# Cleaning up sewage (Years 9 and 10)

Lesson plan

|  |
| --- |
| Victorian Curriculum F–10[[1]](#footnote-1) links:  **Levels 9 and 10**  **Science**  **Science Understanding**  **Science as a Human Endeavour**  The values and needs of contemporary society can influence the focus of scientific research  **Biological sciences**  Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems  **Earth and space sciences**  Global systems, including the carbon cycle, rely on interactions involving the atmosphere, biosphere, hydrosphere and lithosphere  **Geography**  **Geographical Knowledge**  **Environmental change and management**  Different types and distribution of environmental changes and the forms it takes in different places  Environmental, economic and technological factors that influence environmental change and human responses to its management |

## Introduction

Each year, Melbourne Water treats over 320,000 milllion litres of sewage at its Western Treatment Plant and Eastern Treatment Plant. More than half of Melbourne’s sewage is processed further to produce high quality recycled water. The remaining high quality treated effluent is released into Port Phillip Bay or Bass Strait.

In this lesson plan, students explore the terminology and innovative processes involved in treating sewage. They conduct experiments that demonstrate the need to reduce nitrogen levels of the effluent and the effects of changed dissolved oxygen levels in water.

The process of osmosis is examined and students debate the feasibility of treating effluent (using reverse osmosis) to drinking water standards as a supplement to Melbourne’s domestic water supply.

For more information about tours of the sewage treatment plants go to

**Visit the Western Treatment Plant** at <<http://www.melbournewater.com.au/getinvolved/education/programs/WTPtours/Pages/Visit-the-Western-Treatment-Plant.aspx>>

**Visit the Eastern Treatment Plant** at <<http://www.melbournewater.com.au/getinvolved/education/programs/ETPtours/Pages/Visit-Eastern-Treatment-Plant.aspx>>

### Activity 1: Treating Melbourne’s sewage

Students investigate the terminology used in sewage treatment, the processes used and calculate volumes of sewage flow.

### Activity 2: Sludge gas and biosolids—putting waste to work

Students explore how a waste product from the sewage treatment process, biogas, is collected to generate renewable energy.

### Activity 3: The nitrogen cycle at the sewage treatment plant

Students investigate the nitrogen cycle in the real-world context of a sewage treatment plant. They design an experimental investigation to test the effect of different nitrogen compounds on plant growth and draw conclusions about the importance of minimising nutrient levels in sewage treatment discharge into Port Phillip Bay and Bass Strait.

### Activity 4: Dissolved oxygen and aquatic ecosystems

Students conduct an experiment to observe the effects of varying dissolved oxygen levels on the organisms present in pond water. They consider the implications for sewage treatment processes.

### Activity 5: From the sewer to the glass

Students investigate the processes necessary to treat water to a standard sufficient for human consumption, conduct an experiment to demonstrate osmosis and debate whether Melbourne should use suitably treated effluent to augment its domestic water supply.

**Activity 1: Treating Melbourne’s sewage**

Students are introduced to Melbourne’s sewerage system and the role of Melbourne Water’s Eastern and Western Treatment Plants. They define terms used in the sewage treatment industry, identify items and substances that are introduced to the sewerage system, create a flow chart of sewage treatment processes and calculate average daily volumes of annual sewage flow.

**Duration**

Four period sessions

**Activity steps**

1. Students use the internet to research and define the following terms:

* sewage
* sewerage
* greywater
* blackwater
* effluent
* stormwater.

As a starting point, go to:

Sewerage system – how it works, Melbourne Water

<<http://www.melbournewater.com.au/whatwedo/treatsewage/seweragesystem/Pages/how-our-sewage-system-works.aspx>>

Stormwater, Melbourne Water <<http://www.melbournewater.com.au/whatwedo/protectrivers/improving-river-health/Pages/Stormwater.aspx>>

1. Individually, students draw a plan of their house (using ICT if available) and label it to show where connections are made to the sewerage system. Ask them to identify the different items and substances that are introduced to the sewerage system. Encourage students to research and note the chemicals that compose the waste (e.g. laundry detergents contain water softeners, surfactants, bleach, enzymes, brighteners, fragrances, and many other agents).
2. As a class, combine the lists of substances to make a master list. Classify the items as contributing to greywater or blackwater. Classify whether they are organic or inorganic compounds. The class decides how this information can be displayed in a clear and concise manner and each student prepares their list.
3. Explain that the major component of sewage is water (more than 99%) and that treatment involves the separation of the 1% of other materials from it. Discuss how these materials may affect the environment if they are not removed during the treatment process.

