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1-3

Secondary 1 - 3

STEAM Activity Kit

"Design and Make": Upcycling of Waterworks Sludge

GREEN GOAL

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“Design and Make”: Upcycling of Waterworks Sludge

Introduction

Introduction

Objectives

- To cultivate students' keen observation, encourage them to keep abreast of current environmental issues and develop the mindset of engineering design for problem-solving, thereby developing the life-long learning and attitude through exploration.
- To cultivate students' abilities and skills in self-learning, innovative spirit, critical thinking and problem-solving, as well as the pursuit of scientific truth through the process of testing and modifying semi-finished products.
- To integrate engineering design with the 4R principles for upcycling waste to address current waste management issues.

Activity structure

Background	Massive amount of residues are generated from the treatment process in power plants, water treatment works, sewage treatment works and T·PARK (hereinafter referred to as "Public Utility"). Taking local water treatment works as an example, the water treatment process produces waterworks sludge (classified as special waste). In 2022, water treatment works generated approximately 87 tonnes of dewatered waterworks sludge per day which is disposed of at landfills. Since continuing the disposal of waterworks sludge at landfills is an unsustainable approach in waste management, reusing and upcycling these residues could alleviate the pressures on landfills. Apart from the waterworks sludge generated from water treatment works, sewage treatment works also generate a large amount of sewage sludge every day. Over a thousand tonnes of sewage sludge is generated in Hong Kong every day, and it reached 1 092 tonnes in 2022. At present, the daily treatment capacity of T·PARK is 2 000 tonnes of sewage sludge. With the adoption of the fluidised bed incineration technology, the volume of sludge is reduced by 90%, and the remaining ash and residues are disposed of at landfills. Despite the sewage sludge from major sewage treatment works managed by the Drainage Services Department has been treated by incineration at T· PARK, approximately 129 tonnes of ash and residues left in the incineration process still need to be disposed of at landfills every day. Upcycling of these residues could alleviate the burden on landfills and achieve the vision of "Zero Landfill". Moreover, recent researches have demonstrated the feasibility of replacing the conventional construction materials (e.g. sand, stone and cement) with the residues generated in the public utility (e.g. waterworks sludge, sewage sludge, incineration ash, furnace bottom ash, or pulverised fuel ash) for producing eco-materials. This could reduce the amount of waste disposed of at landfills. Yet, such upcycling process for producing functional eco-materials with these residues requires engineering designs and specific formulas.

Activity arrangements	STEAM is a cross-disciplinary teaching method which combines Science, Technology, Engineering, the Arts, and Mathematics. To promote life-wide learning, STEAM education is applied actively to strengthen students' ability to integrate and apply knowledge and skills within and across the Key Learning Areas (KLAs) of Science, Technology and Mathematics Education. Also, projects for students, as one approach, integrate relevant learning elements from different KLAs for organising learning activities.

Activity arrangements	The STEAM activity will focus on the residues generated from the treatment process of public utility, leading students to think critically and apply engineering design along with the 4R principles to address current waste management issues. Students will upcycle waterworks sludge generated from the water treatment process to eco-products for replacing conventional construction materials. Through adjusting the material ratios and modifying production process, the final upcycled product could fulfill the requirement of different engineering parameters and is compatible with different characteristics (e.g. hardness and water absorption).

KLAs	STEAM elements and activity design
Scientific exploration (Science)	Strengthen understanding of natural phenomena and objects through scientific theories, hypotheses, experiments, and testings • Understand the scientific principles of water absorbent coasters • Identify the factors affecting the strength and water absorption capacity of the eco-coasters, e.g. optimal material ratio of waterworks sludge to sand and the curing duration
Innovation and Technology (Technology)	Explore technology products, e.g. 3D printing, to strengthen students' scientific thinking and "hands-on and minds-on" ability, and to build a solid foundation of learning • Design and produce moulds for the eco-coasters using 3D printing
Engineering Practices (Engineering)	Review and improve the design through defining an engineering problem, prototyping and testing • Utilise the engineering design cycle to enhance the strength of eco-coasters • Review designs to identify the strengths and weaknesses for modification, e.g. optimal material ratio of waterworks sludge and the curing duration
Artistic creation (The Arts)	Integrated with the school-based curriculum of Visual Arts to cultivate students' creativity, imagination, and innovation • Incorporate personal and school features when designing 3D printing moulds • Make use of eco-coasters as art displays to be displayed at schools
Data processing (Mathematics)	Conduct scientific measurements, collect and record data using different methods, and then organise, analyse, and evaluate findings • Identify the optimal design through conducting experiments and recording data to evaluate whether the new design is superior to the original design

Activity arrangements	To facilitate smooth implementation of this STEAM activity ““Design and Make”: Upcycling of Waterworks Sludge” in schools, the Environmental Protection Department also provide this Activity Kit to facilitate the teachers to understand more on this activity.

Activity Kit

1. **Integrated Science Teaching Plan: Part I**
- Teacher can introduce the types of residues (e.g. waterworks sludge, sewage sludge, incineration ash, furnace bottom ash, and pulverised fuel ash) generated in public utility and their current disposal method in Hong Kong
- Teacher can explain the physical properties of waterworks sludge and conventional construction materials that can be replaced
- Teacher can provide examples of upcycling waterworks sludge
- Students to complete the ““Design and Make”: Upcycling of Waterworks Sludge” Student Worksheet

2. **Integrated Science Teaching Plan: Part II**
- Teacher can use examples of upcycling waterworks sludge to instill creative thinking among students
- Students can learn about the characteristics and production procedures of coasters through group discussions and information collection
- Students can design the production process and list out the experimental materials and tools required
- Students can present their works, and teacher can provide comments and recommend the improvement measure
- Students can modify the production process

3. **Upcycling Design Production Guideline**
- To understand the objectives and requirements of the experiment
- To learn and apply the concept of design cycle
- To learn the materials required and procedures for production of eco-coasters

4. **Experiment (I): Guideline on Determination of Material Ratio**
- To test out different material ratio of waterworks sludge and sand in the production of eco-coasters
- To determine the optimal material ratio of recycled materials (waterworks sludge) to conventional construction materials (sand)

5. **Experiment (II): Guideline on Determination of Curing Duration**
- To understand the curing method of eco-coasters (as a concrete product)
- To perform hardness test on eco-coasters
- To learn the methods for enhancing the hardness of eco-coasters

6. **Experiment (III): Guideline on Determination of Water Absorbency**
- To understand the similarities and differences between eco-coasters and market available coasters
- To compare the water absorbency level of eco-coasters and market available coasters

7. **Extended Activity – Production of Eco-acoustic Block**
- To explore other properties of waterworks sludge
- To explore the application of waterworks sludge in the community

Checklist - Design Cycle and Activity Kit of STEAM

Design cycle of STEAM	Self-learning stage	Guiding questions (Other questions could be added as appropriate)	Activity Kit
Identification of problems and needs	Goal Setting	• What problems are you currently facing? • What are the conditions to be considered when formulating a solution? • What are the constraints or difficulties encountered when solving this problem?	Integrated Science Teaching Plan: Part I
Information collection and organisation	Planning	• How do you solve this problem? • What knowledge or skills do you have that could help you to solve this problem? • What new knowledge or skills you need to learn? • How would you learn the necessary knowledge or skills?	Integrated Science Teaching Plan: Part II
Design development		• Based on your equipped knowledge or skills, how would you proceed for the design? • What do you need to pay attention to in the designing stage? • Are there any existing products in the market that you could make reference to? • How does your design look like, or any special design?	Integrated Science Teaching Plan: Part II
Production of eco-coaster	Practice	• What information, materials, tools, and equipment do you need to make your design? • How would you use these materials? • What problems will you encounter during the production process? How would you solve these problems?	Upcycling Design Production Guideline

Design cycle of STEAM	Self-learning stage	Guiding questions (Other questions could be added as appropriate)	Activity Kit
Testing	**Review, evaluate, and reflect**	• How would you use the provided experimental procedures to conduct the tests? • What data do you need to record? • What parameters do you need to measure? How to measure? What instruments should be used? • How would you present the test results?	**Experiment (I): Guideline on Determination of Material Ratio** **Experiment (II): Guideline on Determination of Curing Duration** **Experiment (III): Guideline on Determination of Water Absorption** **Lesson Activity – Eco-acoustic Block Activity Plan and Production Guideline**
Analysis and modification		• Could the test results prove the feasibility of your solution? If not, which parts have been missed out? • Do you think the test results are accurate and reliable? If not, what could be done to make it more accurate and reliable? • What do you need to change to modify your design or production process? • Do you need to collect more information before modifications?	
Presentation		• How would you present your product? • What can be presented or illustrated in your data and products?	

