# Burying Nuclear Waste – Teacher Resource

## Intended Use of Resources

This project has been designed so that teachers from different STEM areas can pick and choose sections relevant to their subject area to work on. All activities in this package do not need to be completed to get value from the package – each activity can be completed as a stand-alone or can be approached, as a team, as a larger project. The package has potential to be extended into a much longer project to include curriculum points from different STEM subjects.

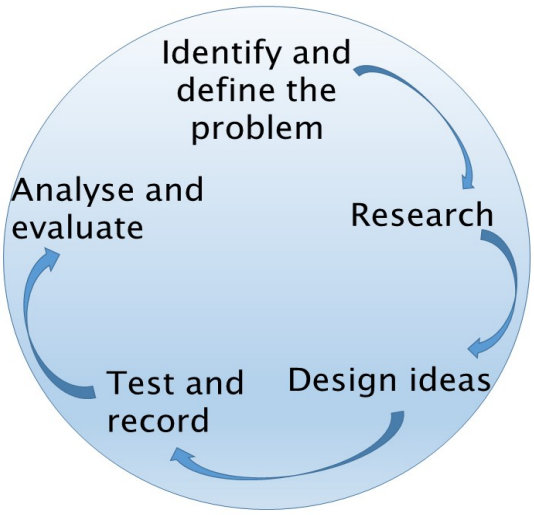
There are three **student workbooks - Open, Guided and Scaffolded,** that go alongside this resource; all have the same suggestions for activities, however, they have been written and edited to provide differentiated learning options to support good teaching practice**.** Teachers may pick and choose which versions they give which students, and may wish to edit them further to address their learning needs. Due to the differentiation of the workbooks, the **Open** activities will enable more syllabus links to be addressed, which is why each activity has its own syllabus links key. However, if you wish to give a truly open ended investigation then you could just give the students the challenge and background information section of the Student Booklet.

The Woodside Australian Science Project (WASP) STEM resources aim to be accessible and supportive for teachers and students, please contact us if you have questions, feedback, require assistance or would like to arrange an incursion or a professional development workshop - www.wasp.edu.au.

## The Student Challenge

With populations increasing at an exponential rate and the volume of electronic devices being used in everyday lives escalating, not to mention the increased use of transport, it is vital that Australia can provide a future energy mix that supports modern lifestyles. Nuclear power is undoubtedly a means of producing vast amounts of energy with relatively low emissions and without the reliance on weather, however, one of the main issues with nuclear power is what to do with the waste.

Your challenge is to investigate the issues with nuclear waste and to produce a report, which could be provided to government, outlining if and where nuclear waste could be safely buried.



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## Background Information

Nuclear power plants mainly use enriched uranium as their source of fuel. In a nuclear power plant the fuel is compacted into fuel rods, which are surrounded by a fluid in the reactor. The fuel undergoes a controlled chain reaction which gives off heat, thus heating the surrounding fluid. The hot fluid then heats water, creating steam which turns turbines, to generate electricity.

