THE WATER MODULE
EDUCATOR GUIDE

2nd Edition

2021

Note to educators

This booklet provides guidance to educators wishing to explore the topic of water with secondary school students in lower and upper levels. Secondary schools in Kwale County, Kenya set up School Water Clubs in 2017 and tested out the information and activities that can be found in the accompanying student booklet. The Water Module was originally designed for use in after-school clubs. Nonetheless, this resource covers many concepts and skills that will be relevant to formal education, particularly in chemistry; biology; geography; personal, social and health education; and in the domain of environment, health and wellbeing. Thus, teachers may wish to use activities and information from the module in class, providing an opportunity for students to see the real-world application of the subjects that they are studying.

The topics covered in the booklet are the following:

1: The water cycle (i.e. the hydrological cycle)
2: Geology
3: Groundwater
4: Water quality
5: Water management

The material in the booklet was designed to be covered over 2 terms, with 9-10 sessions per term. Sessions are designed to take 1 hour but 1.5 hours would be preferable to allow more time for activities. Additional sessions could be used to prepare for and write up experiments or to plan independent research or projects on topics of interest. In the 3rd term of the year you could go on to another area of learning or discovery, or you could extend the final research and awareness-raising sections and/or give the students additional time to develop their own projects or activities around the theme of water.

We have specified the order in which sessions could take place, and have included a student register to track progress through the activities. That said, of course, educators are most welcome to use this material in any way they like – for example, selecting topics or activities that fit with their school's scheme of work and using them with classes at different levels, or selecting particular activities or themes for use in club sessions. To facilitate school decisions on using this material, we have provided list of materials and equipment needed for each activity.

Items listed in further reading sections can be accessed through the weblinks in the booklet or by contacting the authors of the resource.

Recognising achievement

At the back of this document you will find a "Water Champion" Certificate that can be copied and given to students completing the activities.

Water Module – Overview and Contents

Suggested session numbers	Section/Activity Title	Page number in the student booklet	Estimated time for activity
Why learn about water 1: The Water Cycle			
1	Activity 1: The Sustainable Development Goal for water	2	5 mins
	Activity 2: (Maths: Reading graphs)	2	10 mins
	Activity 3 (Maths: Percentages)	2	5 mins
	Activity 4 – Bingo reading	3-4	20 mins
	Activity 5 – Water Cycle Crossword	11	15 mins
	Activity 6 - The “natural” water cycle where I live	8	10 mins
2	Activity 1: Measuring evapotranspiration	7, 9-10	60 – 90 mins
3	Activity 1: Measuring precipitation	9	60 – 90 mins (plus on-going data collection)
2: Geology			
4	Activity 1: Engaging with the information	12-15	40-50 mins
	Activity 1A/Homework – Water use in mining	18	10 mins, plus homework
	Activity 2./Homework Crossword	21	5 mins, plus homework
5	Activity 1: Using geology to understand water flow in the distant past	16-20	60 mins
3: Groundwater			
6	Activity 1: Infiltration Experiment	22-25, 29	40-60 mins
	Activity 2: Saturation Experiment	22-24, 30	20-50 mins
7A	Activity 1: How do scientists study groundwater?	24-26	25 mins
	Activity 2: How do people access groundwater?	26	15 mins
	Activity 3: Sustainable use of groundwater	26-27	10 mins
	Activity 4: Crossword	31	10 mins plus homework
7B	Groundwater where I live (optional field visit)	28	60 – 180 mins

Suggested session numbers	Section/Activity Title	Page number in the student booklet	Estimated time for activity
4: Water Quality			
8	Activity 1: Source protection quiz	35-37	20 mins
	Activity 2: Teaching groundwater protection	37	40 mins
9A	Activity 1: Doing a sanitary inspection of a water supply	42-47	60 mins
	Activity 2: Background reading on sedimentation	37-38, article	Homework
9B	Extension ideas: Source protection/sanitary inspection fieldwork / Arrange an expert talk		90-180 mins
10	Activity 1: Sedimentation practical	47-48	60-90 mins
	Activity 2: Investigate how turbidity is measured	49	30 mins
11	Activity 1: Engaging with the information: Filtration	38	15 mins
	Activity 2: Engaging with the information: Disinfection	34, 39	15 mins
	Activity 3: Safe storage	41	15 mins
	Activity 4: Water Quality crossword	50	15 mins
12-13	Activity 1: Different water disinfection methods	39	20 mins
	Activity 2: Solar still design challenge	49	90 – 120 mins
5: Water management			
14	Activity 1: The water cycle with human activity	52, 57	30-60 minutes
	Activity 2: Water management crossword	61	15 mins / homework
15	Activity 1: Who is involved in water management?	53-55	45-60 minutes
	Activity 2: Planning for the future	55	15 minutes
16	Activity 1: Engaging with the information – Water footprints	51-53	30 mins
	Activity 2: Can a t-shirt have a footprint?	59-60	60 mins
17-19	Activity 1: Choose a research report to work on Follow-up: Presentations and poster reports	As required	60-90 mins x 2 60-90 mins
Our Vision for Water			
20	Activity 1: The big picture	62	20 mins
	Activity 2: Sharing our vision for water	62	40-70 mins and ongoing
	Activity 3: Host a debate	62	60-120 minutes

Session 1: Why Learn About Water?

Activity 1: The Sustainable Development Goals for Water – 5 mins (p. 2 student booklet)

Materials:

- Students must be able to see page 2 of the student booklet

Steps:

1. Ask a student to read out the Sustainable Development Goal Target 6.1
2. Discuss as a class the meanings of the words **universal** and **equitable**

Universal = for everyone
Equitable = fair, fairly shared between people

Activity 2: Reading graphs (maths) – 10 mins (p.2 student booklet)

Materials:

- Students must be able to see page 2 of the student booklet

Steps:

1. Ask the class to look at the graph on the bottom of page 2. Ask: "What % of people in Sub-Saharan Africa took their drinking water from surface water in 2000? What about in 2020?"
2. Ask the class to read the definitions of the 5 types of drinking water (surface, unimproved, limited, basic, safely managed) or write them up on the board. Ask: "Which one of these is the least safe category of drinking water on the graph?" Once they have given their thoughts, explain that SURFACE is the least safe option, followed by UNIMPROVED (unprotected dug well or unprotected spring), because they may have been exposed to contamination and cause disease in the people drinking them. The LIMITED, BASIC and SAFELY MANAGED categories cover 'IMPROVED' drinking water sources – these are drinking water sources that have been designed to be able to provide safe water if correctly constructed, managed and maintained. Improved sources include piped water supplies to households, public taps or standpipes, boreholes with pumps, protected wells and springs and rainwater collection. You could suggest that students look up the definition of improved water in the glossary.
3. Ask the class: "Do the graphs show that access to **improved** drinking water got better or got worse in Sub-Saharan Africa between 2000 and 2020?"

Activity 3: Working with Percentages (maths) – 5 mins (p.2 student booklet)

Materials:

- Students must be able to see page 2 of the student booklet
- Pens and paper; calculator

Steps:

1. Write the population figures below and this question on the board: How many people in Sub-Saharan Africa (SSA) had access to BASIC improved drinking water in 2020 compared to 2000?

2. Get the class to read the percentages for BASIC drinking water access in 2000 and 2020 from the graph, write these on the board and use the figures to calculate the answer. Give them the method if required.

Method:

Total population SSA in 2000 = 665 million

Total population SSA in 2020 = 1,136 million (Source: World Bank)

% with BASIC drinking water access in 2000 = _______________

% with BASIC drinking water access in 2020 = _______________

SSA population in 2020 x % with basic drinking water access in 2020 ÷ 100 = ________(a)

SSA population in 2000 x % with basic drinking water access in 2000 ÷ 100 = ________(b)

Calculate: (a) – (b) = the change in number of people in Sub-Saharan Africa with access to BASIC improved drinking water between 2000 and 2020 = ______________ million people

3. Extend this activity by looking up or arranging for students to be able to look up drinking water access statistics for their own country online. This can be done by selecting Country using the drop down menus on the UNICEF/WHO Joint Monitoring Programme website at this link: https://washdata.org/data/household

Activity 4: Bingo reading – 20 mins (p. 3-4 student booklet)

Note: This is one possible way to make reading from a text as a group more interactive.

Materials:

- Pieces of paper with these words written on them (enough for each group to have one of each of the word)

climate	water scarcity	run-off
condensation	reservoirs	drought
climatology	precipitation	discharge
evapotranspiration	vapour	hydrology
transpiration	hyporheic zone	evaporation

Steps:

1. Arrange the class into groups sitting in circles around tables or on the ground. Each group is given a number or a name – written up on the board with room for a tally of points. Choose one student to help keep score.
2. Give the pieces of paper with the words to each group (tell them to put them face up on the table or floor in the middle of their circle)
3. Tell the class that they will listen while you read out some text and to listen out for the words on the pieces of paper. When a word from the table is read out, the first group to hold up the piece of paper with the word on it gets a point – recorded by the score-keeper on the board.
4. Read out the text on pages 3 and 4 and be ready to award and record points. Applaud the winning group for close listening!
5. To finish the game, share the words out between the groups. Ask each group to look up the words in the glossary and prepare to present the definitions to the other groups. Give extra points for creative presentations of the definitions.

Activity 5: Water Cycle crossword – 15 mins (p. 11 student booklet)

Note: This could be given as homework or added to another session.

Materials:

- Enough copies of the crosswords for individuals, pairs or groups to fill in together.
- Text in Chapter 1 The Water Cycle, and the glossary in the student booklet.

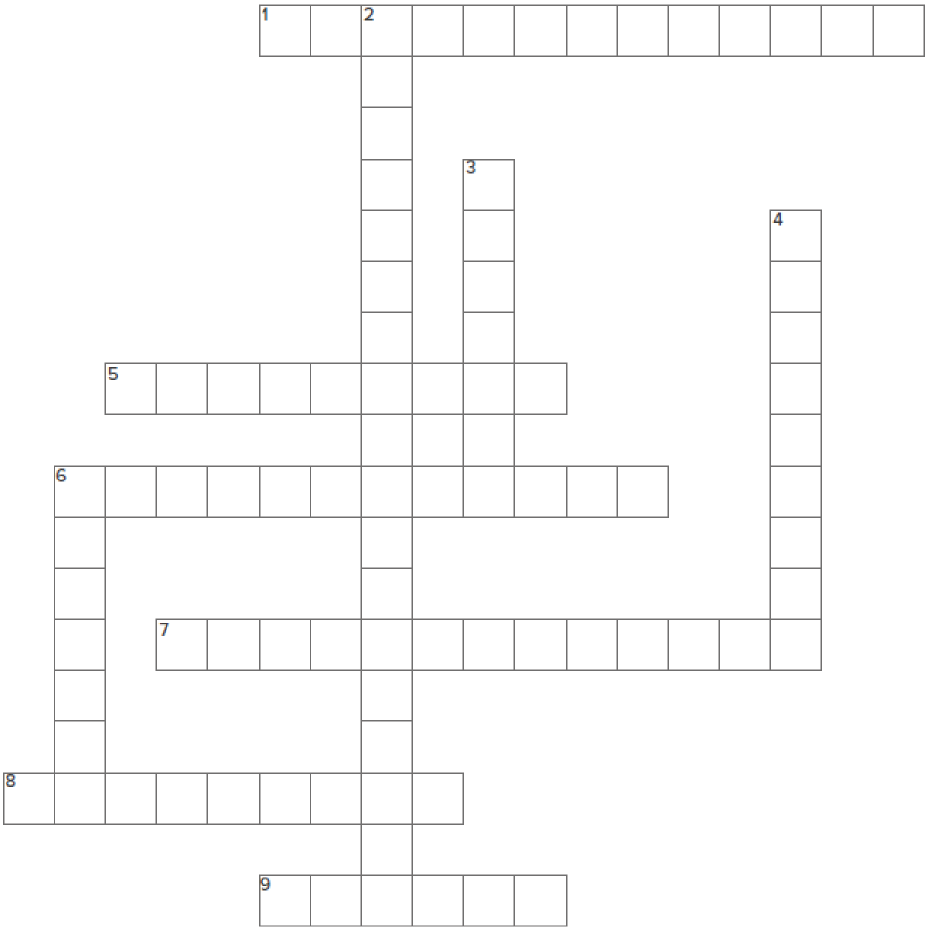
Steps:

1. Tell them to work on the crosswords using pencil, reading the student booklet text to find the answers.
2. Get them to do the crossword. Make it easier by leaving the words from the game with each group, or make it harder by taking them away (depending on the level of the class).
3. If it is taking a long time, write additional clues on the board such as the first letter of each word. If you think it necessary for the class, copy the handout below which provides the first letter of each word.