“Design and Make”: Upcycling of Waterworks Sludge

Teaching Plan

Form 1 to Form 3

"Design and Make": Upcycling of Waterworks Sludge

Integrated Science Teaching Plan: Part I

Topic:
Design Craft of Upcycling Waterworks Sludge I

Learning time:
35 minutes

Learning objectives

Skills

1. To upcycle waste into eco-products by adopting 4R principles

Knowledge

1. To understand the residues generated from the public utility and their current disposal method
2. To understand physical property of waterworks sludge and conventional construction materials that can be replaced
3. To learn examples of upcycling waterworks sludge
4. To understand the importance of defining the problems

Learning objectives	Time	Teaching flow	Teaching materials
	3 MINS	**Lead-in / Motivation** • Teacher can display photos of waterworks sludge, sewage sludge, incineration ash, furnace bottom ash, and pulverised fuel ash, and ask the students if they could identify the materials shown in the pictures	PowerPoint slides
1 **To understand the residues generated from the public utility and their current disposal method**	10 MINS	**Topic demonstration** **(Students could learn and work in groups)** **Understand the residues generated from the public utility** • Teacher can show the photos of waterworks sludge, sewage sludge, incineration ash, furnace bottom ash and pulverised fuel ash, and introduce their corresponding public utility • Teacher can introduce the disposal methods for different residues in Hong Kong, e.g. waterworks sludge, sewage sludge, incineration ash, furnace bottom ash and pulverised fuel ash • Teacher can illustrate relevant data of landfills, and raise questions on the current situation of landfills (landfills are nearing their full capacity). Then, teacher can guide students in understanding the current environmental issues and explore the possibility of reusing or upcycling the residues • Teacher can explain the 4R principle and definition of upcycling 1. Reduce : - Minimising the use of unnecessary items or energy 2. Reuse : - Reusing items before they become waste 3. Reuse : - Using eco-friendly items	PowerPoint slides

4. Recycle:
   - Separating waste for recycling and turning them into recycled materials
5. Upcycle:
   - Transforming waste into innovative new products with new values

- Teacher can outline the objectives and aim of this project, which is to use residues generated in the public utility (waterworks sludge) to replace some conventional construction materials (sand) and upcycle into eco-products (eco-coaster), thereby reducing the disposal quantity of residues

2

To understand physical property of waterworks sludge and conventional construction materials that can be replaced

10 MINS

Understand waterworks sludge

- Teacher can present a sample of waterworks sludge for groups observation and discussion on physical properties and conventional construction materials that can be replaced
- Teacher should emphasis that waterworks sludge is selected in this project due to safety reasons

PowerPoint slides

waterworks sludge

3

To learn examples of waterworks sludge upcycling

5 MINS

Upcycling of waterworks sludge

- Teacher can display photos of upcycled products to demonstrate how waterworks sludge can replace the conventional construction materials and be upcycled into eco-products (e.g. eco-magnetic chess and eco-coaster)

PowerPoint slides

4

To understand the importance of defining problems

5 MINS

Environmental impacts generated by waterworks sludge and corresponding solutions

- Teacher can briefly explain the concept of design cycle
- Teacher can point out that keen observation is necessary in identifying and defining problems, and stress the importance of defining problems. Furthermore, students should study relevant scientific principles to brainstorm and explore potential solutions

PowerPoint slides

2 MINS

Conclusion

- Teacher can ask students by an open-ended question: "What did you learn today?" and make a conclusion at the end
- Teacher can instruct students to complete the ""Design and Make": Upcycling of Waterworks Sludge" Student Worksheet at home for submission in the next class

Student worksheet

Form 1 to Form 3

"Design and Make": Upcycling of Waterworks Sludge

Topic:
Design Craft of Upcycling Waterworks Sludge II

Integrated Science Teaching Plan: Part II

Learning time:
70 minutes

Prior knowledge

1. The residues generated from the public utility and current disposal methods
2. The physical property of waterworks sludge and conventional construction materials that can be replaced
3. The examples of upcycling waterworks sludge
4. The use of 3D printing software to make simple 3D shapes

Learning objectives

Skills

1. To develop self-learning, and to study relevant research topics for brainstorming solutions and developing problem-solving skills

Knowledge

1. To investigate characteristics of coasters
2. To understand the production process of eco-coasters
3. To produce moulds for coasters by using 3D printing

Learning objectives	Time	Teaching flow	Teaching materials
	10 MINS	**Lead-in / Motivation** • Teacher can lead students to recap what they learnt during the first class • Teacher can use the examples of upcycling waterworks sludge as an introduction and interact with students to introduce today's topic: making eco-coaster	
1 To investigate characteristics of coasters	15 MINS	**Topic Research** • Teacher can guide students to do a basic research on necessary information: common materials of coasters, raw materials, properties, water absorption principles, production process for making coasters, etc. • Students can carry out group discussion to collect information, and then present their findings in groups • Teacher can summarise the results of topic research	
2 To understand the production process of eco-coasters	15 MINS	**Design concepts** **(Students continue to work in groups)** • Teacher can ask "How can we upcycle waterworks sludge into eco-coasters?"	

- Students can engage in group discussions to discuss the design production process, list out the materials, steps and necessary tools, and then present their findings
- Teacher can provide comments and recommend improvements accordingly for students to modify and enhance their designs

3

To produce moulds for eco-coasters by using 3D printing

20 MINS

Production of eco-coaster by 3D printing

- Teacher can raise question on "How to produce moulds for eco-coaster", and introduce 3D printing
- Students use the software TinkerCad to design and print their own moulds
- Teacher can guide students to incorporate artistic creativity when designing moulds, for example:
  → Design 3D printing moulds in various shapes
  → Incorporate personal and school features in the design (might make reference to the "Big Waster" and "6" eco-coaster moulds designed by the Environmental Protection Department)

10 MINS

Conclusion

- Teacher can summarise and point out the importance of:
  1. understanding on the research topic during engineering design; and
  2. designing products with high practicability

“Design and Make”: Upcycling of Waterworks Sludge

Student Worksheet

"Design and Make": Upcycling of Waterworks Sludge

Student Worksheet | **Name** ____________

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1 Multiple choice: Put a " √ " in the box for the correct answer

1. Which of the followings are special wastes?

A Animal carcasse
B Yard waste
C Radioactive waste
D Food waste
E Thermal paper
F Construction waste
G Sewage sludge and waterworks sludge
H Waste tyres

○ B, D, E, F
○ A, B, E, H
○ A, C, G, H
○ A, C, D, G

2. Which of the following is the correct concept of "Reduce"?

○ Avoid disposal of useful items
○ Separate and recycle waste and put into corresponding recycling facilities
○ Minimise the use of unnecessary items or energy
○ Replace environmentally harmful or wasteful items with those that are harmless to nature

3. Which of the following is the correct concept of "Reuse"?

○ Reuse items before they become waste
○ Separate and recycle waste and put into corresponding recycling facilities
○ Minimise the use of unnecessary items or energy
○ Replace environmentally harmful or wasteful items with those that are harmless to nature

4. Which of the following is the correct concept of "Recycle"?

○ Avoid disposal of useful items
○ Separate and recycle waste and put into corresponding recycling facilities
○ Minimise the use of unnecessary items or energy
○ Replace environmentally harmful or wasteful items with those that are harmless to nature

5. Which of the following is the correct concept of “Replace”?

- Avoid disposal of useful items
- Separate and recycle waste and put into corresponding recycling facilities
- Minimise the use of unnecessary items or energy
- Replace environmentally harmful or wasteful items with those that are harmless to nature

6. Which of the following is the correct concept of “Upcycling”?

- Transforming waste into innovative new products with new value
- Separate and recycle waste and put into corresponding recycling facilities
- Minimise the use of unnecessary items or energy
- Replace environmentally harmful or wasteful items with those that are harmless to nature

7. Which of the following is an example of upcycling?

- New fabric product made out of leftover fabric scraps
- Create storage containers in the shape of birds from aluminium cans
- New wallet made out of leftover wallpaper
- All of the above

8. Please arrange the most preferable waste reduction methods according to the 4R principle.

- Recycle → Replace → Reuse → Reduce
- Reduce → Reuse → Replace → Recycle
- Replace → Recycle → Upcycle → Reduce
- Upcycle → Recycle → Reuse → Reduce

9. What kind of waste is being treated by T·PARK ?

- Dewatered sludge
- Construction waste
- Food waste
- All of the above

10. Which of the following is the operation process of T·PARK?

- Incineration → Ash and residue handling → Sludge reception → Flue gas treatment and power generation
- Flue gas treatment and power generation → Ash and residue handling → Sludge reception → Incineration
- Sludge reception → Incineration → Flue gas treatment and power generation → Ash and residue handling
- Sludge reception → Ash and residue handling → Flue gas treatment and power generation → Incineration

11. How does T·PARK generate electricity through incineration?

- Use ashes to drive the generator through gears
- Heat energy generated by the incineration process boils the water to produce steam, which then passes through a turbine to generate electricity
- Use coal to generate electricity
- Use steam generated during the incineration process to drive gears for transporting coal to the generator

12. What kind of incineration technology is used in T·PARK and what temperature will it reach within a short period of time?

- Waste incineration; above 600°C
- Waste incineration; above 850°C
- Fluidised bed incineration; above 600°C
- Fluidised bed incineration; above 850°C

13. According to the Monitoring of Solid Waste in Hong Kong 2022 published by the Environmental Protection Department, what is the percentage of special waste accounted in the total amount of waste disposed of at landfills?

