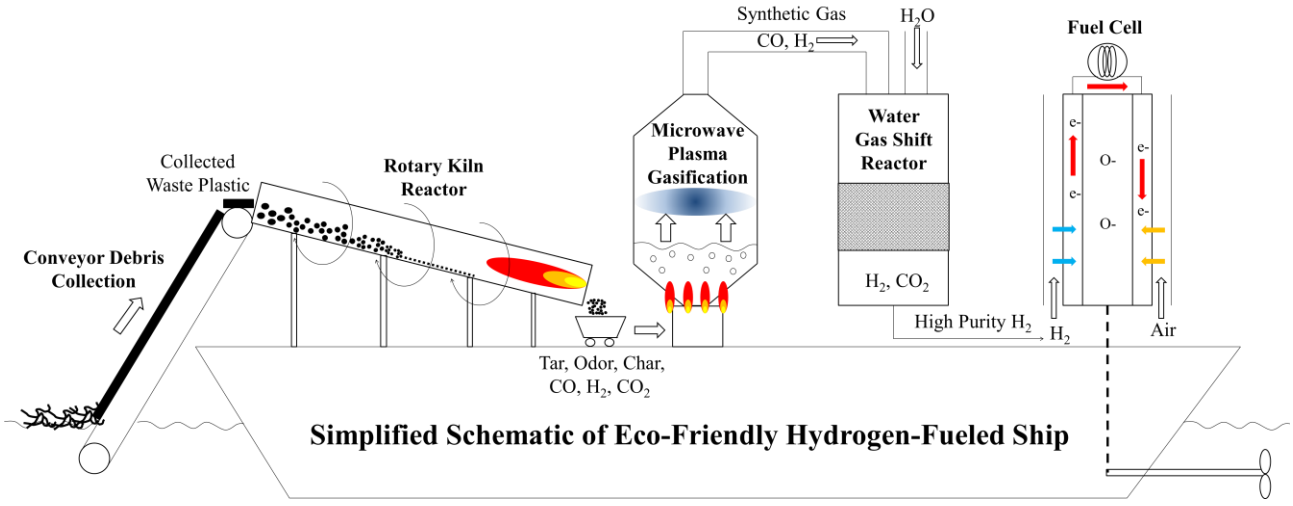

Figure 1: Simplified schematic diagram of the eco-friendly hydrogen production process on the hydrogen-fueled waste cleaning ship.

reactor which transforms the pretreated waste into particulate and low-level synthetic gas including heavy hydrocarbons. These products are then reformed by a microwave plasma gasification process which is the third process depicted in the schematics. The gasification process produces a so-called synthetic gas consisting of carbon monoxide and hydrogen. However, the purity of the synthetic gas is insufficient to be directly used in the fuel-cell system or hydrogen-based dual fuel engine. Thus, the synthetic gas from the gasification process is required to be further purified, and thus the water gas shift process that is chosen for the fourth process. Finally, the produced hydrogen can be used to generate useful energy to operate the ship.

RESULTS AND DISCUSSION

This study is focused on improving the hydrogen purification process employing the low temperature water gas shift reaction. The typical catalyst used for such reactors is a commercial $Cu/ZnO/Al_2O_3$ catalyst (MDC-7, Clariant) (Nishimura el al., 2010). Based on the Cu-Zn-Al, various calcination methods have been employed with a view to improving the catalyst activity. While the commercial catalyst is usually sintered with air, the calcination with N_2 treatment led to a notable increase in the catalyst activity. The enhanced performance is mainly attributed to more oxygen vacancies in the Cu-Zn-Al catalyst structure, which results in the improvement of thermochemical activity dictated by the increased carboxyl pathway. In comparison to the commercial catalyst, the conversion of carbon monoxide in the water gas shift reaction increased up to 23% at the operating temperature in the range of 220-280 ℃.

CONCLUSION

This study demonstrates the conceptual design of the eco-friendly hydrogen production process on the waste cleaning ship in particular for the improvement of the hydrogen purification process. The catalyst prepared with the calcination method using nitrogen greatly outperformed the commercial catalyst for water gas shift reaction. The improved hydrogen purification plays a crucial role for onboard waste recycling process, which eventually enables the continuous long-term operation in the ocean.

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Accelerating a Circular Economy in South Korea

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Keywords: Circular Economy, Carbon Neutrality, Implementation Plan, Policy

INTRODUCTION

Under the linear economy, a large amount of waste has been generated, causing various environmental and social problems. It also significantly impacts the climate crisis as the processes from mining natural resources to manufacturing, consumption, distribution, and disposal of products emit lots of greenhouse gases. The circular economy is a concept in contrast to the linear economy. It can reduce the use of resources in the product life cycle and maximize the value of the product through reuse and remanufacturing, etc. It can reduce dependence on natural resources by using recycled materials, and contribute to the reduction of greenhouse gas emissions caused by landfill or incineration. In addition, it can respond to resource security issues through recycling and create opportunities as a growth power source through new business models.

South Korea declared carbon neutrality by 2050 in October 2020 and announced its '2050 Carbon Neutral Strategy of the Republic of Korea' in December of that year. "Scaling up the circular economy" was suggested to improve industrial sustainability and achieve carbon neutrality. In addition, it is reflected in Korean Green New Deal 2.0 version. Especially, 'K-Circular Economy Implementation Plan' was announced in December 2021. The circular economy was also included in the government tasks announced in May 2022. In the past, the policy focused on the post-management of generated waste such as material recycling and energy recovery, but from now on, it will focus on the direction of reducing resource use and extending product lifetime in the production and consumption stages.

PURPOSE OF RESEARCH

In this study, the policy direction and roadmap for the transition to a circular economy as a means of reducing greenhouse gas in Korea are presented. The roadmap can be used to develop a circular economy strategy that can actively respond to environmental regulations. It is expected to contribute to reducing the carbon intensity of each product and accelerate the transition to a circular economy by strengthening sustainable product policies.

METHODS

Since the circular economy is a field in which multi-ministerial policies are interconnected, it is necessary to propose a multi-ministerial policy that considers the design of circular products, eco-friendly consumption and consumer choice, the conversion of waste to resources, and the activation of the secondary material market. Especially, industry plays a key role in the circular economy, we listened to the opinions of industries and considered their roles in the circular economy. The research was carried out by establishing a cooperative system with practitioners and experts from various institutions. In addition, the K-Circular Economy Policy

Forum was launched and operated with the Ministry of Environment and the Ministry of Trade, Industry, and Energy so that the industry and civil society, the main stakeholders in implementing the circular economy, could participate in the policy design stage.

KEY RESULTS

Circular Economy Policy Roadmap (draft) for Achieving Carbon Neutrality in Korea

To transition to a circular economy, it is important not only to promote material recycling and energy recovery in terms of post-management of already generated waste but also to reduce the consumption of resources from the stage of production and consumption before waste is generated.

In addition, for eco-friendly products to have market competitiveness in consideration of resource circulation, they must be linked with consumption in the public and private sectors. It is necessary to provide support from various angles through the improvement of public procurement, eco-labeling certification, and sustainability management indicators so that companies can promote product material and structure improvement activities. In this study, in terms of material resources (product unit), the circular economy policy roadmap framework was established consisting of the following phases: “management of the entire cycle of resource circulation”-“promotion of circular economy implementation”-“evaluation and monitoring of the implementation status.” In addition, we have prepared a priority strategy considering the characteristics of each sector for separate management of sectors (plastics, batteries, food, textiles, buildings) that have a significant impact.

CONCLUSION

The goals and key strategies set in this study are as follows.

- Three goals: To ① reduce the carbon footprint of the entire resource cycle, ② secure competitiveness in the circular economy innovation industry, and ③ build a sustainable circular economy ecosystem
- Key strategies: ① Encouraging enterprises to design resource-circulating products, ② spreading a culture of resource-circulating consumption that the public agrees with, ③ enhancing eco-friendly recycling of resources, ④ creating an innovative circular economy model and making it a growth engine, and ⑤ promoting the implementation of a digital information-based circular economy. As a strategy to realize the circular economy vision and goals, we derived three major actions – nine topics – 26 detailed roadmaps

Market incentives such as tax incentives, green public procurement, and technology support should be prepared to secure market competitiveness of products designed in consideration of the circular economy. This result can be used to amend subordinate laws such as the Framework Act on Resource Circulation.

ACKNOWLEDGEMENT

This paper was written following the research work “Developing a circular economy policy roadmap for achieving carbon neutrality in Korea” (WO2021-03), funded by the Korea Environment Institute (KEI)

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Shaping Strategy for the Preparation of CuBTC–Embedded Activated Carbon Beads using Expanded Polystyrene Filler for Toluene Removal and Anti-Pathogen

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Keywords: VOC removal, Metal-organic framework, Activated carbon

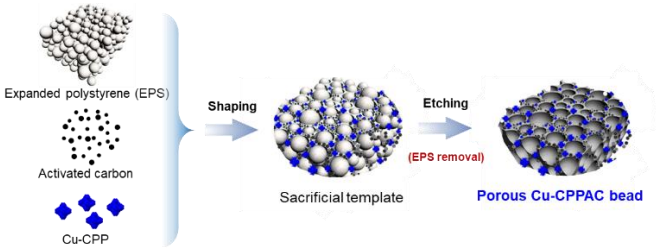
INTRODUCTION

Over the years, the spread of global industrialization as a main issue has increased the emitted volatile organic compounds (VOCs). Therefore, designing and developing ultra-filters for high VOCs removal are critical, however, it is still a challenge. Herein, we report the fabrication of an efficient filter composed of metal-organic framework (CuBTC) – grafted activated carbon beads using expanded polystyrene (EPS) filler. Compared with conventional activated carbon beads, the final filters show high VOC removal efficiency (98.80%) and excellent toluene adsorption capacities (97.12 mg.g-1) owing to the synergistic effect of physical and chemical properties in the adsorptive composites. In addition, the pathogen disinfection for E.Coli was also conducted. CuBTC/AC beads show an efficiency of 95.00%, which is higher than that for activated carbon (34.60%) after 120 min of exposure.

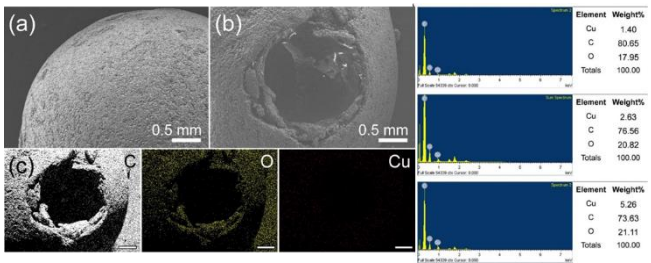
MATERIALS AND METHODS

Preparation of porous Cu-CPP/AC beads

Synthetic procedure



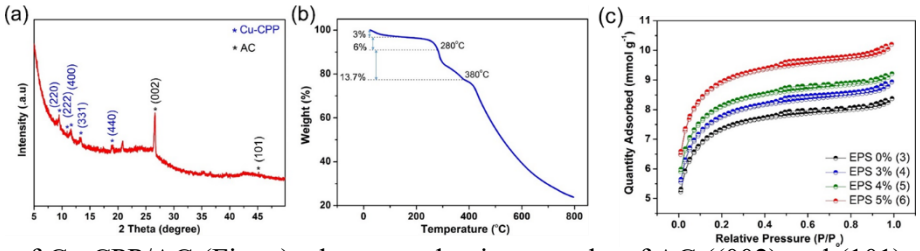
Characterization



Scanning electron microscopy (SEM): rough surface morphology of Cu-CPP/AC beads.

After etching EPS, porous structure of Cu-CPP/AC beads are maintained (Fig. b).

Energy-dispersive X-ray spectroscopy (EDX) confirms the uniform distribution of major components of Cu-CPP, including Cu, C, and O (Fig. c).



XRD pattern of Cu-CPP/AC (Fig. a): shows predominant peaks of AC ((002) and (101) planes) and Cu-CPP ((220), (222), (400), (331), and (440) facets).

Thermogravimetric analysis (TGA) (Fig. b): confirms the thermal stability until 380 °C and loading amount of Cu-CPP in Cu-CPP/AC beads.

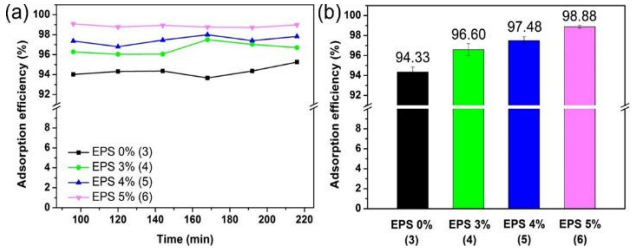
Nitrogen sorption of porous Cu-CPP/AC beads (Fig. c): shows high specific surface area of 742 m^2 g^{-1}.