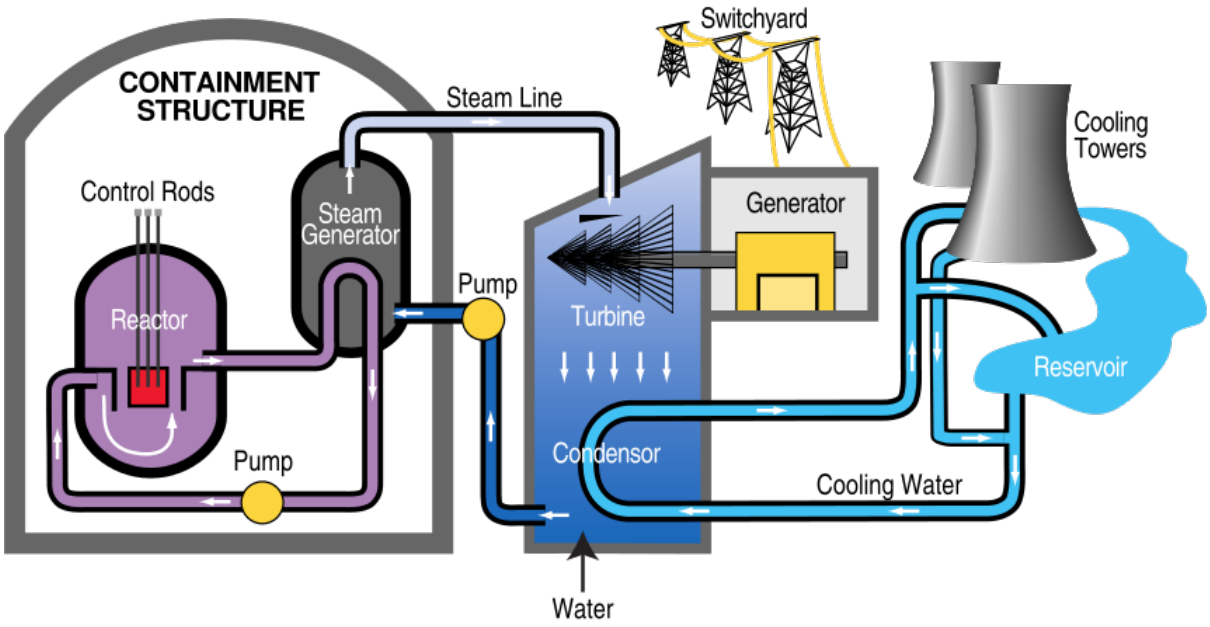


*Figure 1. Image showing the key parts of a nuclear reactor and how it generates electricity. (Tennesee Valley Authority, 2018)*

Nuclear waste is radioactive, and therefore it is very important that it is disposed of safely. At present the most common method of nuclear waste disposal is to bury it in a geologically stable area (far from any faults or volcanic areas). The waste is buried around 500 – 1,000 m below the surface, with the aim to permanently isolate it from the human environment.

Some issues with burying the waste can be that the material that it is stored in starts to crack, allowing water in which can become contaminated. Some radioactive isotopes also can remain radioactive for very long periods of time (several hundreds of thousands of years), which makes it very hard to monitor and to be confident that there will be no geological changes affecting it over this time period.
A suitable solution to deal with nuclear waste is one of the most important factors in making decisions around nuclear power generation in Australia.

## Activities

This booklet contains extra information on each activity, including syllabus links the overall activity objective, suggestions for recommended equipment or alternative ways to run investigations as well as useful resources and website links*.
The syllabus links have been colour coded. These links to the Australian Curriculum are also relevant to the Western Australian Syllabus. – Please see the colour key below:

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|---|
| Covered in Scaffolded, Guided and Open Student Booklet |
| Covered in Guided and Open Student Booklet |
| Covered in Open Student Booklet |
| *Italics – WA syllabus for DT and D and T* |

## *List of activities*



**Please note that any reference websites provided we accessed in March 2018 – these addresses may change slightly, we would be grateful if you could let us know if these sites are no longer accessible.*

# Burying Nuclear Waste – Teacher Resource

## Background Research

### Objective

Students should gain a general understanding of how a nuclear reactor works and the hazards involved with radioactive material.
It is recommended that students already have some background knowledge and understanding of nuclear radiation and have covered this topic in science, or at least some of it – otherwise they will need more support for this activity.
The background questions should lead them to start thinking about further investigations they could do to find out more about the different types of nuclear radiation, as well as the different hazards associated with it.
The most important factors for students to realise from the background research is that a very geologically stable area is required for nuclear waste to be buried. The main reason for this is if waste contaminates ground water nuclear isotopes can enter the food chain and household water supplies. Absorption nuclear isotopes can result in serious health issues in humans.

| | Australian Syllabus Links |
|---|---|
| **Science** | ACSSU175<br>Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment.<br><br>ACSSU177<br>All matter is made of atoms that are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms<br><br>ACSSU179<br>Chemical reactions, including combustion and the reactions of acids, are important in both non-living and living systems and involve energy transfers.<br><br>ACSSU180<br>The theory of plate tectonics explains global patterns of geological activity and continental movement.<br><br>ACSSU182<br>Energy transfer through different mediums can be explained using wave and particle models. |
| **Design and Technology** | ACTDEK046<br>Investigate and make judgments on how the characteristics and properties of materials, systems, components tools and equipment can be combined to create designed solutions |

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## Useful resources and websites:

- Different ideas for what can be done to dispose of/ reuse nuclear waste. https://oilprice.com/Alternative-Energy/Nuclear-Power/6-Things-to-do-with-Nuclear-Waste-None-of-them-Ideal.html
- An explanation of how to deal with nuclear waste with good scientific explanations (high level) http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-waste-management.aspx
- BBC bitesize educational information on nuclear power plants and how they work. https://www.bbc.co.uk/education/topics/zf4cwmn
- Really interesting read – particularly some of the comments. This is an excellent article for students to consider validity of sources and where information comes from: http://www.abc.net.au/radionational/programs/ockhamsrazor/5242786
- Clear, scientific explanation of how uranium is used and which type of uranium is used to create energy in nuclear power plants. http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/uranium-resources/uranium-and-depleted-uranium.aspx
- Disposal suggestions for nuclear waste: http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/storage-and-disposal-of-radioactive-wastes.aspx
- The hazards of eating crops which contain high levels of nuclear isotopes: https://news.vice.com/article/30-years-after-the-chernobyl-disaster-locals-are-still-eating-radioactive-food

# Blocking Radiation

## Objective

Students will learn how to block different types of radiation (alpha, beta and gamma) and relate this to burying radioactive waste.

*This activity is a teacher demonstration of different types of radiation. Please consult with your laboratory technician and make sure you are following the procedures for handling sealed radioactive sources - https://assist.asta.edu.au/keyword/radioactive-source.*

*Alternatively you could have students use this online radiation lab - http://www.scootle.edu.au/ec/viewing/L45/index.html*

Use different materials, of differing thicknesses, to demonstrate blocking radiation – alpha, beta and gamma.

1. Set the Geiger counter onto the desk you will be demonstrating at and ask students to measure the radiation in the room for one minute (counts/minute) – this is the background radiation level.
2. Set out your source of alpha radiation (usually a small sealed, circular clear plastic disk of americium-241 or polonium-210).
3. Move the Geiger counter close to the source of radiation and then away slowly so students can observe what happens.
4. Now place each of the materials listed between the radiation source and Geiger counter allowing students to measure the 'counts' for one minute for each (be sure to have each at a good distance from each other so that you are still getting clear 'counts').
5. Repeat step 4 for sources of beta radiation (usually strontium) and gamma radiation (usually cobalt).
6. Note: your samples will be different thickness so allow students to measure their thickness, as this will obviously make the test less fair.

| | Australian Syllabus Links |
|---|---|
| **Science** | ACSIC166<br>Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately.<br><br>ACSIS169<br>Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies.<br><br>ACSIS170<br>Use knowledge of scientific concepts to draw conclusions that are consistent with evidence.<br><br>ACSIS171<br>Evacuate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the |

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| | data.<br><br>ACSSU177<br>All matter is made of atoms that are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms |
| **Design and Technology** | ACTDEK046<br>Investigate and make judgments on how the characteristics and properties of materials, systems, components tools and equipment can be combined to create designed solutions<br><br>ACTDEK047<br>Investigate and make judgements, within a range of technologies specialisations, on how technologies can be combined to create designed solutions. |
| **Mathematics** | ACMNA208<br>Solve problems involving direct proportion. Explore the relationship between graphs and equations corresponding to simple rate problems.<br><br>ASMNA210<br>Express numbers in scientific notation.<br><br>ACMMG221<br>Solve problems using ratio and scale in similar figures.<br><br>ACMSP228<br>Identify everyday questions and issues involving at least one numerical and at least one categorical variable, and collect data directly and from secondary sources. |

## Useful websites and resources:

- Interactive animation for students to use to look at the reactions in a nuclear power plant and what happens during nuclear fission. https://phet.colorado.edu/en/simulation/legacy/nuclear-fission
- Video on how to block different types of radiation. https://www.bing.com/videos/search?q=blocking+radiation+animation&&view=detail&mid=9496D51EEFE6BC9634079496D51EEFE6BC963407&&FORM=VDRVRV

# Burying Nuclear Waste – Teacher Resource

## Decay Rate Modelling

### Objective

Students will model radioactive decay of elements, using popcorn, and relate this to the time required for radioactive waste to become "safe".
*Notes: It is best not to use buttery popcorn for this as it gets very greasy. Salted popcorn works well.*
*Although using more than one microwave will reduce the time required for this activity, unless they are the same power rating it will effect results considerably.*
*The microwave may start to heat up a little after continuous use, so it is best not to rush between groups for cooking.*
*So that all groups are busy, you may wish to give them a pre-popped bag to count while they are waiting for their turn (a control you know the time it was in the microwave for). They can then try to determine how long it was cooked for by using their calibrated graphs.*

| | **Australian Syllabus links** |
|---|---|
| | |
| **Science** | ACSSU177<br>All matter is made of atoms that are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms.<br><br>ACSIC166<br>Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately.<br><br>ACSIS169<br>Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies.<br><br>ACSIS170<br>Use knowledge of scientific concepts to draw conclusions that are consistent with evidence.<br><br>ACSIS171<br>Evacuate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data. |
| **Mathematics** | ACMNA296<br>Graph simple non-linear relations with and without the use of digital technologies and solve simple related equations.<br><br>ACMMG219<br>Investigate very small and very large time scales and intervals. |