- 0.6%
- 2.5%
- 3%
- 5%

14. According to the Monitoring of Solid Waste in Hong Kong 2022 published by the Environmental Protection Department, which of the following special wastes attribute to the highest average daily disposal quantity (including both disposed of and not disposed of at landfills)?

- Incineration ash and stabilised residue
- Dewatered sewage sludge
- Grease trap waste
- Livestock waste

15. Which of the following special waste has a higher average daily quantity (not disposed of at landfills) and what is the treatment method?

- ◯ Incineration ash and pulverised fuel ash, incinerated at T·PARK
- ◯ Dewatered sewage sludge, incinerated at T·PARK
- ◯ Incineration ash and pulverised fuel ash, used to manufacture concrete or stored in lagoon
- ◯ Dewatered sewage sludge, used to manufacture concrete or stored in lagoon

16. Which of the following is the treatment method for sewage sludge generated from sewage treatment works in Hong Kong?

- ◯ Disposed of at landfills
- ◯ Incineration
- ◯ Concrete manufacturing, stored in lagoon
- ◯ Export to oversea

17. According to the Monitoring of Solid Waste in Hong Kong 2022 published by the Environmental Protection Department, what is the average daily quantity of dewatered sludge disposed of at landfills in Hong Kong?

- ◯ 0 tonnes
- ◯ 68 tonnes
- ◯ 27 tonnes
- ◯ 34 tonnes

18. Which of the following is the treatment method of the waterworks sludge generated from water treatment works in Hong Kong?

- ◯ Disposed of at landfills
- ◯ Incineration
- ◯ Concrete manufacturing, stored in lagoon
- ◯ Export to oversea

19. According to the Monitoring of Solid Waste in Hong Kong 2022 published by the Environmental Protection Department, what is the average daily quantity of dewatered waterworks sludge disposed of at landfills in Hong Kong?

- ◯ 30 tonnes
- ◯ 67 tonnes
- ◯ 72 tonnes
- ◯ 87 tonnes

2 Short questions

1. Which of the existing waste treatment facility in Hong Kong can turn special wastes to energy or resources?

2. If the sludge generated from the sewage treatment works is not incinerated at T· PARK and is directly disposed of at landfills, please elaborate on the negative environmental impacts.

3 Open-ended question

1. What would you propose to optimise the future waste management policy in Hong Kong to reduce the disposal of special waste (such as waterworks sludge or sewage sludge) at landfills so as to alleviate the pressure on landfills?

“Design and Make”: Upcycling of Waterworks Sludge

Production Guideline of Eco-coaster

“Design and Make”: Upcycling of Waterworks Sludge

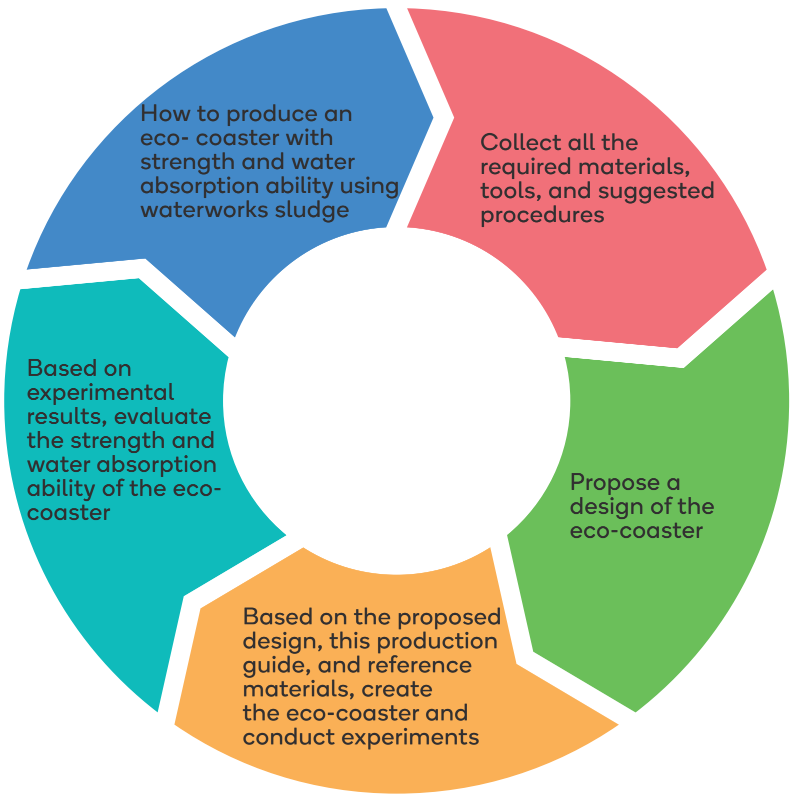
Production Guideline of Eco-coaster

Theme	Upcycling waterworks sludge into eco-coasters

Objectives	1. To learn the concept of “waste-to-energy”, practice resource circulation, and address environmental problems generated by waste 2. To raise students’ awareness of resource reuse by experiencing the process of turning waste into eco-products: making eco-coasters 3. To upcycle waterworks sludge into eco-coasters by applying scientific knowledge and creativity
Requirements	1. Replacing some conventional construction materials (i.e. sand) with waterworks sludge to make eco-coasters 2. Eco-coasters should reach a certain hardness level to prevent it from breaking 3. Eco-coasters should be able to absorb water
Principles of water absorption in coasters	• The phenomenon of water flowing upwards or along cracks is known as the capillary action • **Principle of water absorption in diatomaceous earth coasters:** Diatomaceous earth has many small pores which allows water to enter • **Principles of water absorption in ceramic coasters:** Ceramics are mainly made of a combination of silicon dioxide and other substances. In order for water to slowly flow into the gaps and remain in the layers, ceramic coasters need to be heated to a high temperature of more than 1 000°C. This causes the atoms of silicon dioxide and other substances closer together while leaving some tiny gaps between them

The concept of design cycle

1. Identify problems and needs
2. Collect and summarize information
3. Propose design options
4. Conduct experiments and testing
5. Evaluate the effectiveness of the solution



Preparations	• The material kits (i.e. fine waterworks sludge, sand, and cement) can be provided by The Education University of Hong Kong upon request. Please contact The Education University of Hong Kong 5 working days before the activity to collect the kit • The 3D printing files can be provided by The Education University of Hong Kong upon request. 3D-printed moulds need to be self-printed by school using a 3D printer • School is required to purchase or prepare all the remaining materials, including water, cooking oil, measuring cups with capacity not less than 200 mL and 500 mL respectively, 5 mL needle-free syringes, gloves, wooden sticks, electronic balances, sealable plastic bags, and newspaper (as tablecloth)
Activity flow (suggested)	1. Teacher can explain the procedures and the objectives of making eco-coasters 2. Based on the production guideline and procedures, teacher can guide students to make the eco-coasters, conduct three experiments and record the data 3. Teacher can discuss the experimental results with students to find out the factors affecting the hardness and water absorbency level of the eco-coasters, e.g. optimal material ratio and curing duration 4. Students can evaluate their own designs to identify their strengths and weaknesses and make necessary modifications accordingly, e.g. by adjusting the material ratio or the curing duration 5. Students can reproduce the eco-coasters based on the updated design 6. Students can repeat the experiments and record data to check whether the new design is better, thereby determining the best design 7. Teacher can summarise the experimental results and review the activity 8. Eco-coasters can be further transformed into art displays, e.g. building floor numbers in a mosaic style for displaying at school
Materials	• Fine waterworks sludge • Cement • Sand • Water • Cooking oil • 3D-printed moulds • Measuring cups with capacity not less than 200 mL • Measuring cups with capacity not less than 500 mL • 5 mL needle-free syringes • Gloves • Wooden sticks • Electronic balances • Sealable plastic bags • Newspaper (as tablecloth)

Procedures

1. Measure the required amount of waterworks sludge and sand according to the replacement ratio in Experimental Data Sheet I

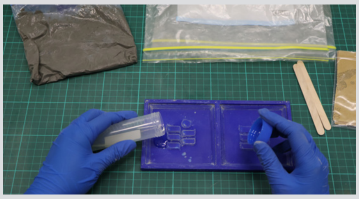
2. Add the measured materials in Step 1 and 120 g of cement into a sealable plastic bag, seal the bag, and mix thoroughly

3. Add 30 mL of water using a syringe and mix with the ingredient mixture

4. Press thoroughly until all the water is absorbed

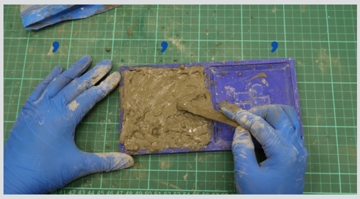
5. Add approximately 1 mL of water drop by drop (make sure the ingredient mixture is not too moist)