A list of items that might end up in the sewerage system and their effect is available at <<http://www.melbournewater.com.au/getinvolved/protecttheenvironment/Pages/Help-us-keep-sewers-clean.aspx>>

1. Students take their lists with them on their visit to the treatment plant and identify where these materials are treated and removed during the purification process.
2. Students can access resources about the Western Treatment Plant process and information about the stages in the treatment that use bacteria.
   1. Western Treatment Plant Sewage treatment process <<http://www.melbournewater.com.au/whatwedo/treatsewage/wtp/Pages/Sewage-treatment-process.aspx>>
   2. Primary treatment of sewage and anaerobic treatment of sludge
   3. <<https://www.youtube.com/watch?v=--GS_djOzcg&list=PL1zDcvEb76G6FdTMg-_VRmAE4jMoarrKr&index=1>>
   4. Secondary treatment of sewage
   5. <<https://www.youtube.com/watch?v=yF9hQUebDNA&index=2&list=PL1zDcvEb76G6FdTMg-_VRmAE4jMoarrKr> >
   6. Where does wastewater go? ABC Splash video [3:43]
   7. <<http://splash.abc.net.au/home#!/media/524873/>>

**Calculating average daily volume of sewage flow**

1. Students locate their school in Google Earth. (Google Earth will need to be downloaded from www.google.com/earth/index.html if it is not already available on the students’ computers.) Students use the measuring tool to determine the school’s dimensions and then calculate its area. If Google Earth is not available, students can physically measure their school ground’s dimensions to calculate the area.
2. Use the following data for students’ calculations. A total of about 320,000 megalitres (ML), or 320 gigalitres (GL), of sewage is treated by Melbourne Water, the Western Treatment Plant treated 60% and the Eastern Treatment Plant 40%. (Note: 1 megalitre (ML) = one million litres, one gigalitre (GL) = one-thousand million litres.)
3. Students determine the annual sewage flow one of the treatment plants and calculate average daily volume. Using the area of the school ground calculated previously, they determine the depth that that volume of water would be if it was contained within their school grounds, assuming the grounds are level. For instance, for a school with an area of five hectares, using a total volume of 271 GL of sewage, the average daily throughput of the Western Treatment Plant would equate to a height of about nine metres. Relate this height to physical features in the school or local area, such as sportsgrounds or shopping centres.
4. Discuss the need for sewage treatment and the processes involved and ask students to envisage what they might see, smell and hear when they visit the treatment plant.

## Activity 2: Sludge gas and biosolids—putting waste to work

Students investigate how materials traditionally thought of as waste products, can be used to improve efficiency, lower costs and decrease the carbon footprint of sewage treatment. This activity focuses on the benefits of biogas production as a renewable energy source.

### Duration

Two period sessions

### Activity steps

1. For an overview of how Melbourne Water’s Eastern and Western Treatment Plants use biogas produced through the treatment process to meet most of the plants’ electricity needs, students visit:

Energy efficiencies and renewable sources

<<http://www.melbournewater.com.au/whatwedo/Liveability-and-environment/energy/Pages/Energy-efficiencies-and-renewable-sources.aspx>>

Western Treatment Plant:

Waste to resources

<<http://www.melbournewater.com.au/whatwedo/Liveability-and-environment/waste/Pages/Waste-to-resources.aspx>>

Sewage treatment process

<http://www.melbournewater.com.au/whatwedo/treatsewage/wtp/Pages/Sewage-treatment-process.aspx>

1. Students work in groups and use the internet to research the following questions:

* What is biogas?
* What are anaerobic, aerobic and facultative bacteria and how do they get their energy?
* How do bacteria contribute to the production of biogas?
* How can biogas be used?
* What are the environmental advantages of using biogas?
* How is biogas made and collected at the plant they are visiting?
* How does it differ from the process at the other plant?