### Useful websites and resources

- Students can use this animation to see that just like the kernels, it is an unknown which atom will decompose or when it will happen, but that if there is a large volume of kernels or atoms in a source then the half-life can be determined. https://phet.colorado.edu/en/simulation/legacy/alpha-decay

# Burying Nuclear Waste – Teacher Resource

## Investigating Rocks

### Objective

Students will investigate the properties of different rock types and evaluate their strengths and weakness in relation to storing nuclear waste.

Most nuclear waste is buried underground at a depth of 500 – 1,000 m below the surface. This is a long way to dig through very hard rock, and can be challenging. The surrounding bedrock is very important to ensure the safety of the waste, or more importantly the safety of living things near where the waste is buried. If ground water can reach and pass through where the waste is stored it can carry some nuclear isotopes with it. If the surrounding rocks are weak or crumbly they can collapse and this can mean the burial chamber is not stable – again this can lead to water leaching in. As nuclear waste can be reactive for thousands of years it is vital that it will be secure for the whole of this time.

Students can investigate the properties of different rocks which will surround the buried waste to determine which types will be least likely to crack/fail and allow water to pass through. They may want to also investigate other materials, such as concrete, which could be used to strengthen/support and seal the burial chamber.

Students can then use a geological map of Australia to try and locate a suitable area. The issue with the geological map however is that it only shows the surface geology, and the rocks below the surface could be very different.

Looking at a whole map of Australia may be intimidating for some students so you may prefer to select a smaller area that students will be familiar with.

| | **Australian Syllabus links** |
|---|---|
| **Science** | ACSSU180<br>The theory of plate tectonics explains global patterns of geological activity and continental movement.<br>ACSIC166<br>Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately.<br>ACSIS170<br>Use knowledge of scientific concepts to draw conclusions that are consistent with evidence.<br>ACSIS171<br>Evacuate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data. |
| **Design and Technology** | ACTDEK046<br>Investigate and make judgments on how the characteristics and properties of materials, systems, components tools and equipment can be combined to create designed solutions<br>ACTDEP050<br>Work flexibly to effectively and safely test, select, justify and use appropriate technologies and processes to make designed solutions. |

### Useful websites and resources

- Interactive geological and geophysical maps of Australia: http://www.ga.gov.au/interactive-maps/#/theme/minerals/map/geology

# Burying Nuclear Waste – Teacher Resource

## Probability of Earthquakes

### Objective

Students will determine the probability of an earthquake occurring which may disturb buried nuclear waste causing leakage.

| | Australian Syllabus links |
|---|---|
| **Science** | ACSSU180<br>The theory of plate tectonics explains global patterns of geological activity and continental movement.<br><br>ACSHE160<br>People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities. |
| **Mathematics** | ACMSP225<br>List all outcomes for two-step chance experiments, both with and without replacement using tree arrays. Assign probabilities to outcomes and determine probabilities for events. |

### Useful websites and resources

- Information from the USGS Earthquake catalogue (customisable): https://earthquake.usgs.gov/earthquakes/search/
- Geoscience Australia resources – Record of historical events in Australia: https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search?node=srv#/metadata/111223
- Geoscience Australia interactive earthquake hazard map http://www.ga.gov.au/interactive-maps/#/theme/hazards/map/earthquakehazards
- Information on the Meckering earthquake http://www.allshookup.org/swsz/history.htm

# Burying Nuclear Waste – Teacher Resource

## Case Studies

### Objective

Students will use case studies to compare the strengths and weaknesses of different burial sites for nuclear waste.
Many countries have been using nuclear power as a source of energy for decades and therefore have accumulated nuclear waste. There are many burial sites globally, some of which have been hosting waste since the 1980s. Most of the sites, fortunately, have not had any issues or reports of nuclear waste leaching into the surrounding areas, however, this has not been the situation for all.

