AUSTRALIAN WATER ASSOCIATION

Science: Using membrane technologies to separate water

This PDF is interactive. Click on underlined words and sentences to be directed to online resources.

RESOURCE OVERVIEW

This resource presents four teaching ideas that support Australian Curriculum Year 7 Science in the context of using of new membrane technologies to separate water from other substances.

1. Solving problems with membrane selection

Examines the challenges of providing drinking water and how membrane separation technologies can assist.

2. How does membrane separation work?

Investigates semi-permeable membranes and how membrane technologies such as reverse osmosis, ultrafiltration and microfiltration work. It also shows how these technologies fit in a sequence of techniques to separate water from other substances.

3. Making evidence-based decisions

Evaluates a media article, video, alternative sources of drinking water and scientific evidence to develop an argument about whether we should be recycling water for drinking.

4. How do membrane separation plants affect the water cycle?

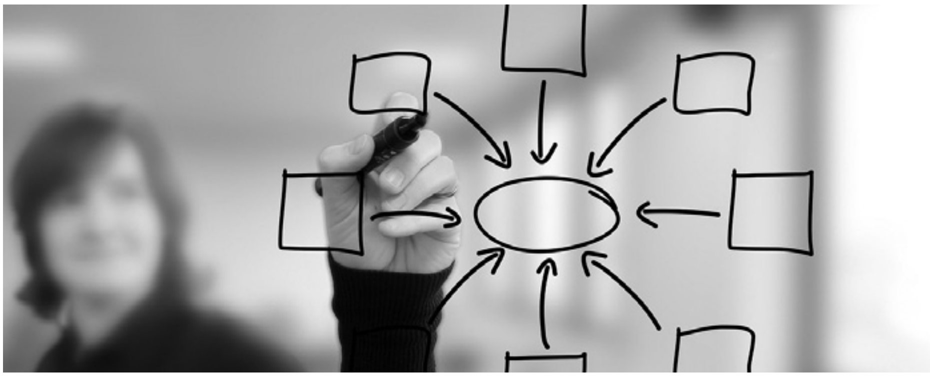
Explores how membrane separation plants affect the water cycle in a region.

The first teaching idea highlights the water supply issues we face in the 21st century and the role that membrane separation technologies play in addressing these issues. The second teaching idea explores how membrane technologies such as reverse osmosis, ultrafiltration and microfiltration work. The third teaching idea engages students in evidence-based decision-making about building large membrane separation treatment plants to solve water supply problems while the fourth teaching idea examines how these treatment plants affect the water cycle in a region.

These teaching ideas are useful to augment classroom discussions about traditional separating techniques such as filtering, decanting or distillation and can be used at the end of a unit to show the cutting-edge technologies used in water treatment in Australia.

These teaching ideas offer students opportunities to:

- brainstorm, generate and discuss ideas using strategies such as think-pair-share and compare-and-contrast
- research different technologies, applications and design solutions
- conduct a simple scientific investigation using a predict-observe-explain strategy
- explore how membrane separation technologies work
- analyse and evaluate information from a range of sources to make evidence-based decisions.



AUSTRALIAN CURRICULUM LINKS [1]

Year 7 Science Understanding

- Chemical sciences

Mixtures, including solutions, contain a combination of pure substances that can be separated using a range of techniques (ACSSU113)

- Earth and space sciences

Some of Earth's resources are renewable, including water that cycles through the environment, but others are non-renewable (ACSSU116)

Year 7 Science as a Human Endeavour

- Use and influence of science

Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations (ACSHE120)

People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity (ACSHE121)

Years 7 and 8 Design and Technologies

- Knowledge and Understanding

Investigate the ways in which products, services and environments evolve locally, regionally and globally and how competing factors including social, ethical and sustainability considerations are prioritised in the development of technologies and designed solutions for preferred futures (ACTDEK029)

---

1. Solving problems with membrane selection

Students explore the challenge of supplying safe drinking water globally. They examine where our drinking water comes from as it cycles through the environment and how membrane technologies are used to address problems of water supply and water quality. Specifically, students explore the global distribution of freshwater, the issues related to drinking water supply in developing countries and the concept of a water footprint. They examine the issues relating to drinking water supply in Australia and explain how a range of solutions including membrane separation technologies in seawater desalination and wastewater recycling can assist in providing additional drinking water supplies. Students also research other applications for membrane separation technologies (ACSSU116; ACSHE120; ACSHE121).

1a. What is the drinking water challenge?