1. Groups prepare a presentation to argue a case for collecting the gas produced during sewage treatment on economic and environmental grounds. Appoint students to the board of directors of a sewage authority and have groups of students make presentations for the board to decide the most compelling case.
2. Discuss the need for sustainability and the measures taken by Melbourne Water to reduce their plants’ carbon footprints and make them more sustainable.

### Extension activity

In groups, students investigate other sustainability projects undertaken by Melbourne Water such as the recycling of biosolids and water and their possible uses, and then present their findings to the class. Visit: Liveability and environment <<http://www.melbournewater.com.au/whatwedo/Liveability-and-environment/Pages/liveability-and-environment-.aspx>>

### Teacher background

**Anaerobic digestion of solids to produce biogas**

Bacteria types:

* aerobic—requires oxygen for respiration so live in oxic environments
* anaerobic—does not require oxygen for respiration, but uses other substances such as nitrates, sulphates and sulphur. Anaerobic bacteria die in the presence of oxygen and thus exist in an anoxic environment.
* facultative—live in either oxic or anoxic environments and can use either aerobic or anaerobic respiration, depending on their environment.

Biogas is a mixture principally of methane with carbon dioxide and traces of other gases such as ammonia and hydrogen sulphide. It is produced by anaerobic bacteria as they break down the organic matter in sewage in the absence of oxygen. Oxygen, present in the sewage initially, is removed by aerobic oxygen-loving bacteria and, when this is complete, the anaerobic bacteria can convert complex organic compounds into methane and carbon dioxide.

Several kinds of anaerobic bacteria feed on the raw sewage, with the by-products of digestion of one type of bacteria providing the food for another bacterial population. The first stage involves liquefaction during which acid-producing bacteria (acidogens) secrete enzymes, which convert long-chain fats, proteins and starches into simpler substances, especially low molecular weight organic acids like acetic acid and alcohols. In the second stage, known as gasification, methane-producing bacteria (methanogens) use enzymes to break down the acids into methane and carbon dioxide.



Figure 1 Sequence of anaerobic bacteria in the production of biogas

|  |  |  |
| --- | --- | --- |
|  | **Eastern Treatment Plant** | **Western Treatment Plant** |
| Biogas | Towards the final stage of treatment, methanogenic bacteria produce methane gas which is captured in large tanks. The tanks are kept at 37˚C; no oxygen is present.  Biogas is used to produce electricity to run the plant and heat pipes.  This reduces the amount of dangerous greenhouse gases that are released into  the atmosphere, as well as the amount of electricity Melbourne Water needs to import from the grid. | In the early stage of treatment, methanogenic bacteria in the large lagoon produce methane gas which is captured. Black plastic covers the lagoon which keeps the temperature high and ensures no oxygen is present.  Biogas is used to produce electricity to run the plant.  This reduces the amount of dangerous greenhouse  gases that are released into the atmosphere, as well as the amount of electricity  Melbourne Water needs to import from the grid. |

## Activity 3: The nitrogen cycle at the sewage treatment plant

Students investigate the role of nitrogen in the environment and how it is recycled. Students design and conduct an experiment to observe the effect of different nitrogen compounds on the growth of plants and then relate the findings to the need to reduce the nitrogen levels of effluent before its release into Port Phillip Bay and Bass Strait.

### Duration

Two period sessions for research. One period session for design and set up of experiment. Allow about one to two weeks for plants to grow and students to make measurements. One period session for analysis of results.

### Equipment

Some equipment students may need includes:

petri dishes or saucers

thermometers

hygrometers

growing lamps

time-lapse cameras/software/applications

data loggers.

### Activity steps

**The nitrogen cycle**

1. In small groups, students use the internet to research the nitrogen cycle and its importance for life on Earth. Ask them to also research the sources of nitrogen in sewage. Students use ICTs (e.g. PowerPoint, Keynote) to prepare a simple animation depicting the nitrogen cycle including sewage processes.
2. Discuss as a class how nitrogen compounds might get into sewage and why it is necessary to control the nitrogen levels in effluent before the effluent is released.

