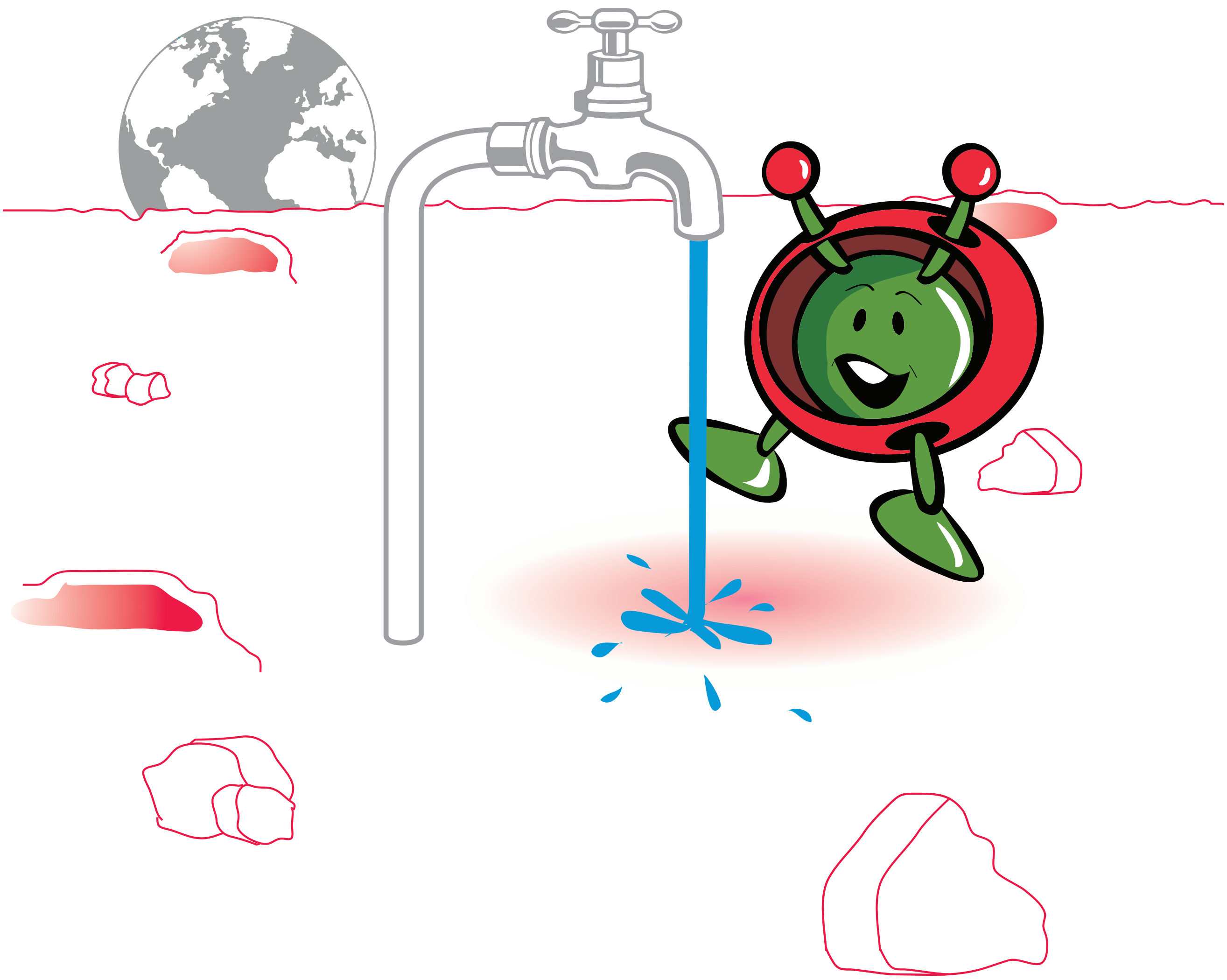
primary | PR33

teach with space

→ WATER ON THE MOON

Filtering "lunar ice cores" to extract water



teacher guide & student worksheets

European Space Agency

teach with space – water on the moon | PR33
www.esa.int/education

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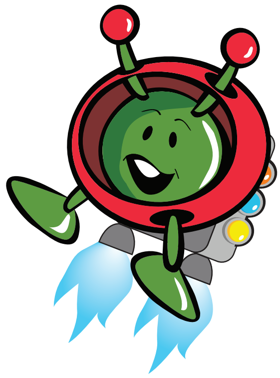