Answers:

Across	Down
1. precipitation	2. evapotranspiration
5. discharge	3. drought
6. condensation	4. hydrology
7. water scarcity	6. climate
8. reservoir	
9. run-off	

Water Cycle Crossword (with letter clues)



Across

1. Water falling out of the atmosphere in a liquid or solid state (13 letters, first letter p)
5. Water flowing out; the opposite of recharge (9 letters, first letter d)
6. The process by which vapour becomes a liquid often due to cooling (12 letters, first letter c)
7. When there is not enough water to meet the needs of people, animals, and the environment in a region (2 words; 13 letters, first letter w)
8. A body of water that forms behind a dam (9 letters, first letter r)
9. Water that flows over land to surface streams, rivers, and lakes and eventually to the ocean / sea (6 letters, first letter r)

Down

2. Movement of water vapour into the atmosphere due to both evaporation from soil and transpiration from plants (18 letters, first letter e)
3. An extended period of less than normal precipitation that often affects the availability of water supplies – a natural hazard caused by climate variability (7 letters, first letter d)
4. The branch of science that focuses on how water moves and changes form (9 letters, first letter h)
6. The overall conditions of weather in an area over time (7 letters, first letter c)

Activity 6: The "natural" water cycle where I live – 10 mins (p. 8 student booklet)

Steps:

1. Tell students to work individually or in groups to complete the table on page 8 of the student booklet.
2. Share responses as a class.

Water cycle process	Have I ever seen it with my own eyes?	Description of an example of what can be seen of this process in my local area
Surface water flow		
Precipitation		
Condensation		
Evaporation		
Groundwater flow		
Infiltration		
Run-off		
Evapotranspiration		
Melt-run-off		

Session 2: Measuring Evapotranspiration – A Small Sip of Hydrology

Activity 1: Evapotranspiration experiment – 60 to 90 mins (pp. 9-10 student booklet)

Materials:

Students will work in groups of 2 – 4. Each group will require:

- 1 small leafy plant in a small pots or half plastic bottle (if you can, provide groups with different species of plant with a range of leaf shapes and surface areas, to add interest to comparison of results)
- 1 clear plastic bottle cut in half so that the bottom half is large enough to go over the top of the plants. (Alternative - clear plastic bag)
- A marker pen
- Access to a reasonably accurate weighing scale
- A stopwatch or timer
- A litre of water in jug
- Calculator
- Pencils and ruler
- Food colouring
- Worksheet and instructions (pages 9 and 10 in student booklet, Water Cycle diagram p. 7)

Teacher's notes:

The plastic bottle half is placed over the plant. Water from transpiration from the plant and evaporation from the soil will condense on the inside of the bottle, thereby demonstrating "evapotranspiration" in action. Coloured water makes this more interesting as the dye is not released by the plant into the atmosphere. This is because only pure water can evaporate. Any pollutants in the water are adsorbed by soil or remain in the plants' organic biomass. The activity can be simplified into a simple demonstration of transpiration without collection of data or extended by using different plant species and comparing the transpiration rates of different plants. In the activity, students record data, determine transpiration rates and answer comprehension questions. To gauge comprehension, review their worksheet predictions, data, calculations, and answers.

This activity was adapted with permission from:

https://www.teachengineering.org/activities/view/usf_stormwater_lesson02_activity1

Steps:

1. Get groups ready and set up with materials (a plant and a plastic bottle) and worksheets/instructions. This activity works best conducted outside on a sunny day. The rate of evapotranspiration will vary with the weather conditions. You may be able to reduce the time period of the trials to 5 or 10 minutes.
2. Look again at the Water Cycle diagram on page 7 and explain that we are zooming in on the phase of the water cycle called Evapotranspiration. Can anyone provide a definition of this word?
3. Explain by demonstration that students will use food colouring to colour the water, use this water to water the plant, cover the plant with the clear plastic bottle and collect the water that evaporates from the soil (evapo….) and the water that travels through the plant and is transpired into the air around the plant (…transpiration).
4. Ask students to fill in the first section of the worksheet and answer: "What do you predict that you will see accumulate on the bottle(/bag)?"
5. Ask students to follow the steps in their instructions and conduct the experiment, recording the results on the worksheet. Ask students to note that they must shake and dry the bottle/bag after weighing to remove the water between each timed trial period.

Student instructions:

A) Use the food colouring to colour the water in the jug. Water the plant with the coloured water.

B) Record the time of day and the weather on the worksheet. Think about what you think will happen and write down your predictions.

C) Weigh the cut bottle or clear plastic bag and record its weight to the nearest 0.1g in the cell marked (A) on the table in the worksheet.

D) Place the cut bottle of clear plastic bag over the top of the plant. If using a bag, put the mouth of the bag over the sides of the pot.

E) Set the stopwatch or timer for 15 minutes.

F) When the 15 minutes is up, carefully remove the cut bottle or clear plastic bag from the plant without letting any water drip out.

G) Weigh the cut bottle or clear plastic bag and record its weight on the table below.

H) Dry the cut bottle or clear plastic bag well, or use a new bag that is dry.

I) Put the cut bottle or clear plastic bag back on to the plant and time again for 15 minutes. Weigh again and record.

J) Dry the cut bottle or clear plastic bag and replace for another 15 minutes before weighing again.

K) Convert weight to volume and fill in the table (1g = 1ml).

L) Calculate the rate of evapotranspiration.

M) Calculate the average rate of evapotranspiration during the experiment.

N) Discuss the questions on the worksheet and record your answers.

O) Tidy up and put things away.

6. When everyone has finished recording results, ask students to use the table on the worksheet (copied on the next page) to work out the transpiration rate measured during each time period. Show students or get them to find out that 1 ml of water weighs 1 g. Share the results and draw up a table on the board to allow calculation of the class average. If groups have used different plant species, separate these into columns on the table.
7. Discuss as a class: What was the colour of the water that condensed on the inside of the bottle and why? How would you design an experiment to measure evaporation and transpiration separately? Would you need more equipment?
8. If other groups have conducted the same experiment using different species of plant, use the table to compare results. Did one plant species have a higher rate of transpiration than the other? If so, what were the physical differences in the plants? Why might this make a difference? (e.g. surface area of leaves, texture of leaves)
9. Ask students to consider the final question. How would you design an experiment to measure evaporation and transpiration separately? Would you need more equipment?

Evapotranspiration student worksheet

Plant ID label:	Common name of plant:			
	Scientific name of plant (if known):			
	Time of day:		Weather conditions:	

Predictions

What do you predict that you will see accumulate on the bottle/bag?	

Results

Measurement period (minutes)	Weight bottle/bag (g)	Weight of water collected (g)	Volume of water (ml) (1g = 1 ml)	Rate of evapotranspiration (ml/min)
0	A)*	–	–	–
	(B)	(B-A)		
	(C)	(C-A)		
	(D)	(D-A)		

*This is where you record the initial weight of your cut bottle or bag.

Discussion

What was the average rate of evapotranspiration (ml/min) across the three measurement periods?	
What was the colour of the water that condensed on the inside of the bottle/bag and why?	
If other groups have conducted the same experiment using different species of plant, you could compare results. Did the various species have different rates of transpiration? If so, what were the physical differences in the plants? Why might this make a difference?	
How would you design an experiment to measure evaporation and transpiration separately? Would you need more equipment?	

Session 3: Measuring Precipitation

Activity 1: Collect your own rainfall data – 60 to 90 mins to set up (ongoing data collection and analysis in later sessions) (mentioned on page 9 of student booklet – instructions do not appear in the student booklet)

Materials:

- Plastic bottle (2 litre) with straight sides (1 per raingauge)
- Paperclips or tape
- Sharp knife or scissors
- Sunflower oil or other non-toxic oil
- Plastic measuring cylinder
- Pencil
- Ruler
- Notepad with data collection table and room for calculations
- Graph paper

Teacher's notes:

In this session, students construct and set up low-cost raingauge(s) which can be used to collect precipitation data on school grounds. You may want to make one or several rain gauges – it would be interesting to compare data from different gauges set up nearby and in different places. Once data collection has been taking place for some time, the data can be presented in graphical form and compared to other sources of rainfall data. The design used here has been adapted from Wrage, K.J., Gartner, F. R., Butler, J.L., (1994) Journal of Range Management 47 (3).

Steps:

1. Ask students to define the word "precipitation" (consult the glossary in the Water Booklet and ask a student to write the definition on the board).
2. Use the following page to introduce measurement concepts to explain how a rain gauge can be used to measure the volume of rain that is falling in a specific area. [Answer to question 1: 50L; Answer to question 2: Area of roof in m2 x 2mm = amount you can collect in Litres (excluding evaporation). Answer to A: *This would be heavy rain though it depends on the rate at which is fell (see table below).*
3. Use the next 4 pages to introduce a real example of rainfall data and to instruct pupils on how to build and fix their rain gauge in place. Work in groups to make multiple gauges or if you are only making one raingauge, select volunteers to do different stages.

Hydrologists want to know the volume of rain that falls. Imagine if the rain fell and did not infiltrate into the ground or run downhill. Imagine if it just stuck where it landed – all the raindrops stacking on top of one another. If that happened, we could easily measure how deep the water was and multiply that by the area of land it was covering – then we would know the volume of rain that fell. Of course, in reality rain does infiltrate into the ground, run off over the land and evaporate back to the atmosphere so, to measure rainfall, hydrologists use an instrument called a rain gauge. The rain gauge captures the rain and makes it possible to measure the height of the water that accumulates over a specified period of time. That height can then be multiplied by the land area where the rain was falling and volume of rainfall can be estimated.

Rain gauge measurements are usually made in millimetres. If the rain falling on a square metre (m2) of land reaches a height of 1 millimetre (mm) in a rain gauge, a total of 1 litre (L) of rain will have fallen on that land. Here is the mathematical explanation for this:

height x area = volume

height = 1 mm = 0.001 m

area = 1 m x 1 m = 1 m^2

volume = 0.001 m x 1 m x 1 m = 0.001 m^3

(converting to litres) 0.001 m^3 = 1 L

So, when weather reports say that there has been 100mm of rain on a particular day what they mean is that 100 litres of rain has fallen per 1 m^2:

height x area = volume

height = 100 mm = 0.1 m

area = 1 m x 1 m = 1 m^2

volume = 0.1 m x 1 m x 1 m = 0.1 m^3

(converting to litres) 0.1 m^3 = 100 L

Calculate the following:

1. How many litres of rain have fallen in one square metre if the height of rain in the rain gauge was 50mm?
2. Now, estimate the area of your school roof. Can you calculate how many litres of rain would have fallen on the roof if the height of rain in the rain gauge was 2 millimetres?

Questions:

A. Do you think 100 mm rain in 24 hours would be light rain or a heavy storm?

B. How often does it rain where you live? Does anyone collect rainwater from roofs?

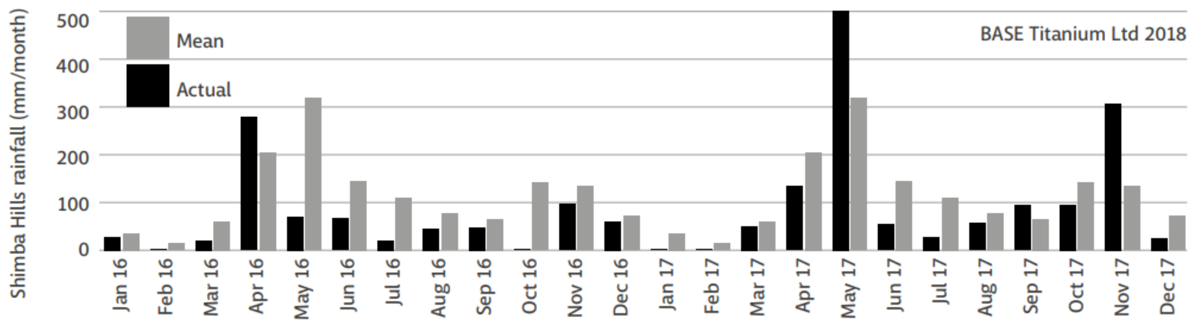
Long term rainfall data can show us how the weather at a particular site changes through the seasons and how it compares to other years. This figure shows monthly rainfall measured in a rain gauge on Shimba Hills, south coast of Kenya in 2016 and 2017 (black) and the average rainfall over many years (grey). The data was supplied by BASE Titanium Ltd.

