

SUSTAINABILITY OF THE ENVIRONMENT

Why do solar cells which do not release carbon dioxide into the atmosphere have carbon footprint?

Why are plastic bags being replaced with paper bags for environmental sustainability?

Are electric cars zero-emission vehicles?

What are the international organisations that play an important role in addressing environmental issues?

Let's study

- Product life cycle
- Environmental pollution
- Preservation and conservation of the environment



Upcycle is a recycling process to produce new products of higher value than the original product. The above photograph shows a sofa made from recycled waste paper. Is this sofa an upcycle product?



Keywords

- Upcycle
- Product life cycle
- Carbon footprint
- Carbon handprint
- Greenhouse gas
- Cradle-to-cradle life cycle of a product
- Cradle-to-grave life cycle of a product
- Microplastics
- Biochemical Oxygen Demand (BOD)
- Effective microorganism
- Negative Emission Technologies
- Zero carbon emission

3.1 Product Life Cycle

Carbon Footprint

Carbon footprint refers to the **total amount of carbon dioxide** released into the atmosphere as a result of the activities of an **individual, event, organisation, community or products** which are used in daily life.

Identify and discuss processes which influence **carbon footprint** (Figure 3.1). Name two processes in Figure 3.1 that can reduce carbon footprint.

The carbon footprint study of an individual begins by breaking down the products used in a day. As an example, the refrigerator represents a product that is used throughout the day in the life of an individual from the early hours of the morning until bedtime.



Figure 3.1 Carbon footprint



Figure 3.2 Energy efficiency labels

Study the energy efficiency labels in Figure 3.2. What is the relationship between the energy efficiency label on an electrical appliance with its carbon footprint?

Photograph 3.1 shows an example of a carbon footprint label on a food product. Based on the label, 900 g of carbon dioxide (CO_2) is released for every 500 ml.

Photograph 3.1 Example of carbon footprint label

Science Info

Offset refers to processes that can reduce the release of greenhouse gases such as planting of green plants.



Let us carry out Activity 3.1 to break down the products used in the daily life of an individual.

Activity 3.1

To break down the products used in the daily life of an individual

Instructions

1. Carry out this activity individually.
2. Choose an electrical lighting device (filament lamp, energy-saving lamp or LED lamp).
3. Observe and record in the table:
 - power of the electrical lighting device in kilowatts (kW)
 - frequency of its use in a day from wake-up until bedtime in hours (h)
4. Calculate and record the electrical energy used by the electrical lighting device in kilowatt-hours (kWh) (refer to the example given).
5. Calculate and record the mass of carbon dioxide released from using the electrical lighting device for one day by using the following formula:

$$\text{Amount of carbon dioxide released (g)} = \frac{\text{Electrical energy used (kWh)}}{50 \text{ kWh}} \times 39 \text{ g}$$

(Assumption: A usage of 50 kWh of electrical energy produces 39 g of carbon dioxide)

Observation

Example:

Electrical lighting device	LED lamp
Power of electrical lighting device (kW)	0.009
Frequency of use in one day (h)	5
Electrical energy used in one day (kWh)	0.045
Amount of carbon dioxide released into the air (g)	0.0351
Carbon footprint of the electrical lighting device used in a day (g)	0.0351

Discussion

1. Discuss the carbon footprint of the electrical lighting device you used with your classmates.
2. Discuss ways on how to reduce the carbon footprint of the device.

Besides carbon footprint, some questions that need to be considered regarding products used in daily life to preserve the sustainability of the environment include:

- Is the product environmentally friendly?
- What are the negative impacts of the manufacturing process of the product?
- Is the product safe to be used?
- How much waste is produced after the product is used?
- What other products can be produced from its waste (Photograph 3.2)?



Photograph 3.2 Coffee waste can be used as a fertiliser

Carbon Footprint and Carbon Handprint of a Product

The **carbon footprint** of a product refers to the **negative impacts** on environmental sustainability caused by the product throughout its **life cycle**.



The **carbon handprint** of a product refers to the **positive impacts** on environmental sustainability caused by the product throughout its **life cycle**.



Figure 3.3 Carbon footprint and handprint

The **carbon handprint** of a product is aimed at reducing its carbon footprint and increasing its positive impacts on environmental sustainability. Some of the **carbon handprint** steps to reduce greenhouse gas emissions throughout the life cycle of a product are as follows:

Use of materials with low carbon footprint in product manufacturing

Non-renewable building materials, which emit a lot of greenhouse gases are replaced with renewable building materials, which emit less greenhouse gases. As an example, cement is replaced with timber.