RESULTS AND DISCUSSION

Toluene removal efficiency

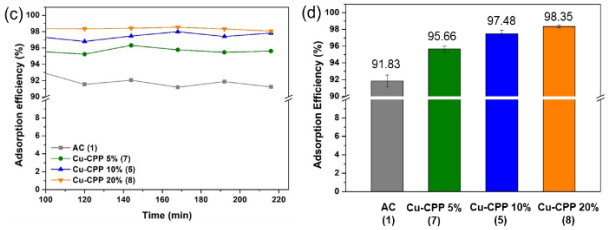
Effect of EPS Dose

The toluene removal yield was increased from 94% to 98.8% equivalent the increased amount of EPS from 0% to 5% containing in the precursor beads.



Effect of Cu-CPP Dose

Cu-CPP/AC beads are dominant for toluene removal compared with conventional AC.



CONCLUSION

The obtained results in this study indicate that the synthesized Cu-CPP/AC bead composed of copper-based metal-organic framework and activated carbon conventional can serve as dual functional abilities for removing VOCs and pathogen. The novel materials with good activity and cost efficiency render them promising candidates for real-life application towards indoor air pollution control.

ACKNOWLEDGEMENT

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Estimation of Greenhouse Gas Reduction Potential -Case study of Household Waste Prevention at Kyoto City-

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Keywords: waste prevention, greenhouse gas, life cycle analysis, household waste

INTRODUCTION

Carbon neutral society is strongly promoted in the entire world. In Japan's Resource Circulation Strategy for Plastics, basic principle of 3R (reduce, reuse, and recycle) has been developed into the "3R+Renewable." Then waste prevention or 2R (reduce and reuse) was still placed at the top of the waste management hierarchy. This study aimed to estimate the GHG reduction effect of preventing avoidable household waste in Kyoto City, Japan. The results of the present work could be used to estimate the GHG reduction potential of all prevention behavior while considering their feasibility and practicability. Moreover, the findings herein could identify the prevention behaviors and avoidable products that should be prioritized in future GHG reduction efforts

MATERIALS AND METHODS

Avoidable products targeted

This study considered 40 avoidable products in household waste, of which 32 were identified in, household waste composition survey by the Kyoto City (KCEPB, 2020), according to the 18 behaviors associated with preventing them. The total amount of avoidable product (waste) generated was estimated to be 113,727 t/yr.

The Business as Usual (BAU) (S1) and Prevention (S2) scenarios were compared. Under S1, no prevention behaviors were assumed and the current situation was reflected. Under S2, prevention behaviors reduced the generation of avoidable products by 50% in order to evaluate the GHG reduction potential of household waste prevention.

Estimation of life cycle GHG reduction effects

The functional unit was "the annual rate of provision of services and products consumed at households within Kyoto City". Among 18 prevention behaviors, five behaviors were required to facilitate the use of substitute products. For these, the required service times were estimated.

This study considered the production, use, and waste treatment of various products. For S1, the use and waste treatment of avoidable products were considered. For S2, the production, use, and waste treatment of substitute products were considered. For use prevention behavior in the absence of substitute products, a virtual flow was assumed for the provision of services equivalent to avoidable products (Yano and Sakai, 2016). Moreover, virtual flow was assumed for a substitute products flow preventing the production, use, and waste treatment of avoidable products. The waste collection was not considered in both of S1 and S2.

RESULTS AND DISCUSSION

The total GHG reduction effect for all prevention behaviors was estimated to be 120,000 t CO_2/yr. The estimated contributions of avoidable products to the GHG reduction effect were shown in Figure 1. In terms of raw materials, food made the largest contribution (28%) followed by plastic (24%) and paper (18%). Untouched food and leftovers made the largest contributions, namely, 16% and 12%, respectively. Improving dietary habits had the greatest GHG reduction effect because the generated amount of untouched food was large. GHG reduction effect of avoiding single-use products and beverage and seasoning bottles was also large.

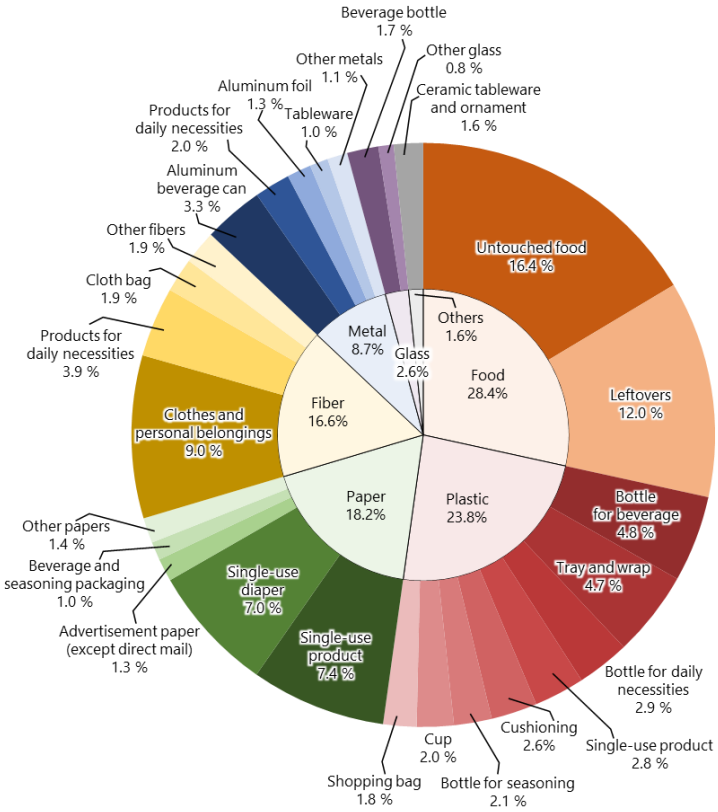

Figure 1 Contribution of each avoidable product to total GHG reduction effect

CONCLUSION

This study estimated GHG reduction potential by preventing 50% avoidable products in household waste in Kyoto, Japan. It was suggested that preventing the raw materials of food and plastic production substantially reduced GHG emissions. In the context of carbon neutral society, these results suggested that preventing food loss is important because it is impractical to reuse or recycle food. It should be also evaluated to utilize renewable materials such as bio-based plastics and paper which does not contain fossil-based carbon in cases where waste prevention is difficult and single-use plastic products in addition to waste prevention.

ACKNOWLEDGEMENT

This research was performed by the Environment Research and Technology Development Fund (JPMEERF20153K01 and JPMEERF20223001) of the Environmental Restoration and Conservation Agency of Japan.

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Effectiveness of goods and ICT for managing food in refrigerators on the reduction of avoidable food waste

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Keywords: household food waste, social experiment, waste reduction, food management tools, evaluation

INTRODUCTION

The authors have been analyzing the composition of household waste to determine the categories and amounts of food waste from households. We define that avoidable food waste consists of “unused foods” and “leftovers” among total household food waste. Some interventions such as refrigerator management goods or ICT to reduce household food waste were devised, and a social experiment to use these tools in a community area was conducted in Maizuru city, Kyoto prefecture. Waste sorting analyses were conducted to monitor the efficacy of the tools. This paper reports the results of the social experiment.

MATERIALS AND METHODS

Social experiment (Schedule)

September 11, 2022: Sorting analyses in the experimental area (236 households) before intervention...(1)

September 12, 2022: Sorting analyses in the control area (219 households) before intervention...(2)

Mid-September, 2022: Tools distributed to all households in the experimental area (236 households)

September 24: Instructional meeting at the experimental area on the use of the tools

December 4, 2022: Sorting analysis in the experimental area (236 households) after the intervention...(1)'.

December 5, 2022: Sorting analysis in the control area (219 households) after the intervention...(2)"

The effect of food waste reduction was evaluated by comparing the results of (1) and (1)' , (2) and (2)',

Classification of food waste (Tokyo Method)

The sorting analysis was conducted based on the Tokyo Method classification developed by the authors (Okayama et al 2021). The details of the classification of food waste is shown in Table 1.

Table 1 Classifications of food waste

Food waste	Avoidable food waste	A/B: Unused food	A: Unused ingredients	A1 :【Unopened ingredients】(in packaging)
				A2w :【Whole unused ingredients】（not in/no packaging）
				A2wf :【Home-grown vegetables】
				A2p :【Partly used ingredients】
			B: Unused ready-to-be-eaten food	B1 :【Unopened ready-to-be-eaten food】(Unopened ready-to-be-eaten food in packaging)
				B2 :【Uneaten ready-to-be-eaten food】Uneaten ready-to-be-eaten food (whole portion, not in packaging or open packaging)
				B’:【Unopened drinks】
		C: Leftovers		C:【Leftover food】(partly eaten)
				C’:【Leftover drinks】
	Non-Avoidable food waste	D:【Intentionally removed parts】Parts that are not usually eaten		De:【Possibly avoidable】Potentially edible residues
				Di:【Inedible parts】
		E: Unclassifiable		E:【Unclassifiable】Blended fine particles not possible to be sorted further

RESULTS AND DISCUSSION

Comparison of experimental and control areas

Table 2 shows the comparison of experimental and control areas.

Table 2 Comparison of experimental and control area

Experimental area						
	Sampling total waste (kg)	Food waste (kg)	Avoidable food waste (kg)	Percentage of food waste in total waste (%)	Percentage of avoidable items in food waste avoidable food waste (%)	Percentage of avoidable food waste in total waste (%)
Pre-intervention	770.64	199.83	93.94	26.75	46.87	12.19
Post-intervention	773.77	263.97	104.8	34.49	39.70	13.54
Fluctuation	3.13	64.14	10.86	7.74	-7.17	1.35
Control area						
	Sampling total waste (kg)	Food waste (kg)	Avoidable food waste (kg)	Percentage of food waste in total waste (%)	Percentage of avoidable items in food waste avoidable food waste (%)	Percentage of avoidable food waste in total waste (%)
Pre-intervention	440.01	142.35	66.79	33.42	46.91	15.18
Post-intervention	479.26	167.72	60.73	35.60	36.21	12.67
Fluctuation	39.25	25.37	-6.06	2.18	-10.7	-2.51

Result of Sorting analysis pre- and post- intervention

The composition of food waste before intervention is shown in Figure 1 and after intervention in Figure 2.

CONCLUSION

Avoidable food waste tended to increase in the experimental area. Tools for reducing avoidable food waste at households, such as goods to support management of food in refrigerator were distributed to all households in the experimental area by September 24, but it is unclear to what extent they were being used as of December, when the composition analysis was conducted.

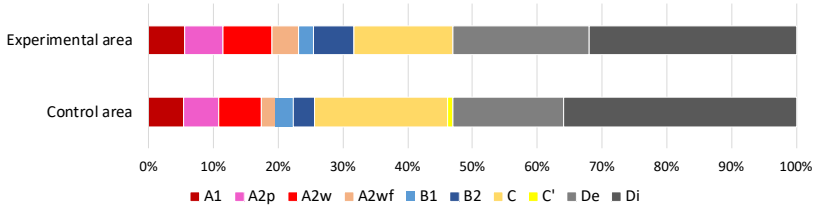

Figure 1 Pre-intervention Food Waste composition

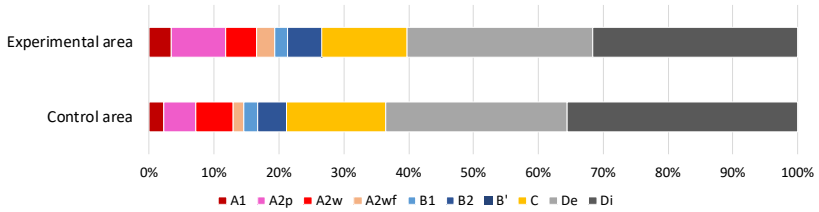

Figure 2 Post-intervention Food Waste composition

ACKNOWLEDGEMENT

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Source Estimation of Atmospheric Polychlorinated Naphthalenes (PCNs) in Japan by Chemical Mass Balance (CMB) Model

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Keywords: polychlorinated naphthalene, atmospheric concentration, source estimation

INTRODUCTION

Polychlorinated naphthalenes (PCNs) are one of persistent organic pollutants, and it is required to ban the production and use of PCNs internationally. In Japan, the production, use, and import of PCNs had been already banned in 1970s. Previous study reported that PCNs have been still emitted from the stock of products containing PCNs and thermal process such as cement kiln, metal smelting, and waste incineration (Liu, G., Cai, Z., et al., 2014). However, few research focused on PCN emission sources and their contributions into Japanese atmosphere in recent years. The objective of this study was to estimate the contributions of PCN emission sources to atmospheric PCNs in Kyoto, Japan using Chemical Mass Balance (CMB) model.