**Nitrates in the environment**

1. Review students’ ideas about the nitrogen cycle. Discuss the fact that plants need nitrogen to make proteins and nucleic acids to grow and be healthy. However, if nitrogen levels get too high in waterways this can promote rapid plant growth. This rapid growth can, in turn, result in reduced dissolved oxygen levels because, as the plants die, the aerobic bacteria that decompose them use up the oxygen in the water. Reduced oxygen levels can cause the death of other aquatic life that requires oxygen.
2. Students work in groups to design an experiment that investigates the effect that different nitrogen compounds have on the growth of wheat, alfalfa, watercress or other fast-growing seeds. They need to consider necessary controls and how they will determine the rate of growth before commencing the experiment. Students are to consider factors that may affect the dissolved oxygen levels in the samples and how they will be controlled in their experiment. Further details of the activity can be found in **Student worksheet: Nitrogen and plant growth**. Ensure that all safety requirements are followed.
3. Allow about one to two weeks for plant growth.
4. When students have drawn conclusions from their observations and related them to the need to control nitrogen levels in the effluent released from the sewage treatment plants into the sea. Discuss how high nitrogen levels could have a detrimental effect on the marine environment.

Note: This task could be used for assessment purposes to assess student understanding of the selection of appropriate equipment and measurement procedures that will ensure a high degree of reliability in data collected and enable valid conclusions to be drawn.

## Activity 4: Dissolved oxygen and aquatic ecosystems

Dissolved oxygen is an indicator of the health of aquatic ecosystems. It is a measure of the amount of dissolved oxygen needed by aerobic organisms to break down the organic material present. It is widely used as an indicator of organic pollutants in water and, as such, gives a measure of the effectiveness of the sewage treatment process.

Students conduct an experiment to observe the effects of varying dissolved oxygen levels on the organisms present in pond water. They consider the implications of this for sewage treatment processes.

### Duration

Two period sessions with at least 24 hours between them

### Equipment

Some equipment students may need includes:

fresh water sample from a local stream or pond

beakers

jars

USB or stereo microscope

graduated cylinder

dissolved oxygen meter

petri dishes

pipettes

fish-tank pump, tubing and air stones.

### Activity

1. Students undertake the experiment as outlined in the **Student worksheet: Dissolved oxygen and aquatic ecosystems** to determine the effect of oxygen levels on aquatic organisms. They then analyse their observations and relate them to the use of the measurement of oxygen levels as a viable indicator of water quality. Students present their results in a suitable format. Ensure that all safety requirements are followed.
2. Discuss how the method used by students can determine the biological oxygen demand of the water at various stages in the treatment process and as a measure of the quality of the effluent released from the treatment plants.

Note: This task could be used for assessment purposes to assess student understanding of the selection of appropriate equipment and measurement procedures that will ensure a high degree of reliability in data collected and enable valid conclusions to be drawn.

## Activity 5: From the sewer to the glass

The Western Treatment Plant treats some sewage to Class A standards, making it suitable for the irrigation of human food crops and cattle production. But it is not suitable for use as drinking water. To take this further and make water suitable for direct human consumption, further treatment is necessary.

Students investigate the processes necessary to treat water to a standard sufficient for human consumption, conduct an experiment to demonstrate osmosis and debate whether Melbourne should use suitably treated effluent to augment its domestic water supply.

### Duration

Two period sessions

### Activity steps

**Purifying effluent**

1. Students view the video of Singapore’s NEWater system at <https://www.youtube.com/watch?v=DWWU-8_4wu0> [3:28] to identify the steps used to purify their treated sewage effluent for human consumption. They then use the information gained to produce a flow chart describing the process.

**What is osmosis?**

1. Students conduct an experiment using potatoes to demonstrate osmosis. They extend this knowledge to explain the process of reverse osmosis and how it can be used to remove mineral and biological contaminants from treated effluent. Further information is available in **Student worksheet: Potato osmosis**.

**Debate**

1. Students form teams to research and debate the question: Should Victoria use recycled water to augment Melbourne’s domestic water supply?