Cement



Timber

Photograph 3.3 Building materials

Extending the life cycle and increasing the efficiency of a product

Rechargeable batteries and solar panels are examples of products with extended life cycle and increased energy efficiency.

Solar panels

Rechargeable battery

Photograph 3.4 Products with extended life cycle and increased energy efficiency

Use of energy that emits less greenhouse gases and highly-efficient energy converters

Electrical energy is generated by power stations such as hydroelectric power stations which use renewable energy sources and do not emit greenhouse gases into the atmosphere. Is the use of electrical appliances carrying 5-star energy efficiency label a carbon handprint measure? Give your reasons.



Photograph 3.5
Bakun hydroelectric power station

Carbon handprint measures

Efficient management of waste towards environmental sustainability

The 5R (Refuse, Reduce, Recycle, Reuse, Rot) concept of waste management reduces waste by:

- refusing unnecessary products
- reducing the quantity of products used
- recycling products
- reusing products
- enabling the rotting of waste through composting



Photograph 3.6
Reuse of products

Elimination of greenhouse gases and storage of carbon dioxide in carbon sinks

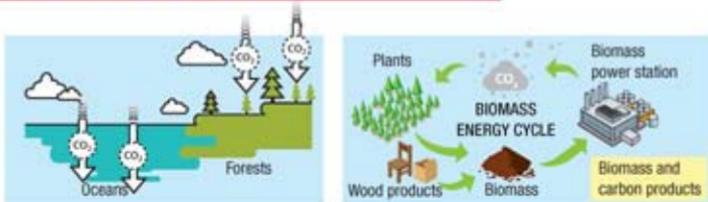


Figure 3.4 Elimination and storage of carbon dioxide in carbon sinks

Carbon sinks are natural places such as forests and oceans that remove carbon dioxide from the air. The reduction of carbon dioxide in the air occurs when carbon dioxide dissolves in seawater and when it is absorbed by green plants in the forests. Carbon accumulated in **biomass** can also help to reduce carbon dioxide in the air.

Video

Carbon sink
<http://buku-teks.com/sc5095>



Life Cycle of a Product

The common life cycle of a product starts from source to disposal either through recycling (cradle-to-cradle life cycle) or decay (cradle-to-grave life cycle) (Figure 3.5).

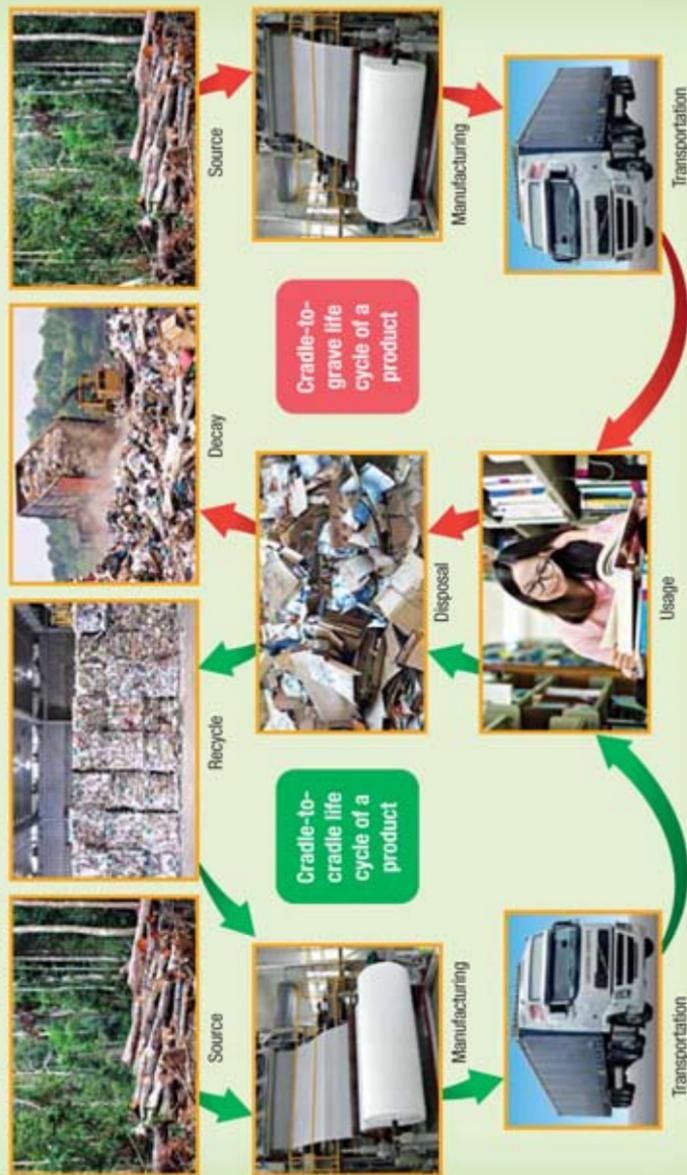


Figure 3.5 Life cycle of a product

Activity 3.2

To sketch the common life cycle of a product from source to disposal either through recycling or decay