Students briefly explore why drinking water is a precious resource, simple water treatment processes and how to use our water wisely using ‘Part 1: What’s the problem?’ in Enough Water: Fit for drinking (Australian Academy of Science, Science by Doing Program).

The teacher guide (M014122), student guide (M014120) and student digital resources (M014121) are available to teachers through Scootle. *Teachers need to register to access this free resource: www.scootle.edu.au*

1b. How do membrane separation technologies help?

Students examine possible solutions to Australia’s drinking water supply issues and how membrane separation technologies are used to address some of these issues.

A. Students brainstorm where their drinking water comes from. Ideas could include above-ground sources (reservoirs, dams, rivers, lakes), ocean or groundwater. Encourage more lateral thoughts (e.g. rain, pipes, tanks, bottles, fridge, utility, treatment plant, etc.).

If you have 25 minutes available, one strategy that encourages students to generate ideas is to expand a think-pair-share activity. Present the problem and ask students to work on the problem individually for five minutes then share their ideas in a group for five minutes before students again consider the problem individually for five minutes. Students then discuss their final list in their groups for five minutes before the group presents their ideas to the class.

Focus discussion points:

B. What are some solutions to Australia’s drinking water supply issues? Using a think-pair-share strategy, ask students to suggest answers to this question. Ideas should include reduce (using the water we have more efficiently), re-use (processing greywater for use), recycle (treating wastewater) and finding new sources such as purifying poor quality groundwater.

New technologies have been devised to treat and purify poor quality water. Explain that one of the new water purification techniques involves the use of sheets of polyamide (synthetic) membranes.

C. Discuss what a semi-permeable membrane is, e.g. a semi-permeable membrane is a thin layer of material that forms a selective barrier. In seawater desalination, for instance, the sea water (source water) is forced through the membrane elements resulting in a permeate stream (freshwater) and concentrate stream (brine). This process of separation is called reverse osmosis. Membranes are also used in other water treatment processes such as wastewater treatment and also in food and beverage industries (see footnote 2) such as cheese making. There are different types of membranes and different types of membrane separation processes: e.g. reverse osmosis, nanofiltration, ultrafiltration, microfiltration and multi-effect distillation.

2 European Food Information Council (2005) <http://www.eufic.org/article/en/food-technology/food-processing/artid/membrane-filtration-food-quality/> Accessed 1 August 2016

D. Play the following video clips featuring membrane technologies and ask students to answer the question: What are the issues being addressed in each video?

a) The first five minutes of Crystal Clear—the story of desalination [12:13]. This video talks about the limited supplies of freshwater and the impact of Australia's unpredictable climate (see footnote 3).

b) The first two and half minutes of Water Recycling at St Marys [5:18]. This video explains the water recycling plant was built to maintain the flow and quality of water in the Hawkesbury–Nepean River system near Sydney and to increase the volume of water in the Warragamba Dam (see footnote 4).

c) Compile a class list of student responses.

Extension: Students use a CORT strategy to analyse these videos (e.g. PMI, OPV, APC, AGO, FIP, etc.).

1c. What are other uses of membrane technologies?

Providing a climate-independent supply of drinking water through seawater desalination is important, but there are also many other applications for membrane separation technologies. Students should appreciate that there are hundreds of water treatment plants of differing sizes that use membrane treatment technologies in various sectors such as mining, agriculture, power generation, petroleum refining, food processing, pharmaceutical production and wastewater treatment. Students research how membrane separation technologies are used in these industries and applications.

2. How does membrane separation work?

Students examine how different kinds of membranes work to separate water from other substances (ACSSU113). Students undertake a simple scientific investigation using the semi-permeable membranes of potato cells. They compare reverse osmosis membrane separation with thermal distillation then learn how reverse osmosis fits in a sequence of separation techniques used in space to treat wastewater back to drinking water standard. Students focus on the variety of seawater desalination processes used in large plants around Australia. They compare microfiltration, ultrafiltration and reverse osmosis membrane technologies and explore some of the applications.

2a. Semi-permeable membranes in action

Students explore how membranes selectively allow water to pass into cells. They observe the effect of placing pieces of fresh potato in potable water and in salty water. This activity can be used as a demonstration, a hands-on group activity or a science inquiry activity where students design their own experimental investigation.

When exposing Year 7 Science students to newer separating techniques, it isn't necessary to fully explain the science behind these membrane technologies i.e. diffusion, osmosis and reverse osmosis. These concepts are covered in later years. However, there is much scope to extend interested students.