### Resources

Melbourne Water

Western Treatment Plant Sewage treatment process <<http://www.melbournewater.com.au/whatwedo/treatsewage/wtp/Pages/Sewage-treatment-process.aspx>>

Tertiary treatment of sewage at the Western Treatment Plant

<<https://www.youtube.com/watch?v=_v39CRr8gGY&list=PL1zDcvEb76G6FdTMg-_VRmAE4jMoarrKr&index=4>>

Eastern Treatment Plant tertiary upgrade

<http://melbournewater.com.au/whatwedo/projectsaroundmelbourne/Pages/Eastern-Treatment-Plant-tertiary-upgrade.aspx>

Tertiary treatment of sewage at the Eastern Treatment Plant

<<https://www.youtube.com/watch?v=GHCtYU2YAgI&index=3&list=PL1zDcvEb76G6FdTMg-_VRmAE4jMoarrKr>>

## Student worksheet: Nitrogen and plant growth (Activity 3)

## Introduction

Plants need nitrogen to make proteins and nucleic acids to grow and be healthy. Nitrogen is found naturally in the atmosphere and in the soil, but even though there is an abundance of nitrogen available, the most common form of nitrogen (N2) cannot be used by plants. Nitrogen can be combined chemically with oxygen or hydrogen to form nitrogen compounds that plants can use. These nitrogen compounds can be added to the soil in the form of ammonium (NH4+) and nitrate (NO3–) fertilisers.

If nitrogen levels get too high in waterways, this can promote rapid plant growth. This can result in the reduction of dissolved oxygen levels because, as the plants die, the aerobic bacteria that decompose them use up the oxygen in the water. Reduced oxygen levels can cause the death of other aquatic life that requires oxygen.

In this activity you are to design an experiment to demonstrate how different nitrogen compounds affect plant growth.

### Hypothesis

What do you think you are going to find out?

### Controls

Consider factors that may affect the dissolved oxygen levels in the samples and how they will be controlled in your experiment. Record them in a table like the one below.

|  |  |  |
| --- | --- | --- |
| **Control factor** | **Effect** | **Method of control** |
| Amount of light | Amount of light will affect rate of growth | Keep all plants under the same lighting conditions |
|  |  |  |
|  |  |  |

### Equipment

quick-growing seeds (e.g. wheat, alfalfa, water cress, radish)

solutions of nitrate and ammonium compounds of different concentrations

list any other materials or equipment you may need (refer to outline for Post-activity 1 Nitrates in the environment).

### Procedure

Describe what you will do, considering the necessary controls, and how you will measure the growth of the plants.

### Observations and results

Use tables and graphs to record and display your observations.

### Conclusions

What has this experiment shown about the role of nitrogen in plant growth?

Why is it necessary to limit the number of nitrogen compounds in effluent before it is released into Port Phillip Bay or Bass Strait?

How are nitrogen levels in the effluent reduced during the sewage treatment process?

## Student worksheet: Dissolved oxygen and aquatic ecosystems experiment (Activity 4)

### Introduction

In this activity you will conduct an experiment to observe the effects of varying dissolved oxygen (DO) levels on the organisms present in pond water. You will then consider the implications of this in sewage treatment.

Oxygen enters the water as rooted aquatic plants and algae undergo photosynthesis, or by direct transfer across the air-water interface. The amount of oxygen that can be held by the water, the dissolved oxygen, ranges between 0–18 ppm (parts per million) under normal conditions and depends on the water temperature, salinity and pressure.

DO is an important indicator of a healthy aquatic ecosystem as oxygen is essential for respiration by aquatic animals. To support a diverse population, natural systems generally require DO levels of at least 5–6 ppm. If organic matter such as animal waste or improperly treated sewage is introduced to the system, algae growth can increase. As the algae die off and decompose, oxygen is consumed by aerobic bacterial action which can cause DO levels to fall below those needed to support some aquatic species, upsetting the balance in the ecosystem.

### Hypothesis

How do you think the DO levels of the samples will change over the 24-hour period and how will this affect biodiversity?

### Controls

Consider factors that may affect the DO levels in the samples and how they will be controlled in your experiment. Record them in a table like the one below.

|  |  |  |
| --- | --- | --- |
| **Control factor** | **Effect** | **Method of control** |
| Temperature | Increased temperature will decrease the solubility of oxygen in water | Measure the DO at the same temperatures |
|  |  |  |
|  |  |  |

### Materials

fresh water sample from a local stream or pond (follow safety procedures)

1,000 mL beaker or large container

3 x 500 mL beakers or jars to set up miniature water ecosystems

USB or stereo microscope

500 mL graduated cylinder

dissolved oxygen meter or test kit

petri dishes

pipettes

fish-tank pump, tubing and air stones set up to provide air to two beakers regulator or paper clip to reduce the air flow to Beaker 2.