Instructions

1. Carry out this activity in groups.
2. Gather and analyse information on the common life cycle of:
 - (a) a product from source to disposal through recycling (cradle-to-cradle life cycle of a product)
 - (b) a product from source to disposal through decay (cradle-to-grave life cycle of a product)
3. Discuss the information analysed and sketch the life cycles of both products.
4. Present the life cycle sketches of the chosen products to the class.
5. Conduct a 'Gallery Walk'.

21st Century Skills

- ICS, TPS
- Inquiry-based activity

Efficient Management of Plastic Waste towards Environmental Sustainability

In this modern era, our society must manage plastic waste using an efficient management idea towards environmental sustainability. For example, the recycling process, upcycle represents an efficient management idea that can be used to produce a new plastic product.

Photograph 3.7 shows a plastic broom as a new product of a higher value than its original product, used plastic bottles.



Photograph 3.7 Plastic broom made from used plastic bottles

To generate ideas about efficient management of plastic waste towards environmental sustainability based on projects using the STEM approach

Instructions

1. Carry out this activity in groups in a safe area in your school or neighbourhood to study the following statement:

Plastic pollution is the accumulation of plastic products that has adverse effects on the environment, wildlife, their habitats and humans. Furthermore, the chemical structure of most plastics allows them to withstand the natural decomposition process and take a longer time to decompose.

2. Carry out a project using the STEM approach to generate ideas on the efficient management of plastic waste towards environmental sustainability through the following actions:
 - (a) conduct a study on plastic pollution
 - (b) gather data and run a campaign on the impact of plastic use to raise awareness in the school and local communities
3. Gather and analyse information or available solutions from relevant and reliable sources, for example:

Modul Teknologi Hijau Kimia, CETREE USM.
 Title: Melestarikan Polimer Mesra Alam (Student's Activity) page 47
<http://buku-teks.com/sc5098>
 Note: Modul Teknologi Hijau, prepared by CETREE USM, is only available in bahasa Melayu.
4. Discuss the creative and innovative ideas generated among your group members. Then, present the outcome of your group discussion to the class.



Microplastics in the Food Chain

According to the U.S. National Oceanic and Atmospheric Administration (NOAA), **microplastics** are plastic pieces, less than 5 mm in length, which can become hazardous if found inside the body of aquatic organisms. The main source of microplastics is plastic waste from various types of plastic products such as bottles, man-made textiles, paint and discarded electronic devices.

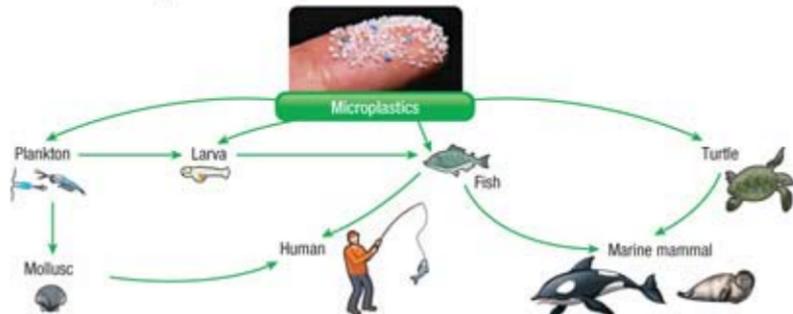


Figure 3.6 Microplastics in a food web

Figure 3.6 shows the transfer of microplastics between various types of organisms through the **food web** until they end up in humans and marine mammals.

The issue of microplastics in the food chain can be solved by reducing plastic waste and the use of plastic products. Do you agree that the use of plastic products such as plastic bags and plastic straws in supermarkets and restaurants should be stopped? Give your reasons.

Formative Practice 3.1

1. What is meant by carbon footprint?
2. State **seven** factors that normally influence the impact of a product that is used in an individual's daily life on environmental sustainability.
3. What is the difference between carbon footprint and carbon handprint of a product?
4. State **two** types of common life cycles of a product.
5. What is upcycle?
6. What is the issue of microplastics that is associated with the food web?