A. Cut a large potato into one centimetre slices and cut out potato shapes with a smaller metal cookie cutter. Explain that potatoes are made of tiny cells and that each cell has a membrane. Display a copyright-free image of potato cells—sourced from the internet—and point out the cell membranes. These semi-permeable membranes allow water to pass through but not other substances.

B. Use a Predict-Observe-Explain strategy to explore what happens when some potato pieces are soaked in water and in very salty water. Students can record their ideas in their notebooks or you can design a worksheet for students to record their ideas and observations.

Note that a short training module from the Science By Doing program about this strategy is available from Scootle using the search term 'Predict-observe-explain'.

---

3 National Centre of Excellence in Desalination Australia: Crystal Clear—the story of desalination <https://www.youtube.com/watch?v=0vEbHPsYrTs>

4 Sydney Water: Water recycling at St Marys <https://www.youtube.com/watch?v=xeK0IQV03J0&list=PLE2S1b3s927dMtt7S4THVGOSYWu8Ao354>

Explain that some of the potato shapes will be placed in a bowl with water and some will be placed in a bowl of very salty water. Leave the potato shapes for at least an hour and preferably overnight. Students record their 'Predict' ideas (what they think will happen) and the reasons why they think it will happen.

To make the salty water, stir to dissolve the salt until no more salt can be dissolved and there are a few salt grains in the bottom of the bowl.

C. Students conduct their experiment and record their observations and record their observations and their updated explanation about why it happened.

D. Students discuss whether the water is moving in or out of the cells through the potato cell membranes in water and in salty water.

Extension:

i. The movement of water through a semi-permeable membrane is an example of a process called osmosis. Osmosis can be investigated in many ways i.e. with ziplock bags or dialysis tubing. One experiment using dialysis tubing can be found in the student guide of 'Part 4: What's in your water?' in 'Enough Water: Fit for drinking' resource published by the Australian Academy of Science Science by Doing Program.

The teacher guide (M014122), student guide (M014120) and student digital resources (M014121) are available to teachers through Scootle. *Teachers need to register to access this free resource: www.scootle.edu.au*

ii. To design a 'fair test', students predict what will happen if some of the variables are changed: for example, if different solutions are used (iced water, saltier water, sugar-sweetened water, coke, milk, honey).

iii. Investigate applications of osmosis in the natural world—plants (e.g. mangroves) and animals (e.g. supraorbital gland).

iv. Students research the link between drinking sea water and osmosis.

2b. How does reverse osmosis membrane separation work?

Students examine how reverse osmosis works in the context of seawater desalination. While distillation is the oldest method of separating water from sea water or salty groundwater, all large desalination plants in Australia utilise reverse osmosis (RO) membrane separation technology—which uses much less energy than thermal desalination (distillation) processes.

A. Play the rest of the Crystal Clear—the story of desalination video [4:50-12:13] to introduce how the reverse osmosis process works.

B. From the information provided in the video, ask students to compare and contrast distillation and reverse osmosis. Students could use a compare and contrast chart by drawing two intersecting circles (Figure 1). Play the video segment again so that the students can capture the key points.

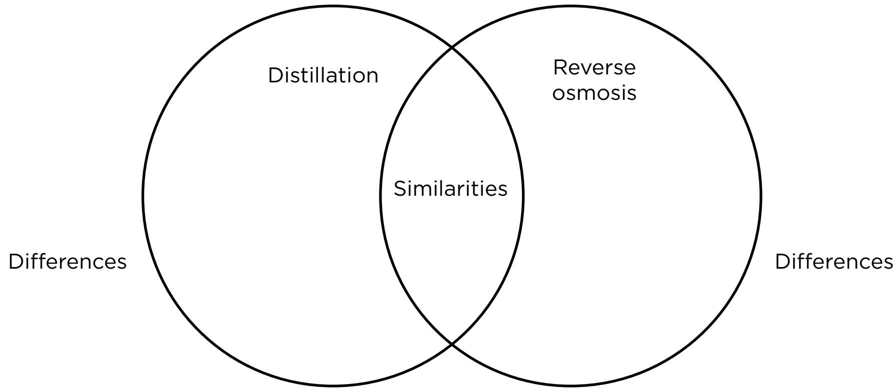


Figure 1 Compare and contrast chart

The video mentioned that the reverse osmosis membranes used in the desalination process worked in a similar way to the kidney. Reverse osmosis membranes are manufactured synthetically but membranes also occur in nature. All our cells and the cells of other organisms are enclosed by a semi-permeable membrane, which means they let certain substances through but not others (see Activity 2a).