6. Press thoroughly until the ingredient mixture reaches a clay-like texture



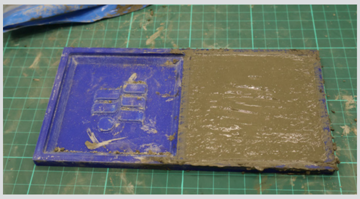
7. Add 1 mL of cooking oil onto the 3D-printed mould and spread evenly

8. Take small amount of the ingredient mixture and fill the bottom of the mould by using a wooden stick

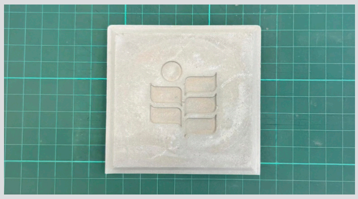


9. Fill the mould with the ingredient mixture

10. Smooth the surface with a wooden stick in a zig-zag motion



11. Allow it to air-dry for approximately 36-48 hours, then demould



12. Finished

Reference video for the production procedures：
https://drive.google.com/drive/folders/1riTZObq8VyXbQq50AF7DFm2GBtFjlBYA?usp=drive_link

Remarks

1. Wear protective equipment, including gloves, mask, and lab coat when making the eco-coasters
2. If your eyes come into contact with cement or waterworks sludge, rinse them immediately with water for several minutes. If you still feel unwell after rinsing, seek medical advice immediately
3. Remind students to be cautious when participating in the activities to avoid accidents
4. Encourage students to clean up the venue after the activity to ensure a tidy environment and proper disposal of waste materials
5. The used syringes, 3D-printed moulds, measuring cups, and wooden sticks can be rinsed, dried, and reused for the next time

Note

If schools are interested in obtaining the material kits, please contact Miss Cheng Yan Laam (2948 7217) or Miss Xu Hui (2948 8826) of The Education University of Hong Kong. As the preparation of material kits takes time, please contact them 5 working days before the activity and provide the school address and contact information (i.e. name and phone number) for the delivery of the material kits. The supply of material kits is limited and will be distributed on a first-come, first-served basis.

“Design and Make”: Upcycling of Waterworks Sludge

Experiment

“Design and Make”: Upcycling of Waterworks Sludge

Experiment (I): Guideline on Determination of Material Ratio

Objective

To determine the optimal material ratio of eco-materials (i.e. waterworks sludge) to conventional construction materials (i.e. sand)

Overview

Sand and waterworks sludge have similar physical properties. Waterworks sludge could therefore be used to replace conventional construction materials and upcycled into eco-coasters

Materials

- Rulers
- Weights (10 g, 25 g, 50 g, 100 g, 250 g, 500 g)
- Eco-coasters (4 pieces per group)
- Flat bottom plastic boxes
- Labour working gloves
- Experimental Data Sheet I (A) / Experimental Data Sheet I (B)

Making eco-coasters

- Divide students into 6 groups, each group will make 4 eco-coasters according to the material ratios (1 eco-coaster for each material ratio)
- For detailed procedures, please refer to “Production Guideline of Eco-coaster”

Method 1: Testing with weights

Procedures

1. Record the material ratios used for the 4 eco-coasters in Experimental Data Sheet I (A)
2. Place the eco-coaster in the centre of a plastic box
3. Drop the weight vertically onto the eco-coaster at a predetermined height (reference height: 1 m), starting with the lightest weight (i.e. 10 g). If the coaster does not break, repeat the test by progressively increasing the weight (i.e. 25 g, 50 g, 100 g, 250 g, 500 g) until the coaster breaks
4. Record the weight required to break the eco-coaster and the degree of damage
5. Upon completion of the experiment, complete Experimental Data Sheet I (A) and determine the optimal material ratio based on the weight required to break the eco-coaster and the degree of damage

If schools do not have weights or similar tools, please refer to the following procedures:

Method 2: Testing without weights

Procedures

1. Record the material ratios used for the 4 eco-coasters in Experimental Data Sheet I (B)
2. Drop the eco-coaster vertically into a plastic box at a height of 1 m. If the eco-coaster does not break, repeat the test by increasing the height by 10 cm each time until the eco-coaster breaks. Record the height at which the coaster breaks and the degree of damage
3. Upon completion of the experiment, complete Experimental Data Sheet I (B) and determine the optimal material ratio based on the height required to break the eco-coaster and the degree of damage

Remarks	1. Wear protective equipment, including gloves, mask, and lab coat when making the eco-coasters 2. If your eyes come into contact with cement or waterworks sludge, rinse them immediately with water for several minutes. If you still feel unwell after rinsing, seek medical advice immediately 3. Wear protective equipment, including labour working gloves, goggles, and lab coat during the experiment 4. Remind students to be cautious when conducting experiments to avoid accidents, e.g. to ensure there is no students in the vicinity before dropping weights / eco-coasters from a height to avoid spattering debris on them 5. Encourage students to clean up the venue after the activity to ensure a tidy environment and proper disposal of waste materials 6. The used syringes, 3D-printed moulds, measuring cups, and wooden sticks can be rinsed, dried, and reused for the next time

“Design and Make”: Upcycling of Waterworks Sludge

Experimental Data Sheet I (A)

Method 1: Determine the Material Ratio using Weights

	Eco-coaster I	Eco-coaster II	Eco-coaster III	Eco-coaster IV
Replacement ratio (%)	0			
Waterworks sludge (g)	0			
Sand (g)	6			
Cement (g)	120	120	120	120
Height at which the eco-coasters break (m) (Reference height: 1 m)				
Weight (g)				
Degree of damage				

Conclusion: The optimal material ratio of waterworks sludge to sand is

____ ,

in which the eco-coaster breaks when ______ g of weight drops vertically at a height of ______ m.

“Design and Make”: Upcycling of Waterworks Sludge

Experimental Data Sheet I (B)

Method 2: Determine the Material Ratio without using Weights

	Eco-coaster I	Eco-coaster II	Eco-coaster III	Eco-coaster IV
Replacement ratio (%)	0			
Waterworks sludge (g)	0			
Sand (g)	6			
Cement (g)	120	120	120	120
Height at which the eco-coasters break (m) (Reference height: 1 m)				
Degree of damage				

Conclusion: The optimal material ratio of waterworks sludge to sand is

____,

in which the eco-coaster breaks when dropped vertically at a height of ______ m.

“Design and Make”: Upcycling of Waterworks Sludge

Experiment (II): Guideline on Determination of Curing Duration

Objectives

1. Based on the optimal material ratio obtained in Experiment (I), explore ways to enhance the hardness and durability of eco-coasters
2. To determine the optimal curing duration

Overview

Curing (i.e. immersing concrete products in water) can increase the hardness of concrete products and prevent them from cracking, thus increasing the durability of the product

Materials

- Approximately 3 L of tap water (volume can be adjusted accordingly)
- Plastic basins (L 50 cm × W 30 cm × H 5 cm)
- Eco-coasters (1 piece per group)
- Rulers
- Weights (10 g, 25 g, 50 g, 100 g, 250 g, 500 g)
- Flat bottom plastic boxes
- Labour working gloves
- Experimental Data Sheet II (A) / Experimental Data Sheet II (B)

Making eco-coasters

- Divide students into 6 groups, each group will make 1 eco-coaster according to the optimal material ratio obtained in Experiment (I)
- For detailed procedures, please refer to “Production Guideline of Eco-coaster”

Method 1: Testing with weights

Procedures

1. Record the material ratio used for the eco-coaster in Experimental Data Sheet II (A)
2. Place the eco-coaster in a plastic basin filled with at least 3 L of water (the water level should be about 3 cm)
3. Immerse the eco-coaster in the water based on the curing duration specified on Experimental Data Sheet II (A)
4. Take out the eco-coaster according to the scheduled time for hardness test
5. Place the eco-coaster in the centre of a plastic box
6. Drop the weight vertically onto the eco-coaster at a predetermined height (reference height: 1 m), starting with the lightest weight (i.e. 10 g). If the coaster does not break, repeat the test by progressively increasing the weight (i.e. 25 g, 50 g, 100 g, 250 g, 500 g) until the coaster breaks
7. Record the weight required to break the eco-coaster and the degree of damage
8. Upon completion of the experiment, complete Experimental Data Sheet II (A) and determine the optimal curing duration based on the weight required to break the eco-coaster and the degree of damage

If schools do not have weights or similar tools, please refer to the following procedures:

Method 2: Testing without weights

Procedures	1. Record the material ratio used for the eco-coaster in Experimental Data Sheet II (B) 2. Place the eco-coaster in a plastic basin filled with at least 3 L of water (the water level should be about 3 cm) 3. Immerse the eco-coaster based on the curing duration specified on Experimental Data Sheet II (B) 4. Take out the eco-coaster in the water according to the scheduled time for hardness test 5. Drop the eco-coaster vertically into a plastic box from a height of 1 m. If the coaster does not break, repeat the test by increasing the height by 10 cm each time until the coaster breaks. Record the height at which the coaster breaks and the degree of damage 6. Upon completion of the experiment, complete Experimental Data Sheet II (B) and determine the optimal curing duration based on the height required to break the eco-coaster and the degree of damage

Remarks	1. Wear protective equipment, including gloves, mask, and lab coat when making the eco-coasters 2. If your eyes come into contact with cement or waterworks sludge, rinse them immediately with water for several minutes. If you still feel unwell after rinsing, seek medical advice immediately 3. Wear protective equipment, including labour working gloves, goggles, and lab coat during the experiment 4. Ensure you take out the eco-coasters according to the scheduled curing duration and measure their strength 5. Encourage students to clean up the venue after the activity to ensure a tidy environment and proper disposal of waste materials 6. The used syringes, 3D-printed moulds, measuring cups, and wooden sticks can be rinsed, dried, and reused for the next time

“Design and Make”: Upcycling of Waterworks Sludge

Experimental Data Sheet II (A)

Method 1: Determine the Material Ratio using Weights

Based on the results of Experiment (I), the optimal material ratio for eco-coasters is

________________________________.

Group	I	II	III	IV	V	VI
Curing duration	0 hour	4 hours	12 hours	1 day	4 days	7 days
Height at which the eco-coasters break (m) (Reference height: 1 m)						
Weight (g)						
Degree of damage						

Conclusion:

Hardness of eco-coasters (can / cannot) be enhanced through curing,

the optimal curing duration for eco-coasters is ________________________________ ,

in which the eco-coaster breaks when ______ g of weight drops vertically at a height of ______ m.