1. Which was the wettest month in 2016?

2. Was it the same month in 2017?

3. Which month is usually the wettest?

4. Do you think Shimba Hills regularly receives more than 50mm of rainfall a day?



Different types of rain:

"Rain" is usually widespread and goes on for more than an hour	Light rain:	Less than 0.5 mm per hour (mm/hr).
	Moderate rain:	More than 0.5 mm/hr, but less than 4.0 mm/hr.
	Heavy rain:	More than 4 mm/hr, but less than 8 mm/hr.
	Very heavy rain:	More than 8 mm/hr.
"Showers" come and go more quickly and may only affect a small area.	Light showers:	Less than 2 mm/hr.
	Moderate showers:	More than 2 mm/hr, but less than 10 mm/hr.
	Heavy showers:	More than 10 mm/hr, but less than 50 mm/hr.
	Violent showers:	More than 50 mm/hr.

[USGS website: *https://water.usgs.gov/edu/activity-howmuchrain-metric.html*]

Questions:

A. How often does it rain where you live?

B. What are some local names and phrases used for slight, moderate, heavy and very heavy rain and showers?

C. Does anyone collect rainwater from roofs?

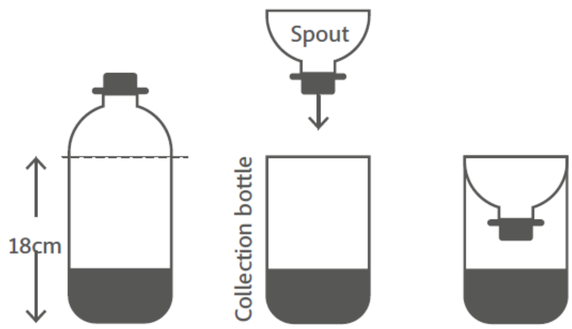
Commercially available standard rain gauges that measure the height of rainfall directly are designed with perfectly straight edges and a flat base. They are calibrated so you can read precipitation height directly from the scale. You can also purchase more expensive gauges that empty automatically using a tipping bucket design and produce a digital dataset that can be downloaded from the equipment. In this experiment, we are going to measure the volume of rainwater collected in a homemade rain gauge and convert it into millimetres of precipitation.

Materials:

- Plastic bottle (2 litre) with straight sides (1 per raingauge)
- Paperclips or tape
- Sharp knife or scissors
- Sunflower oil or other non-toxic oil
- Plastic measuring cylinder
- Pencil, ruler, notepad with data collection table and room for calculations
- Graph paper

Method:

1. Remove cap and lid from bottle and rinse out with water.
2. Use a marker pen or scratch to mark points straight around the top of the bottle, 18cm from the base then carefully cut at this height all the way around.
3. Turn the top of the bottle upside-down and insert into the bottle to create a funnel. Fix with tape or paperclips. This is your raingauge.

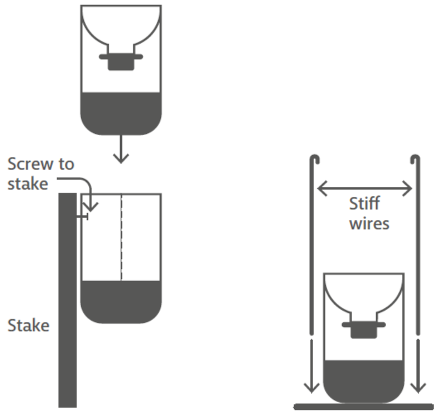


Raingauge made by students (by Fotokannan) CC BY 3.0. Wikimedia Commons)

4. Choose the site for your rain gauge and fix it in place (see next page), keeping the base horizontal. Add a small drop of non-toxic oil to the bottle to reduce evaporation. (Oil is less dense than water so it floats on top, forming a layer that stops or slows evaporation.)

5. **Fix your rain gauge in place:**

- Ideally fix the gauge 90cm above ground level on a wooden post stuck into the ground. Suggested ways to do this include cutting the top off another plastic bottle and fixing it to the post with screws, then using this as a sleeve for the rain gauge. If it is on a grass or muddy surface, you could use 2 pieces of stiff wire bent into hooks to attach it to the ground.



6. **Choose a good site for your rain gauge:**

- Away from any buildings or trees. If you estimate the height of any buildings or trees in the area, then the rain gauge should be at least 2 and ideally 4 times that distance away from the obstruction so that it does not influence the amount of rain that is captured in the gauge.
- Away from places where it will be disturbed by people or animals
- Fixing the rain gauge at about 90cm off the ground is a good idea if there is shrubby vegetation below this level or it is on a surface which could produce splashing. However, a rain gauge fixed too high up would be likely to be affected by the wind.

7. **Prepare data collection notebook:**

- Copy this table into a notebook

Time	Date	Height in gauge (mm)	Volume in gauge (ml)	Precipitation (mm)

8. **Take readings from the gauge:**

- Each day, ideally at the same time, visit the gauge to take a reading. Tap the bottle to dislodge any droplets that have formed from evaporation on the inside bottle walls. Pour the water from the rain gauge into a measuring cylinder and record the volume in millilitres in your results table. When you read your measurement, read along the lowest point of the liquid surface (due to surface tension, the level will be slightly higher where the water touches the edge of the cylinder). Empty the gauge after each measurement and add a small drop of oil.

> What's the best way to organise the rainfall data collection to get a measurement every 24 hours? Who will collect the rainfall data and at what time of day?

- Use the formula given below to calculate precipitation in mm.
- Repeat this for as long as possible until you have built up your own rainfall dataset.
- Make a graph of rainfall (mm) over time to investigate seasonal changes and extreme rainfall events where you live.

9. Convert the volume in the gauge to the volume of precipitation:

Practice converting measurements to fill in the final column of the data table. The steps below convert the volume of rain collected in the gauge into a measurement of precipitation in mm by. If you don't have a measurement yet, imagine that you have just measured a volume of 10ml in the gauge and use that to practice the conversion.

Step 1. Convert volume in ml to volume in mm^3

____________________(volume in ml) x 0.001 = __________________(volume in mm^3)

Step 2. Measure the diameter across the top of the gauge and divide by 2 to get the radius.

Diameter = _____________________(mm)

Radius = ________________________(mm)

Step 3: Use the radius to calculate the area of top of the funnel. **A** = πr^2 (π = 3.1416)

π x ________radius (in mm) x _______radius (mm)) = _____________area (mm^2)

Step 4: Work out the height of precipitation in mm using this equation and record.

Precipitation (mm) = volume ____________(mm^3) ÷ area________________ (mm^2)

10. Discuss the following questions in groups or as a class:

How does the rain gauge work? What are the advantages of the funnel design for the gauge? What might happen if you didn't include the funnel? How will you decide where to position the raingauge?

Maximum capacity will be reached when the water reaches the bottom of the funnel spout. What is the maximum rainfall that your raingauge could measure? Is it regularly exceeded? How could you make the raingauge bigger? What else could you do to keep accurate records during periods of high rainfall?

Can you find an official source of daily rainfall data from a meteorological station in your area? You might be able to download data from Internet sites such as https://en.tutiempo.net/ or www.wunderground.com. Plot your data next to this data and compare. How similar is it? Why might it be different?

Can you design an alternative homemade gauge where you can read precipitation height directly from a scale put on the side? You would need to find a suitable container with straight sides and flat base and a funnel with a collection area the same size as the container to avoid the need for calibration.

Teacher's notes continued: Extension of rain gauge activity into later sessions

As time goes on, students can also make a graph of rainfall (mm) over time to investigate seasonal changes and extremes where you live. Students can draw a:

- Simple bar graph

- Comparative Bar Graph

- Cumulative Bar Graph

Students can use data to calculate:

1. Monthly Rainfall Total
2. Annual Rainfall Total
3. Mean Monthly Rainfall
4. Mean Annual Rainfall

Students may also be able to find an official source of daily rainfall data from a meteorological station in your area, or download data from Internet sites such as https://en.tutiempo.net/ or https://www.wunderground.com. You can then ask students to compare data from the school raingauge with data from the meteorological station and compare it. How similar is it? Why might it be different?

You may also like to visit the TAHMO website to find out about a network of schools involved in weather monitoring across Africa and more relevant learning resources. https://tahmo.org

Session 4: Geology – Understanding Rocks

Activity 1: Engaging with the information – 50 mins (p. 12-15 student booklet)

Materials:

- pages 12-15 in the student booklet
- rock samples and/or additional photographs if possible
- pens
- A3 paper for presentations if you want

Steps:

1. Ask students: Is rock or stone seen on the surface of the land in our area? What colour is it? What texture does it have? (Bring samples if available). (2 mins)
2. Ask: Is there a mine or quarry in our area? What rock or mineral are they extracting and what is the material used for? (Find some details before this session or get students to find out as a side project) (3 mins)
3. Tell the students they have 5 minutes to read through pages 12 and 13 of the booklet. They can start looking for the elements in page 14 if they finish early.
4. After the time has elapsed, ask for students to raise hands to answer this question: "What colour are the names of elements written in? [Answer: Orange]. Using the periodic table in the booklet, ask students to look up the scientific symbols for the elements mentioned in the text (5 mins). You could write this table up on the board for students to copy out and fill in their notebooks.

Element	Symbol	Mentioned as occurring in which minerals
e.g. Carbon	C	Diamond
e.g. Silicon	Si	Plagioclase feldspar; Biotite, Garnet

5. To introduce the information on page 15, split the students into groups of three or four and assign each group either "igneous", "sedimentary" and "metamorphic" and sit the different groups in different parts of the classroom. Tell them that they will have 15 mins to prepare a short explanation of how their rock type formed to the rest of the class. Before they start to prepare their presentations write this up on the board and ask them to copy it onto a piece of paper as a "score sheet" for peer appraisal.

Group name	Clarity (score out of 10 for how clearly was the formation of the rock type explained)	Creativity (score out of 10 for creativity of the way in which the group explained the formation of the rock type)	Teamwork (score out of 10 for how well was the whole group involved in giving the explanation)	Total score (out of 30)

6. Once that is done, as a first step, get each group to read through the paragraph about their rock type and make a list of questions about what they have read and to come up with ideas for how to present the information to the rest of the class. Go around the groups (perhaps talking to all groups working on same formation type together) and discuss the questions they have before encouraging them to work on their presentations. Give them a 2-minute warning before they need to be ready to present. If you have a longer session, you can give them more time to prepare.
7. During the presentations of the explanations, everyone awards points in the different categories. Score sheets are handed in and added up at the end. The winning team could get a prize.

Extra ideas:

If you have access to rock samples of any of the three types, use them to illustrate this section. For further geological lessons or photos to illustrate rock types in more detail, this resource may be helpful: https://www.earthlearningidea.com/PDF/134_Building_stones.pdf More pictures of rock types can be seen on this website: https://geology.com/rocks/

Activity 1A: Water use in mining (optional local research/homework)

If feasible or interested, students could find out about how local mining industry uses water to access or process minerals.

Activity 2: Geology crossword – 5 min intro for homework or another session (p. 21 student booklet)

Note: This could be given as homework or added to another session.

Materials:

- Enough copies of the crosswords for individuals, pairs or groups to fill in together.
- Text in Chapter 2 Geology, and the glossary in the student booklet.