3.2 Environmental Pollution

Types and Sources of Environmental Pollution

Environmental pollution refers to the unwanted changes in the physical, chemical or biological characteristics of environmental components, that is, air, water and soil. Environmental pollution causes harm and discomfort to all life forms. Environmental pollution also causes environmental issues such as flash floods.

Observe the types of environmental pollution shown in Figure 3.7.

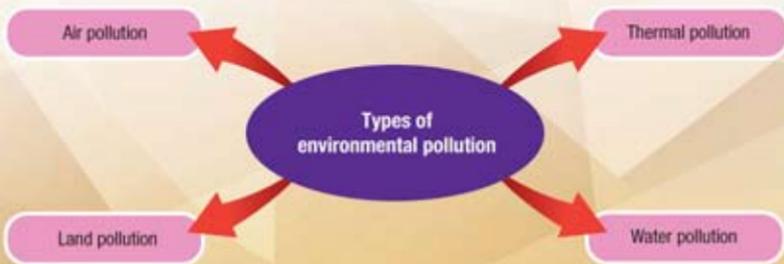


Figure 3.7 Types of environmental pollution

Observe and study the types and sources of environmental pollution in Table 3.1. Do your own research and add other types and sources of environmental pollution, if any.

Table 3.1 Types and sources of environmental pollution

Type of environmental pollution	Sources of environmental pollution
Air pollution	<ul style="list-style-type: none"> • Burning of fossil and biomass fuels, automobile exhaust gases, decaying organic substances and waste which release greenhouse gases and various types of toxic gases such as sulphur dioxide into the air. • Natural air pollution <ul style="list-style-type: none"> – volcanic eruptions – forest fires – dust storms – decaying organic waste • Man-made air pollution <ul style="list-style-type: none"> – exhaust gases from motorised equipment or vehicles – blast furnaces – thermal power stations – industries and garbage disposal sites
Water pollution	<ul style="list-style-type: none"> • Waste <ul style="list-style-type: none"> – wastewater – domestic waste such as detergents and sewage – solid waste such as rubbish – industrial waste such as grease • Chemical substances used in agriculture such as chemical fertilisers and pesticides • Oil spills
Land pollution	<ul style="list-style-type: none"> • Excessive use of fertilisers and pesticides • Inappropriate management of solid waste • Acid rain • Nuclear waste • Electronic waste
Thermal pollution	<ul style="list-style-type: none"> • Deforestation • Industrial activities • Fuel combustion in vehicles or machines

Activity 3.4

To use a graphic organiser to show types and sources of environmental pollution

21st Century Skills

- TPS, ICS, ISS
- Innovative activity

Instructions

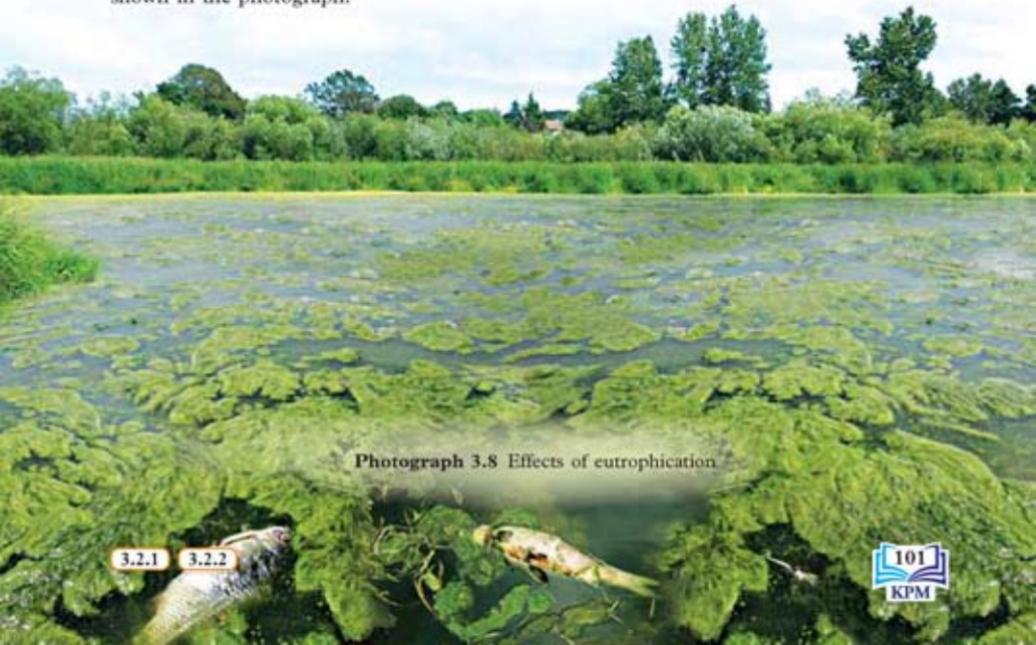
1. Carry out this activity in groups.
2. Use a graphic organiser to present in a creative and innovative way, the types and sources of environmental pollution shown in Table 3.1.
3. Discuss and improve on the graphic organiser of your group.
4. Present your group's graphic organiser to the class.