→ WATER ON THE MOON

Filtering "lunar ice cores" to extract water

Fast facts

Subject: Mathematics, Science

Age range: 8-12 years old

Type: pupil activity

Complexity: medium

Teacher preparation time: 45 minutes

Lesson time required: 2 hours in total – divided into at least two parts

Cost per class: low (0-10 euros)

Location: classroom and homework

Keywords: Mathematics, Science, Water, Moon

Brief description

In this resource, pupils will spend a day recording approximately how much water they use for different activities. This is followed by an experimental activity in the classroom, where they will use pre-prepared "lunar ice cores" and filter these to get water. They will use the results of the first and second activity to calculate how much lunar ice they would need to dig or drill to give them enough water for one day. The resource suggests discussions of water use and recycling, both on Earth and in space.

Learning objectives

- Calculate how much water a person uses in an average day.
- Learn that some permanently shadowed regions of the Moon contain water ice.
- Estimate how much lunar soil they would need to extract the water needed for one person for an average day.
- Understand that a filtration system can be used to separate solids and liquids.
- Work scientifically: setting up practical enquiries, taking systematic measurements and recording data.
- Solve problems using addition, multiplication, division; measurements and unit conversions.

→ Summary of activities

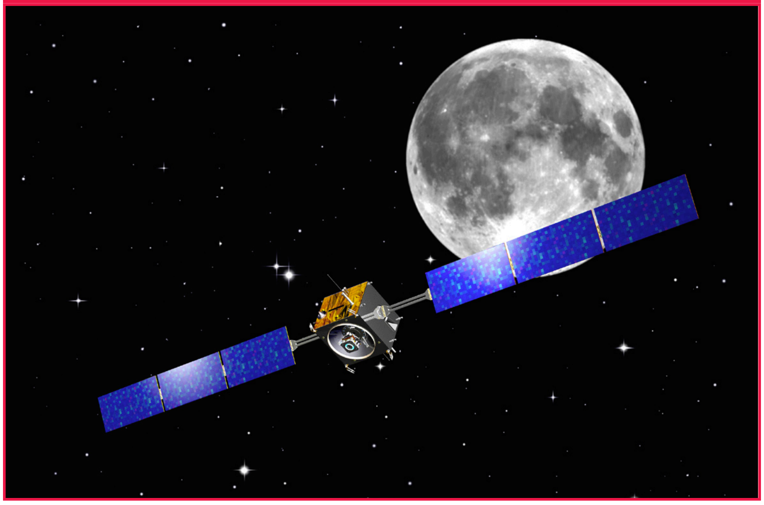
activity	title	Description	outcome	requirements	time
1	How much water do you use every day?	Using a table to estimate water use over 24 hours.	How much water they use every day.	None	Filled in over one day but only 10-20 minutes in total
2	Dirty ice to clean water	Filtering ice/sand samples to measure the water content.	How much ice would they need to drill for one days' water.	Completion of activity 1	1 hour
3	Water conservation on the Earth and Moon	Pupils share ideas on water recycling and conservation.	Class decides on top 5 ways to conserve water.	Completion of activity 1 and 2 or an introduction about water usage on Earth and in Space	40 minutes

* Note: Activity 2 requires ice to melt at room temperature, which may take around 2 hours. Pupils could complete activity 3 whilst they are waiting for their samples to melt and they could be left over a lunch break, or another activity could take place.

→ Introduction

Between 1969 and 1972, twelve astronauts visited the Moon. These lunar missions were the only time humans walked on another world besides Earth.