### Procedure

1. Take an approximate 1,000 mL sample of the water from a local stream or pond.
2. Pour a portion of the sample into a petri dish and examine it under the microscope.
3. Capture photographs, draw or describe in detail the types and numbers of living organisms you observe.
4. Use the DO meter to measure the DO level of the water sample.
5. Measure three equal samples of the water into three beakers or jars and label as follows:

Beaker 1 – Control. No aeration

Beaker 2 – Slight aeration

Beaker 3 – Increased aeration

1. Place the beakers in an area where they will not be disturbed for 24 hours. Connect Beakers 2 and 3 to the fish-tank pump.
2. Reduce the flow of air to Beaker 2 using the regulator or paper clip so it is about half that going into Beaker 3.
3. Leave the beakers undisturbed for 24 hours, ensuring that the pump keeps running.
4. After 24 hours, place a sample from each beaker into a petri dish and view them under the microscope. Photograph, draw or describe in detail the types and numbers of living organisms you observe.
5. Use the meter to measure the DO level in each beaker and record your results.

### Results and observations

Devise a suitable table to record your observations and measurements.

### Conclusions

Does the data collected support your hypothesis? Why or why not?

Write a short paragraph explaining how each water sample changed based on the DO levels.

What can you conclude about the DO levels and biodiversity?

What implications do your findings have regarding the discharge of effluent from sewage treatment plants?

How does the treatment process at the plant you visited control the DO level of its effluent water?

## Student worksheet: Potato osmosis (Activity 5)

### Introduction

Osmosis occurs when water molecules are allowed to pass through a semi-permeable membrane that stops solutes from passing through. Osmosis will happen when the concentration of the solutions is different on each side of the semi-permeable membrane and so water moves from the side of lower concentration to that of higher concentration, tending to dilute it, until equilibrium is reached. Reverse osmosis occurs when pressure is applied to the more concentrated solution forcing the water backwards through the membrane.

### Hypothesis

What changes do you think you may see over the period of observation?

### Controls

Consider factors that may affect the dissolved oxygen (DO) levels in the samples and how they will be controlled in your experiment. Record them in a table like the one below.

|  |  |  |
| --- | --- | --- |
| **Control factor** | **Effect** | **Method of control** |
| Temperature | Increased temperature will increase the rate of evaporation of water | Keep both potatoes at the same temperature |
|  |  |  |
|  |  |  |

### Materials

1 large potato

100 mL saturated sodium chloride solution

distilled water

2 petri dishes

sharp knife

### Procedure

1. Use the knife to cut the potato in half and cut about 1 cm from the bottom of each half so they have a flat base to stand on.
2. Carefully scoop out a well in the top of each half, being careful not to cut through the bottom of the potato.

Dish 1 – High concentration

Dish 2 – Low concentration

1. Pour saturated sodium chloride solution into Dish 1 until about 5 mm deep.
2. Two-thirds fill the well in the potato with distilled water. Mark the levels in the petri dish and on the potato.
3. Pour distilled water into Dish 2 until about 5 mm deep. Two-thirds fill the well in the potato with the saturated sodium chloride solution. Mark the levels in the petri dish and on the potato.
4. Over a number of days, let the dishes stand undisturbed and away from direct sunlight. Observe what happens to the liquid levels in the potato and the dish and any other changes that occur.

### Results and observations

Devise a suitable table to record your observations and record what you see over a number of days.

What did you notice about the movement of water in Dish 1?

What did you notice about the movement of water in Dish 2?

What was the trend in the movement of the water?

What would you expect to happen if the pressure on the salt solution was increased?

What would you expect to happen if the pressure on the distilled water was increased?

### Conclusions

Write a simple statement describing the movement of water and salt, and what could be causing it.

Explain the process of reverse osmosis and how it can be used to treat effluent to drinking water standards.

1. Creative Commons Licence Victorian Curriculum and Assessment Authority (VCAA) <<http://victoriancurriculum.vcaa.vic.edu.au/>> Accessed 14 August 2016. [↑](#footnote-ref-1)