MATERIALS AND METHODS

Atmospheric PCNs concentrations survey

Atmospheric PCNs concentrations were surveyed on two sampling sites in Kyoto, Japan (site A in Sakyo-ku and site B in Nakagyo-ku). The sampling was conducted from March 15 to 18, 2021 for site A and B and from October 3 to 6, 2022 for site A. A high-volume air sampler was used to collect the air for three days, and atmospheric PCNs were captured by silica fiber filter paper, polyurethane foam, and activated carbon fiber felt. Pretreatment and analysis were conducted following monitoring survey manual by Japan Ministry of the Environment.

Chemical Mass Balance model

CMB model can estimate the contribution rate of each emission source with the chemical profile in the environmental sample and emission sources. This study used the CMB software published by the Institute of the Statistical Mathematics. The target chemicals substances were PCN isomers of Mono- to Hexa-CNs; Hepta- and Octa-CNs were excluded because they were not detected or they were lower than the limit of detection. The PCN emission sources assumed in this study were Halowax series (Noma, Y., Yamamoto, T., et al., 2004) and thermal processes such as municipal solid waste incineration (Dat, N.D., Huang, Y.J., et al., 2020), cokes production (Liu, G., Liu, W., et al., 2013), copper smelting (Nie, Z., Liu, G., et al., 2012), electric arc furnace (Liu, G., Zheng, M., et al., 2012), and cement kiln (Liu, G., Zhan, J., et al., 2016). This study also conducted hierarchical cluster analysis and aggregated the emission sources to avoid multicollinearity.

RESULTS AND DISCUSSION

The observed total PCN of site A was higher in October 2022 (121 pg/m^3) than March 2021 (91 pg/m^3), and it was suggested that the atmospheric PCN concentrations was influenced by atmospheric temperature.

The total PCN concentrations in Kyoto were close to the average level of recent JMoE sampling survey.

The cluster analysis aggregated the Halowax sources into 1 source profile and thermal sources into 3 source profiles. The CMB results suggested that Halowax source had higher contribution rate in the atmospheric PCNs. The contribution from Halowax source was higher in warm season (2022) than in cold season (2021), suggesting that volatilization from Halowax source would influence atmospheric PCNs.

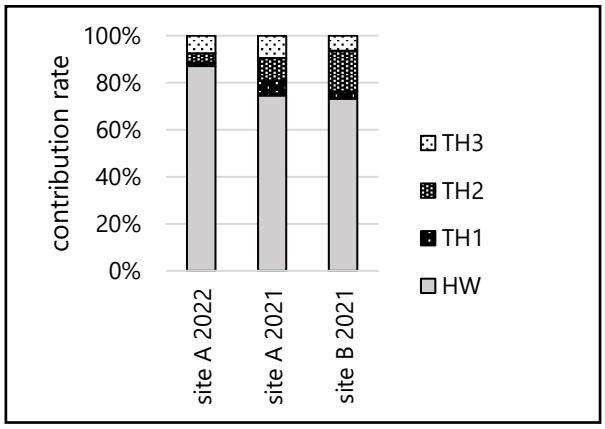

Figure 1 Estimation results of contribution rate of each emission sources in atmospheric PCNs

CONCLUSION

This study estimated contribution rates of PCN emission sources into atmosphere in Kyoto, Japan using CMB model. From the results of CMB analysis, it was suggested that the contribution of Halowax sources were larger than thermal sources in the atmospheric PCNs in Kyoto.

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Single-use plastic products from households through waste composition survey in 2019-2022

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Keywords: single-use products, single-use plastics, waste composition survey

INTRODUCTION

In Japan, the Plastic Resource Recycling Strategy in 2019 set a goal of reducing the generation of one-way plastic by a cumulative 25% by 2030, and in the following year, 2020. In addition, in April 2022, the Plastic Resources Recycling Law came into effect, instructing businesses that handle 12 specified items to work toward streamlining their operations. From the viewpoint of marine pollution, greenhouse gas emissions, and other environmental burdens, the use of single-use plastics, such as shopping bags, is of significant concern (UNEP, 2018; Ellen MacArthur Foundation, 2016). The importance of reducing the generation of plastic and substituting materials for plastics has been emphasized. Therefore, to clarify the actual disposal status, this study investigated the amounts (weight, number, and material) of single-use plastic products generated from households through waste composition survey during 2019-2022.

MATERIALS AND METHODS

Household waste investigated

The surveys have been conducted at Kyoto City every autumn (November to December) since 2018. Combustible waste and plastic containers and packaging (plastic C&P) were considered while other waste categorizations such as PET bottles, which were designated at Kyoto City were excluded. Household waste samples were collected from 3 districts within the city every year. However, only one district (district A) was investigated in 2020 and 2022 due to Covid-19 and work time limitation. From every district, approx. 300 kg of combustible waste and 60 kg of plastic C&P were investigated.

Estimation of single-use plastic products generated per capita

Weight, material, and number of single-use products were measured one by one for over which resulted in counting over 60 plastic product items. Then the amount (weight or number) of the products were converted into the annual amount per capita.

RESULTS AND DISCUSSION

Estimated results of total amount of single-use plastic products during 2019-2021 were listed in Table 1. Results of 2022 will be also introduced in the conference presentation. A decreasing trend over time was observed. One of the reasons was the plastic carrier bags were significantly decrease from 269 bags/capita in 2019 to 115 bags/capita in 2021: the effectiveness of the plastic carrier bag fee system was suggested.

As listed in Table 2, top 5 products generated were disposable polyethylene bag, carrier bag, wrap film, PET bottle, and garbage bag. Therefore, prevention and/or substitution measures for them were important. Plastic carrier bags were still one of the representative single-use products although they were more than halved during 2019 to 2021. For wrap film, disposable polyethylene bag, and carrier bags, they were also top 3 as number basis. Except them, caps of PET bottle, and release sheet of poultice were nominated within top 5 as number basis.

Table 1 Estimated amount of single-use plastic products annually generated (kg/capita)

	District A		District B		District C	
Year	Combustible	Plastic C&P	Combustible	Plastic C&P	Combustible	Plastic C&P
2019	5.4	0.9	5.7	1.1	3.1	0.7
2020	5.3	0.8	-	-	-	-
2021	3.7	0.5	4.4	0.3	2.8	0.3

Table 2 Top 5 of single-use products generated in each district in 2021

District A		District B		District C	
Disposable polyethylene bag	942.0	Carrier bag	1169.4	Carrier bag	738.7
Carrier bag	846.0	Wrap film	1142.2	Wrap film	561.2
Wrap film	615.8	Disposable polyethylene bag	366.1	Disposable polyethylene bag	411.0
PET bottle	271.6	PET bottle	268.4	PET bottle	217.9
Garbage bag*1	204.1	Garbage bag*1	238.3	Garbage bag*1	179.9

*1: Garbage bags refer to commercially available garbage bags, not the city-designated waste collection garbage bags.

CONCLUSION

This study revealed that decreasing trend of single-use plastic products generated from households during 2019-2022. Carrier bag, disposable polyethylene bag, and wrap film were identified as the representative ones as both weight and number basis and therefore should be considered for preventing and/or substitution measures. This composition survey needs to be continued and monitored to consider and evaluate reduction measures in the future.

ACKNOWLEDGEMENT

This research was performed by the Environment Research and Technology Development Fund (JPMEERF21S11905) of the Environmental Restoration and Conservation Agency of Japan, and the “Demonstration Project for a Plastic Resource Circulation System toward a Decarbonized Society” supported by Ministry of the Environment, Japan (MOEJ).

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Detection of Asbestos of Wasted Building-Materials by Staining for On-site Analysis

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Keywords: asbestos, detection, staining, wasted building-materials,

INTRODUCTION

The production and use of materials containing of asbestos was banned about 20 years ago in many countries. However, materials containing asbestos still remain in old houses and/or buildings built before the ban. As a result, many asbestos containing building materials are unintentionally discarded during disasters or g building demolition. In order to prevent damage to the human body caused by asbestos, it is necessary to investigate the presence of asbestos before demolishing houses and buildings and disposing of disaster-waste. In this study, we report a method for directly detecting asbestos on the surface of building materials as color images using a stereomicroscope without pulverizing its use at demolition sites or disaster sites.

MATERIALS AND METHODS

Materials

Samples of building materials were collected from areas affected by the Kumamoto and Great East Japan earthquakes and from house demolition sites. Samples were washed with a brush to remove mud and soaked for about 10 minutes in chemical solution of 1M HCl or 20% formic acid, or in commercial detergents such as dishwashing detergent, oil remover, wall cleaner, silica remover, and etching agent.

Method

The surface of the building material was washed with water and divided into small pieces of 1–2 cm^2 in size. After drying the samples in a room, they were first stained with MB and then with Red3. The stained building materials were observed using a stereomicroscope (SMZ745T, NIKON SOLUTIONS Co., Ltd., Japan) or a metallurgical microscope an imaging software (WinRoof 2018, 2021, MITANNI Cooperation, Japan).

RESULTS AND DISCUSSION

Staining with dyes

Cationic dye MB dyes building materials blue, but asbestos remains white. Red 3, on the other hand, stains asbestos pink. On the other hand, Red 3 stained asbestos pink. Therefore, asbestos on the surface of building materials cannot be detected by microscopic observation (x 50) without staining (Figure 1A), but asbestos can be easily detected when stained

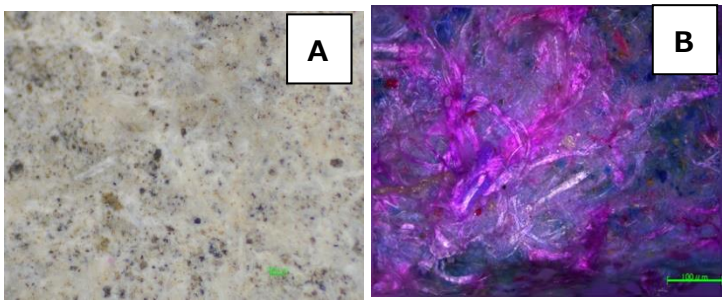

Fig. 1. Pictures of the surface of building materials before (A) and after staining by MB and Red 3.

with dye MB and Red 3 (Fig. 1B). staining with dyes MB and Red3 (Fig. 1B). Asbestos was also confirmed by polarized microscopy (PLM). Asbestos appeared and disappeared (darkened) with each 45 rotation of the sample holder, while the color of the non-asbestos red fibers remained constant as the sample holder was rotated.

X-ray diffraction and Raman spectra of the surface of building materials

The peaks in XRD patterns at $2\theta = 12.18^{\circ}$ ($d = 7.27$ Å) and 24.44° ($d = 3.64$ Å), which are consistent with the values of standard asbestos (JAWE 131: $2\theta = 12.4^{\circ}$; 24.4°), indicate chrysotile contained in building materials. Laser Raman microscopy showed four clear peaks, 127.4, 231.5, 389.2, and 690.8 cm^{-1}, which are consistent with those of a standard chrysotile: 131.4, 232.5, 388.8, 694.4 cm^{-1}.

Composition of fibrous materials in building materials

We examined 35 building materials, especially boards, for the presence of asbestos using our proposed staining method. Sixteen of the materials contained asbestos (chrysotile) (Fig. 2A), 8t building materials contained asbestos and other fibrous materials (mainly plastic) (Fig. 2B), and 11 building materials contained only fibrous materials and glass fiber (Fig. 2C).

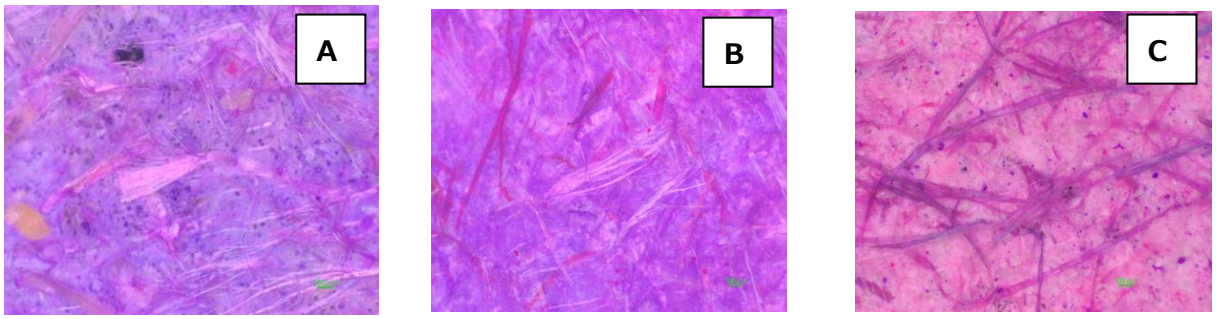

Fig. 2. Pictures of building materials stained with MB and Red3. Building materials containing only asbestos (A), asbestos and fibrous compounds (B) and fibrous compounds (C).