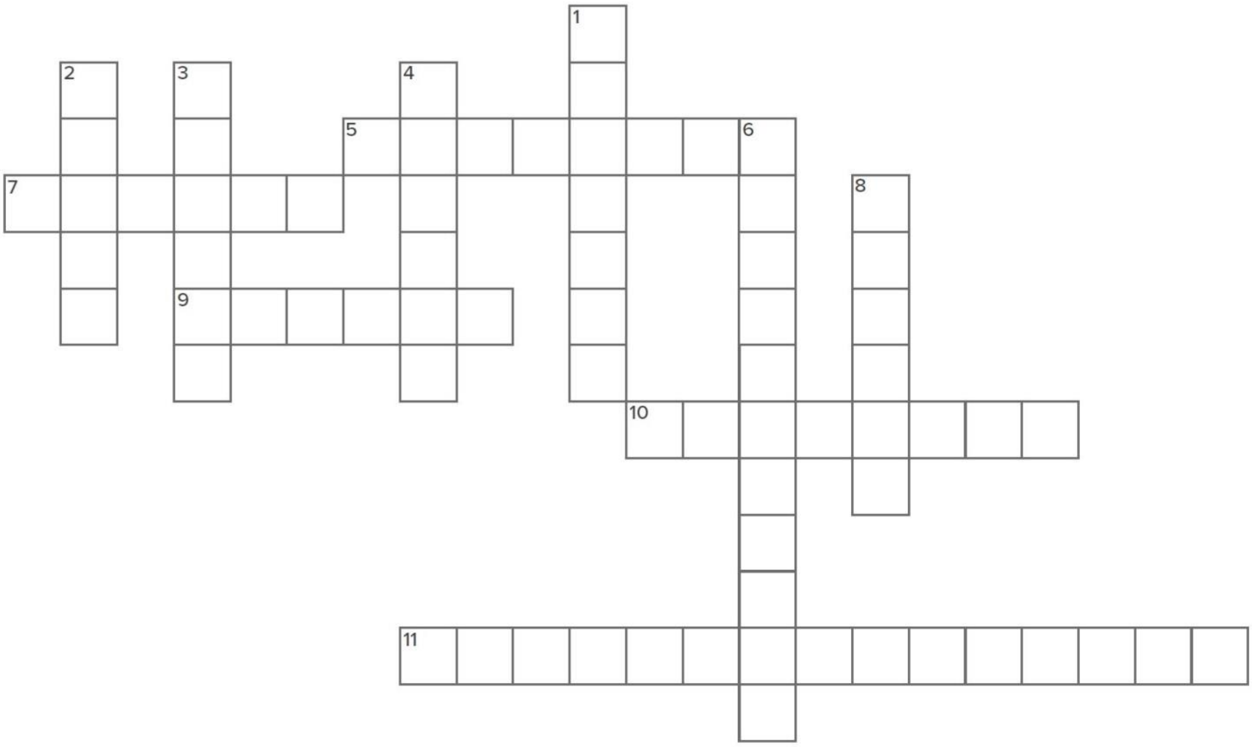
Steps:

1. Tell them to work on the crosswords using pencil, reading the student booklet text to find the answers.
2. If it is taking a long time, write additional clues on the board such as the first letter of each word. If you think it necessary for the class, copy the handout below which provides the first letter of each word.

Answers:

Across	Down
5. corundum	1. igneous
7. quartz	2. crust
9. oxygen	3. carbon
10. biogenic	4. molten
11. photomicrograph	6. metamorphic
	8. garnet

Geology Crossword (with letter clues)



Across

5. The scientific mineral name for ruby (8 letters; first letter: c)
7. A mineral found in granodiorite rock that is formed of only two elements (6 letters; first letter: q)
9. The most common element in the Earth's crust (6 letters; first letter: o)
10. The name for rocks that form from the remains of once living creatures (8 letters; first letter: b)
11. The name for an image captured by a microscope (15 letters; first letter: p)

Down

1. The category of rocks that form directly from cooled magma (7 letters; first letter: i)
2. The outermost layer of the Earth (5 letters; first letter: c)
3. The element that forms diamonds (6 letters; first letter: c)
4. The name for rock that is so hot it has become liquid (6 letters; first letter: m)
6. The category of rocks that form from heating and crushing of existing rock (11 letters; first letter: m)
8. A red mineral found that is less valuable than ruby (6 letters; first letter: g)

Session 5: Using Geology to Understand Water Flow in the Distant Past

Activity 1: Using geology to understand water flow in the distant past – 60 mins (p. 16 - 20 student booklet)

Materials:

- Access to page 16-20 of the student booklet
- Pencil
- Notebook
- Graph paper

Steps:

1. Ask the students to read pages 16 and 17 (copied on the next page) noting that this is real information from a published scientific paper which illustrates how geologists can understand past environments by studying the shapes and sizes of rocks and rock particles. Ask them to copy the diagram on page 17 into their books and note down a question that they would ask the scientists from the University of Dschang and Yaoundé.
2. Ask them to complete the tasks on pages 18 and 19 (reproduced below) using what they have read and figure out which environment matches which picture. The three key rules that applied in the example from Cameroon were:
    - Large rock pieces like pebbles and cobbles require more power to move and are associated with fast-flowing water.
    - Rounded, smooth shapes are created when rock pieces are moved by water over long distances.
    - Sedimentation of smaller rock particles like sands and clays occurs when water is moving slowly or is still.

The Udden-Wentworth grade scale for clastic sediments

Clay particles:	less than 0.004 mm
Silt particles:	0.004–0.06 mm
Fine sand grains:	0.06–0.5 mm
Coarse sand grains:	0.5–2 mm
Granules:	2–4 mm
Pebbles:	4–64 mm
Cobbles:	64–256 mm
Boulders:	more than 256 mm

Sedimentary rocks can tell a story about water in the past

A closer look at sedimentary rocks can tell us about how water was flowing in an area many, many years ago. For example, on a mountainside near Dschang in Northwest Cameroon, geologists from the University of Dschang and the University of Yaoundé conducted a geological study of rocks known as the Ngwa deposits to understand how and when they formed.

First, the geologists figured out that there are five layers between the surface and 11 metres of depth into the ground. You can see the layers in the diagram below. The first is a thin layer of soil in which plants can grow. Below that is a layer of tuff, which is loose igneous rock that was ejected out of the Mount Bambouto volcano more than 5 million years ago! Below that they found a layer of sedimentary sandstone rock which is even older than the tuff. The sandstone is made up of coarse sand grains mixed together with clay particles. Below the sandstone they found a layer of even older sedimentary rock. This older sedimentary rock contains pebbles and cobbles mixed with sand grains - it is called conglomerate rock. Below the conglomerate, they found a layer of igneous rock called trachyte that formed when magma cooled.

These geological layers tell a story about what the environment was like in this area more than 5 million years ago. The trachyte rock is underneath the other four layers, which means that it is the oldest of them all. It formed when volcanic activity brought magma to the surface.

After the magma cooled, sand, pebbles and cobbles were washed down by water from hills and mountains to cover the trachyte rock and create the conglomerate layer. We know that there must have been a lot of fast-moving water at this time because the pebbles and cobbles are heavy and the water must have been powerful to move them. The shape of the pebbles and cobbles tells us that they must have been moved for many kilometres in a powerful river that bashed them around and slowly caused them to become smooth and rounded.

But the sandstone layer above the conglomerate is different. It contains only small sand grains and tiny clay particles. These particles are so small and light that they only settle out of the water when it is moving very slowly or not at all (this process is like the sedimentation step that you will learn about in Section 4: Water Quality). The clay in the sandstone layer tells us that over time the landscape changed and a lake or a swamp formed over the land. Slowly, as sedimentation continued, the lake or swamp would have filled up with sand and clay and eventually there would be no space remaining for water to rest in that place.

After the formation of the sandstone, there must have been another volcanic eruption and the tuff layer was formed on top of the sandstone. Geologists have tested this tuff rock and judged that it is at least 5 million years old. Above this old tuff is the soil layer, which formed more recently from a mix of weathered rock particles and organic remains.

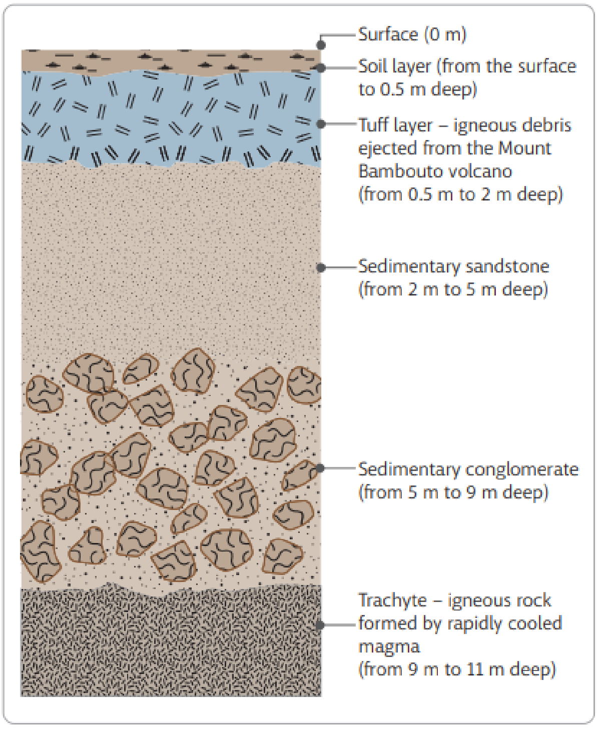


Diagram showing how the rock type changes moving down into the Ngwa deposits. Adapted from Kenfack et al. (2011) CC by 4.0

- Larger rock pieces like pebbles and cobbles require more power to move and are associated with fast-flowing water.
- Rounded, smooth shapes are created when rock pieces are moved by water over long distances.
- Sedimentation of smaller rock particles like sands and clays occurs when water is moving slowly or is still.

Sample Information

Data on sizes of rock pieces:

Size range (mm)	Sediment grade	Sample 1	Sample 2	Sample 3
		Weight percent	Weight percent	Weight percent
more than 256				20
64–256			10	45
4–64			40	20
2–4			30	10
0.5–2			15	5
0.06–0.5		20	5	
0.004–0.06		30		
less than 0.004		50		

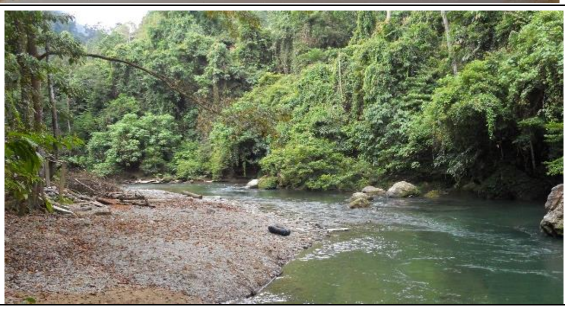
Now, can you complete the three tasks on the next page and figure out which sample matches which environment pictured below?

A slope near the top of a mountain where rock is exposed to weathering

Image by brewbooks on Flickr CC BY SA 2.0

The bottom of a lake

Image by Jochem Koole on Flickr CC by 2.0



The bottom of a fast-flowing river

Image by Joe Coyle on Flickr CC BY-NC 2.0

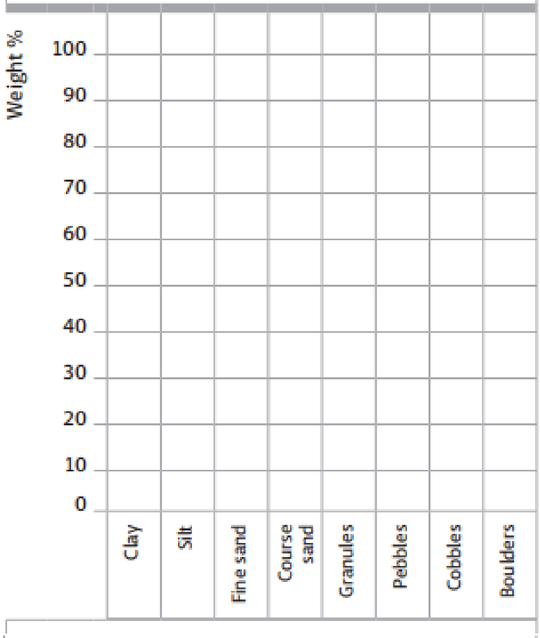
Tasks:

1 Fill in the sediment grade label for each size range in the table above.

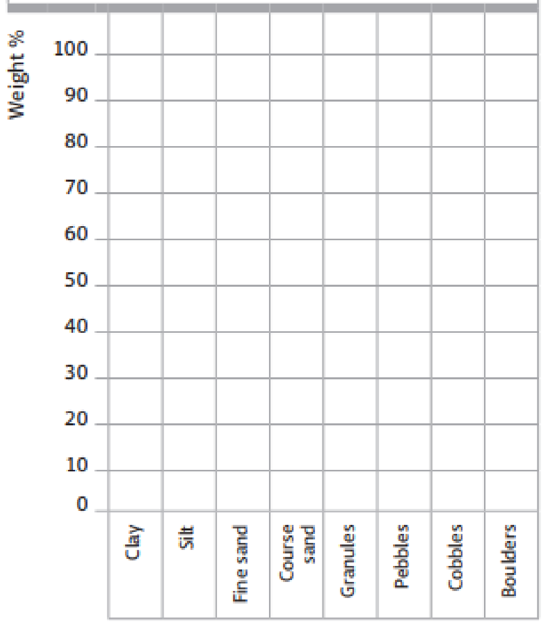
2 Create a bar graph for each sample to see what the data looks like.