"Design and Make": Upcycling of Waterworks Sludge

Experimental Data Sheet II (B)

Method 2: Determine the Material Ratio without using Weights

Based on the results of Experiment (I), the optimal material ratio for eco-coasters is

______________________________ .

Group	I	II	III	IV	V	VI
Curing duration	0 hour	4 hours	12 hours	1 day	4 days	7 days
Height at which the eco-coasters break (m)						
Degree of damage						

Conclusion:

Hardness of eco-coasters (can / cannot) be enhanced through curing,

the optimal curing duration for eco-coasters is ______________________________ ,

in which the eco-coaster breaks when dropped vertically at a height of ______ m.

Experiment (III): Guideline on Determination of Water Absorbeny

Objectives

1. To compare the water absorbency level of eco-coasters and commercially available coasters
2. To explore more feasible modification measures based on the experimental results (e.g. increasing the thickness of eco-coasters or using waterworks sludge with different particle sizes)

Overview

Currently, the two primary materials used to make commercially available coasters are ceramic and diatomaceous earth. These coasters absorb water from the surface by making use of the properties of their raw materials and the capillary action.

Waterworks sludge contains a large amount of silicon dioxide and aluminium oxide. Silicon dioxide (the main component of desiccant beads) absorbs water and can be reused after the moisture is evaporated with heat, while aluminum oxide has a strong water adsorption capacity. Consequently, waterworks sludge which is water absorbent can also be used to make coasters.

Materials

- 100 mL beakers
- 5 mL needle-free syringes
- Approximately 3 L of tap water
- Eco-coasters (1 piece per group)
- Commercially available ceramic coasters
- Commercially available diatomaceous earth coasters
- Timers
- Electronic balances
- Experimental Data Sheet III

Making eco-coasters

1. Divide students into 6 groups, each group will make an eco-coaster according to the optimal material ratio obtained in Experiment (I) and optimal curing duration obtained in Experiment (II)
2. For detailed procedures, please refer to “Production Guideline of Eco-coaster”

Procedures	**Water Absorption time** 1. Dry the coaster in oven at 103°C for 24 hours 2. Drop 1 mL of water onto the surface of the coaster and start the timer. Stop the timer when the water is completely absorbed. Record the time taken on Experimental Data Sheet III 3. Both sides need to be tested. After completing one of the sides, turn the coaster upside down and repeat Step 2 **Water Absorption capacity** 1. Dry the coaster in oven at 103°C for 24 hours 2. Place the coaster on an electronic balance (a small container can be used to hold the coaster to prevent water from draining onto the balance and affecting the results) and set zero 3. Drop 1 mL of water onto the surface of the coaster using a syringe. Wait until the water is completely absorbed, then continue adding water until the water on the surface could no longer be absorbed, or seeps out from the bottom of the coaster. Record the weight of the coaster on Experimental Data Sheet III

Remarks	1. Wear protective equipment, including gloves, mask, and lab coat when making the eco-coasters 2. If your eyes come into contact with cement or waterworks sludge, rinse them immediately with water for several minutes. If you still feel unwell after rinsing, seek medical advice immediately 3. Wear protective equipment, including labour working gloves, goggles, and lab coat during the experiment 4. Remind students to be cautious when conducting experiments to avoid accidents 5. Encourage students to clean up the venue after the activity to ensure a tidy environment and proper disposal of waste materials 6. The used syringes, 3D-printed moulds, measuring cups, and wooden sticks can be rinsed, dried, and reused for the next time

Experimental Data Sheet III

Experiment (III): Comparing the water absorbency level of eco-coasters and market available coasters

Group		Brand	Origin	Water absorption time (Front) (min:sec)	Water absorption time (Back) (min:sec)	Water absorption capacity (g)
I	Eco-coaster I					
II	Eco-coaster II					
III	Eco-coaster III					
IV	Eco-coaster IV					
V	Eco-coaster V					
VI	Eco-coaster VI					
	Ceramic coaster					
	Diatomaceous earth coaster					

Coaster with the shortest absorption time: ____________________ , water absorption time: ____________________

Coaster with the highest absorption capacity: _________________ , water absorption capacity: ________________

“Design and Make”: Upcycling of Waterworks Sludge

Extended Activity

Production of Eco-acoustic Block

Objectives	• To identify the problems using engineering design thinking, develop and design feasible solutions through research and integration of the 4R principle, and continuous modifications through testing • To develop students' abilities of self-learning, exploration and problem solving through project-based learning
Activity arrangements	**Lead-in** • Teacher can review the Activity Kit (1-6) on how to apply engineering design thinking to waterworks sludge and upcycle it into eco-coasters • Ask question: How to use waterworks sludge to make eco-acoustic blocks? **Topic Research** • Teacher can guide the students to collect all the necessary information, such as sound-insulating materials, raw materials for the product, properties, principles of acoustic insulation, and production process • Students can carry out group discussion and then present their findings in groups • Teacher can summarise relevant information **Design** • Based on the information collected from students, teacher can guide them to list out the production process, materials, procedures, and tools required for the production of eco-acoustic blocks • Students can use 3D design software TinkerCad to design moulds **Making eco-acoustic blocks** • Students produce eco-acoustic blocks according to the designed procedures **Performance test and modification** • Students perform sound insulation test • Students evaluate the effectiveness of eco-acoustic blocks in the test • Students evaluate the design and make modifications to achieve better results **Product demonstration and presentation** • Students demonstrate the modified eco-acoustic blocks and report the results of the sound insulation test
Time	6 lessons

Production Guidelines of Eco-acoustic Block

Theme	Upcycling waterworks sludge into eco-acoustic blocks
Objectives	• To learn the concept of "waste-to-resources", practice resources circulation, and address environmental impacts generated by waste • To produce eco-acoustic blocks with high hardness and sound insulation ability by applying scientific knowledge and creativity
Requirement	• Utilising the knowledge and experience gained from the production of eco-coasters to produce eco-acoustic blocks
Principle	• Sound-insulating materials reduce the transmission of sound by absorbing, reflecting or blocking sound waves. The high density of sound-insulating materials (e.g. acoustic walls) prevents sound from penetrating, in contrast to the porous and breathable nature of sound-absorbing materials.
Preparations	• The material kits (i.e. sand, stone, fine waterworks sludge, coarse waterworks sludge, and cement) can be provided by The Education University of Hong Kong upon request. Please contact The Education University of Hong Kong 5 working days before the activity to collect the kit • The 3D printing files can be provided by The Education University of Hong Kong upon request. 3D-printed moulds need to be self-printed by school using a 3D printer • Purchase or prepare all the remaining materials, including water, cooking oil, 1 L measuring cups, gloves, finishing trowels, putty knives, aluminium foil trays, electronic balances, and newspaper (as tablecloth)  finishing trowel

Production of Eco-acoustic Block

Activity flow (suggested)	1. Teacher can explain the procedures and objectives of making eco-acoustics blocks 2. Based on the production guideline and procedures, teacher can guide students to make the eco-acoustic blocks, conduct experiments and record the data 3. Teacher can discuss the experimental results with students to find out factors affecting the hardness and sound insulation effectiveness of the eco-acoustic blocks, e.g. optimal material ratio 4. Students evaluate their own designs to identify their strengths and weaknesses and make necessary modifications, e.g. by adjusting the material ratio or the curing duration 5. Students reproduce the eco-acoustic blocks based on the updated design 6. Students repeat the experiments and record data to check whether the new design is better, thereby determining the best design and optimal material ratio 7. Teacher can summarise the experimental results and review the activity
Materials	• 500 g of sand • 500 g of stone • 100 g of fine waterworks sludge • 100 g of coarse waterworks sludge • 1 080 g of cement • No less than 324 mL of water • 5-6 mL of cooking oil • Finishing trowels • Putty knives • Aluminium foil trays • Measuring cups of no less than 1 L • 3D-printed / plastic moulds • Gloves • Electronic balances • Newspaper (as tablecloth)