CONCLUSION

Asbestos in building materials was able to be easily identified by the color and characteristic shape of the stained material through stereomicroscopy by dying the surface of building materials. The type of asbestos was reconfirmed to be chrysotile by XRD patterns and laser Raman spectra. The surface of the dye-stained building materials was analyzed using image analysis software, and the percentage of asbestos area increased with the concentration of asbestos in the building materials.

ACKNOWLEDGEMENT

This research was performed by the Environmental Research and Technology Development Fund (JPMEERF20221M01) of the Environmental Restoration and Conservation Agency provided by Ministry of the Environment of Japan.

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Carbon Footprint of Plywood and Laminated Veneer Lumber (LVL) Manufactured in Japan

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Keywords: greenhouse gas, adhesives, wood material

INTRODUCTION

Wood materials such as plywood and laminated veneer lumber (LVL) are composed of wood elements and adhesives, which emit fossil-derived CO_2 during incineration at their disposal stage. However, GHG emission factors for these wastes are not yet estimated. Therefore, we conducted a questionnaire survey of raw material and fuel consumption at plywood and LVL manufacturing plants to estimate GHG emissions during the manufacturing and disposal stages of these products in Japan.

MATERIALS AND METHODS

Questionnaire survey

Plywood and LVL manufacturing plants were surveyed on their material and fuel use from January through December 2019. Seven plywood plants and four LVL plants participated in the survey, which covered 30% and 80% of the total domestic production volumes of plywood and LVL, respectively, in Japan.

Functional unit and system boundaries

The functional unit of this study is the production of 1 m^3 of plywood or LVL. The system boundary in this study includes the growing and harvesting of wood, transportation of logs, production of adhesives, production of wood materials, and incineration of end-of-life wood materials. The use phase of wood materials, such as the construction of buildings or furniture, was outside the scope of this study.

Inventory data collection

GHG emissions from log production (from seedling cultivation to harvesting) were estimated using the emission factors for log production by tree species by the Forestry Agency, 2016. GHG emissions from log transportation were calculated by multiplying the transportation distance and the GHG emissions factors by transportation mode. Transportation distances on land were calculated using the Google Maps for routes from log production areas to the plywood/LVL plants via log distribution centers near the plants. GHG emission factors for trucks, railroads, and ships along with electricity production and fuel consumption were obtained from the Ministry of the Environment, 2020. GHG emissions from the production of adhesives and packaging materials were estimated using the LCI database IDEA Version 2.3 by AIST and SuMPO, 2021.

RESULTS AND DISCUSSION

GHG emissions from production and incineration of 1 m^3 of plywood and LVL

Table 1 shows the estimated GHG emissions from the production and incineration of plywood and LVL by processes. Emissions from adhesive production and incineration together accounted for about 1/2 of the

plywood and 1/3 of the LVL emissions. For non-adhesive-related processes, the contributions from the log transportation and electricity consumption at plants were significant. On the other hand, fuel consumption at plywood and LVL plants was relatively small, and the contribution of packaging materials was almost negligible.

Domestic logs account for about 90% of the raw lumber for plywood and about 83% for LVL, but further increasing the percentage of domestic lumber is expected to reduce greenhouse gas emissions from log transportation. Furthermore, all the plants surveyed utilized wood waste as fuel, which accounts for the low GHG emissions from fuel consumption. The yield rate for manufacturing plywood and LVL from logs was about 60%, resulting in a large amount of wood waste, accelerating the utilization of waste wood. On the other hand, only a few plants utilize in-house power generation using wood waste, meaning there is room to expand its introduction.

Table 1 GHG emissions from production and incineration of 1 m^3 of plywood and LVL (kg-CO_2eq/m^3)

Process	Plywood		LVL	
	Average	Standard deviation	Average	Standard deviation
Log production	29.2	2.39	32.8	4.61
Log transport	44.0	10.6	106	65.8
Adhesives production	59.5	5.12	72.5	16.0
Electricity	41.5	25.8	105	15.5
Fossil fuel	5.75	3.65	12.6	17.0
Packaging	0.0323	0.0104	0.0568	0.0650
Subtotal (production)	180	36.9	329	82.9
Waste incineration	46.7	4.01	50.2	11.1
Total	227	37.1	379	83.6

CONCLUSION

This study estimated GHG emissions from the production and incineration of plywood and LVL. Nine plants for plywood and four plants for LVL participated in the survey. The average GHG emission factors were 227 kgCO_2eq/m^3 for plywood and 379 kgCO_2eq/m^3 for LVL.

ACKNOWLEDGEMENT

This research was supported by the Environment Research and Technology Development Fund (JPMEERF20192006) by the Ministry of Environment of Japan.

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Consumer Knowledge and Behavior on Plastic Consumption, Reuse and Disposal: Case study in Pemba, Mozambique

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Keywords: household waste, Plastic, Waste littering, Women's Role, Mozambique

INTRODUCTION

Waste generation in Africa, as in other developing regions, is driven by socio-economic transition, changes on consumption and production patterns, and global waste trade (JICA, 2019). In particular, the environmental pollution in the region caused by inappropriate waste discharge from residents such as open dumping is one of the important problems (UNEP, 2018). Lack of knowledge, low education levels, and insufficient public service are main reasons for inadequate waste management practices in Mozambique (Sallwey J. et al, 2017) Other major constraints to integrated waste management in Africa include low level of public awareness and limited involvement of households as key stakeholders. Additionally, community consultation processes often fail to take gender equality into consideration, thereby neglecting the needs of women (UNEP, 2018). Thus, this study aims to observe status of consumers' knowledge and behaviors on plastic waste, obtain statistical information on plastic consumption, and understand gender role on household waste, thus propose potential of gender inclusion in household waste management system in Mozambique.

MATERIALS AND METHODS

This study was carried out in Pemba, capital of Cabo Delgado province, northern Mozambique. Data was collected from 220 respondents (129 females, 91 males) through a household survey (door-to-door) using a structured questionnaire from 14th September to 14th October 2022. From the main sample, 20 housewives were selected for in-depth interview using a semi-structured questionnaire from 1st to 20th November 2022. Secondary data mainly from publications, reports, journals, and the internet and field observation technique were gathered. A mixed analysis combining quantitative and qualitative methods was conducted. The products that were the target of this research are found in Figure 1.

Figure 1 Plastic products under study

RESULTS AND DISCUSSION

The questionnaire revealed only 32% of respondents know about 3R (reduce, reuse, and recycle). 37% strongly agree and 8% agree that there is no problem with consuming plastic product. 26% of respondents use 1 to 4 new

plastic bags weekly, while the rest consume more than 4 plastic bags per week. 39% and 20% of respondents reuse PET bottles always and often respectively, while plastic food containers are always and often reused by 55% and 20% of them respectively. 176 respondents reuse PET bottles to store liquids at home, 99 offer women who sell beverages, 28 use as vases for flowers, 23 sell drinks and 3 reuse for other purposes. 80 % of respondents replied female household members are responsible for cleaning and waste disposal while 14% answered male members are taking charge of those task. Results from the interview showed initiative to reuse plastic products is from women. Key results of the survey are charted in Figure 2.

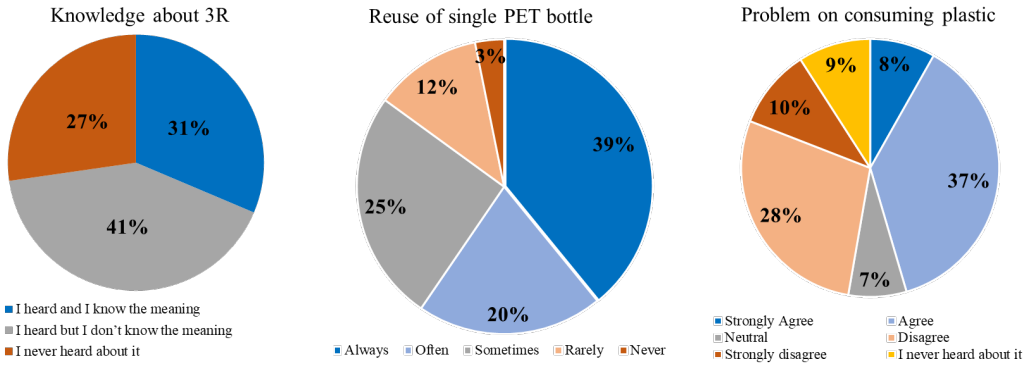

Figure 2 Key results of survey

CONCLUSION

This study reveals that 3R is still a new concept to most consumers in Pemba, Mozambique. Considering the answers given by most of the respondents on plastic consumption, it can be concluded that it will be difficult for people to reduce plastic consumption as long as plastics are continuously offered by retailers in local markets. Knowledge about plastic waste is not everyone's domain regardless of the respondents' academic level. It was observed that women play an important role in managing household wastes and reuse PET bottles to earn a living beyond mere utilization in their homes. From these findings, it can be concluded women can be key stakeholders in reducing plastic wastes and improper disposal and contribute reuse of plastic products with their commitment. Through this conclusion, it is expected that it can be not only advantageous to the environment but also a source of women empowerment.

ACKNOWLEDGEMENT

This research was performed by the Graduate School of Global Environmental Studies-Kyoto University fund.

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Synergistic effect of co-pyrolysis of polyvinyl chloride (PVC) and oil sludge on pyrolysis kinetics

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Keywords: plastic waste recycle, pyrolysis, environment protection

INTRODUCTION

With increase of the importance of plastic-based products in our daily lives and industries consistently, the plastic waste recycle is an emerging social problem. According to the Ministry of the Environment Japan, the cumulative plastic waste generation all over the world will increase 5 times larger than the amount in 2020. [1]. Moreover, the 67% of plastic residues were incinerated and 8% of the residues were landfilled although merely 25% was used to direct recycle [2]. Amongst three main recycle ways of plastic wastes, the pyrolysis-gasification, which belong to both chemical recycle and thermal recovery, are considered as the best way which has large potentials to supply energy resources such as syngas, oil and activated carbon products comparing to the serious limitation of material recycle. In this research, synergistic effect of co-pyrolysis of polyvinyl chloride (PVC) and oil sludge derived from crude oil production on pyrolysis and gasification were investigated focusing on apparent activation energy.

MATERIALS AND METHODS

Materials

PVC was used as a test plastic waste in this study owing to its high market-share, high additives and plasticizers contents needed to be recycled properly. PVC and magnesium sulfate (Fujifilm Wako Pure Chemical Corporation,(Japan) were used. Oil sludge is a new type of resource that relatively high content of solid matter and a certain content of oil matter around 20~30%. Oil sludge used in this study was sampled from China. Distilled water produced by Monota RO,Co.,Ltd (Japan) was used. Nitrogen (G3, purity = 99.9995%, TAIYO NIPPON SANSO Corporation (Japan)) was used as pyrolysis carrier gas. All reagents were used as received.

Methods

This study consisted of pyrolysis experiments and analysis sections. Section 1 was the basic analysis including proximate analysis and ultimate analysis for the PVC and Oil sludge, and chemical components analysis for char from co-pyrolysis. Experiments were performed using a pilot-scale fixed bed co-pyrolysis of PVC and Oil sludge in section 2. Section 3 was tar analysis. An analysis for the composition of organic compounds in collected tar from experiments were carried out. Section 4 was that calculating the apparent activation energy of co-pyrolysis. Identified the best proportion of PVC and Oil sludge during the co-pyrolysis and discussed the results with the data of metal composition of char and tar content.

RESULTS AND DISCUSSION

Apparent activation energy and main chemical components

Apparent activation energy was calculated by Kssinger-Akahira-Sunose(KAS) method and Flynn-Wall-Ozawa(FWO) method [3]. A decreasing trend of activation energy with increase of oil sludge ratio was confirmed in the co-pyrolysis experiments. It might indicate that oil sludge could act as a key role in lowering down the apparent activation energy and facilitating the process of pyrolysis. In order to confirm the effect of oil sludge on the co-pyrolysis, solid matters contained in oil sludge was measured using the X-ray Fluorescence to analyze the main active metal oxides in char. The results were summarized in Figure 1. Catalytic effect of oil sludge on co-pyrolysis, in particular lower activation energy, was confirmed.