Figure 1



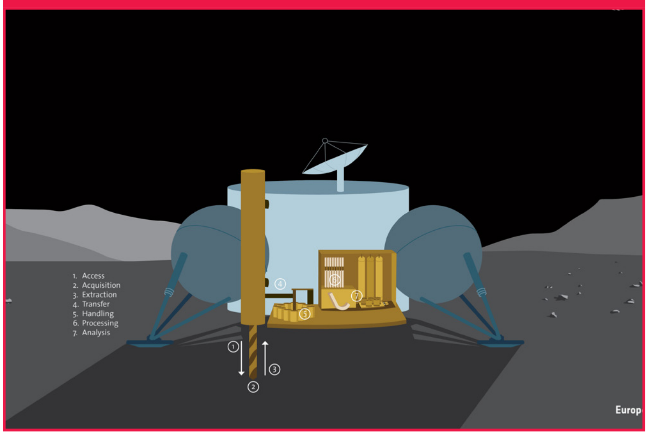
↑ Europe's SMART-1 was Europe's first Moon orbiter

Since then several satellites and robotic missions have studied the Moon. One of those missions was SMART-1, which orbited the Moon between November 2004 and September 2006. SMART-1 took detailed images of the surface and studied what the rocks are made of. The mission ended with a deliberate crash into the lunar surface.

Nowadays ESA, in collaboration with other Space Agencies, is planning to send robotic missions and astronauts to explore the surface of the Moon once more. This time preparing and testing technologies to go further into the Solar System.

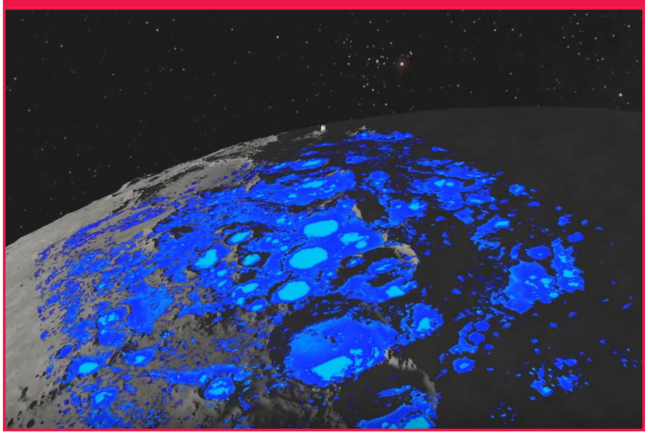
Once on the Moon's surface, probes will be used to explore local lunar resources such as the regolith (soil) and the water ice at the Moon's poles.

Figure 2



↑ Artistic impression of a Moon lander extracting lunar resources.

Figure 3



↑ Map of the lunar south pole of where water ice would be stable buried in the top 1 meter (dark blue), and on the surface (light blue).

In this set of activities students will have to imagine they are on a lunar mission and will have to extract water from icy material at the lunar poles, comparing these values to their average water consumption every day.

→ Activity 1: How much water do you use every day?

In this activity, pupils will use a table to record the number of times they complete a task that requires the use of water, including activities such as using the dishwasher or cooking that also take place in their home. In the classroom they will then calculate the total water they have used in one day.

Equipment

- Student worksheet printed for each pupil.
- Pen/pencil

Exercise

Table A1 in the student worksheet will help them to record the total amount of water that they use in a normal day. They need one day to complete the table, at school and at home. In the classroom, they calculate the total for each activity by multiplying the number of times by the litres of water used each time. To find the grand total for the day, add up all the numbers in the totals column.

Results

Pupils will have different results for this activity. A reasonable total may be around 110 litres.

Discussion

Pupils should now compare their totals. In the discussion, pupils can share some ideas on how they could use less water, ahead of Activity 3, where they come up with their top five ways to conserve water.

To conclude Activity 1 the pupils can have an introduction about water recycling on the International Space Station and about water on the Moon, in preparation for Activity 2. Several links where to find extra information are available in the Links section.