Production of Eco-acoustic Block

Procedures	1. Measure the required amount of materials: 500 g of sand, 500 g of stone, 100 g of fine waterworks sludge, 100 g of coarse waterworks sludge, and 1080 g of cement 2. Add the measured materials into an aluminium foil tray and mix thoroughly 3. Add 200 mL of water and mix with the ingredient mixture 4. Press thoroughly until all the water is absorbed 5. Slowly add approximately 124 mL of water (make sure the ingredient mixture is not too moist) 6. Press thoroughly until the ingredient mixture reaches a clay-like texture 7. Add 1 mL of cooking oil onto the 3D-printed / plastic mould and spread evenly 8. Take a small amount of the ingredient mixture and fill the bottom of the mould, then fill 1/3 of the mould, and shake it side to side to evenly spread the mixture ingredient 9. Take a small amount of the ingredient mixture and fill the middle of the mould, shake it side to side to evenly spread the mixture ingredient 10. Take a small amount of the ingredient mixture and fill the top of the mould, shake it side to side to evenly spread the mixture ingredient 11. Smooth the surface with a finishing trowel in a zig-zag motion 12. Allow it to air-dry for approximately 36-48 hours, and then demould
Remarks	• Remind students to be cautious during the activity to avoid accidents • Wear protective equipment, including gloves, mask, and lab coat when making the eco-acoustic blocks • If your eyes come into contact with cement or waterworks sludge, rinse them immediately with water for several minutes. If you still feel unwell after rinsing, seek medical advice immediately • Encourage students to clean up the venue after the activity to ensure a tidy environment and proper disposal of waste materials • The used finishing trowels, putty knives, aluminium foil trays, 3D-printed / plastic moulds, and measuring cups can be rinsed, dried, and reused for the next time
Note	If schools are interested in obtaining the material kits, please contact Miss Cheng Yan Laam (2948 7217) or Miss Xu Hui (2948 8826) of The Education University of Hong Kong. As the preparation of material kits takes time, please contact them 5 working days before the activity and provide the school address and contact information (i.e. name and phone number) for the delivery of the material kits. The supply of material kits is limited and will be distributed on a first-come, first-served basis.

Guideline on Determination of Acoustic Insulation

Objective	To explore the sound insulation ability of eco-materials, and test the suitability of these materials for sound insulation purposes through experiments
Materials	• Soundproof box • Sound meters (1 per group) • Portable speakers (1 per group) • Eco-acoustic blocks (1 piece per group)
Making eco-acoustic blocks	1. Divide students into 6 groups, each group will make an eco-acoustic block according to the optimal material ratio obtained in Experiment (I) 2. For detailed procedures, please refer to “Production Guideline of Eco-acoustic Block”
Procedures	1. Find a suitable soundproof box or soundproof room for the test (make sure the windows and doors are closed) 2. Place the eco-acoustic block in the soundproof room and place a speaker on one side of the block while placing a sound meter on the other side 3. Start playing music and record the sound level measured by the sound meter (repeat 3 or more times to minimise the error) 4. Remove the eco-acoustic block, start playing the same music and record the sound level measured by the sound meter
Remarks	• Remind students to be cautious during the activity to avoid accidents • Wear protective equipment, including gloves, mask, and lab coat when making the eco-acoustic blocks • If your eyes come into contact with cement or waterworks sludge, rinse them immediately with water for several minutes. If you still feel unwell after rinsing, seek medical advice immediately • Ensure that the volume of the music is consistent each time and the same playback device is used • Encourage students to clean up the venue after the activity to ensure a tidy environment and proper disposal of waste materials

Experimental Data Sheet - Sound insulation test

Group		Test 1	Test 2	Test 3
		Sound level (dB)	Sound level (dB)	Sound level (dB)
I	Eco-acoustic block I			
II	Eco-acoustic block II			
III	Eco-acoustic block III			
IV	Eco-acoustic block IV			
V	Eco-acoustic block V			
VI	Eco-acoustic block VI			
/	Without eco-acoustic blocks			

When no eco-acoustic block was placed, ____________________dB was recorded;

When eco-acoustic blocks were placed, an average of ______________ dB was recorded;

The lowest of which is ______________dB and the highest is _____________ dB.

Conclusion: Based on the above test, eco-acoustic block (has / does not have) sound proofing effect and is therefore (suitable / not suitable) for sound insulation purposes.

“Design and Make”: Upcycling of Waterworks Sludge

Supplementary Information

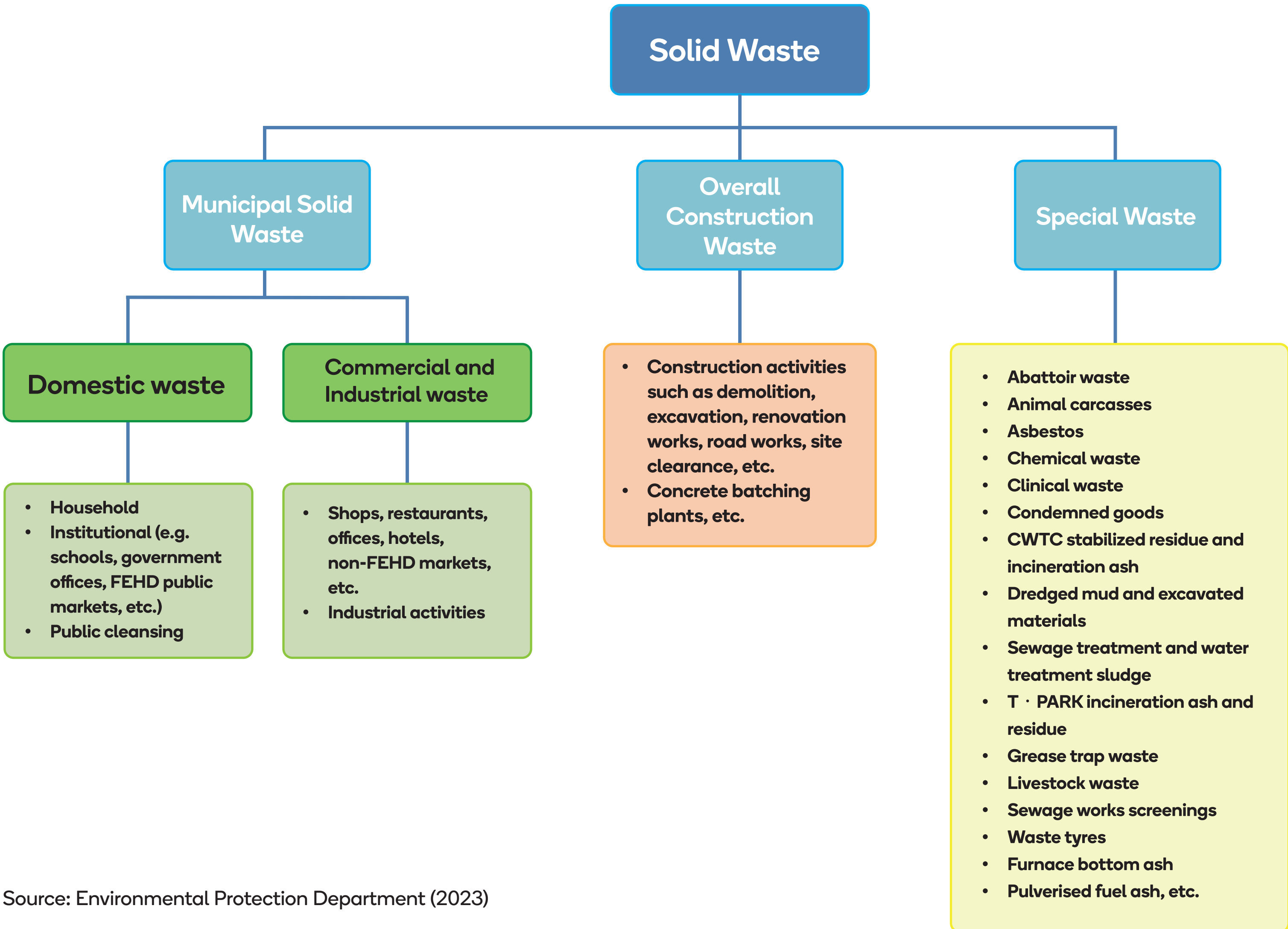
Supplementary Information

1. The current situation of special waste in Hong Kong

Special waste includes abattoir waste, animal carcasses, asbestos waste, chemical waste, clinical waste, dredged mud and excavated materials, sewage sludge, waterworks sludge, incineration ash and stabilised residue, grease trap waste, livestock waste, sewage works screenings, waste tyres, condemned goods, furnace bottom ash, pulverised fuel ash, etc. These wastes need to be treated separately.