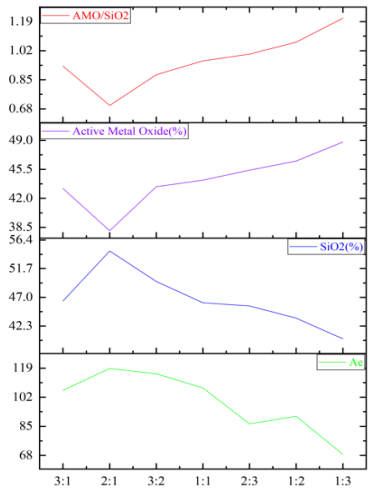

Figure 1 Active Metal Oxide/SiO_2, Active Metal Oxide(%), SiO_2(%), Apparent activation energy in different ratio of PVC and Oil Sludge by prompt pyrolysis

CONCLUSION

With the increase of Oil sludge ratio in co-pyrolysis, the apparent activation energy indicated that pyrolysis proceeded more easily. Much more active metal matter and less relative content of silicon dioxide brought by Oil sludge could be considered as a key to achieve a lower apparent activation energy. What's more, the quality of tar could be improved from the carbon atoms side according to the results of tar composition. In short, the effect of oil sludge acted in co-pyrolysis was confirmed and the ratio of co-pyrolysis may provide better choice for the PVC pyrolysis.

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Shrimp Shell-derived Adsorbent for Nutrient Recovery from Shrimp Pond Wastewater: A Preliminary Test using Methyl Orange as a Model Nutrient

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Keywords: Shrimp shell, Pyrolysis, Methyl Orange, Adsorption

INTRODUCTION

The aquaculture shrimp production went up to about 9.66 Mt tons (FAO,2021), resulting in approximately 5 Mt of shrimp shell waste and serious water pollutants from nitrate and phosphate (Funge-Smith and Briggs, 1998).

Shrimp shell waste is rich in calcium minerals (80%), playing an important role in the adsorption of anionic dyes (Wu J., Yang J et.al.,2022). Pyrolysis with alkaline hydroxides was an effective method to change the surface properties and pore size structure of adsorbents, which could be used to remove a variety of water pollutants such as heavy metal, organic and inorganic compounds (Kaya N., Uzun Z. Y. et.al., 2021).

Herein, shrimp shell wastes were thermochemically pyrolyzed with different alkaline hydroxides (KOH and $Ca(OH)_2$), and then evaluated its performance by using methyl orange (MO) as a model of anionic pollutant.

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MATERIALS AND METHODS

Shrimp shell-derived adsorbent (SSs) synthesis

Shrimp shell powder was obtained from Foods World Co., Ltd., Japan. Two different methodologies were used to develop SSs: a) thermal pyrolysis alone; and b) thermochemical pyrolysis with alkaline hydroxides (KOH or $Ca(OH)_2$) in a weight ratio of 0.5:1. Pyrolysis was performed under a nitrogen atmosphere, at 700 ℃ for 1 h with a heating rate of 15 ℃/min.

Adsorption experiments

2 g SSs was added into 200 mL MO solution with different concentrations. The mixture was stirred for 72 h, and collected at different time intervals. The residue MO concentration was measured by using a UV-VIS spectrophotometer (Shanghai Jinghua Technology, Japan) at a wavelength of 464 nm.

RESULTS AND DISCUSSION

As shown in Figure 1a, after being thermally treated at 700 °C, MO adsorption capacity reached 55370.89 mg/g. The combined thermochemical $Ca(OH)_2$ treated SSs also exhibited high adsorption capacity, with 56591.33 mg/. However, the experimental data for MO adsorption on pyrolyzed and $Ca(OH)_2$ activated SSs could not fit neither Langmuir nor Freundlich isotherms because the adsorption equilibrium level was not reached yet. On the other hand, the KOH-activated SSs could be investigated using the two isotherm models

(Figure 1a). According to the R^2 value, the Freundlich Isotherm (R^2, 0.933) was better suited than the Langmuir isotherm (R^2, 0.859), indicating possibly multilayer type adsorption. The maximum adsorption capacity was much lower, with 23904.99 mg/g.

Additionally, MO adsorption onto the SSs adsorbents was both fitted by pseudo-first-order and second-order models with a higher R^2 (0.980-0.999) (Figure 1b), suggesting that both physical and chemical processes may simultaneously affect and influence MO adsorption on the surface.

Interestingly, the adsorption capacity and rate revealed that the thermally treated sample was not significantly different from the $Ca(OH)_2$-activayted sample. The performances of SSs were in the order of Pyrolysis=Ca> K. These results involved in MO adsorption will be confirmed by the characterization techniques i.e., BET and Zeta potential.

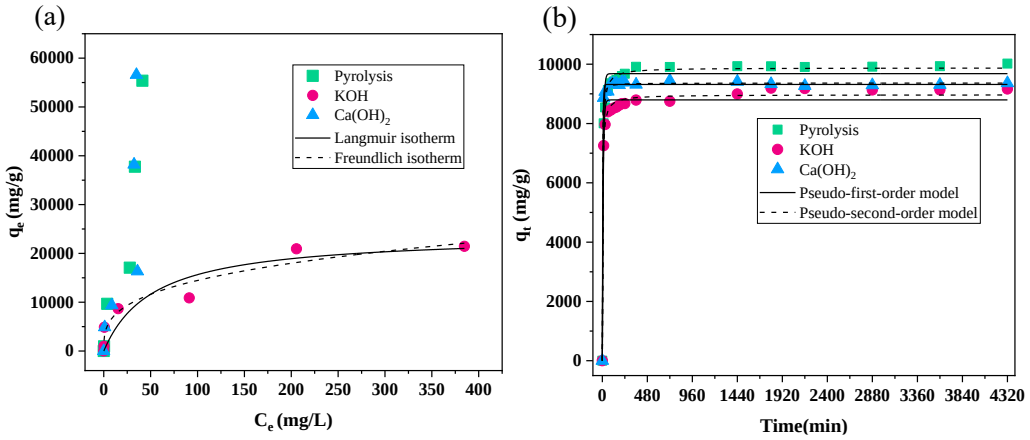

Figure 1. MO adsorption experiment results onto SSs (a) adsorption equilibrium data and (b) adsorption reaction kinetics (initial MO concentration= 10-600 mg/L; SSs dose= 2 g; initial pH = 5; volume= 200 mL; temperature= 22 °C; adsorption time= 4320 min (72 h))

CONCLUSION

SSs was prepared and performed as a highly efficient adsorbent to remove anionic dyes. The sample treated with pyrolysis only and $Ca(OH)_2$ activation provided a greater affinity for negative MO. Through the fitted model, the adsorption that occur on the surface of SSs are possibly both physical and chemical processes.

ACKNOWLEDGEMENT

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Effect of alkaline-treated coal fly ash on water evaporation mitigation capacity of soil: A preliminary trial

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Keywords: coal fly ash, potassium hydroxide, water evaporation mitigation capacity

INTRODUCTION

As a byproduct of coal combustion, coal fly ash (CFA) accounts for 60-90% waste residue in thermal power plant (Dindi et al., 2019). The complex chemical composition and current low-grade utilization of CFA causes land waste and environmental pollution (Han et al., 2016). Consequently, high-grade management of CFA is necessary to eliminate its negative impact on eco-system and human health. As home of over 38% population in the world, arid and semi-arid area feature of seasonal or permanent water deficiency. In addition, high temperature in this area makes the soil-holding-water evaporate quickly, leading to low soil moisture. Whereas, the requirement of water for crop in specific grow and develop stage is higher than the remaining water available in the soil, resulting in low crop productivity and reduced biodiversity in arid and semi-arid areas. Therefore, to meet the food demand of the increasing world population, it is urgent to prevent water evaporation from soil to keep moisture required for crop growth. Soil amendment is expected to ameliorate soil for both soil moisture and fertility.

Recent researchers found that CFA was effective to improve water retention capacity in soil. However, CFA amendment was limited to increase soil water holding capacity and prevent water evaporation in soil (Song et al., 2020). Therefore, it is essential to treat CFA that can increase water holding capacity in soil significantly. In this study, we treated CFA with potassium hydroxide (KOH) to evaluate the effect of treated CFA on water mitigation capacity in soil.

MATERIALS AND METHODS

Before treatment, CFA was dried in an oven 105 °C for 24 h. Then, KOH and CFA was mixed at different ratios, and 2 g deionized water was also added into the mixture. After 10 min standing time, mixtures in crucibles were calcinated in a muffle furnace at 500 °C for 1 h, and the calcinated residue was collected for further analysis.

Akatama soil was used in this study, which was crushed and sieved smaller than 75 μm. Before evaporation mitigation capacity (EMC) test, CFA, KOH modified CFA and soil were dried in an oven at 105 °C for 24 h to eliminate moisture inference. Then soil was mixed with raw CFA (R-CFA), calcinated-CFA (C-CFA), calcinated KOH-modified CFA (KOH:CFA=1:1 (KC11), KOH:CFA=2:1 (KC21), KOH:CFA=3:1 (KC31)), and calcinated-KOH (C-KOH) at a ratio of 4:1, repectively. The initial DI water added in mixed soil was 34.96 %. 36 h weight

measurement was conducted with 2 h interval to estimate water evaporation capacity of mixed soil in nature temperature and 40 °C.

RESULTS AND DISCUSSION

As shown in **Fig 1**, the addition of KOH improved the water EMC of soil in natural temperature. However, the highest blending ration of KOH led to the lowest EMC of soil.

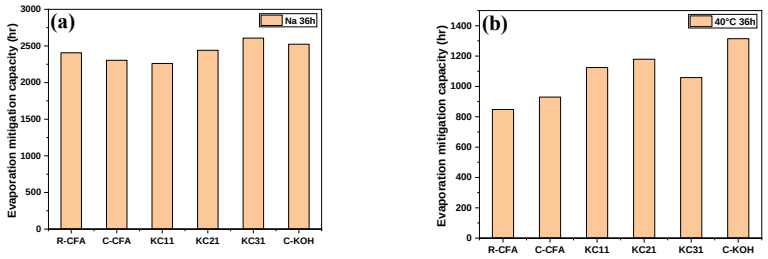

Figure 1 Evaporation mitigation capacity with KOH treated CFA amendment in (a) nature temperature and (b) 40°C

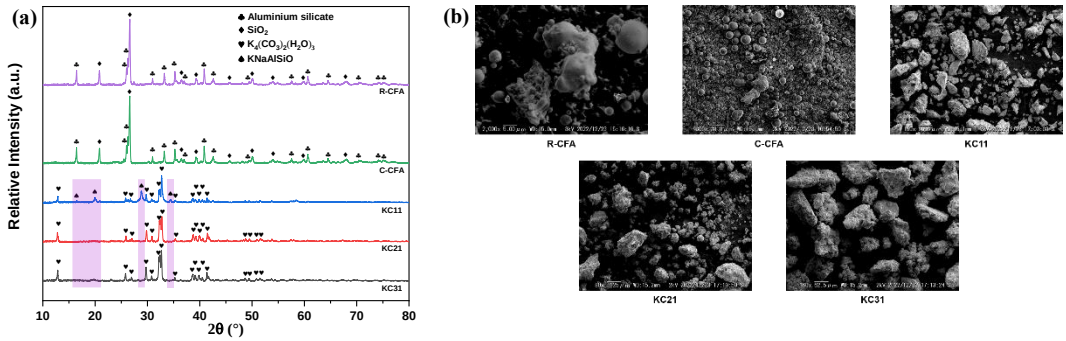

Figure 2 (a) XRD analysis result and (b) SEM observation with KOH treated CFA amendment

Fig 2 (a) indicates that KOH modification produced $K_4(CO_3)_2(H_2O)_3$ at the expense of SiO_2 and aluminum silicate. As shown in **Fig 2 (b)**, increasing addition of KOH led to the accumulation of angular particles, conversely the smooth ball-like particles were disappeared in R-CFA and C-CFA, confirming the appearance of $K_4(CO_3)_2(H_2O)_3$.

CONCLUSION

The water EMC of soil was improved with the addition of KOH modified CFA. However, the blending ratio of KOH resulted in different water EMC under natural and 40 ° C temperature.