→ Activity 2: Dirty ice to clean water

Pupils preform an experiment to retrieve water from frozen lunar soil samples and compare it to the amount of water they would need on the Moon.

Equipment

- Sand
- Student worksheet printed for each group.
- Pen/pencil
- Ice cube trays
- Plastic water bottles / beakers / jam jars
- Weighing scales
- Filter paper (e.g. for a coffee filter)
- Equipment to measure the water volume: measuring cylinder or 5ml spoons
- Calculators
- Funnels (optional)

Preparation

The "lunar ice cores" must be made in advance of the practical activity. To make the ice cores, fill ice cube trays half way up with sand, then fill to the top and place in a freezer (preferably overnight, or at least a few hours before carrying out the activity). It is recommended that pupils work in groups of 3 and have around 5 ice cubes per group.

Health and safety

Pupils should take care if handling glassware.
They should be made aware that the ice cubes are not edible.

Exercise

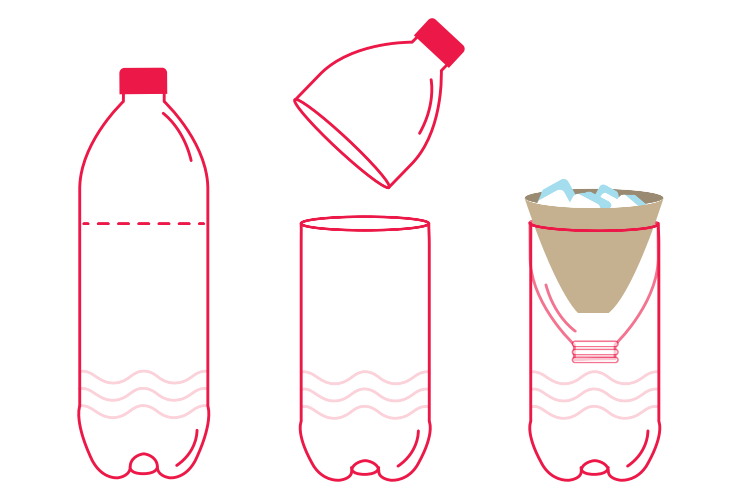
By way of introduction to water on the Moon, you can use a video about the local lunar resources and expand on how astronauts may be able to find water, in the form of ice, at the lunar poles. The following video is a good example: lunarexploration.esa.int/#/explore/science/224?oa=250

Water can only exist in the form of ice on the surface of the Moon. The pressure is very low on the surface of the Moon since there is no atmosphere. The low pressure means that if ice from a crater was brought to the surface, it would turn into a gas. This is called sublimation. To enable water to exist as a liquid it would need to be in a pressurised container. Depending on the age and ability of the pupils you may want to discuss this or focus just on the practical activity and analyses.

The ice in lunar craters will be mixed with the sandy/rocky material at the surface of the Moon. This means that the water must be separated from other materials before it can be used. Before starting the practical activity, pupils could discuss how they think rocky materials could be removed from the ice core. They may need to be guided towards melting the ice from the samples first and then filtering the mixture.

The first step is for the filtering equipment to be set up. Each group should place filter paper in a container, for example a plastic bottle with the top cut off. It is best if the filter paper can be secured with tape, or a lid, so that it is a few centimetres from the bottom of the container – alternatively a plastic funnel can be used for this purpose, if available, or the top of the plastic bottle can be inverted and placed in the bottom (see Figure 4).

Figure 4



↑ How to build your water filtration system

The second step is for the pupils to weigh their lunar ice cores and record this in their results sheet. This is so that they can eventually calculate what mass of lunar material they would need to give them water for one day. There are two methods for this: either each group can weigh their own samples, or the entire sample for the class can be weighed and then divided by the total number of groups. The second method may be preferable if there is only one set of scales, and ice cores are melting whilst waiting to be weighed.