3 Using the data and the descriptions from the geologist's notebook, match the sample with the environments shown in the three pictures on the next page.

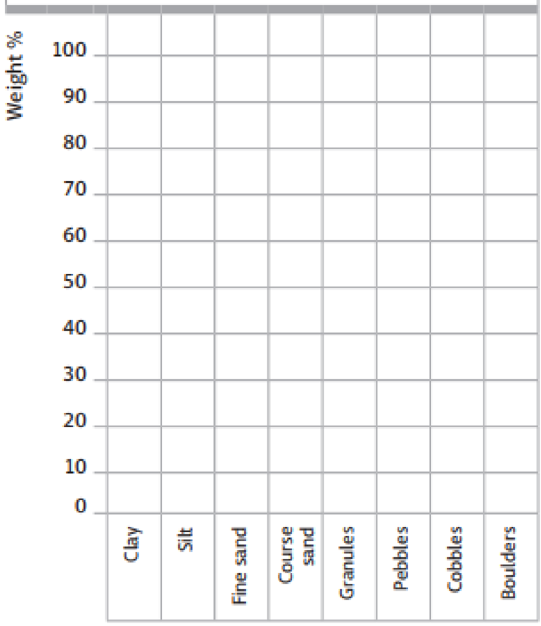
Sample 1



Sample 3



Sample 2



Notes on shape of rock pieces from the geologist's notebook:

- **Sample 1** – the geologists have not assessed the shapes yet, so you have no data about this.
- **Sample 2** – the rock pieces are rounded and smooth.
- **Sample 3** – the rock pieces are jagged and sharp.

Session 6: Infiltration and Saturation Experiments

Activity 1: Infiltration Experiment – 40 to 60 mins (p. 22-25; 29 student booklet)

Materials:

Each group could work independently with 4 bottles and 4 sets of materials; however, if equipment or space is an issue each group could work with 1 or 2 of the materials instead and results can be combined, or you could do a front of class demonstration involving students in preparation and measurements.

- A worksheet to fill in (page 29 and 30 in the student booklet or print from below)
- 1 to 4 plastic bottles ***with lids***
- A place to hang the bottles up above measuring jugs (e.g. outside on the ground where it wouldn't matter if water spilled)
- A measuring jug or bottle
- Stopwatch
- Scissors/knife
- String or wire
- Small circle of fine cloth or window screen
- Tape
- Water
- Access to reading page 22-25 in the student booklet
- Earth materials to fill the containers:
    - Large gravel or pebbles* (enough to fill the bottle) and/or
    - Small gravel or pebbles* (enough to fill the bottle) and/or
    - Sand (enough to fill the bottle) and/or
    - Soil (enough to fill the bottle) (or a different texture of sand if soil not available)

    *You could get students to sort gravel into different sized pieces or collect from different spots if available locally.

Teacher's notes:

This experiment aims to show how the rate of infiltration (how fast rainwater soaks into the ground) varies depending on the material at the surface. It will also demonstrate the porosity and permeability of different materials. Set the materials up before the session and if possible, allow at least 90 mins to give time for both experiments. Encourage students to read pages 22-25 during the session.

Steps:

1. Ask students to think about the following questions:
    a. If you dig into the ground where you live, what do you find? Soil? Sand? Pieces of gravel? Rock?
    b. Does this vary depending on exactly where you dig?
2. Tell students that they will be experimenting with different materials to compare their permeability and porosity. Read out or give students 5 minutes to read the sections about permeability and porosity section on page 23 of the student booklet.
3. Tell them to follow the instructions on page 28 in the student booklet (or write the instructions below on the board) to prepare their bottles and conduct the experiment (adapt the instructions or work more closely with groups if necessary).

Instructions for students:

1. Make 4 holes at the base of each plastic bottle 3 cm from the base.
2. Cut off the bottom of the bottle 1-2 cm from the base. (When we tried this, we found it was easier to do this step first!)
3. Thread 4 pieces of string through the holes so that the bottles can be suspended upside down.
4. Take the lids off the bottles and tape a piece of fine cloth over the opening.
5. Hang the bottles up in a row
6. Fill the first with soil, the second with sand, the third with pebbles or gravel. If you have different sizes of gravel, add another bottle.
7. Draw a picture of the set up (on the Infiltration worksheet). Can you see any pores in the material?
8. Make a prediction (on the Infiltration worksheet) – which material do you think will allow fastest infiltration of water?
9. Place the empty measuring jug underneath one of the bottles and get your stopwatch ready.
10. One person starts the timer whilst another person pours 250ml of water into the top of the first bottle (slowly so it doesn't overflow).
11. Observe and record the volume of water in the measuring jug after 1 minute, 5 minutes, 10 minutes, 30 mins. Use spare time to read pages 22-25 of the student booklet.
12. Repeat timed experiment for the other bottles (If in groups, compare your results with the groups with other materials in the bottles). What did you observe? Make a graph of your results (on the Infiltration worksheet).

Optional extension/development:

You could add a clay or other impermeable layer in the bottles or further develop into a model aquifer to show how groundwater and pollutants travel through different layers within an aquifer. To see on Internet, search Kingwede All About Aquifers.

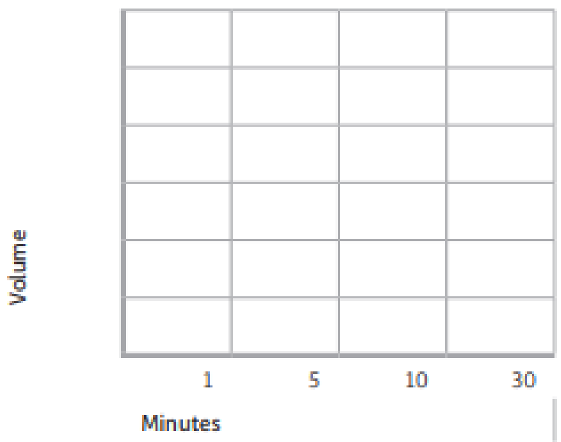
Infiltration experiment worksheet

Draw a picture or diagram to show how the experiment is set up:	
Make a prediction: Which material do you think will have the fastest infiltration rate and why?	

Soil		Sand		Gravel	
Time (mins)	Volume (ml)	Time (mins)	Volume (ml)	Time (mins)	Volume (ml)
1		1		1	
5		5		5	
10		10		10	
30		30		30	

Graph

Plot soil, sand and gravel data in different colours. The slope of the graph shows the infiltration rate.



Conclusion

Which material allows water to infiltrate the fastest?	

Activity 2: Saturation Experiment – 20 to 50 mins (p. 22-24, 30 student booklet)

If there is time remaining after completing Activity 1, continue to the saturation experiment (worksheet on page 30 in the student booklet). This extension will help communicate the idea of saturation of a material to help understand the saturated and unsaturated zone in the diagram on page 24 of the student booklet.

Saturation experiment

After 30 minutes put the lids back on each of the bottles. Had all 250ml been filtered through the bottle into the measuring jug?

Fill the measuring jug with 1 litre of water and pour slowly into each bottle, slow enough so that it soaks in and doesn't overflow over the sides straight away. What is the maximum volume each bottle can hold?

Saturation experiment worksheet

	Soil	Sand	Gravel
Volume left in bottle after 30 mins (ml) [A] (250ml minus volume recorded in previous table)			
Volume poured into the bottle before it cannot hold any more (ml) [B] (1000ml minus what is left in measuring jug)			
Maximum saturated volume (A+B)			
Which material holds the most water?			

Using your results, how would you rank the different materials in terms of porosity and permeability? • Soil • Gravel • Sand	↑ Most porous … Least porous Most permeable ↑ … Least permeable

If you wanted to make an impermeable layer in one of the bottles, what material could you use?	

Session 7A: Finding Out About Groundwater

Activity 1: How do scientists study groundwater? – 25 mins (p. 24-26 student booklet)

Materials:

- Pencils and paper
- Access to reading pages 24 - 26 of the student booklet or printed handout below

Steps:

1. Ask students to copy the diagram on page 24 into their notebooks.
2. Explain that before the boreholes were drilled down into the ground, geologists would have surveyed the ground looking at the different types of rock visible at the surface and assessing whether or not they were likely to be permeable and thus able to form underground aquifers. They would then have used geological mapping techniques and geophysical methods to map out the geological structures of the rocks under the surface. This research would make them able to advise on where to drill and how deep to drill to get access to groundwater.
3. Write this question on the board: What happened when the borehole near the stream was drilled into the confined aquifer?
4. Ask students to read page 24 and 25 and answer the question. Ask them to try to explain why this happened? (Remind them that they can look words up in the glossary.)

Answer:

The water started to flow up out of the confined aquifer, forming a flowing artesian well. This is because the confined aquifer is under pressure and the well exits the ground below the potentiometric surface – the level to which water from a confined aquifer would rise to because it is under pressure exceeding that of atmospheric pressure.

Activity 2: How do people access groundwater? – 15 mins (p. 26 student booklet)

Steps:

1. Change groups around if need be.
2. Ask students to flick through the Water Module chapter on groundwater and put their hands up to call out a way in which people get groundwater. (e.g. handpumps, wells, electric pumps, diesel pumps, solar pumps).
3. Go through the list to discuss which methods are used in your area, if any. For a fun finish to this activity, ask for a volunteer to act out one of the ways as a charade and get the other students to guess which they are doing.
4. Discuss these questions:
    a. In what ways do you think handpumps are better than solar pumps?
    b. In what ways are solar pumps better than hand pumps?
5. If a field trip is planned (see 7B below), talk about it with the students and tell them what they need to prepare.

Activity 3: Sustainable use of groundwater – 10 mins (p. 26-27 student booklet)

Materials:

- The student booklet pages 26-27 and the glossary

Steps:

1. Ask a student to read the definition of "sustainable" from the glossary of the student booklet.
2. Ask them to discuss in groups:
    a. Do you think this word "sustainable" can relate to groundwater use?
    b. Can groundwater be used sustainably?
3. Following the discussion, explain that there is ancient groundwater beneath the Sahara Desert in North Africa from a million years ago when more rain fell there.
4. Tell students to look at the pictures on page 27 to show how groundwater is being used to irrigate crops in the desert. The huge pivoting arms of a pivot irrigator swing round spraying water out (bottom picture). The aerial photo from a plane shows how these are used to create huge circular crop fields in very dry areas (top picture).
5. Write on the board:

Rate of recharge (rainfall and runoff) into Sahara Desert aquifer = ☐ km^3 per year

Rate of abstraction out of Sahara Desert aquifer = ☐ km^3 per year

6. Ask students to read page 27 and to put their hands up when they have the numbers to fill in the boxes on the board.
7. When the boxes have been filled in correctly (recharge = 1.4 km^3 per year; abstraction = 2.75 km^3 per year), seek students' answers to these questions:
    a) Do these figures suggest that the groundwater in the aquifer under the Sahara Desert is being used sustainably?
    b) Why was the groundwater in this area called paleowater or fossil water?
    c) What is it being used for?
    d) What do you think should be done by the people and governments of the North African countries involved?

Activity 4: Groundwater crossword – 10 mins and homework/optional (p. 31 student booklet)

Note: This could be given as homework or used in another session.

Materials:

- Enough copies of the crosswords for individuals, pairs or groups to fill in together and access to the text in Chapter 3 Groundwater, and the glossary in the student booklet.