Level of Water Pollution from Domestic Waste

Air Pollutant Index (API) is the air pollution parameter which is measured to determine air pollution level while **Biochemical Oxygen Demand (BOD)** is the water pollution parameter which is measured to determine water pollution level.

Eutrophication is the ecosystem response towards an increase of phosphate ions and nitrate ions (from detergents, fertilisers and garbage) in an aquatic ecosystem. The rapid growth of algae in water bodies containing an excessive supply of nitrate ions is an example of eutrophication. The negative effects of eutrophication include reduced oxygen content in water that can cause the death of aquatic animals and plants.

Observe Photograph 3.8. Why are animals and plants unable to live in the lake shown in the photograph?



Photograph 3.8 Effects of eutrophication

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) is the amount of dissolved oxygen needed by microorganisms such as bacteria to decompose organic substances in a water resource. The higher the BOD of a water sample, the more microorganisms can be found in it. What is the relationship between BOD and level of water pollution in a water sample?

The level of water pollution in a water sample can be determined by measuring the time taken for methylene blue solution to decolourise after being mixed with the water sample. When methylene blue solution is added to a contaminated water sample with a low concentration of dissolved oxygen, the blue colour of the solution will decolourise rapidly. The higher the level of water pollution, the shorter the time taken for the methylene blue solution to decolourise.

Activity 3.5

To determine the water pollution level in different water samples

Materials

0.1% methylene blue solution and four different water samples (200 cm³ for each sample)

Apparatus

Four reagent bottles fitted with covers, syringe, watch and measuring cylinder

Instructions

1. Prepare the apparatus set-up shown in Figure 3.8.

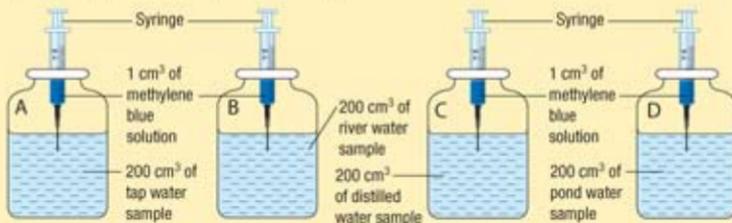


Figure 3.8

2. Add 1 cm³ of methylene blue solution into each reagent bottle A, B, C and D, using a syringe and close all the reagent bottles.
3. Keep all the reagent bottles in a dark cupboard.
4. Observe the colour of the water samples every 30 minutes and record the time taken for the methylene blue solution to decolourise.

21st Century Skills

- TPS
- Inquiry-based activity



Safety Precautions

Make sure the needle of the syringe is placed under the surface of the water sample when adding the methylene blue solution.

Observation

Reagent bottle	Type of water sample	Time taken for methylene blue solution to decolourise (minute)
A	Tap water	
B	River water	
C	Distilled water	
D	Pond water	

Questions

1. What is the use of methylene blue solution in this activity?
2. What is the relationship between the time taken for the methylene blue solution to decolourise and the amount of dissolved oxygen in the water sample?
3. Which water sample is the most polluted? Explain your answer.

**Click@Web**

Experiment to determine water pollution level by measuring the time taken for methylene blue solution to decolourise
<http://buku-teks.com/sc5103>
 (Medium: bahasa Melayu)



Purification Method for Contaminated Water using Green Technology

Use of Effective Microorganism Mud Balls (EM Mud Balls)

Efforts to invent purification methods for contaminated water using Green Technology is a continual process in Malaysia. Among the Green Technology methods used to treat contaminated rivers in Malaysia include the use of effective microorganism mud balls (EM mud balls) as shown in Photograph 3.9.