In the third step, pupils place their ice cores into their filtering equipment. The cores then need to be left to melt. This may take a couple of hours, depending on the temperature in the classroom. Ideally, they should not be left in direct sunlight so that little evaporation of the water takes place.

After waiting for the samples to melt, and the water to filter through, pupils should then remove the filter paper containing the sand. The final step then requires the pupils to measure the volume of the water, in millilitres, that they have left. They can either do this using measuring cylinders, syringes, or if these are not available then 5ml spoons could be used to find the approximate volume of the water remaining.

An example set of results obtained by Paxi is provided in Table 2.

Table 2

At the start of the experiment	At the end of the experiment	Calculated in Table 1 – Activity 1
Mass Lunar Sample (g) (mass of the ice cubes)	Volume filtered water (ml)	Volume of water used by you per day (litres)
60	30	120

↑ Example of results from Activity 2.

While waiting for the samples to melt students can use Paxi's results to calculate how much lunar soil he would have to dig to have water for one day. This example is also presented in the student worksheet.

The analysis of the results has been differentiated for age/ability below.

7 to 9 years

For this age group we recommend that once they have measured the total volume of water in ml that they compare this to a one litre bottle of water. It will help to have one or more filled bottles for the children to see. They could estimate how many of their samples they think they would need to make up one litre. They could combine their samples into one container and compare.
For higher ability pupils, they could use the scaling method that is outlined in the student guide, and in the next section for 10-12 years.

10 to 12 years

For this age group, we recommend using some example figures for the calculation. These are provided in the student sheet and below. This method could then be repeated for their own samples if you wish.

Let's use an example:
Paxi worked out that he needed **102 litres** of water each day when he was on the Earth. When Paxi did his experiment, his lunar sample weighed **93 grams**. This gave him **48ml** of water when melted and filtered.

Paxi decided to round his numbers to make the estimation easier.
- He rounded 102 litres to 100 litres.
- He rounded 93 grams to 100 grams.
- He rounded 48 ml to 50 ml.

In Paxi's sample 100 grams of lunar soil gave him 50ml when melted and filtered.

First, can you help Paxi scale up to get to 1000ml (which is the same as 1 litre)?

100g → 50 ml

200 g → **100** ml

2000 g → **1000** ml

1000g is the same as 1 kg and 1000ml is the same as 1 litre.

2 kg → **1** litre

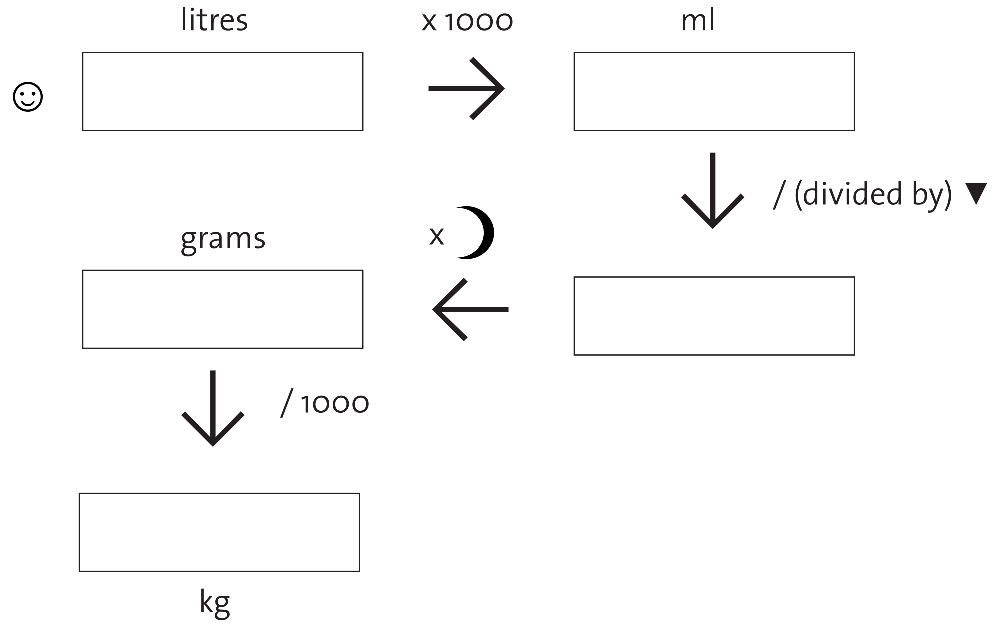
Can you now estimate how many kg of soil Paxi would need to dig to get 100 litres of water?