2c. Reverse osmosis for wastewater recycling in space

Students explore how reverse osmosis (RO) is one of a series of techniques used in space travel to treat wastewater to drinking water standard.

Play the Unzipping the secret to water in space video [6:29] which explains how water is separated from other contaminants in wastewater treatment (see footnote 5). Record the sequence of treatment processes featured on a board: microfiltration, reverse osmosis, ion exchange, granular activated carbon.

Explain that microfiltration is another membrane technology.

The first two minutes of the video talks about the water produced when launching a rocket. Not really relevant to this topic but interesting for students.

2d. How do seawater desalination plants work?

While reverse osmosis is the key separation technique in seawater desalination plants, it is only one of a series of treatment processes used to separate water from a salty source. In this activity, students examine the treatment processes used in a range of seawater desalination plants.

A. To explore how reverse osmosis is used in seawater desalination, play the rest of the Crystal clear—the story of desalination video [4:50-10:30]. Record the sequence of treatment processes featured on a board: intake, pre-treatment, reverse osmosis, post-treatment, energy recovery, outfall and diffuser system. Compare the treatment processes with those recorded in Activity 2c for recovering drinking water from wastewater in space. Microfiltration (MF) or Ultrafiltration (UF) are also used in the desalination process. Ask students to predict which treatment process mentioned in the 'Crystal clear' video involves ultrafiltration (pre-treatment).

B. Students can then investigate their closest large seawater desalination plant (see links below). Students, working in groups, explore the virtual tours and video segments:

- Perth — Perth Seawater Desalination Plant (Kwinana) [6]
- Sydney — Kurnell Desalination Plant [7]
- Gold Coast — Tugan Desalination Plant [8]
- Adelaide — Port Stanvac Desalination Plant [9]
- Melbourne — Wonthaggi Desalination Plant [10]

Extension:

i. Construct a compare and contrast table to show the different processes used at each seawater desalination plant.

ii. Draw a process flow diagram showing the flow of water through each stage of the desalination process. Reverse osmosis uses more energy than other types of water treatment and engineers have designed energy recovery devices (ERDs) to address this issue. These ERDs use the flow of the water to recover more than 50% of the energy invested and are an important part of a desalination plant's operation. Watch this short video explaining how the ERI Pressure Exchanger [3:50] works (see footnote 11 on next page).

---

5 ABC Splash: Unzipping the secret to water in space <http://splash.abc.net.au/home#!/media/1341894/unzipping-the-secret-to-water-in-space>

6 Water Corporation Western Australia: Perth Seawater Desalination Plant <https://www.youtube.com/watch?v=qAcxK5mYtSc>

7 Sydney Desalination Plant <https://www.youtube.com/watch?v=TRGxk7-rCE0&feature=youtu.be>

8 Seqwater: Gold Coast Desalination <http://www.seqwater.com.au/education/virtual-tour/desalination>

9 SA Water: Adelaide Desalination Plant <http://www.sawater.com.au/community-and-environment/our-water-and-sewerage-systems/water-sources/desalination/adelaide-desalination-plant-adp>

10 Aquasure: Victorian Desalination Project <http://www.aquasure.com.au/desalination-plant>

2e. How do microfiltration and ultrafiltration membranes work?

Students focus on microfiltration/ultrafiltration and their applications.

A. Review how microfiltration was used in the Unzipping the secret of water in space video (Activity 2c). Explain that, in contrast to reverse osmosis technology, microfiltration membranes work more like everyday filters. The membranes have tiny pores which filter substances based on the size of the molecules. Microfiltration membranes have a pore size of approximately 0.1-3 microns while ultrafiltration membranes have a pore size of approximately 0.01-0.1 microns. One micron (or micrometre) is one-thousandth of a millimetre in length and an average human hair has a diameter of 100 microns. Apart from water treatment, microfiltration and ultrafiltration are also used in a wide range of applications.

B. View the Ultrafiltration at St Mary's Water Recycling Plant video [4:01] to see how the ultrafiltration process works at the St Marys plant in Sydney, NSW (see footnote 12). While they watch the video, ask students to consider how ultrafiltration (or microfiltration) differs from reverse osmosis (e.g. they operate at lower pressure, the membranes have simpler molecular structure than the more complex reverse osmosis membranes).