In 2022, the quantity of special waste disposed of at landfills was 469 tonnes per day (0.17 million tonnes), which has decreased by 11.4% as compared to 2021. The drop was mainly driven by the decrease in sewage works screenings. On the other hand, as from April 2015, the Sludge Treatment Facility (T·PARK) in Tuen Mun has started treating dewatered sewage sludge from major sewage treatment works managed by Drainage Services Department by incineration, leading to a cumulative reduction of 96% in disposal of dewatered sludges at landfills in 2022 as compared with 2014. On average, 1 058 tonnes of dewatered sewage sludges per day was treated at the T·PARK in 2022.

Figure 1) Current classification of solid waste



Source: Environmental Protection Department (2023)

1. The current situation of special waste in Hong Kong (Cont')

Table 1) Disposal of special waste at landfills from 2013 to 2022

Special waste	Average daily quantity [1] (tonnes per day)									
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Abattoir waste	8	8	8	9	12	11	7	5	6	9
Animal carcasses and kennel waste	9	10	9	7	4	4	7	4	5	6
Asbestos waste	3	4	3	4	4	3	3	3	4	3
Chemical waste other than asbestos waste	7	7	4	9	7	7	6	5	4	4
Clinical waste (with package material)[2]	1	1	1	1	1	1	1	3	1	4
Dewatered dredged materials	10	12	0.2	4	7	4	4	4	15	0
Dewatered sludges[3]	900	824	304	68	98	103	103	65	39	34
Dried waterworks sludge	50	58	58	58	56	55	65	75	85	87
Incineration ash and stabilised residue	11	35	138	173	152	147	150	137	146	129
Livestock waste[4]	59	57	61	63	65	65	68	69	74	76
Sewage works screenings	65	69	64	65	62	71	69	72	77	53
Waste tyres[5]	26	25	49	71	73	66	61	52	57	47
Others (including condemned goods)[6]	25	25	44	32	36	50	92	18	16	16
Total	1 173	1 135	743	565	575	587	635	513	529	469

Notes:
1. Some types of special waste may not arise and be disposed of daily throughout the whole year. The average daily quantity is obtained by dividing the total amount of waste disposed of at landfills in the whole year by the number of days in the whole year.
2. Clinical waste is incinerated at Chemical Waste Treatment Centre except during normal maintenance or emergency shut-down maintenance of the incineration treatment system for more than two days. During the shutdown, clinical waste is packed and transferred to designated landfill for disposal in accordance with the Clinical Waste Disposal License of Chemical Waste Treatment Centre.
3. Dewatered sludges include dewatered sludges and other sludges from industrial activities. Dewatered sludges originate from sewage treatment works managed by the Drainage Services Department, wastewater treatment facilities and grease trap waste treatment facility at refuse transfer stations managed by the EPD, and private sewage treatment plants. Except that dewatered sewage sludge from major sewage treatment works managed by Drainage Services Department is treated by incineration at T·PARK, other sludges are disposed of at WENT and NENT Landfills.
4. In 2022, the generation of livestock waste amounted to 160 tonnes per day, out of which 76 tonnes per day were disposed of at landfills. Livestock waste disposed of at landfills mainly include the livestock waste collected by the free collection service for solid livestock waste provided to local livestock farmers by the Government. The remaining livestock waste was treated by other environmentally-acceptable means such as on-site composting, aerobic treatment, and dry muck-out.
5. Waste tyres are shredded or cut prior to disposal at landfills.
6. Others include condemned goods, contaminated waste and government items.

Source: Environmental Protection Department

1. The current situation of special waste in Hong Kong (Cont’)

Table 2) Treatment of special waste not disposed of at landfills from 2014 to 2022

Special waste type	Treatment method	Average daily quantity [1] (tonnes per day)									
		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Chemical waste other than asbestos waste	Chemical Waste Treatment Centre	26	26	31	35	41	39	36	34	29	22
Clinical waste	Chemical Waste Treatment Centre	5	5	6	6	6	6	7	8	11	12
Grease trap waste	West Kowloon Transfer Station [2]	461	383	411	371	471	499	537	493	490	469
Horse stable waste	Animal Waste Composting Plant	22	22	20	21	26	26	27	26	26	25
Dredged mud and excavated materials	Marine dumping [3]	81 918	104 658	73 973	53 552	23 288	16 712	13 699	15 574	3 288	5 205
Dewatered sewage sludge [4]	Incineration at T·PARK	-	-	801	1 144	1 058	1 075	1 052	1 034	1 123	1 058
Furnace bottom ash	Concrete manufacturing, stored in lagoon [5]	122	141	108	115	120	124	132	73	80	59
Pulverised fuel ash	Concrete manufacturing, stored in lagoon [5]	1 308	1 467	1 126	1 236	1 156	1 263	1 253	759	797	663

Notes:

1. Some types of special waste may not arise and be treated daily throughout the whole year. The average daily quantity is obtained by dividing the total amount of waste treated outside landfills in the whole year by the number of days in the whole year.
2. The figure is the quantity of grease trap waste treated by the Grease Trap Waste Treatment Facility at West Kowloon Transfer Station.
3. The density of the dredged mud and excavated materials is assumed to be one tonne per cubic metre.
4. Dewatered sewage sludge from major sewage treatment works managed by Drainage Services Department has been treated by incineration at T·PARK from April 2015 onwards.
5. Furnace bottom ash and pulverised fuel ash are wastes resulting from coal-fired electricity generation. Their figures are provided by the Power Companies.

Source: Environmental Protection Department

2. Waterworks sludge and sewage sludge

	Waterworks sludge	Sewage sludge
Source	• Water Treatment Works managed by Water Supplies Department	• Sewage treatment works managed by Drainage Services Department • Wastewater treatment facilities and grease trap waste treatment facilities at refuse transfer stations managed by the Environmental Protection Department • Private sewage treatment works
Generation	• Treatment of raw (untreated) water to fulfill drinking water standard. Waterworks sludge is a by-product of the clarification stage of the water treatment process	• Treatment of domestic, commercial, and industrial sewage. Sewage sludge is a thick mud-like by-product of sewage treatment
Treatment	• Dewatered sewage sludge generated is disposed of at landfill	• Dewatered sewage sludge from major sewage treatment works managed by Drainage Services Department is treated by incineration at T·PARK. Other sewage sludges are disposed of at WENT and NENT Landfills

3. Waste-to-resources – Waterworks sludge and sewage sludge

Waste-to-resource is a sustainable and environmental-friendly approach for waste management. Massive amount of residues are generated in the treatment processes from different public utility. Taking waterworks sludge and sewage sludge as the examples of resources circulation, they could be recycled as eco-raw materials or eco-products (e.g., eco-concrete blocks) through a series of pre-treatment (i.e., drying, crushing, sieving, mixing, moulding, vibrating, and curing). This can not only reduce the reliance on natural resources, but also reduce the adverse impacts on environment, and promote resources circulation.