200 kg

10-12 years – higher ability

This method requires children to match symbols to numbers – introducing simple algebra and a flow chart to perform the calculations. It is likely that they will need to use a calculator for this method and they should round to the nearest gram, kg, ml, and litre during their calculations. This method is not in the pupil sheet.

☽	▼	☺ (from activity 1)
Mass Lunar Sample (g)	Volume filtered water (ml)	Volume of water used by you per day (litres)



You may want to set this up in a spreadsheet for pupils to fill in. You can use the formulae below, if you wish the spreadsheet to perform the calculations for the pupils:

Mass lunar sample (g)	Volume of filtered water (ml)	Volume of water used by you per day (litres)	Volume used by you in ml	Multiplication factor M	Mass of lunar soil (g)	Mass lunar soil (kg)
A2	B2	C2	= C2* 1000	= D2/B2	=E2*A2	= F2/ 1000

Discussion

The final value that the pupils calculate will probably seem like quite a large amount. This could lead into a discussion as part of Activity 3, or if this activity has already been completed then a short discussion could take place as to the importance of minimising the use of and recycling water on the Moon.

→ Activity 3 – Water conservation on the Earth and the Moon

Pupils preform an experiment to retrieve water from frozen lunar soil samples and compare it to the amount of water they would need on the Moon.

Equipment

- Pen / pencil
- Paper / card / post-it notes
- Student worksheet printed for each pupil

Exercise

It is best to start this activity by considering how to reduce their own use of water on the Earth, and then separately considering the use of water on the Moon. This activity is suggested as a pair and share. They should write down up to 5 ideas individually. They should then share these with one other person, and pick the top five ideas from the two lists. Next, they share with a group of around 6 to again come up with their top 5 ideas. Finally, they should share ideas for the whole class to come up with their top 5.

Results

Some possible suggestions for reducing water usage and recycling water on the Earth are:

- Turning off the tap when you brush your teeth
- Reducing the time spent in the shower
- Installing water capture devices to use rain water for flushing toilets
- Collecting rain water for use in the garden
- Not using sprinklers in the garden
- Fixing leaking pipes / dripping taps
- Washing clothes, towels, bedclothes less often

Some suggestions for reducing water usage on the Moon are:

- Not using flushing toilets
- Not showering (as on the International Space Station)
- Not washing clothes
- Using disposable food containers for eating/cooking
- Recycling waste water (e.g. from toilets)
- Recycling water breathed out by astronauts (all breath contains water vapour)

Discussion

Once students have decided on their top five ways to reduce or recycle water on the Earth and on the Moon, they could discuss the practicality of each. Would they be willing to take any steps on the Earth to reduce their use of water? Would they be happy to live on the Moon and possibly drink water recycled from their own urine (on the ISS, the recycled water is purer than most tap water back on Earth)?

→ Conclusion

In this set of resources, pupils have used scientific enquiry and mathematics to discover a method of working out how much lunar soil/ice they would need to dig in order to survive on the Moon. They have discussed water use and how to reduce and recycle water.

There are many more videos available with background information at:
www.lunarexploration.esa.int – most of these are only appropriate for teacher information but parts could be shown to pupils.

For example: www.lunarexploration.esa.int/#/explore/technology/231?ia=293
or www.youtube.com/watch?v=Xg0Nj5sMqW4
show how ice cores could be drilled on the surface of the Moon.

→ WATER ON THE MOON

Filtering "lunar ice cores" to extract water

→ Activity 1: How much water do you use every day?