Extension: Students investigate electrodialysis, forward osmosis or multi-effect distillation as emerging separation technologies and how they might be used.

3. Making evidence-based decisions

Students examine how science can inform decisions about controversial issues (ACSHE120). The construction of large seawater desalination or potable water recycling plants can be contentious and attract significant political and media attention. It should be noted that all the separation technologies mentioned in this guide have application in both seawater desalination and water recycling. Teachers should encourage discussion about the application of the technology. Students are encouraged to consider differing opinions as they make their own evidence-based decisions.

In this activity, students read media articles, view a Catalyst video segment and investigate a range of water source options before they develop an argument about whether we should be recycling water for drinking.

Students work through 'Part 5: How can science help us make evidence-based decisions?' and 'Part 6: How might you defend your position?' in the Enough Water: Fit for drinking resource published by the Australian Academy of Science, Science by Doing Program. The teacher guide (M014122), student guide (M014120) and student digital resources (M014121) are available to teachers through Scootle. *Teachers need to register to access this free resource: www.scootle.edu.au. The 'Enough water: fit for drinking' resources are also available free of charge from the Science by Doing home page. You will need to register.*

4. How does membrane separation affect the water cycle?

In previous activities in this guide, students discussed some of the human impacts on the natural water cycle: building dams, water treatment plants and the environmental effects of wastewater (effluent) outflow. This teaching idea uses students' understanding about the natural and human water cycle in their region to evaluate the effects that large membrane separation treatment plants (e.g. water recycling, desalination, mine water processing) have on their water cycle (ACSSU113; ACTDEK029).

If you don't have a large membrane separation plant in your region, you can conduct this activity as a hypothetical or choose another area as a case study. For the case study option, you will need to spend some time setting up the context for the students.

A. Review student ideas about the water cycle in your region of interest by brainstorming the different pathways water takes as it cycles through the region. Incorporate relevant natural and human elements such as clouds, rain,

11 ERI pressure exchanger <https://www.youtube.com/watch?v=udffed4Pq3g>

12 Sydney Water: Ultrafiltration at St Marys Water Recycling Plant <https://www.youtube.com/watch?v=Ge6RT6eAXDA&list=PLE2S1b3s927dMtt7S4THVGOSYWu8Ao354&index=4>

run-off, vegetation, creeks, rivers, ocean, groundwater, dams, bores, urban development, water and wastewater treatment plants and industrial wastewater (which are also treated by wastewater treatment plants). Include pathways for clean treated water and the effluent from wastewater treatment plants. Display an urban water cycle diagram to provide ideas such as the Total water cycle management poster (see footnote 13).

B. Working in groups, students draw a rough sketch of the landscape in the region of interest on an A3 sheet of paper or butcher's paper. Sketch in the towns, cities and key landscape features. Add the relevant water cycle elements identified in Step 4a). Trace the movement of water using arrows. Add ticks beside the arrows with good quality water and crosses beside the arrows with poor quality water. Negotiate a prescribed time limit for this activity (e.g. 20 minutes).

C. Each group presents their ideas to the class. Discuss the similarities and differences between the diagrams prepared by different groups.

D. Discuss the types of large membrane separation treatment plants and the location of these plants. Groups add the membrane separation plant to their diagram, drawing the new water pathways in a different colour. Add the ticks and crosses to the new arrows to show which water pathways have good or poor quality water. Where does the waste stream from the treatment plants go? For instance, concentrate from seawater desalination is returned to the ocean via diffusers and biosolids waste from water recycling plants can be re-used in agriculture, forestry and land rehabilitation or landscaping. Add the waste stream pathway from the membrane separation plant to their diagram in a different colour.

E. Each group lists the effects that the large membrane separation plant has on the water cycle in the region including on the quantity and quality of the water in the new water pathways. Ask students to consider as many factors as they can, including future needs and social, ethical and sustainability considerations.

F. Ask one group to share their ideas with the class. The next group then shares their ideas that were not mentioned by the first group and so on, to collate the class list. Add any other social, ethical or sustainability impacts of membrane separation plants discussed in other activities such as the cost of building and operating the plants or the provision of drinking water during droughts. Use a Plus-Minus-Interesting CORT strategy to evaluate the effects of large membrane separation plants on the water cycle and the design of water-related infrastructure in the region.

13 Queensland Government: Total water cycle management poster <https://publications.qld.gov.au/dataset/waterwise-education-resources/resource/fdc01c10-af82-458e-93ff-0f050c6681eb>