Steps:

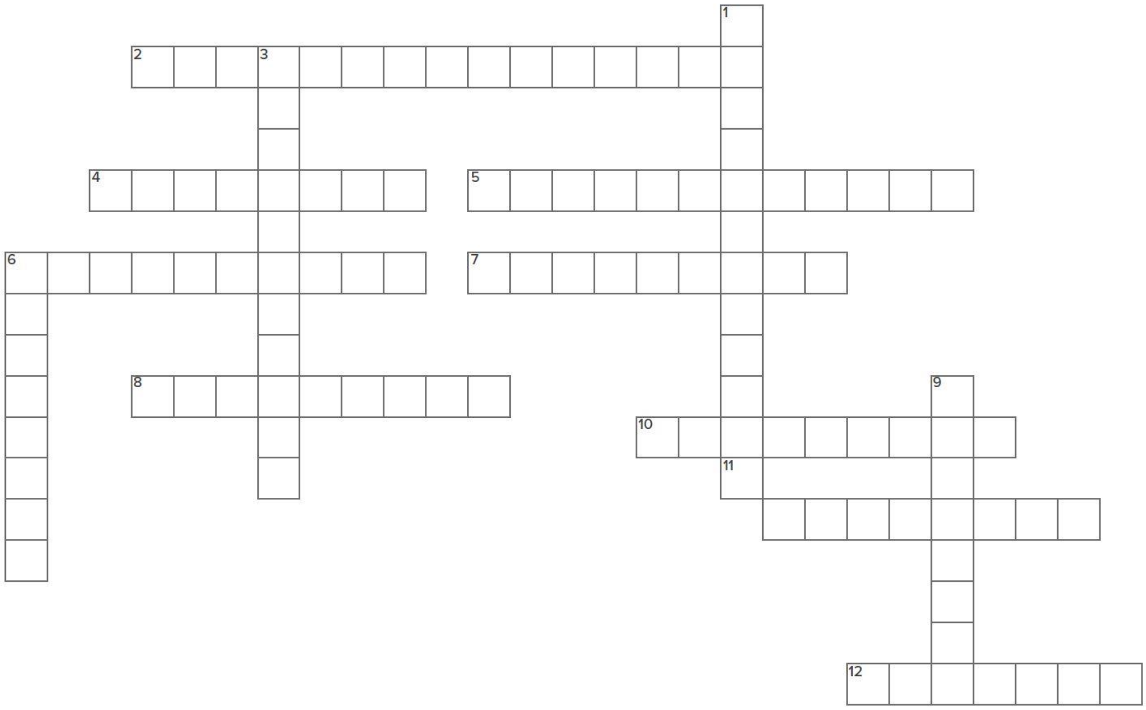
1. Tell them to work on the crosswords using pencil, reading the chapter to get the answers
2. If necessary or if it is taking a long time, write additional clues on the board – e.g. the number of letters; first letter of each word (alternative handout on next page)
3. You may need to give them a hint for 12 across. Tell them it starts with s and is in the glossary.

Answers:

Across
2. unsaturated
4. fracture
5. hydrogeology
6. paleowater
7. permeable
8. aquiclude
10. saturated
11. borehole
12. seepage

Down
1. permeability
3. abstraction
6. porosity
9. recharge

Groundwater Crossword (with letter clues)



Across

2. The zone between the land surface and the water table where pore space contains both water and air (two words) (11 letters, 4 letters; first letters: u, z)
4. A break or crack in a rock (8 letters; first letter: f)
5. The study of groundwater and the geological and non-geological materials that it interacts with (12 letters; first letter: h)
6. Groundwater that has been stored in an aquifer for thousands of years (10 letters, first letter: p)
7. What we call material that has connected void spaces so water can flow within it (9 letters; first letter: p)
8. A layer of geological material that is impermeable, it stops the flow of water (9 letters; first letter: a)
10. What we call material that is holding as much water as possible (9 letters; first letter: s)
11. A deep, narrow hole made in the ground, usually to locate water or oil (8 letters; first letter: b)
12. Movement of water a) into the ground from a surface waterbody or b) out of the ground into the ocean or onto land (7 letters; first letter: s)

Down

1. A measure of the connectivity of void spaces in the ground (12 letters; first letter: p)
3. The process of taking water out of the ground temporarily or for permanent use (11 letters; first letter: a)
6. The ratio of the volume of void spaces in a rock/sediment to the total volume of the rock/ sediment (8 letters; first letter: p)
9. Water that is added to an aquifer (e.g. when rain infiltrates into the ground) (8 letters; first letter: r)

Session 7B: Groundwater Where I Live

***Optional extra session for field visit (1 - 3 hours).

If there are safe-to-visit boreholes, wells or handpumps near to your school, arrange an extra session for a field trip or local walk to visit these groundwater sources. To make the walk more interesting, visit the location before and see if you can arrange for students to interview some of the people using the groundwater source – students can prepare a list of questions. For example:

- What do people use the water for?
- How often do they visit to collect water?
- Are there any problems with the water source?
- What other sources of water do they use?

If possible, you could also help students to find out who drilled the borehole or well and/or who installed the handpump. Could they contact them to find out how deep it goes into the ground? Who looks after the water supply and keeps it in good condition?

Session 8: Water Quality – Source protection

Activity 1: Source Protection Quiz – 20 mins (p. 35-37 student booklet)

Materials:

- Access to reading on pages 35 to 36 of the student booklet

Steps:

1. Tell the students to read pages 35 to 36 from the water module in groups. When they are finished reading they should close their booklets.
2. Read out the quiz questions that are listed below.
3. Tell each student to write their answers on a sheet of paper.
4. Tell the students to mark each other's answer sheets as you read out the right answer.
5. Ask students who got the right answer to point out which sentence in the text gave them the answer.

Quiz:

Question	***Option A***	***Option B***	***Answer***
1. If you needed to collect water near to where people are washing clothes should you go upstream or downstream to collect the water?	Upstream	Downstream	A
2. Pollution that got into groundwater down a well or borehole has travelled along:	An aquifer pathway	A localised pathway	B
3. Which is usually safer from faecal contamination? Groundwater or surface water?	Groundwater	Surface water	A
4. If the ground above an aquifer is permeable, pollution is:	More likely	Less likely	A

Activity 2: Teaching groundwater protection – 40 mins (p. 37 student booklet)

Materials:

- Access to text on page 37 of the student booklet: Protecting groundwater from pollution

Steps:

1. Ask the students to imagine that they want to teach ways to protect groundwater from pollution to someone who cannot read.
2. Ask them to draw simple pictures or pairs of pictures to communicate each of the 8 steps that a community could take.

Session 9A: Water Quality – Source protection

Activity 1: Doing a sanitary inspection of a water supply – 60 mins (p. 42 – 47 student booklet)

Materials:

- Access to text on pages 42-47 of the student booklet

Steps:

1. Read the introduction to the activity on page 42 of the student booklet.
2. Look at the two pictures on pages 43 and 44, showing a handpump installed on a covered dug well in a rural area.
3. For each picture, answer yes or not to the WHO sanitary inspection questions on page 45 and count how many hazards you have identified for each.
4. Having assessed the hazards, work in groups to create a plan to reduce the hazards at each of the sites pictured.

Via the link below or through the Water Learning Partnership contact you should be able to access the WHO technical fact sheet and management advice sheet for dug wells and handpumps, which provides more information relating to this exercise.

https://www.who.int/teams/environment-climate-change-and-health/water-sanitation-and-health-(wash)/water-safety-and-quality/water-safety-planning/dug-well-with-a-hand-pump

5. Discuss:
   A. What are some of the challenges you would face if you tried to put this idea into action to protect the water source?
   B. Who should be informed of problems with wells or handpumps?

Note:

This activity has used the World Health Organisation sanitary inspection guidance for dug wells with handpumps.

The WHO also provides guidance for doing sanitary inspections and making water safety management plans for other types of small water supplies including:

- Dug wells that are open, from which water is drawn with a bucket
- Boreholes with handpumps
- Boreholes with motorized pumps
- Small piped water systems
- Spring sources
- Rainwater collection and storage
- Surface water sources
- Household water practices including water collection, treatment and handling, and storage

All the inspection and guidance documents can be found on their website:

https://www.who.int/teams/environment-climate-change-and-health/water-sanitation-and-health/water-safety-and-quality/small-water-supply-management

Activity 2: Background reading on sedimentation – 20 mins and homework (p. 37-38 student booklet)

Materials:

- Page 37-38 of the student booklet (Sedimentation).
- Moringa article from Science in School website.

Ask students to read the section on sedimentation on page 37 and 38 of the student booklet. If possible, also provide students with this article about Moringa in water treatment as background reading: http://www.scienceinschool.org/2011/issue18/moringa This has been reproduced at the end of this document.

Session 9B (Optional): EXTENSION IDEAS

If feasible in your area, source protection or sanitary inspection could be developed into a practical activity. If so, it is important to consult first with all the people who use the water source to make sure they agree with all the actions. The school administration should also be involved in planning so that parents can be consulted if necessary. Full planning of the activity should include an assessment of any risks that students could face and plans to avoid or reduce risks associated with the activity should be put in place. Actions could range from fencing a water source to prevent livestock accessing it to a poster campaign about disposal of liquids. Alternatively or additionally, you could organise an expert talk for the pupils. Ideas for this could include:

- Find a **sanitation expert or toilet construction project** in your area and arrange for them to give a talk to students about design and siting of latrines.
- Find out if there is a **water treatment facility** in your area and see if you can arrange a guided visit or a phonecall where students ask questions about the processes used at the facility.

Session 10: Sedimentation practical

Activity 1: Comparing methods to speed up sedimentation – 60 to 90 mins (p. 37-38; 47-48 student booklet)

Safety glasses should be worn during these activities. It should be emphasized that the clarified water may not be safe to taste or drink. The students should be made aware of this at the start of the activity.

Materials:

- 2 litre sample of murky water from a muddy place or a water sample made by mixing dirt and water
- 3 x 2 litre plastic bottles cut in half
- 1 tablespoon of Alum (potassium aluminium sulphate)
- Small pestle and mortar
- Moringa seed (1 seed per litre of water; choose good quality seed)
- 2 x tablespoon and 3 x metal spoon or stirrer
- Funnel
- Timer/Clock
- Text from the student booklet: information about sedimentation (pages 37-38), instructions (page 47), student observation sheet (page 48)

Note: If only moringa or alum is available you can still compare one of these to no treatment.

Steps:

1. Explain that sedimentation is often the first step in treating water to improve its quality and make it safer to drink. It happens naturally if you leave water to stand – particles suspended in the water will fall to the bottom/settle out due to gravity. Various substances known as coagulants can be added to water to speed up the process of sedimentation, by making the particles group together into clumps. In this experiment, you will compare two different coagulants to see how they affect the rate of sedimentation.
2. Tell students to get their materials ready, follow the instructions and record their observations on the student observation sheet.

Student Instructions:

- Grind moringa seed into a powder
- Put lid on original water sample and shake it.
- Use a funnel to pour the same amount of water into each bottle
- Add ground moringa seed to one bottle and a tablespoon of alum powder to another; Stir all three bottles for 5 minutes.
- Record your observations of the appearance of each bottle at the start, and then at 5-minute intervals.

Water appearance	No treatment	Alum	Moringa seed
Appearance and smell before the start of treatment			
Appearance 5 minutes after adding coagulant			
10 minutes after adding coagulant			
15 minutes after adding coagulant			
20 minutes after adding coagulant			
30 minutes after adding coagulant			
Which treatment worked fastest?			

Activity 2: Investigate how turbidity is measured – if time, 30 mins (p. 49 student booklet)

Materials:

- Instructions on page 49 of the student booklet
- A flashlight
- Four flat-bottomed transparent cylindrical drinking glasses
- Samples of:
  - unfiltered water (the original untreated water)
  - water after sedimentation with alum
  - water after sedimentation with moringa, and
  - the clearest water you can find (bottled drinking water?)

Steps:

1. Explain that turbidity is one of the physical quality of waters measuring how transparent the water column is, or ask the students to look up the word **turbidity** in the Water Module glossary.
2. Tell the students to follow the instructions on page 49 of their booklets.

Student instructions:

- Pour equal volumes of each type of water into the flat-bottomed transparent drinking glasses.
- Move the glasses of water into a dark room and place them on a flat surface.
- Place the flashlight against the side of each glass and shine a beam of light through each of the samples. Look at the path of the flashlight beam.
- Discuss how does the path of the flashlight beam appear through the different water samples?
- Now pour half of the unfiltered water out and replace it with the clear water. Examine the effect by shining the flashlight through the glass. How many times must you repeat this dilution before you can see no difference between what started as unfiltered water and the clearest water?

3. Tell students to discuss why does the path of the flashlight tell us anything about the turbidity? Ask them to read the explanation on page 49, or share the explanation below with them.