Photograph 3.9 Effective microorganism mud balls (EM mud balls)

Effective microorganisms (EM) are made up of the following **three** types of microorganisms:

Lactic acid bacteria such as *Lactobacillus casei* treats sewage, eliminates foul odour in water, stunts the growth of dangerous microorganisms, and facilitates the decay of organic substances.

Photosynthetic bacteria such as *Rhodospseudomonas palustris*. Photosynthetic bacteria use organic substances to synthesise useful substances such as amino acid and sugar for aquatic animals and plants to feed on.

Yeast (*Saccharomyces cerevisiae*) Yeast produces substances needed for the growth of green plants.

Activity 3.6

To make EM mud balls to treat polluted water

Materials

1.4 kg of soil, 70 g of EM Bokashi or rice bran, 500 cm³ of EM solution and newspaper

Apparatus

Tray, watering can and basin

Instructions

1. Carry out this activity in groups.
2. Prepare materials to make 10 EM mud balls according to the procedure shown in Figure 3.9.



Figure 3.9

3. The EM mud balls can be used to treat polluted water resources.

21st Century Skills

- TPS
- Inquiry-based activity

Thinking Skills

"LOVE OUR RIVERS" CAMPAIGN

Gather and study information on the effectiveness of the "Love Our Rivers" campaign

<http://buku-teks.com/sc5105>

(Medium: bahasa Melayu)



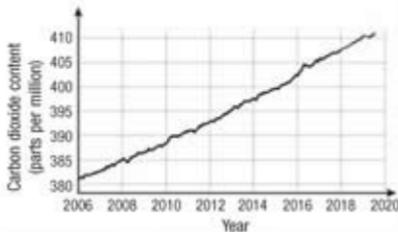
Formative Practice 3.2

- Name **three** types of environmental pollution.
- (a) What is eutrophication?
(b) Name the type of pollution related to eutrophication.
- Name **one** type of pollution which causes the following harmful effects:
 - greenhouse effect and global warming
 - climate change
- (a) What is Biochemical Oxygen Demand (BOD)?
(b) What is the relationship between BOD and the level of water pollution in a water sample?
- How does methylene blue solution function as an indicator of the water pollution level in a water sample?
- (a) Name the microorganisms used to make effective microorganism mud balls (EM mud balls).
(b) How do effective microorganisms treat polluted water?

3.3 Preservation and Conservation of the Environment

Based on Figure 3.10, answer the following questions.

- What can be observed about the carbon dioxide content in the atmosphere from 2006 till 2019?
- What are the harmful effects of high carbon dioxide content in the atmosphere?
- Why does every individual need to play a role in reducing the content of carbon dioxide in the atmosphere?



Source: <https://climate.nasa.gov/>

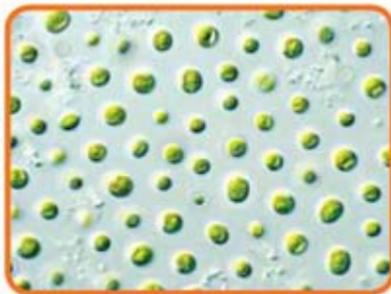
Figure 3.10 Graph of carbon dioxide content in the atmosphere

Negative Emission Technologies

Negative Emission Technologies are technologies that remove the carbon dioxide content in the atmosphere.

One way is by using microalgae. What is the process carried out by microalgae that can help reduce the carbon dioxide content in the atmosphere?

The microalgae commonly used in Negative Emission Technologies are **marine microalgae**, that is, microscopic algae which live, grow and reproduce abundantly in seawater. Photograph 3.10 shows marine microalgae under an electron microscope. Marine microalgae are suitable for use in Negative Emission Technologies because these microalgae reduce the carbon dioxide content in the atmosphere through photosynthesis (Photograph 3.11).



Photograph 3.10 Marine microalgae under an electron microscope



Photograph 3.11 Microalgae plant used in Negative Emission Technologies

Science Info

Eco currency

The preservation and conservation of the environment requires global efforts to manage natural resources. As such, a type of universal currency known as eco currency has been proposed as a medium of exchange in transactions as one of the many efforts to maintain environmental balance.