ACKNOWLEDGEMENT

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Stochastic estimation of location-independence earthquake disaster risk of temporal storage facility of mercury wastes

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Keywords: mercury, earthquake disaster risk, temporal storage, stochastic approach

INTRODUCTION

According to The Minamata convention on mercury, phase-out of mercury applications means that mercury used in society should be collected and long-term safe storage of collected mercury is also necessary in near future. Mercury storage in engineered landfill sites is one option in terms of cost and environmental safety. On the other hand, environmental risk of mercury landfill disposal should be carefully assessed, in particular earthquake regions like Japan. Seismic impact on landfill site safety or durability has been concerned [Krinitzsky et al; 1997]. In addition, the site selection is also socially concerned [Yesilnacar and Cetin; 2005]. Landfill site selection is a complex difficulty in which many factors should be considered [Aksoy and San; 2019]. One of important factors for site selection or screening is Not-In-My-Backyard (NIMBY) syndrome, in other word, public opposition toward landfill site construction [Kontos et al; 2003]. Due to strongly negative attitude toward site screening, pre-assessment of environmental risk for mercury final disposal (landfilling) in candidate sites might cause public confusion and/or miscommunication. On the other hand, geological information of potential landfill sites is necessary for appropriate assessment of earthquake-induced environmental risk of mercury landfill disposal. In order to overcome this paradoxical problem, this study developed a stochastic method to estimate earthquake disaster risk of mercury landfilling without site selection.

MATERIALS AND METHODS

Risk scenario of mercury emission to the environment caused by a big earthquake

This study considered a risk scenario of mercury release event to the environment. In this scenario, mercury storage facility on the ground near landfill site will be hit by a big earthquake. Due to facility destruction, mercury containers will be transferred unintentionally to the environment. Because of container damages, mercury will be emitted from the containers by rain water penetration.

Stochastic approach to estimate the probability of big earthquake hit to mercury storage facility

This work does not take any site-specific scenario for mercury risk estimation. Earthquake event with magnitude more than 6.5 were screened and then the event data (location, hypocentral depth, and magnitude) were extracted around main land Japan. Using these statistical distributions, the probability of a earthquake event at specific time and location can be predicted stochastically as well as the earthquake magnitude and distances to specific location.

Stochastic approach to estimate the destruction probability of mercury storage facility caused by big earthquake hit

This work used empirical response spectrum with 5 % distance attenuation of each earthquake event. Even

when acceleration response spectrum of an earthquake event exceeds maximum durable acceleration response spectrum determined by limit horizontal strength calculation, it does not result in inevitable destruction of mercury storage facility. According to destruction survey of houses and buildings hit by Southern Hyogo earthquake in 1995, the probability of facility destruction was estimated.

Stochastic approach to estimate mercury release from storage containers to the environment via rain water penetration and exposure to human bodies

135-year precipitation data in Tokyo from 1880 to 2015 were used for the Stochastic approach to estimate mercury release from storage containers to the environment. The cumulative amount of released mercury and its probability were calculated for mercury risk assessment.

RESULTS AND DISCUSSION

Cumulative mercury release from a damaged mercury container via rainfall to the environment was estimated to range 0.138 to 41.5 mg-Hg as 25-75 percentiles during 100 years emission. When continuous mercury emissions for 1000 years was assumed, mercury exposure distributions to human bodies estimated in this study was shown in Fig. 1. It proposes that the probability of risk concerned cases, in which mercury exposure exceeds the tolerable intake, is less than 0.01 %.

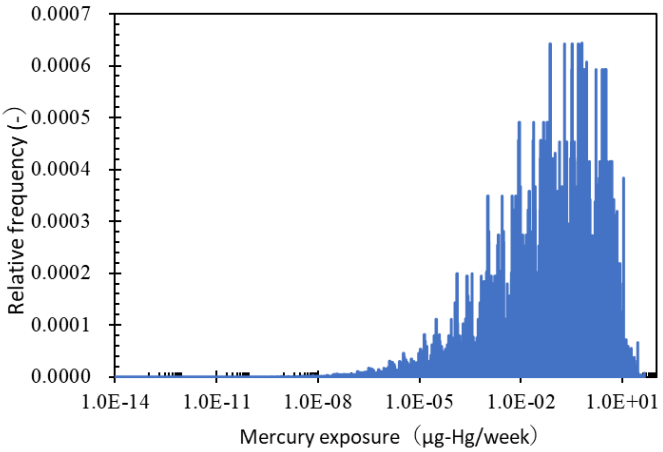

Fig. 1 Mercury exposure after 1000 years mercury releases

CONCLUSION

This study developed a stochastic method to estimate mercury emission risk caused by a large earthquake event without site selection of mercury waste landfill site. The results suggest that mercury risk is negligible even after a large earthquake hit when mercury stabilization treatment is sufficient.

ACKNOWLEDGEMENT

This research was supported by Environment Research and Technology Development Funds (3-1701 and SII-6-1(2) (JPMEERF20S20602)) by MOE, Japan.

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Time-trend and categorical analysis of artworks which use wastes

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Keywords: time-trend analysis, categorical analysis, artworks which use wastes, waste recycling

INTRODUCTION

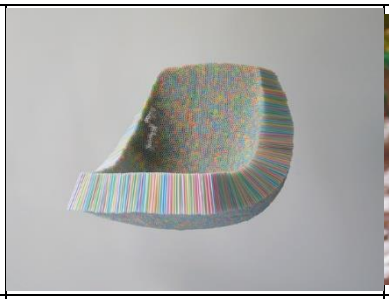
In the research field of waste recycling, many works have focused on technology development, and the research on the psychological factors that hinder recycling is not enough. There is enormous potential to use the arts to promote sustainable development. Chong-Wen Chen mentioned that some factors of artistic thinking can promote sustainable behavior. In recent years, many artists have used waste to create artworks, but their efforts have not been noticed by the academic community. What is the purpose of their works and how their works affected people is still unclear. To understand the characteristics of these artworks, we collected some examples of artworks using wastes and performed time-trend and categorical analysis on them.

MATERIALS AND METHODS

We found papers in the field of waste recycling from the web of science, and counted the number of papers related to art. By using KH Coder to analyze the abstracts of papers in the field of waste recycling, the change of research hotspots in the field of waste recycling since 1983 is investigated.

For each artwork, we collected their name, material, production method, art form, idea, production time, author, author's brief introduction and source. To understand the characteristics of artworks, we have classified these works by the materials used and the production methods, arranged them by year and illustrated them.

Table 1 Examples of artworks which use wastes

Image			
Name	**CLUTCH CHAIR AND LIGHT**	**YES IN MY BACK YARD!**	**Turn Off the Plastic Tap**
Material	Plastic (straws)	Plastic (bottles)	Plastic (tubs, containers)
Environmental Concerns	Waste of resources	Unspecified	Plastic pollution
Time	2008	2015	2021

RESULTS AND DISCUSSION

In the field of waste recycling, the amount of art-related researches is very small. According to the analysis results of KH Coder, there have been many studies on recycling of plastics in the field of waste recycling in recent years.

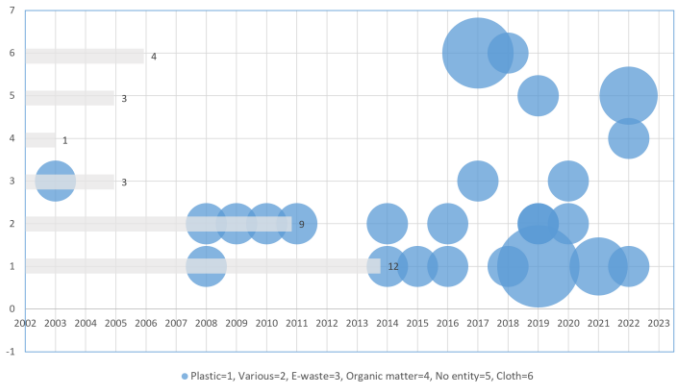


Figure 1 Material used in artworks

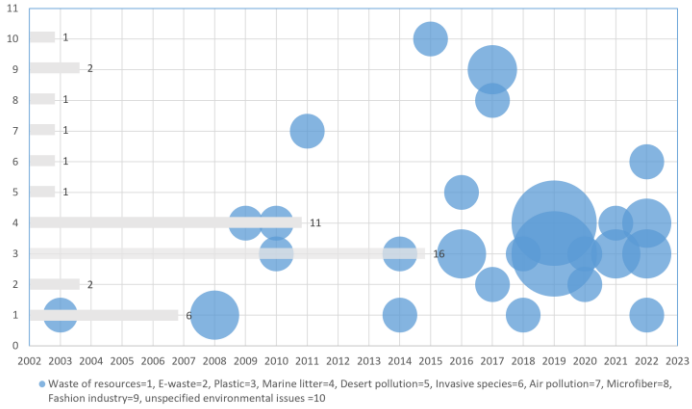


Figure 2 What environmental issues does the work care about?

As shown in Figure 1, the number of artworks using plastic waste is the largest, and there is an increasing trend in recent years. Figure 2 shows that the artworks which concerned plastic pollution are the most, and there is an increasing trend in recent years. From these two pictures, we can understand that the art world has also paid great attention to plastic pollution in recent years.

CONCLUSION

Both academia and the art world have paid close attention to the issue of plastic pollution in recent years, but the efforts of the art world have not been noticed by the academia. I think artworks which use wastes have much more to explore. In future research, I will continue to analyze the characteristics of artworks which use wastes and try to find ways to use them to contribute to waste disposal.

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Environmental impacts estimation of printed circuit boards recycling scenarios in Thailand

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Keywords: printed circuit boards recycling, waste recycling, waste electrical and electronic equipment, environmental impacts

INTRODUCTION

Printed circuit boards (PCBs) are one of the most economically valuable components of electronic and electrical devices due to the high concentration of precious metals like gold and silver. Unfortunately, only 20% of end-of-life electrical and electronic devices are officially documented to be collected and recycled worldwide. The other 80% is not documented, either left in household, thrown to illegal dumping site, or recycled in inferior conditions by informal sectors. Unregulated dumping to landfill leads to ecological damage from heavy metals and toxic elements. Furthermore, recycling WPCBs (waste PCBs) which contain hazardous compounds with unregulated inferior technology could lead to negative impacts including health hazard to workers. Not only that recycling of waste PCBs can prevent these negatives impacts, but it can also reduce the dependency on metal extraction from mining activity which is considered non-renewable and might be depleted in the future. This study aims to estimate the environmental impacts including greenhouse gas emissions, energy consumption, water consumption and chemical reagent consumption of waste PCBs recycling scenarios in Thailand.

SCOPE OF THE STUDY AND METHODS

In this study, we compare the environmental impacts of two scenarios of waste printed circuit board management in Thailand. The source of waste PCBs are the PCBs from the end-of-life mobile phones and personal computers from household sector in Thailand. The two scenarios considered in this study are the following.

Scenario 1: No recycling of waste printed circuit boards. After the end-of-life, all waste PCBs go to landfills.

Scenario 2: All waste printed circuit boards from mobile phones and personal computers from household sector in Thailand is recycled after the end-of-life.

The processes considered in this are metal extraction from mining, WPCB collection/transportation, WPCB recycling and disposal of untreated WPCBs . The recycling method considered in this study is hydrometallurgy as it is one of the most sustainable methods used on an industrial scale. The environmental impacts considered in this study are greenhouse gas emissions, water consumption and chemical reagent consumption. The reuse of metals from recovered metals is also considered.

This study aims to address the uncertainty of variables and models used to estimate the environmental impacts using Monte Carlo simulation. Monte Carlo simulation builds models of possible results by substituting a range of input values – called a probability distribution – then calculates the results over and

over, yielding a result in the form of probability distribution. Several data points variables are collected to build probability distributions for inputs to be used in the estimation of environmental impacts of WPCB recycling.

RESULTS AND DISCUSSION

Recoverable metals from WPCB recycling

In the scenario 2 where all WPCBs from mobile phones and personal computers in Thailand is recycled, we can recover several metals. Copper is the richest metal in PCBs and its recoverable amount in a year is shown Figure 1 as a probabilistic distribution. The mean value of recoverable copper is 247.91 tons/year. On the other hand, gold, while not the richest metal in PCB, is a the most valuable metal even with tiny amount. Figure 2 shows the probability distribution of estimated recoverable amount of gold from WPCBs in a year. The mean value of recoverable gold is 0.5810 tons/year.