Exercise

Have you ever thought about how much water you use every day? It is probably more than you think. The table below will help you to record the total amount of water that you use in a normal day. Fill it in and calculate the total for each activity by multiplying the number of times you repeat the task by the litres of water used each time. To find the grand total for the day, add up all the numbers in the totals column.

Table 1

Activity	Litres water each time	Number of times	Write your amounts here
Taking a shower	60 litres		
Brushing teeth	2 litres		
Washing face	2.5 litres		
Flushing the toilet	6 litres		
Washing hands	1 litre		
Washing the dishes by hand	8 litres		
Using the dishwasher	10 litres		
Cooking	1.5 litres		
Drinking water, tea, soft drinks	0.2 litres		
		Total	

↑ Record the amount of water you use in a day.

Did you know?

Astronauts on the International Space Station recycle most of the water that they use – about 75%. The Water Recovery System can recover water from astronauts' urine and from their breath. This is filtered and cleaned and can be used again. One saying they use is "today's coffee is tomorrow's coffee"!

Astronauts on the International Space Station use typically one tenth of the water of the people on the Earth. On the Moon astronauts probably would have to use even less water per day!

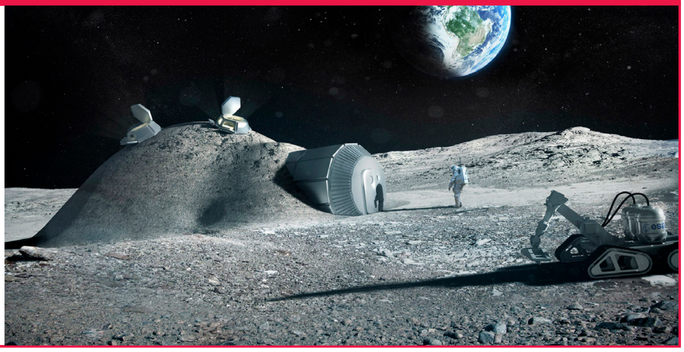
1. Compare your totals within the class. Do you all use the same amount of water each day? How could you use less water?

2. Astronauts use approximately 10 times less water in space than on Earth. If you went to the Moon how much water would you use per day? Assume that you would use the same amount of water as in the International Space Agency.

→ Activity 2: Dirty ice to clean water

Did you know?

Satellites studying the Moon have found that there is water ice at its poles. The ice has been found buried in the bottom of some craters that are always in shadow. On a future Moon base, astronauts might be able to dig or drill the frozen soil to get ice that they can melt to have liquid water.



Any ice that we dig out from the surface layers of the Moon will be mixed with lunar soil, so we have to find a way of separating the water from the lunar soil. In this investigation, you will try to get water from frozen lunar soil samples. You will also calculate how much lunar soil you would need to dig to get the quantity of water that you would need to live on the Moon for one day.

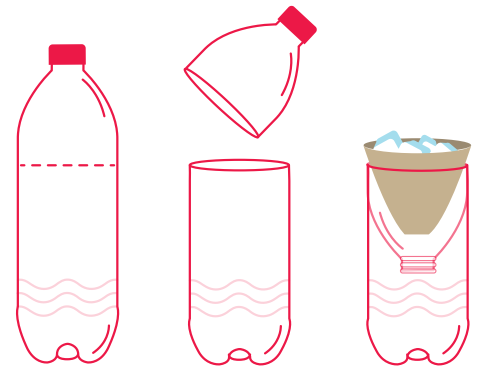
Exercise

- "Lunar" ice cores
- Plastic water bottles
- Filter paper
- Weighing scales
- Equipment to measure the water volume

Exercise

1. Construct your water filter, using a water bottle and filter paper as shown in Figure A2. Use tape to secure the filter to the bottle.

Figure A2



↑ How to build your water filtration system

2. Use scales to weigh the frozen lunar soil sample (all the cubes you have been given by your teacher), and record this value in Table 2.