Click@Web

Introduction of the term eco currency
<http://buku-teks.com/sc5106b>



Video

Importance of eco currency
<http://buku-teks.com/sc5106c>



Activity 3.7

21st Century Skills

- ICS, TPS
- Discussion

To discuss the use of Negative Emission Technologies and Green Technology in several sectors

Instructions

- Carry out this activity in groups.
- Gather and discuss information on the following:
 - use of Negative Emission Technologies to reduce the carbon dioxide content in the atmosphere
 - use of Green Technology in the following sectors:
 - solar technology
 - green buildings
 - zero carbon emission
 - biodiesel
 - hybrid cars

References

Modul Teknologi Hijau Fizik, CETREE USM

Title: *Tenaga Solar dan Matahariku*

<http://buku-teks.com/sc5107a>
pages 42 – 51



<http://buku-teks.com/sc5107b>
pages 66 – 87



Modul Teknologi Hijau Fizik, CETREE USM

Title: *Bangunan Mesra Hijau*

<http://buku-teks.com/sc5107a>
pages 61 – 73



<http://buku-teks.com/sc5107b>
pages 107 – 131



Modul Teknologi Hijau Biologi, CETREE USM

Title: *Teknologi Penanaman Vertikal ke arah Pertanian Lestari*

<http://buku-teks.com/sc5107c>
pages 28 – 39



<http://buku-teks.com/sc5107d>
pages 31 – 59



Note: *Modul Teknologi Hijau*, prepared by CETREE USM, is only available in bahasa Melayu

- Present the outcome of your group discussion in the form of a multimedia presentation.

The Role of United Nations (UN) in Addressing Global Environmental Issues

The United Nations (UN) plays an effective role in addressing global environmental issues. UN increases the cooperation and efforts of countries around the world to address global environmental issues through the following ways:

- finds solutions to address issues related to global climate change by sponsoring international conferences and agreements signed by the global community
- secures adequate supply of clean drinking water
- protects the ozone layer by banning the use of chlorofluorocarbon which causes the thinning of the ozone layer
- bans the use of toxic chemical substances such as DDT pesticides



Science Info

The international conferences and agreements sponsored by UN to promote cooperation and joint efforts among countries of the world include:

- the Rio Conference or United Nations Conference on Environment and Development (UNCED) in 1992, to address global environmental issues
- the Kyoto Protocol in 1997, to reduce the emission of greenhouse gases
- the Paris Agreement in 2016, to reduce the content and emission of greenhouse gases and limit the rise in global temperature by 1.5°C.

Activity 3.8

To debate on the role of the United Nations (UN) on the basis of conventions that have been held such as the Rio Conference, Kyoto Protocol and Paris Agreement

Instructions

1. Carry out this activity in groups.
2. Gather information from the Internet, print media and other electronic media on the role of the United Nations (UN) on the basis of conventions that have been held such as the Rio Conference, Kyoto Protocol and Paris Agreement.
3. Discuss the information gathered.
4. Conduct a debate.