The reason is that the particles in the water scatter the light from the flashlight. Scientists studying water quality often use turbidity meters called nephelometers which measure how much light is scattered at different angles. As more particles cause more scattering of the light, the nephelometer is designed to provide a precise measurement of turbidity, which is given in Nephelometric Turbidity Units (NTU). (Nephele was the ancient Greek goddess of clouds).

Session 11: Filtration, Disinfection and Safe Storage

Activity 1: Engaging with the information: Filtration – 15 mins (p. 38 student booklet)

Materials:

- Text on pages 38-39 of the student booklet
- Paper and pens

Steps:

1. If possible, obtain or visit a water filter to show students.
2. Get students into groups. Ask the students to read section 3 on page 38 and come up with their own definition of **Filtration.** They should write their definition on a small piece of paper without sharing it with any other group and without consulting the glossary.
3. Number the definitions and read them out in order twice, telling students to note the number of the definition which they prefer.
4. Get students to cast votes for the definition they prefer.
5. Read out the definition from the glossary. How does it compare with the definition voted for by the class? Do you as the teacher agree with the class's choice? If not, why not? Discuss: Is voting a good way to decide the best definition of a word?
6. Ask the students to use what they have learnt to write a story to explain the word filtration to a child of 7 years old.

Activity 2: Engaging with the information: Disinfection – 15 mins (p. 34, 39 student booklet)

Steps:

1. Write the word PATHOGEN on the board. Ask students to find this word in the booklet on page 34, 39 and in the glossary and use the information to answer the following questions:
   A. What is a pathogen?
   B. How might pathogens get into drinking water?
   C. How can you kill pathogens in drinking water?
2. Set different groups to work on different questions and get them all to feed back to the class. Alternatively, get all groups to work through all questions and then share answers with each other.

Activity 3: Safe storage – 15 mins (p. 41 student booklet)

Steps:

1. Discuss with the students: Why do you think that the booklet says that it is important to keep your hands out of stored clean water?
2. Choose one of these as a group or individual activity, or give the choice to the students:
   A. Choose one or more of the points about safe water storage and design a poster to share the message.
   B. Draw a design for a storage container that could protect treated water from pollution.

Activity 4: Water Quality Crossword – 15 mins (p. 50 student booklet)

Note: This could be given as homework or added to another session.

Materials:

- Enough copies of the crosswords for individuals, pairs or groups to fill in together and access to the text in Chapter 4 Water Quality, and the glossary in the student booklet.

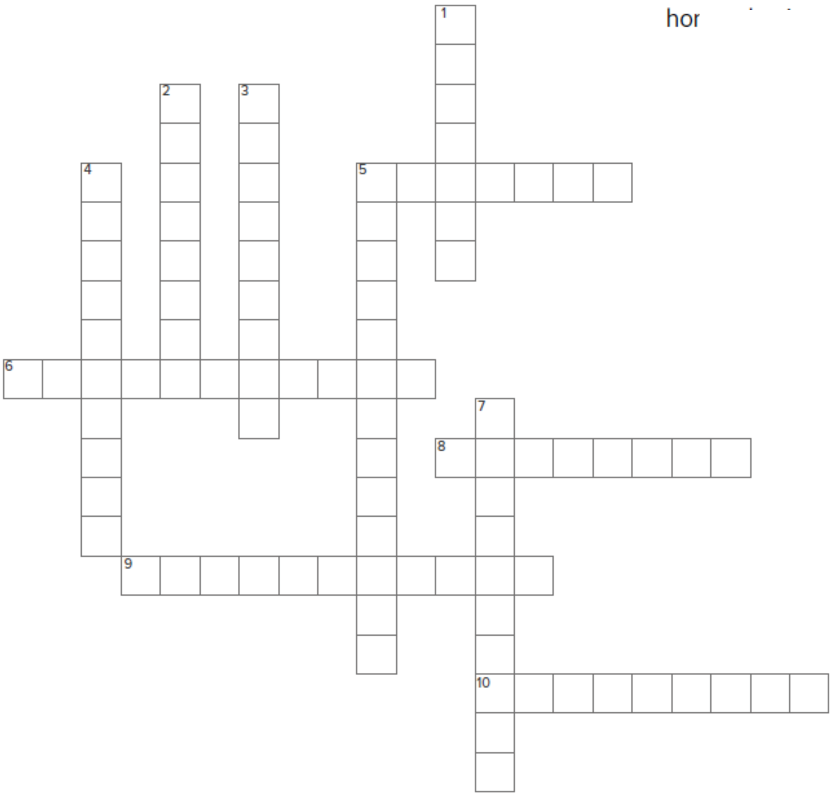
Steps:

1. Tell them to work on the crosswords using pencil, reading the chapter to get the answers
2. If necessary or if it is taking a long time, write additional clues on the board – e.g. the number of letters; first letter of each word (alternative handout on next page).
3. You may need to give them a hint for 12 across. Tell them it starts with s and is in the glossary.

Answers:

Across	Down
5. solvent	1. annulus
6. stakeholder	2. membrane
8. pathogen	3. pollution
9. ultraviolet	4. filtration
10. turbidity	5. sedimentation
	7. wastewater

Water Quality Crossword (with letter clues)



Across

5. Something that can dissolve other substances (7 letters, first letter s)
6. A person that is impacted by / has an interest in the decisions made for a water source (11 letters, first letter s)
8. A biological organism (often bacteria or viruses) that causes disease (8 letters, first letter p)
9. Radiation that comes from the sun and has a wavelength shorter than visible light (11 letters, first letter u)
10. A measure of the cloudiness/haziness of water due to suspended particles (9 letters, first letter t)

Down

1. A ring-shaped hole that forms between the sides of a drilled hole and the pipe or casing that is installed in the hole (7 letters, first letter a)
2. A flexible sheet-like material that acts as a boundary so that some substances are blocked from moving through it (8 letters, first letter m)
3. The process by which the physical, chemical or biological properties of water are changed by addition of any substance that makes the water harmful to humans or the environment (9 letters, first letter p)
4. The action of passing water through a device / material to remove unwanted substances (10 letters, first letter f)
5. The treatment step used to clarify turbid water before using a filter (13 letters, first letter s)
7. Water that contained unwanted materials from homes, businesses and industries (10 letters, first letter w)

Session 12 and 13: Solar still design project

Activity 1: Different water disinfection methods – 20 mins (p. 39 student booklet)

Steps:

1. If possible, bring alternative disinfection methods (e.g. a kettle/saucepan with a lid for boiling, chlorine drops that are available locally, clear plastic bottles for SODIS) to show to the students. If video/internet facilities are available you could share these short videos or similar:

Solar distillation:

https://youtu.be/JQzWLHkrgvY (SODIS how it works)

https://youtu.be/ynoD1BqhhJM (SODIS research in Uganda)

Ultra-violet radiation:

https://youtu.be/vRtBhMweg-w (how does a commercial UV filter work)

https://youtu.be/kpibnX-C-xg (large scale UV treatment at a water treatment plant in the USA)

2. Following any demonstration or videos, tell students to use the information on page 39 to produce a table of advantages and disadvantages for each method that is described in the student booklet. For example, think about time, cost, and availability of materials. Tell students to spend 5 minutes on this and that they will come back to it after doing the practical design project.

Method	Advantages	Disadvantages
Chlorine		
Boiling		
Ultraviolet radiation		
Solar distillation		

Activity 2: Solar still design challenge – 90 to 120 mins (49. No details in student booklet)

Solar Still Challenge Teacher's Notes:

This activity is based on the Global Experiment activities designed by the Global Chemistry Experiment Team of the International Year of Chemistry. These activities were made available under the Creative Commons Attribution-NonCommercial-ShareAlike license (CC BY-NC-SA).

In this activity, students will make a solar still and measure its efficiency. They will develop their understanding of water in liquid and gaseous states and how distillation can be used to purify water. They will be challenged to design and make a more efficient still. The student results sheet can be copied into student notebooks or provided as a worksheet.

Student Learning Outcomes/Science Process Skills

- Observing and comparing the appearance of untreated and treated water.
- Recording of the scientific data and observations in an appropriate manner.
- Interpreting data in terms of environment and nature of the water involved.
- Asking scientific questions about water treatment and water in the environment.
- Carrying out scientific investigations by selecting and controlling variables.

The activity is most successful if students work in pairs but can be carried out individually.

First, in Part A, students make a simple still and use it to purify some water. They are invited to develop their explanation for how the still works.

A class discussion should be used to conclude Part A and to check that students have scientific explanation for the way the still works (see below).

Then, in Part B students are challenged to improve the yield of purified water by modifying the still or the way it is used.

Student proposals should be checked that they are safe and students should be guided to help them develop designs that utilize their understanding of the ways the still works.

After they have carried out their experiments they draw a diagram explaining how their new design has improved the % water purified which is a measure of the efficiency of the still.

Safety

There is very little hazard involved in carrying out the activity. Standard laboratory safety rules suggest that students should not taste or smell the products of activities. However the easiest test for salt is taste, and this can be used if food hygiene safety standards, such as those used in home economic classes, are applied.

Learning Outcomes

During the activity students will:

- Learn about the liquid and gaseous state of matter (water) and their inter-conversion (evaporation and condensation).

- Learn about the use of the process of distillation to purify water
- Develop an appropriate level of scientific explanation for the distillation process.
- Use their knowledge about distillation to carry out a technology process improving the efficiency of a solar still.

Part A: hints for making the solar still work well:

- Carry out the activity on a cloudless day, preferably over the mid-day period.
- Using warm water at the start speeds up the process usefully unless it is a very hot day.
- Help students make sure their still is airtight to avoid water loss.
- The use of coloured salty water is a useful check that the still is operating correctly.
- If sunlight is not available, the activity can be conducted using a suitable container such as a large saucepan warmed gently on a hot plate. In this case the glass or cup should be insulated from the bottom of the saucepan.

Part B: Arranging the design challenge:

This is an opportunity for students to use their ingenuity to improve the efficiency of the solar still. At the same time students learn about the relationship of technology to science. The technological process usually requires criteria on which the technological product can be judged. The criterion for the design challenge should be clearly explained to students before they start on Part B. The basic criterion of percent water purified should be made more sophisticated for older students. For example, the criteria might specify the time length of water collection. e.g. Make the length of time in the sun fixed at around 3 or 4 hours to make the final judgment of the most efficient still easier.

The range of factors which can be explored by students include:

- The length of time
- The type of container
- The colour of the container
- The amount of water added
- The shape of the still
- The collection mechanism

<u>How the Still Works:</u>

Summary

As the water in the still warms, increasing amounts of water evaporate into the air. This water condenses on cool surfaces including the plastic film, turning back into a liquid. As the liquid condenses on the film it collects into droplets that run down the film to the pebble and then fall into the cup.

The purification works because both the salt and the food dyes do not evaporate.

A deeper level of explanation is available if the students have been introduced to the particle nature of matter and the concept of energy:

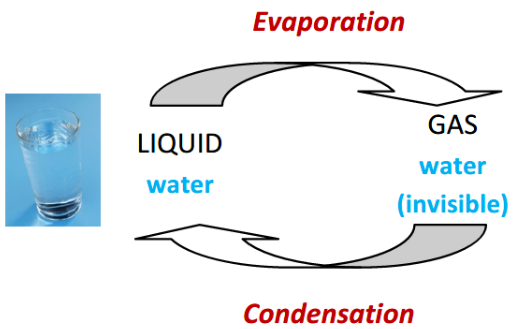
The sunlight entering the still is absorbed by the water and the container. The result is that the molecules and ions absorb the energy. Some of the water molecules absorb enough energy to break free from the liquid water and become gaseous molecules flying about inside the container. Some of these flying molecules collide with the plastic film, lose energy to the film, and stick to the film. The water molecules lose more energy as they join together forming droplets of pure water which run down into the cup.

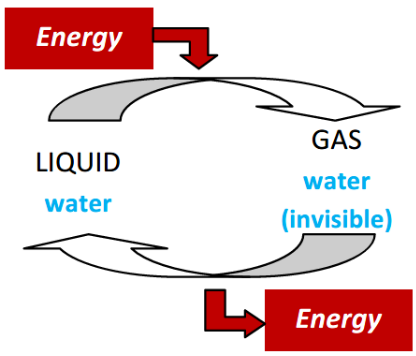
Background

While the activity is set in the context of water purification, students should be aware that the process is a general one for liquids and gases. It is a key to understanding a wide variety of everyday events ranging from why we feel cool when standing in the wind to how the household refrigerator works or how the world gets its fresh water from the water cycle.