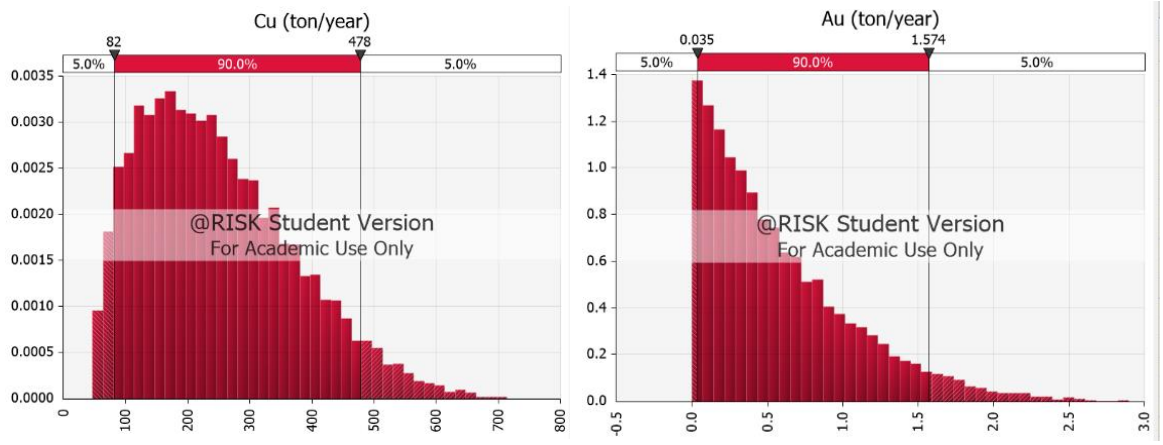

Figure 1 and 2 Recoverable copper and gold from WPCBs from mobile phones and personal computers in a year

CONCLUSION

This study aimed to estimate the environmental impacts from the recycling of waste printed circuit boards from mobile phones and personal computers from household sector in Thailand, and compare the environmental impacts of scenarios with and without the recycling process. Recycling of WPCBs obtains a large number of metals which help reduce the dependency of imported metals and reduce the needs of metal mining which contributes to several environmental impacts. Furthermore, carbon dioxide emission is the most prominent environmental impact presented in WPCBs recycling resulting from all process; metal extraction from mining, WPCB collection, and WPCB recycling.

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Paper or bioplastic bags for food waste collection: a comprehensive assessment

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Keywords: collection bags, anaerobic digestion, BMP, Life Cycle Assessment

INTRODUCTION

More than 7 million tonnes of organic fraction were separately collected in Italy in 2019, following a robust increasing trend. Its treatment is progressively shifting towards anaerobic digestion instead of composting, with about 3 million tonnes currently being processed in integrated anaerobic/aerobic treatment plants or in purely anaerobic ones.

The type of bag used for the organic waste collection is crucial in determining the overall performance of the system, since there is a mounting evidence that bioplastic bags, especially in the form of shoppers, might cause problems during the anaerobic treatment. On the other hand, paper bags allow for a smoother operation of the plant, since they don't need to be removed upstream.

This project aims to analyse the environmental performances of the full treatment chain of the organic waste processed with anaerobic digestion, starting from the assessment of the weight losses during the household storage, and the considering the different behaviour of the bags at the treatment plant.

MATERIALS AND METHODS

Household storage tests

The food waste weight loss during the household storage was analysed by adopting a dynamic, progressive bag filling. In two years, 112 domestic tests were performed in parallel to compare paper and bioplastic bags behaviour: 59 paper vs. bioplastic dedicated bags and 53 paper vs. bioplastic shopper bags. Each test lasted 5 days. Six bags (three dedicated and three shopper bags) manufactured by different companies were tested. The analyses were performed during the different seasons and by different households in order to consider various eating habits.

Evaluation of the anaerobic degradation of food waste collection bags

Preliminary biochemical methane potential (BMP) tests were performed to evaluate the anaerobic degradability and the corresponding biomethane yield of the three bag typologies (paper bag made of recycled fibres - PB, one bioplastic dedicated bag - BDB, and one bioplastic shopper bag - BSB). Bags were manually cut in square pieces of 1 cm side and the tests were performed both under mesophilic (35 ± 0.5°C) and thermophilic conditions (50 ± 0.5°C), with inoculum sampled from full-scale AD plants processing food waste. Then additional lab-scale tests were carried out, consisting of semi-continuous co-digestion with food waste. They were performed on two out of the four bioplastic bags and on the paper bag. The extracted digestates were sieved (2 mm) to recover undigested pieces of bags. All the residual bioplastic pieces were washed with

water, dried at 35°C, and weighed to evaluate their mass losses during the digestion. Moreover, undigested pieces with a surface equal to at least ¾ of that of the input were recovered and counted.

Life Cycle Assessment

The environmental performances of the management chain of the food waste collected from households were evaluated, by means of the LCA methodology, comparing two systems in which the employed collection bags are respectively made of bioplastic and paper. The management of 1 kg of food waste generated at the household was assumed as functional unit. The system boundary included the overall food waste management chain.

RESULTS AND DISCUSSION

Bioplastic and paper collection bags showed a different behaviour during the household storage tests, with paper allowing for higher weight losses: +29% and +44% on average, compared respectively to bioplastic dedicated and shopper bags.

The preliminary BMP assays showed a very limited anaerobic degradability of bioplastic bags (9%-15%) under mesophilic conditions, while thermophilic conditions allowed for a good degradability (>71%), although obtained after more than 40 days. On the contrary, the degradation of paper is much faster, with 90% of the final BMP reached in six days. The semi-continuous co-digestion tests showed once again a low anaerobic degradability of bioplastic bags (<27%), while the anaerobic degradability of the paper bag (82%) resulted even higher than that observed in the BMP tests (74%).

Finally, the comparative LCA highlighted a beneficial influence of the use of recycled paper bags instead of bioplastic bags, in particular the dedicated ones. Shopper bioplastic bags are less impacting than dedicated ones because they are used, as the first purpose, for carrying the grocery shopping, meaning that only 50% of the impacts related to their production end of life treatment are included in the analysed system. The benefits of the use of paper bags are associated to both the bag manufacturing (less impacting, especially thanks to the use of recycled fibres) and the benefits in the AD treatment, since they are not discarded during pre-treatments, differently from bioplastic bags.

CONCLUSIONS

The use of paper bags for the food waste collection should be encouraged because of a number of advantages. First, the reduction of the amount of waste to be collected and the lower odour and leachate release at the household allows for a decrease of the collection frequency, then reducing the environmental impacts. As regards the food waste treatment process, paper bags showed a better compatibility with the AD process than bioplastic bags, which are generally discarded as residues. Moreover, the use of paper bags allows for an 8% increase in the methane production per mass unit of food waste in addition to that obtained from the sole food waste digestion. Finally, the use of paper bags allows for the reduction of the potential environmental impacts of the full value chain of food waste management when compared to the use of bioplastic bags.

Improvement of H_2S selective oxidation using N-doped mesoporous carbon catalyst

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Keywords: Hydrogen sulfide(H_2S); Selective catalytic oxidation (SCO); Nitrogen-doped mesoporous activated carbon (NDC)

INTRODUCTION

Hydrogen sulfide (H_2S) is harmful to humans and damages buildings, so it needs to be properly removed prior to being emitted to the environment. H_2S is emitted from various industrial activities such as petroleum refining, various chemical processes, landfills, and biogas refining processes. Among them, our research proceeds with a focus on the treatment of H_2S generated from landfills. Selective catalytic oxidation is an eco-friendly and economic strategy to remove H_2S by converting it into elemental sulfur using metal or non-metal catalysts. Catalytic activity can be increased by using nitrogen-doped carbon (NDC) as a catalyst because some of the lattice carbon is replaced with nitrogen. And the NDC catalyst activates the catalytic reaction for removing H_2S by improving the electron mobility on the surface of the carbon. Compared to microporous carbon, the mesoporous NDC catalyst facilitates the mass transfer and improves the catalytic reaction. In this study, we aimed to prepare a nitrogen-doped mesoporous carbon catalyst using biochar by using a salt template method to improve the performance of selective catalytic oxidation of H_2S.

MATERIALS AND METHODS

Catalyst preparation (NDC-PZ-0.5)

A series of NDC catalysts was prepared using the Salt Templating method using biochar (MYPLANT, Wood charcoal 95%, Water 5%) as a carbon precursor, melamine (SAMCHUN, 99%) as a nitrogen precursor, and a mixture of KCl (SAMCHUN, 99%) and $ZnCl_2$ (DUKSAN, 98.0%) with 51 mol% KCl used as the pore former (PZ). The dried and mixed biochar powder (2.90g), melamine (1.45g), PZ (7.53 g KCl + 13.36 g $ZnCl_2$) were put in a tube furnace for carbonization and calcination under a nitrogen atmosphere with a flow rate of 200 mL/min. The temperature was increased to 240 °C (3 °C/min) and held for 4 h for carbonation and increased to 800 °C (3 °C/min) and held for 2 h for calcination. Afterward, the tube furnace was cooled down to room temperature. The collected product was ground into powder (60 ~ 170 mesh), washed with HCl, NaOH, and hot deionized water to remove the remaining salts, and finally filtered. The catalyst was dried in an oven at 80 °C for 2 days and then used for catalytic testing.

RESULTS AND DISCUSSION

Catalytic test

The catalyst (0.1g) was loaded in a fixed-bed quartz reactor, and a feed gas with 1.0 vol% of H_2S, whose concentration is similar to that of landfill gases, was flowed to the catalyst with a flow rate of 250 mL/min.

Figure 1 shows the results of catalytic tests with varied temperature (40 ~ 160 °C). When melamine/biochar ratio is increased, H_2S conversion rate (%) is increased. i.e., NDC-PZ- 0 << NDC-PZ-0.5 < NDC-PZ-1 < NDC-PZ-2 (Average 96.91%, Maximum 100 % at 120 °C). The S selectivity is excellent (> 90 %) over the temperature range and The S yield (%) increases as the melamine/biochar ratio increases and shows a similar trend of the H_2S conversion rate (%).

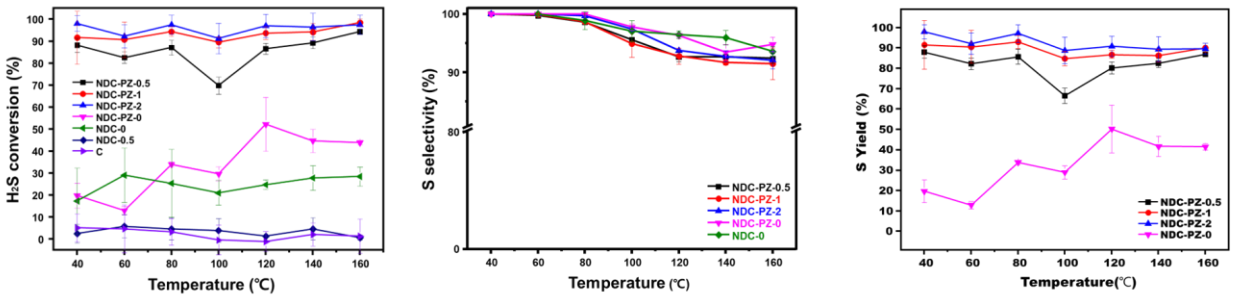

Figure 1 The results of catalytic test with varied temperature (40 ~ 160 °C)

CONCLUSION

The dominant factor influencing the H_2S removal performance is the nitrogen content rather than the pore structure. Catalysts with high nitrogen content can activate the catalytic reaction for H_2S removal by improving the electron mobility on the surface of activated carbon, and the higher the nitrogen content results, the better the performance. Because of the combined effect between PZ and nitrogen content, NDC-PZ-2 exhibits high S_{BET} (1541.26 m^2/g), V_t, V_{mic}, V_{meso} (32.10, 6.84, 25.17 cm^3/g), and high H_2S conversion (100 %), S selectivity (93.88 %) and S yield (93.70 %) at the low temperature of 120 °C.

ACKNOWLEDGEMENT

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Preparation of adsorbent by surface modification for heavy metal adsorption using PET waste

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Keywords: PET waste, KOH activation, acid treatment, functional group

INTRODUCTION

One of the effective methods for removing heavy metals from aqueous solutions is adsorption. Biochar is a promising substance used to adsorb various pollutants such as heavy metal ions and toxic substances. Since biochar without any modification usually have a lower adsorption capacity for contaminants than commercial activated carbon, additional physical or chemical treatment are required to improve adsorption capacity.

Biochar modification to improve adsorption ability includes acid/base treatment. For acid treatment, the porous structure of biochar is modified, and lactone, phenol, and carbonyl functional groups can be introduced. In addition, when treated with a base, the surface basicity is enhanced by the increase of hydroxyl group, resulting in the promotion of metal ion precipitaion.

The purpose of this study is to develop an effective adsorbent for removing heavy metals through surface modification through acid/base treatment. In this study, PET waste was selected as a precursor for biochar production because it is a low-cost biomass.