Table 2

At the start of the experiment	At the end of the experiment	Calculated in Table 1 – Activity 1
Mass Lunar Sample (g) (mass of the ice cubes)	Volume filtered water (ml)	Volume of water used by you per day (litres)

↑ Collect your measurements at the start and end of the experiment in this table.

3. Place the frozen lunar soil samples in to your water filter as shown in Figure 2, step C. Leave for at least 2 hours.

4. While you are waiting for the ice to melt, you can use rounding and scaling to work out how much lunar soil you might need to dig to get enough water for one day.

   Let's use an example:
   Paxi worked out that he needed **102 litres** of water each day when he was on the Earth. When Paxi did his experiment, his lunar sample weighed **93 grams**. This gave him **48ml** of water when melted and filtered.

Paxi decided to round his numbers to make the estimation easier.
- He rounded 102 litres to 100 litres.
- He rounded 93 grams to 100 grams.
- He rounded 48 ml to 50 ml.

100 grams of lunar soil gave him 50ml when melted and filtered.
First, can you help him scale up to get to 1000ml (which is the same as 1 litre)?

100g → 50 ml

200 g → ___ ml

2000 g → ___ ml

1000g is the same as 1 kg and 1000ml is the same as 1 litre.

2 kg → ___ litres

Can you now estimate how many kg of soil Paxi would need to dig to get 100 litres of water?

________ kg

5. Now back to your experiment. If your ice has melted you can take the next steps:

   a. Measure the filtered water in millilitres (ml) using a measuring cylinder, syringe, or a 5ml teaspoon. Record this value in Table A2.

   b. Write down any observations you make about the filtered water – you may want to compare it to tap water. **Do not drink the water!**

6. Compare the water you have collected to the amount of water in a 1 litre bottle. Can you use scaling to work out how many samples you would need to get 1 litre of water?

7. How many times more would you need to repeat the process to get enough water for one day on the Moon?

→ Activity 3: Water conservation on the Earth and the Moon

Exercise

1. Think about how you could reduce or recycle water on the Earth. You will share your top 5 ideas with a partner, and then go on to decide a top 5 with the whole class.

My top 5 ideas of how to reduce or recycle water on the Earth

idea 1	
idea 2	
idea 3	
idea 4	
idea 5	

Top 5 ideas for the whole class (on Earth)

idea 1	
idea 2	
idea 3	
idea 4	
idea 5	

2. Now repeat this for the Moon.

My top 5 ideas of how to reduce or recycle water on the Moon

idea 1	
idea 2	
idea 3	
idea 4	
idea 5	

Top 5 ideas for the whole class (on the Moon)

idea 1	
idea 2	
idea 3	
idea 4	
idea 5	

3. Would you be willing to do any of the top 5 suggestions for the Earth?

4. Would you go to the Moon and would you be prepared to use very little water there?

→ LINKS

ESA resources

Moon Camp Challenge
esa.int/Education/Moon_Camp

Moon animations about Moon exploration
esa.int/Education/Moon_Camp/Making_a_Home_on_the_Moon

A day on the life of an astronaut on the Moon
esa.int/Education/Moon_Camp/Living_on_the_Moon

ESA classroom resources
esa.int/Classroom_resources

ESA Kids
esa.int/esaKIDSen

ESA Kids, Back to the Moon
esa.int/esaKIDSen/SEMQBSXJW7J_OurUniverse_0.html

ESA space projects

The Moon, ESA's interactive guide
www.lunarexploration.esa.int

ESA Smart-1:
sci.esa.int/smart-1

ESA's PROSPECT project is studying a lunar drill for sample collection of lunar ice:
www.lunarexploration.esa.int/#/library?a=293

Testing of the ESA's Lunar ice drill: www.youtube.com/watch?v=Xg0Nj5sMqW4

Extra information

Videos about water recycling on the International Space Station:
www.youtube.com/watch?v=BCjH3k5gODI and www.youtube.com/watch?v=cR_jQ4Is8to

Infographic about water recycling on the ISS:
www.blogs.esa.int/VITAmission/2017/08/30/testing-the-space-station-water/