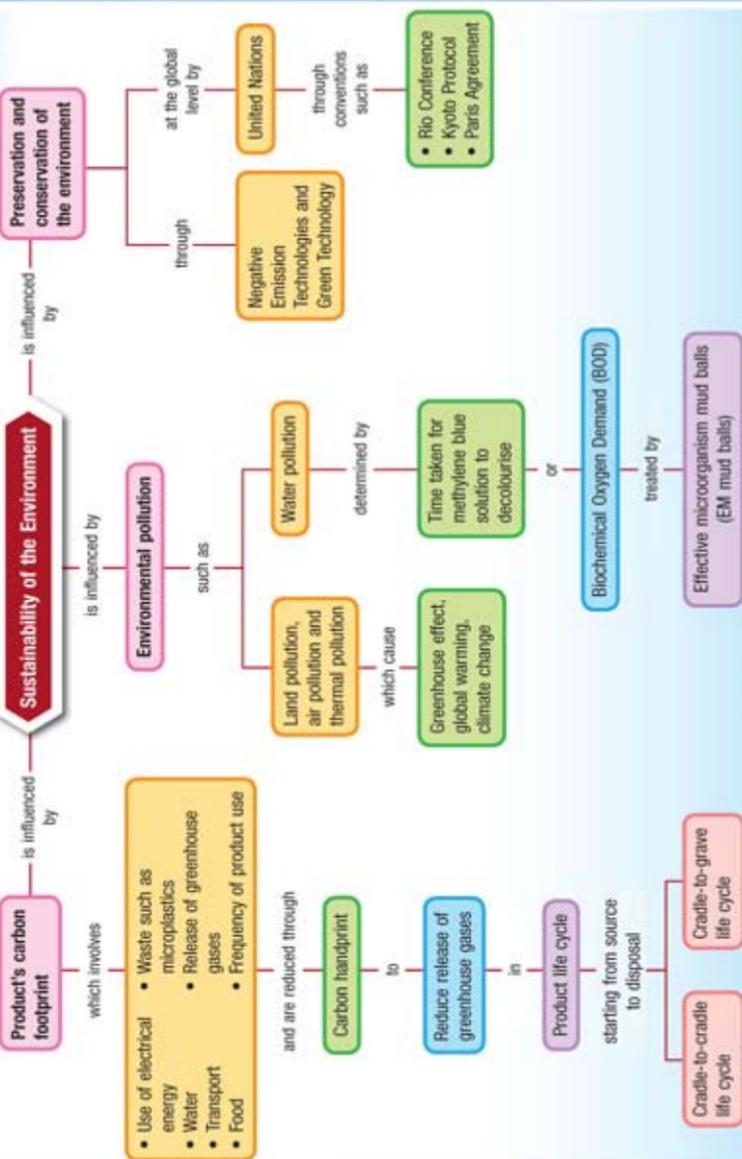
21st Century Skills

- ICS, ISS, TPS
- Debate

Formative Practice 3.3

1. What are Negative Emission Technologies?
2. Give **one** example of microorganism used in Negative Emission Technologies.
3. What is the relationship between solar technology and zero carbon emission?
4. Why does the United Nations (UN) need to play an effective role in addressing environmental issues at the global level?

Summary





Self-Reflection

After studying this chapter, you are able to:

3.1 Product Life Cycle

- Explain the meaning of carbon footprint.
- Break down the products used by an individual in a day.
- Justify the actions that need to be taken, that is, carbon handprint to reduce the greenhouse gas emissions in a day of one's life.
- Communicate about the life cycle of a product.
- Generate ideas about efficient management of plastic waste towards environmental sustainability.

3.2 Environmental Pollution

- Explain the types and sources of environmental pollution.

- Study the water pollution level from domestic waste.
- Create and design a purification method for contaminated water using Green Technology.

3.3 Preservation and Conservation of the Environment

- Justify the role of individuals in managing natural resources to maintain the balance in the environment.
- Debate on the role of the United Nations (UN) in addressing global environmental issues.



Summative Practice 3

Answer the following questions:

1. Figure 1 shows an experiment to study the level of water pollution in different water samples.

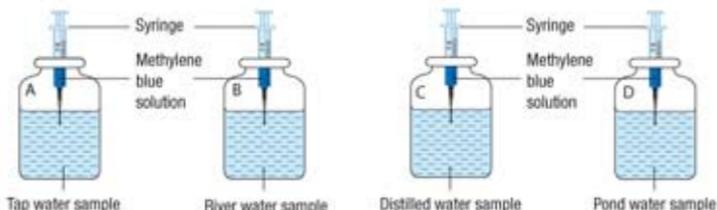


Figure 1

Table 1 shows the time taken for the methylene blue solution to decolourise in the different water samples in Figure 1.

Quiz

[http://buku-
teks.com/
sc5110](http://buku-
teks.com/
sc5110)



(b) Figure 4 shows various types of environmental pollution.

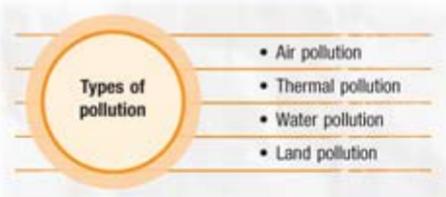


Figure 4

Study the information in Figure 4 and answer the following questions.

- Identify a type of pollution that is related to energy.
- Name the type of pollution related to eutrophication.
- Give **one** example of harmful effect of air pollution.
- State the common characteristics of the pollution types shown in Figure 4.



Enrichment Practice

4. Air conditioners are electrical appliances that are widely used in our daily lives. Have you experienced the hot air emitted from the compressor of an air conditioner (Figure 5)?

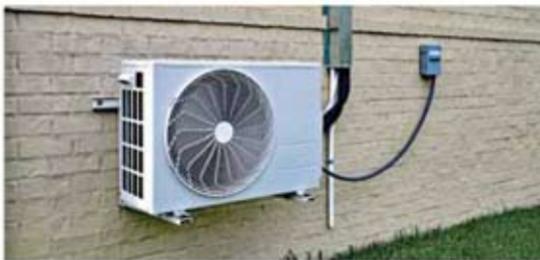


Figure 5

- What is the type of environmental pollution caused by air conditioners?
- How can pollution caused by the usage of air conditioners be reduced?
- Suggest **one** creative way to use the heat released from the compressor of an air conditioner. 