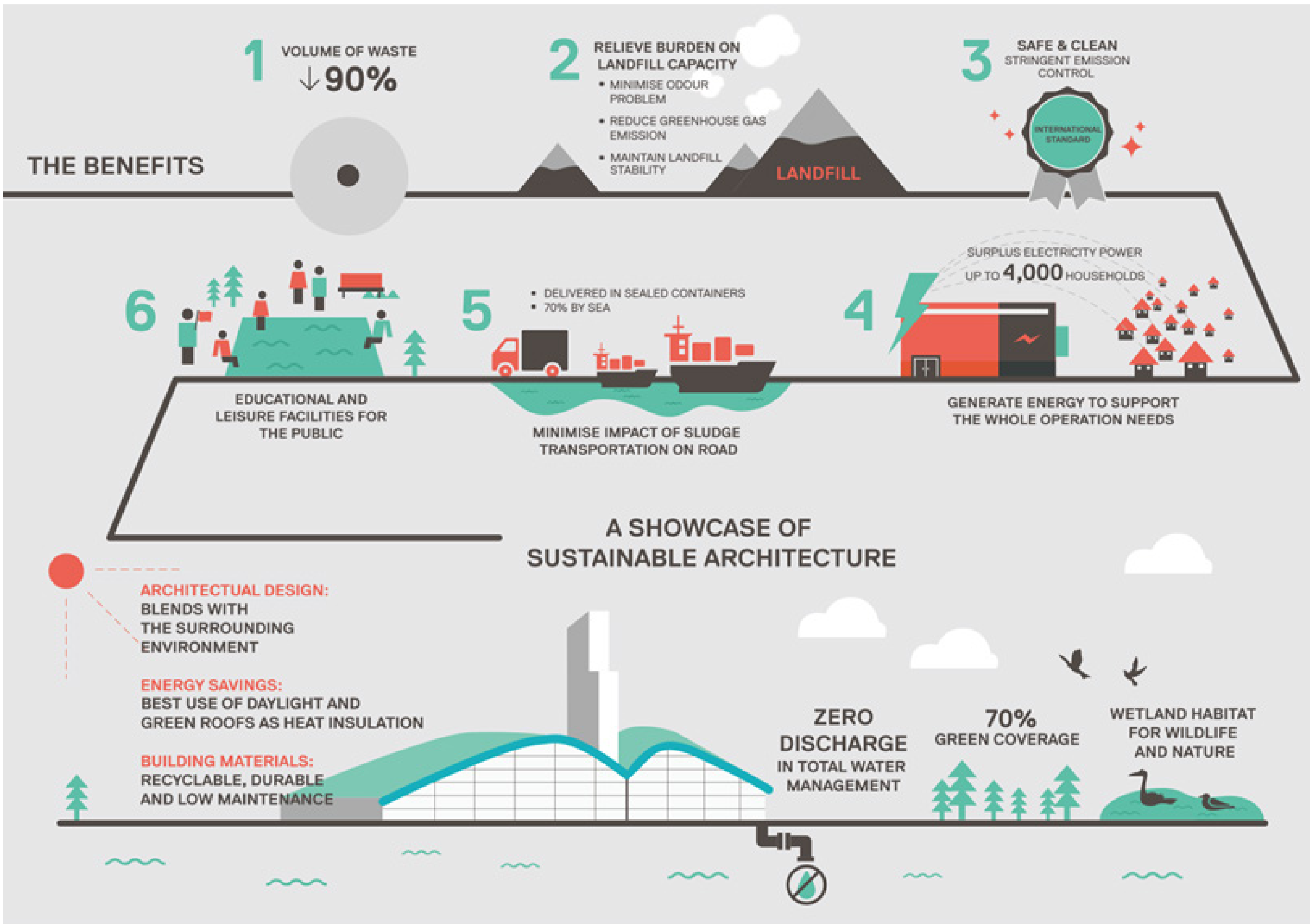
4. Waste-to-energy – Sewage sludge

Waste-to-energy is the process of obtaining energy in the form of electricity or heat from the waste. This is an energy recovery process. Most waste-to-energy processes produce electricity directly through combustion, or produce a combustible fuel commodity, such as methane, methanol, ethanol or synthetic fuels.

T · PARK

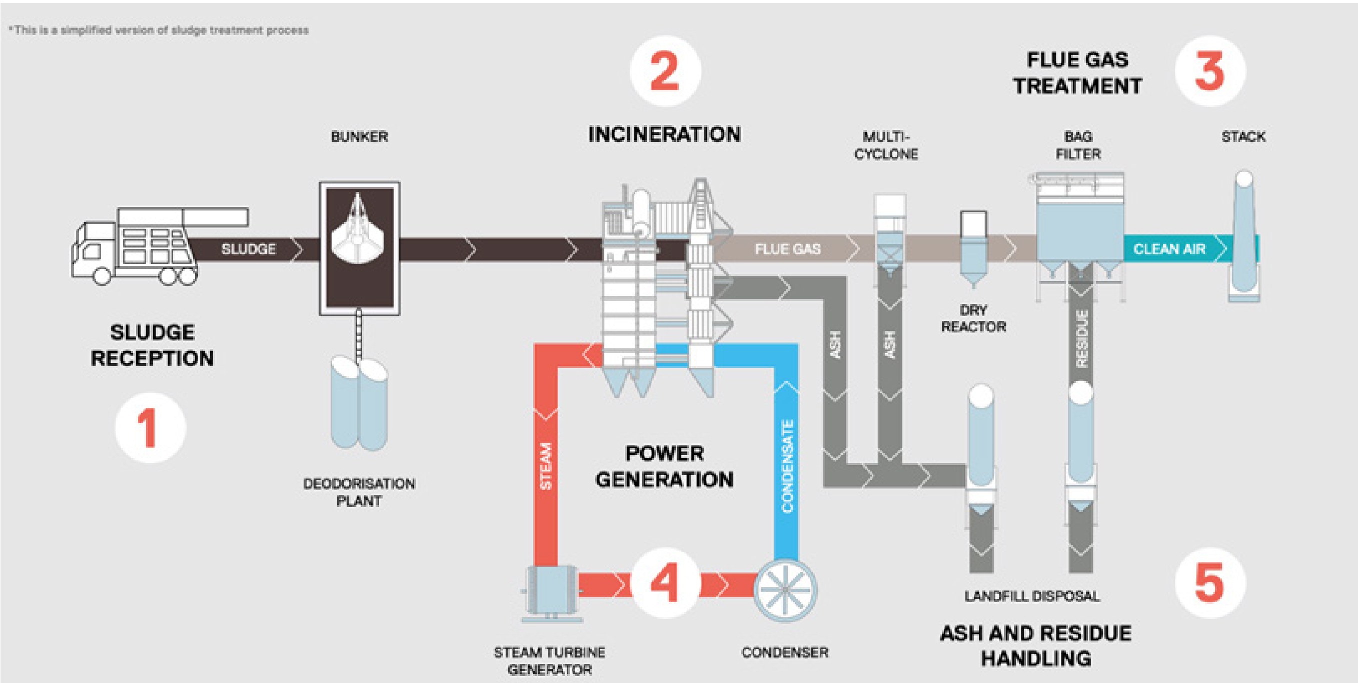
T·PARK is an important step in Hong Kong's waste-to-energy journey. It is a state-of-the-art sludge treatment facility, which is specifically designed to address one of the many waste challenges in Hong Kong. "T" stands for Transformation, representing the city's vision to embrace the concept of "waste-to-energy", and to drive positive change in the attitudes and behaviours of people towards waste management and resource recovery. T·PARK is a unique self-sufficient facility which combines a variety of advanced technologies into a single complex: sludge incineration, power generation, desalination and wastewater treatment. Additionally, T·PARK features an environmental education center with various recreational, educational and ecological facilities, allowing visitors to experience the benefits of "waste-to-energy" management and environmental protection.

Figure 1) The Benefits of T · PARK



4. Waste-to-energy – Sewage sludge (Cont’)

Figure 2) Waste-to-Energy Process



1. **Sludge reception: Advanced Deodorisation System to Minimise Environmental Impacts**

   The sludge is delivered in sealed containers and unloaded to storage bunkers by trucks at the reception bays. The sludge reception bays and storage area are enclosed and equipped with an advanced ventilation system to prevent odour from escaping. The trapped foul air is treated using deodorisers. All trucks are washed and dried before leaving the Facility. An automated grabber places the sludge into dedicated hoppers followed by mixing prior to incineration.

2. **Incineration: Proven Fluidised Bed Incineration Technology**

   An advanced “fluidised bed” incineration system has been adopted to efficiently treat the sludge through thermal combustion. The technology involves suspending the sludge in a hot bubbling bed of sand, through which jets of air are blown to mix the sludge with sand rapidly so as to achieve uniform and complete burning. The thermal gases in the incinerator reach a temperature above 850°C for at least 2 seconds in order to control emissions of organic pollutants.

3. **Flue Gas Treatment: Stringent International Emission Standards**

   The highly effective flue gas treatment system consists of three major components that remove different types of pollutants. It starts with the “multi-cyclone” where larger particles are extracted under a rapid spinning action. This is followed by the “dry reactor” where pollutants are neutralised and captured by chemical and physical processes. The “bag filter” finally removes fine particles through filtration. The cleaned flue gas is constantly monitored by the Continuous Emission Monitoring System as it leaves the stack.

4. **Power Generation: Generation of Clean Energy from Waste**

   The incinerator, turbine and condenser work together to recover the heat generated by the incineration process for power generation. The incinerator acts like a boiler with a large number of water pipes surrounding its walls. Heat generated during incineration boils the water to produce steam. The steam then passes through a turbine to generate electricity which powers the various on-site operational needs. Surplus electricity is capable of supporting up to 4,000 households.

5. **Ash & Residue Handling: Cut Waste Volume By 90 Percent**

   Inert ash and residue collected after the incineration and flue gas treatment processes amount to approximately 10 percent of the original sludge volume. They are temporarily stored in silos and tested to ensure full compliance with the treatment standards before trucking to the adjacent West New Territories Landfill for disposal. T·PARK is a safe and clean facility that substantially reduces the loading on the landfills as well as the greenhouse gases emitted into the environment.

5. Hong Kong waste management infrastructure with waste-to-resources / energy

T・PARK (Sludge Treatment Facility)	Adopts advanced incineration technology to treat up to 2 000 tonnes of sewage sludge from sewage treatment works per day
WEEE・PARK (Waste Electrical and Electronic Equipment (WEEE) Treatment and Recycling Facility)	Treats up to 30 000 tonnes of Waste Electrical and Electronic Equipment (Regulated Electrical Equipment) annually, turning them into valuable secondary raw materials
O・PARK1 (Organic Resources Recovery Centre Phase 1)	Adopts anaerobic digestion technology that can convert 200 tonnes of food waste into electricity per day
O・PARK2 (Organic Resources Recovery Centre Phase 2)	Adopts anaerobic digestion technology that can convert 300 tonnes of food waste into electricity per day
Y・PARK (Yard Waste Recycling Centre)	Equips with plant and equipment to screen, sort and treat the yard waste for transforming into various useful materials such as compost. Some wood materials will also be provided to relevant industries to support their operations
I・PARK (Integrated waste management facilities) (Anticipated to commence operation by 2025)	Adopts advanced incineration technology to treat 3 000 tonnes of municipal solid waste per day