MATERIALS AND METHODS

1. PET pyrolysis for biochar production

PET(Polyethylene terephthalate) waste bottle was used as the material. After removing impurities with distilled water, it was dried in an oven at 70°C for 24 hours. Thereafter, PET using a blender, the particle size was ground to less than 5mm. An electric furnace was used to pyrolyze at 600°C (5°C/min) for 1 hour under a limited oxygen condition using nitrogen flow.

2. KOH Activation and Acid Treatment for Functional Group Generation

For KOH activation, the sample was impregnated in 8 M KOH solution and mixed using a magnetic stirrer for 1 hour. After that, it was filtered using a vacuum filter and dried in an oven at 70°C for 6 hours. The moisture-removed sample was activated in an electric furnace at 600°C (5°C/min) for 1 hour. It was washed with ethanol and distilled water to remove impurities in the sample, until the pH becomes neutral. For acid treatment, the sample and a 0.1 M HCl solution were mixed and stirred using a magnetic stirrer for 2 hours. After that, it was filtered, dried, and washed as the above procedure. Table 1 shows information of different sample to find out the effects of KOH activation and acid treatment.

Sample	KOH activation	HCl treatment
P	X	X
P-KOH	O	X
P-HCl	X	O
P-KOH-HCl	O	O

Table 1. Name of sample according to KOH activation/HCl treatment

RESULTS AND DISCUSSION

Four samples were analyzed in the FTIR spectrum to observe the functional groups on the sample surface. All four samples contain oxygen-containing surface group (C=O, C-O, -OH) and C≡C, C=C, $-CH_2$, $-CH_3$, aromatic ring, and the like. However, samples undergoing KOH impregnation or HCl treatment process show richer functional groups on the surface than samples without two processes. For example, samples subjected to HCl treatment can observe carboxyl, hydroxyl, and phenol groups. According to several papers, it has been reported that the generation of additional functional groups by acid/base treatment has a positive effect on the adsorption of heavy metals (Cu^{2+}, Pb^{2+}, Cd^{2+}, etc.).

CONCLUSION

The adsorption of heavy metals using adsorbents may be affected by various factors such as electrostatic attraction, cation exchange ability, and surface functional groups. The surface functional group can be reformed through acid/base treatment, and in addition, the acid/base treatment increases the performance of the adsorbent by influencing various things such as particle size, micropore generation, impurity removal, etc. In subsequent studies, it is necessary to identify the adsorption characteristics and mechanism of heavy metals using adsorbents modified by this method.

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Redox transformation of As reacted with redox-activated natural clay minerals

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Keywords: Redox-active nontronite, Arsenic removal, Fe-rich clay mineral, Fe(II)/Fe(III) redox couple

INTRODUCTION

Clay minerals are commonly found component in soils and sediment and are considered as an essential chemical player due to their roles as adsorbents for toxic trace metals. Researches on sorption properties of smectite clay minerals has been extensively conducted to examine their applicability in reducing contaminants. One of the 2:1 phyllosilicate clay minerals, nontronite consists of sandwiched one octahedral sheet in two tetrahedral sheets, containing iron (Fe) approximately up to 30 % substituting for aluminum (Al) or silicon (Si). Iron (Fe) is the second largest element contained in nontronite (referred as Fe-bearing clay mineral) and ubiquitous element in natural environment as well. Also, the Fe redox couple (Fe(II)/Fe(III)) of structural Fe in clay mineral plays an essential role in controlling the biogeochemical behavior or toxicity of redox-sensitive elements under oxic or anoxic soil environments. In this study, redox transformation of arsenic (As) by redox-activated natural nontronites was examined under oxic and anoxic conditions to understand reaction mechanisms of As on activated clay mineral surfaces.

MATERIALS AND METHODS

Nontronite NAu1 purification and batch experiments for As redox transformation

Ammonium acetate-acetic acid, NaCl, and deionized water were added in size-fractionated nontronite NAu1 to remove carbonate impurities and saturate the interlayer with Na^+, respectively. Four kinds of redox-active nontronites were prepared after purification using several different activation methods: 1) Natural nontronite NAu1 (NAT), 2) treated with citrate-bicarbonate-dithionite solutions (CBD), 3) aqueous Fe(II) added using ammonium iron (II) sulfate (FAS), and 4) aqueous Fe(II) added using iron chloride (FC). Sodium (meta)arsenite (As(III)) and sodium arsenate dibasic heptahydrate (As(V)) were prepared and spiked to 1.3 mM in each suspensions. The eight kinds of batches were sampled after 24 h and 7 day, respectively.

Solid and aqueous phase analysis

X-ray powder diffraction (XRD) and X-ray photoelectron spectroscopy (XPS) analysis were conducted for clay mineral characterizations and to detect Fe(II)/Fe(III) ratio in activated nontronites. Also, aqueous phase speciation of As was conducted using Bond Elut C18 Solid Phase Extraction cartridge and inductively coupled plasma-optical emission spectroscopy (ICP-OES).

RESULTS AND DISCUSSION

XRD results for redox-active nontronites

Figure 1 shows the X-ray diffraction patterns collected on each redox-active nontronite. The 001 and 060 peaks in all samples corresponds to the d-spacing of 12.07-12.58 Å and 1.52-1.53 Å, respectively. Also,

the 060 peak for reduced-active nontronites (CBD, FAS, and FC) is shifted to the lower 2θ value and the larger d-spacing compared to natural nontronite (NAT). These indicate that there are some trioctahedral domains present in octahedral sheet of reduced-active nontronites compared to natural nontronite which is only dioctahedral exists.

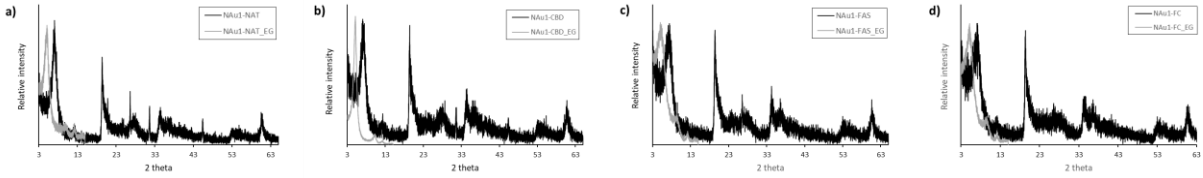

Figure 1. X-ray diffraction patterns collected on a) NAT, b) CBD, c) FAS, and d) FC.

Fe2p XPS spectra of redox-active nontronite

XPS data collect for NAT, CBD, FAS, and FC are shown in Figure 2. The spectra of Fe(II) and Fe(III) peaks presented un up to 709.3 eV and at 711~715 eV, respectively. The CBD sample has the largest Fe(II) ratio (18.2%), and the aqueous Fe(II) added samples contain 9% in FAS and 13.2% in FC, respectively. Significant contribution of Fe(II) is confirmed in reduced-active nontronite.

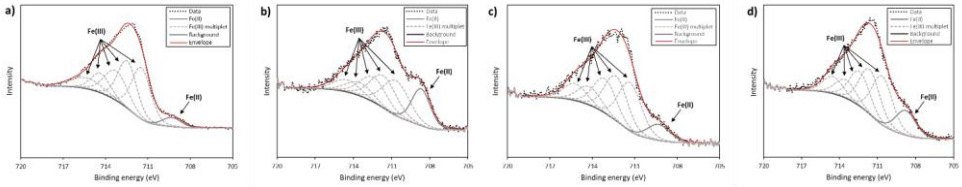

Figure 2. X-ray photoelectron spectra of a) NAT, b) CBD, c) FAS, and d) FC.

Aqueous phase As speciation

As(III) concentration could be calculated by subtracting the concentration of As(V) from the concentration of total As. The results of high adsorption of As(III) on FAS and FC indicate that there is more adsorption sites on aqueous Fe(II) added nontronites surfaces than other nontronites. Also, part of As(III) oxidation happened after 7 d due to the formation of reactive Fe(III) species with Fe(II) addition. Additionally, As(V) spiked in FAS and FC samples showed strong adsorption of As(V) than CBD-treated nontronite which is more reduced owing to high affinity of As(V) for mineral surfaces than As(III).

CONCLUSION

This study aimed to understand As transformation using redox-active nontronite. Redox-active nontronites can be activated by either partial reduction or addition of aqueous Fe(II) and still maintained characteristics of nontronite after activation. A significant contribution of Fe(II) is confirmed in reduced-active nontronite, and more As adsorption on aqueous Fe(II) added nontronites was observed than natural and CBD-treated nontronite. This work will contribute to the fundamental understanding of the mobility and fate of other redox-sensitive elements with Fe-containing clay minerals.

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Synthesis of High Iron-containing Clay Minerals for Removal of Arsenic from groundwater

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Keywords: Clay minerals, hydrothermal synthesis, arsenic removal

INTRODUCTION

The surface of a clay mineral particle is known to adsorb ions that are opposite in surface electrical charge and polarity. This property is useful for removing heavy metal contaminants, and especially iron-rich clay minerals are effective for removing arsenic. In this research, laboratory synthesis method of clay minerals was developed and the arsenic removal capability and characteristics were investigated using the synthesized clay minerals. To synthesize the iron-enhanced clay mineral with high ratio of Fe^{2+} to total Fe content, hydrothermal synthesis was performed followed by filtering and drying process under anoxic conditions. The characterization of synthesis materials and their arsenic removal will be performed in comparison with nontronite, an iron-bearing natural clay mineral.

MATERIALS AND METHODS

Reagent preparation

Hydrothermal synthesis was conducted based on Ilgen et al. (2017)'s method by mixing two different solutions, solution A ad solution B as prepared as a silicate- and iron- precursor, respectively. Reagent A was prepared by mixing 28.835 g of H_4SiO_4 and 60 g of NaOH in a 1 L volume flask and stirred at room temperature for 24 hours. The preparation of reagent B was conducted in a glovebox (96% N_2/4% H_2) to avoid oxygen contact. Reagent B was prepared by dissolving 2 g of sodium dithionite in a 25 mL volume flask of deoxygenated H_2O. Then 6.71g of $FeCl_2 \cdot 4H_2O$ (or 9.385 g $FeSO_4 \cdot 7H_2O$) was added to a sodium dithionite solution and diluted in a 50 mL volumetric flask with deoxygenated H_2O.

Hydrothermal synthesis

After mixing 150 mL of reagent A and 50 mL of reagent B, the mixed solution was moved to a hydrothermal reactor and was stayed still at 150 ℃ for 50 hours. The sample was then cooled and the supernatant was removed by centrifuging at 4000 rpm for 4min. The separated precipitate was washed with 1 M NaCl for three times to saturate the interlayer with Na^+ followed by washing three times with deionized water. After rinsing, the synthesized clay mineral was dried and stored at room temperature inside the anaerobic glovebox. The method of Ilgen et al. (2017) was used only $FeSO_4$ as iron precursor and conducted all procedure under ambient condition without oxygen control but this study applied an anaerobic condition after cooling of 150 ℃ reactor

to keep the sample out of oxygen contact until it used for an arsenic (As) adsorption experiment. Also this study used the 5 times concentration compared to that of Ilgen et al. (2017) to obtain higher amount of the sample.

Arsenic adsorption

The synthesized clay minerals were tested for determine their capacity as an adsorbent for As(III) and As(V) removal from solution. To prepare As(III) and As(V) contaminated water, Sodium (meta)arsenite ($NaAsO_2$) and sodium arsenate dibasic heptahydrate ($Na_2HAsO_4 \cdot 7H_2O$) were used for preparing stock solutions, respectively. The concentrations of 100 ppm As(III) or As(V) concentrations were applied in 5 g/L suspension of synthesized clay minerals. The adsorbed As concentrations from reaction batches were determined by measuring dissolved As concentrations after reacting 24 hours or 7 days.

RESULTS AND DISCUSSION

Figure 1. Sample color comparison between batches prepared under ambient conditions (left) and in an anaerobic glove box (right). The sample not exposed to oxygen shows a darker color.

Figure 1 shows a $FeCl_2$-type synthetic clay minerals prepared under different pretreatment conditions (washing/drying/storing), one with oxygen control (right) and without oxygen control (left). The different Fe^{2+}/Fe^{3+} ratios were expected based on their color difference. The Fe K-edge X-ray absorption spectroscopy will be conducted to estimate the Fe^{2+}/Fe^{3+} ratios from samples prepared different synthesis conditions. The As adsorption capacity is also expected to be varied with the controlled Fe^{2+}/Fe^{3+} ratio.

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