| | **Australian Syllabus links** |
|---|---|
| **Science** | ACSSU180<br>The theory of plate tectonics explains global patterns of geological activity and continental movement.<br><br>ACSIS172<br>Critically analyse the validity of information in primary and secondary sources and evaluate the approaches used to solve problems.<br><br>ACSIS174<br>Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations. |
| **Design and Technology** | ACTDEK040<br>Critically analyse factors, including social, ethical and sustainability considerations, that impact on designed solutions for global preferred solutions and the complex design and production processes involved.<br><br>ACTDEK046<br>Investigate and make judgments on how the characteristics and properties of materials, systems, components tools and equipment can be combined to create designed solutions<br><br>ACTDEP051<br>Evaluate design ideas, processes and solutions against comprehensive criteria for success recognising the need for sustainability. |

### Useful websites and resources

- Detailed explanation of the different types of nuclear wastes.
  http://www.world-nuclear.org/nuclear-basics/what-are-nuclear-wastes.aspx
- Scientific article discussing the issues at the Asse nuclear waste burial site.
  https://www.newscientist.com/article/2075615-radioactive-waste-dogs-germany-despite-abandoning-nuclear-power/
- Article promoting the storage of nuclear waste on the WIPP site.
  http://www.pbs.org/wgbh/nova/next/tech/solving-nuclear-waste-with-wipp/
- List of some geological repository sites for nuclear waste
  https://en.wikipedia.org/wiki/Deep_geological_repository#Repository_sites

- Information on one of Finland's nuclear waste sites: http://www.news.com.au/technology/environment/finlands-incredible-permanent-nuclear-waste-storage-facility/news-story/7a1bda34374825ccae2a6e0fe5b0c2c9

# Burying Nuclear Waste – Teacher Resource

## Designing a Solution

### Objective

Students will design and test a model burial site for radioactive waste, then evaluate the effectiveness of their design.
Students will build a model of the site, using materials of their (or your) choice, and water balloons filled with coloured water to represent the nuclear waste. Food colour is added to the water in the balloon so that when it pops it will be easier to see how far the water spreads though the medium. This is the reason a clear cup or beaker should also be used *(N.B. don't use a beaker if anything is going to set in it).*
The balloon should end up with a small puncture hole in it after the 'earthquake', which will enable the testing of the material surrounding it.
If using salt as the testing medium we recommend adding a little hot water carefully to the salt after it is in the cup to enable it to recrystallise, this will make it more compact (reducing pore spaces). Ensure students allow a few days for the water to evaporate completely before testing their model.
You could also do something similar with very moist clay, burying the balloon in it and then allowing it to dry.

| | **Australian Syllabus links** |
|---|---|
| **Science** | ACSIS165<br>Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data, assess risk and address ethical issues associated with these methods.<br><br>ACSIS170<br>Use knowledge of scientific concepts to draw conclusions that are consistent with evidence. |
| **Design and Technology** | ACTDEK046<br>Investigate and make judgments on how the characteristics and properties of materials, systems, components tools and equipment can be combined to create designed solutions<br><br>ACTDEP049<br>Develop, modify and communicate design ideas by applying design thinking, creativity, innovation and enterprise skills of increasing sophistication<br><br>ACTDEP051<br>Evaluate design ideas, processes and solutions against comprehensive criteria for success recognising the need for sustainability. |
| **Digital Technology** | WATPPS57<br>Design solutions assessing alternative designs against given criteria, using appropriate technical terms and technology. |

# Reporting to Government

## Objective

Students will present the findings of their research, via a written report, presentation or video, outlining if and where nuclear waste could be safely buried.
Presenting the research findings could be an activity which is linked up with other subjects, such as writing a discursive essay, or having a class debate in English. Producing/editing and recording in media. Or even writing a play in Drama.
Students could create models of their proposed designs for a Science fair project.
Writing letters to local politicians is also a useful way for students to realise that they can contact their local politicians, and that they have the power to influence people.

| | **Australian Syllabus links** |
|---|---|
| **Science** | ACSIS170<br>Use knowledge of scientific concepts to draw conclusions that are consistent with evidence<br><br>ACSIS172<br>Critically analyse the validity of information in primary and secondary sources and evaluate the approaches used to solve problems.<br><br>ACSIS174<br>Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations. |
| **Design and Technology** | ACTDEK040<br>Critically analyse factors, including social, ethical and sustainability considerations, that impact on<br>designed solutions for global preferred solutions and the complex design and production processes<br>involved |

## Useful websites and resources

- Earthquake hazard map of Australia from Geoscience Australia
  http://www.ga.gov.au/interactive-maps/#/theme/hazards/map/earthquakehazards

## Bibliography

Figure 1. Tennessee Valley Authority (unknown) Retrieved from https://www.tva.gov/Energy