A central idea to understanding the process involves the role of energy which is required for evaporation and released in condensation. In the case of feeling cool when the wind blows, we can understand the effect by realizing that the wind evaporated moisture from the skin and energy is absorbed from the body making us feel cold. In the case of the solar still, energy is required to evaporate the water in the still and in his case we harness the free light energy that comes from the Sun.

Understanding the process of evaporation and condensation allows students to analyse the design of the solar still and generate ideas about how it might be improved (for the Design Challenge). However, it doesn't provide an understanding of how the water purification occurs.





The purification of water in the still occurs because some substances evaporate more easily than others. Salt and food dyes, for example, are almost impossible to evaporate and biological hazards in water such as bacteria and viruses also don't evaporate easily. (However other substances that are often added to water such as alcohol evaporate readily and much more carefully designed stills are needed to separate alcohol from water.)

The term volatility is used to describe ease of evaporation so that salt and food dyes are involatile while alcohol and water are much more volatile. The reason for these different behaviours can be readily understood if the substances are examined at the molecular level.

At the molecular level, salts are made up of ions and very large amounts of energy are needed to separate ions, making evaporation almost impossible. In the case of food dyes, the molecules are large and ionic and so are similarly involatile. Water is less volatile than alcohol (ethanol), which appears surprising because water molecules are less massive than alcohol molecules. However water molecules stick together particularly strongly. Chemists call this interaction hydrogen bonding and it is responsible for many of the important properties of water. In the case of evaporation, because of the many hydrogen bonding interactions between water molecules more energy is required.

Addressing the Challenge

The challenge arises because the efficiency of the still is dependent on a number of variables. The length of time the still is in the sun is critical, and **you may wish to make the length fixed at around 3 or 4 hours to make the final judgment of the most efficient still easier**. Other factors are more subtle, but also important. For example, a design feature of most commercial stills is the separation of the evaporation stage and condensation stage so they take place in different parts of the still.

Safety glasses should be worn at all times during these activities. It should be emphasized that the disinfected water may not be safe to taste or drink. The students should be made aware of this at the start of the activity.

If access to laboratory equipment is available, there is scope for students to make a greater range of designs using laboratory equipment, and to measure the salinity using laboratory methods. Instructions for this are available from the International Year of Chemistry Global Chemistry Experiment website: **http://water.chemistry2011.org/web/iyc**

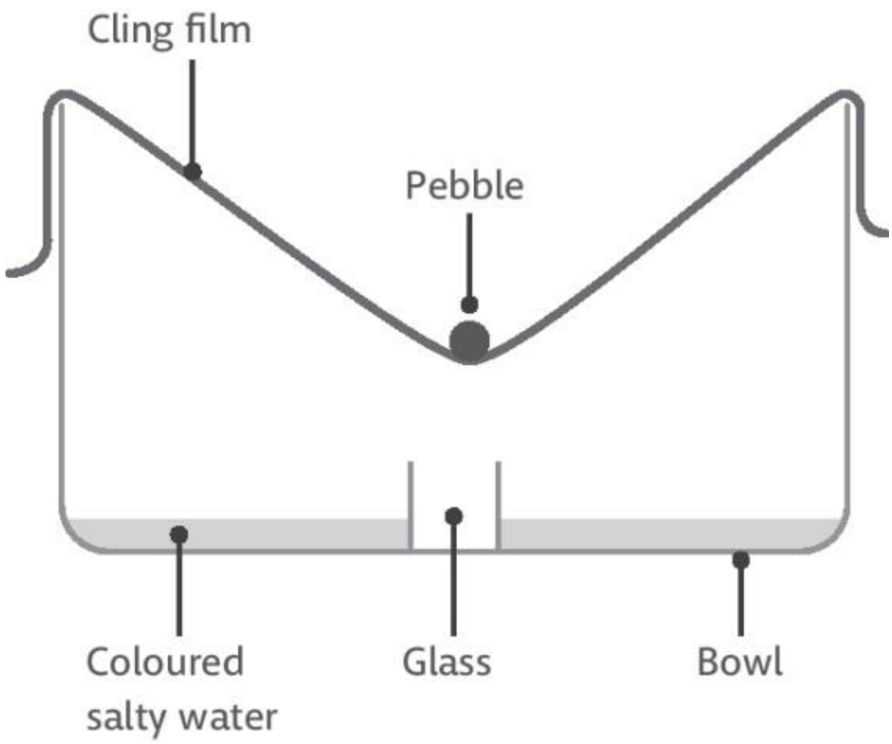
In this activity you will build a solar still and find out how it can purify water. You will be challenged to use your knowledge to build a more efficient solar still.

The solar still is a device that that uses solar energy to purify water. Different versions of a still are used to desalinate seawater, in desert survival kits. They are also available for home water purification.

Part A: Build a simple solar still

Materials:

- Large metal or plastic bowl/basin
- Small, shallow glass or cup (washed in soapy water, rinsed with clean water and dried)
- Measuring jug or cylinder
- Cling film (wider than the bowl)
- Small stone (pebble)
- Hot water (recently boiled and cooled) – it is hot to make the salt dissolve faster
- Food colouring
- Salt



Solar still set-up

1. Add a measured volume of recently boiled and cooled water (about 1 cm) to the bowl. (Record the volume of water added)

2. Add some food colouring and about a teaspoonful of salt to the water in the bowl and check that it has dissolved.

3. Take all the equipment out to a sunny, level place.

4. Place the glass or cup in the middle of the bowl making sure no water splashes into it.

5. Cover the bowl loosely with cling film, sealing the film to the rim of the bowl.

(Use tape or string if necessary.)

6. Place the stone in the middle of the film above the cup.

7. Leave the still for at least an hour (the longer the better) and then check that there is some water in the cup.

8. Take the still back indoors, remove the cling film and take out the cup without splashing any water into or out of the cup.

9. Measure the amount of water in the cup.

10. Observe the colour of the water in the cup and test it for salt (ask your teacher if you can use taste to test).

11. Calculate the percentage of the water that was purified:

$$\%\, water\ purified\ = 100\ \times \frac{volume\ collected}{volume\ added\ to\ the\ still}$$

12. Record your results in the results table.

13. Explain how the still works in your own words.

Part B – The Design Challenge

Your challenge is to modify or make a more efficient solar still than the one that you made in Part A. Your teacher will provide you with rules for the challenge.

1. Write down some ideas about how you might improve the still. For example, you might try using different coloured containers to find out which absorbs the sunlight most efficiently.

2. Draw a diagram of your new design and discuss your ideas with your teacher and get his/her permission to carry out the experiment.

3. Carry out the experiment recording the volume of water you start with and the volume you purify.

4. Calculate the % water purified and record it on the Results Table.

5. If you have time, you can develop your design further. Make sure you get permission from your teacher for each experiment you carry out.

6. Draw a diagram of your most efficient still showing why it is more efficient than your first still.

Results Table

Trial	Volume of water added (ml)	Volume of water collected (ml)	% water purified
Part A: Initial design			
Part B: (Describe design)			

This activity has been adapted from the Solar Stills Challenge Activity part of the Global Experiment that was conducted during the International Year of Chemistry, 2011.

Solar Still - Teacher's Notes continued:

["*ANSWERS"]* Example Results - Student Results Sheet (for Grade 7 student)

Record your results and calculate the percentage of the water purified.

Trial	Volume of water added (ml)	Volume collected (ml)	% water purified
Part A	100	12	12
Part B Second trial 1st still	50	16	32
Second still	50	22	44

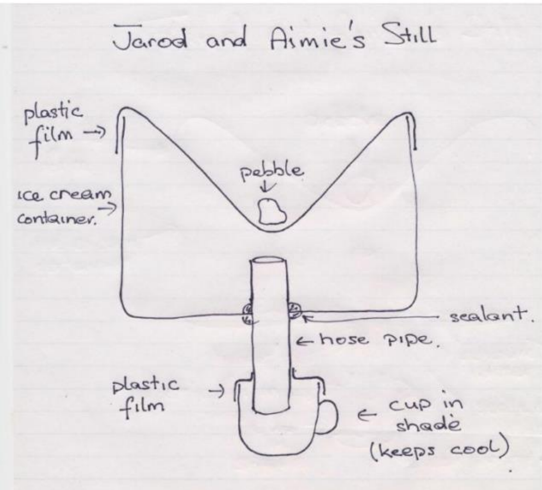
Part A: Explain in your own words how the still works.

The still works by letting the Sun's rays warm the water. Some of the water goes into the air but you can't see it because it is gas not liquid. The water turns back into liquid when it touches the plastic and you can see the drops turn down to the pebble and fall into the cup.

Part B: Write down one way in which you could make your still work better.

We think we could make the still work better by starting with less water. It took a long time for the first drops to form because it was a bit cloudy and the Sun wasn't very hot. Smaller amounts of water will heat up quicker.

Draw a diagram or explanation of a design for a still that will work better and then discuss the ideas with your teacher before building it.



First, we tried to make the still more efficient by using less water so it heated up quicker and then we made sure that the water was warm before we started. Both changes made the still work more efficiently. Then we cut a hole in the bottom of the container (an ice cream carton) and put a piece of hosepipe through the hole. We stopped it leaking with sealant, and then collected the water in a cup that was kept cool in the shade of the container. Then we were able to collect more than half of the water we started with.

Session 14: Managing the Human Impact on the Water Cycle

Activity 1: The water cycle with human activity – 60 to 90 mins (p. 52, 57 student booklet)

Teacher's Notes

The aim of this activity is to reprise the water cycle and understand in your local context how the water cycle is influenced by human activity. Students could do this activity individually or in groups of 2–4. If working in groups, pause at each * to get feedback from each group; if individually, you could tell them to turn to their neighbour and discuss. Students can use what other people came up with to add to their lists and tables. Take photographs of the final Water Cycle diagrams that are produced, or turn them into artwork with drawings of local features to make "the water cycle where you are" come to life.

Materials:

- The tables from the first Water Cycle activity (page 8 student booklet)
- Coloured pens and pencils
- Sticky notes or scissors, pieces of paper and glue
- Large pieces of paper for the water cycle diagrams

Student instructions:

1. Make a list of ways people use water in your area during the rainy season.
2. Look at the diagram of the water cycle including human activity. Are the items on your first list included in the diagram? *
3. Make a list of places where people in your area get water from.
4. Look at the diagram of the water cycle including human activity. Are the items on your second list included in the diagram? *
5. Here are the labels from the water cycle diagram including human activity. Circle the labels which show the ways in which water moves around the cycle. (Clue: You should circle 13).

Condensation	Precipitation	Borehole
Surface water flow	Groundwater abstraction	Evaporation
Saline groundwater	Groundwater flow	Infiltration
Run-off	Dam	Industrial water use and disposal
Reservoir	Evapotranspiration	Agricultural water use and run-off
Melt-run-off	Domestic water use and disposal	

6. Building on the table that was created in the activity on page 8 of the student booklet, fill in the rows and columns for each of the circled words (example over the page). Which of the processes have you seen, and which are taking place where you live?
7. You can do this final step with everyone together, or continue to work in small groups. Put each of the words from your two lists, plus each of the circled words showing processes on to pieces of paper. Arrange them into a water cycle. Use a pen or more paper to make arrows to show the flow of water around your diagram.
8. Discuss as a group: How would your diagram change during the dry season when there is less rain? Does your diagram explain everything about where the water used in your area comes from and goes to? What else does your diagram make you want to find out?

The natural water cycle + human influence on the water cycle where I live

Human processes influencing the water cycle	Have I ever seen it with my own eyes?	Description of an example of what can be seen of this process in my local area
Surface water flow	...Yes	...The river
Precipitation		
Condensation		
Evaporation		
Groundwater flow		
Infiltration		
Run-off		
Evapotranspiration		
Melt-run-off		
Groundwater abstraction		
Industrial water use and disposal		
Agricultural water use and run-off		
Domestic water use and disposal		

Activity 2: Water management crossword – 15 mins /homework (p. 61 student booklet)

Note: This could be given as homework or added to another session.

Materials:

- Enough copies of the crosswords for individuals, pairs or groups to fill in together and access to the text in Chapter 5 Water Management, and the glossary in the student booklet.

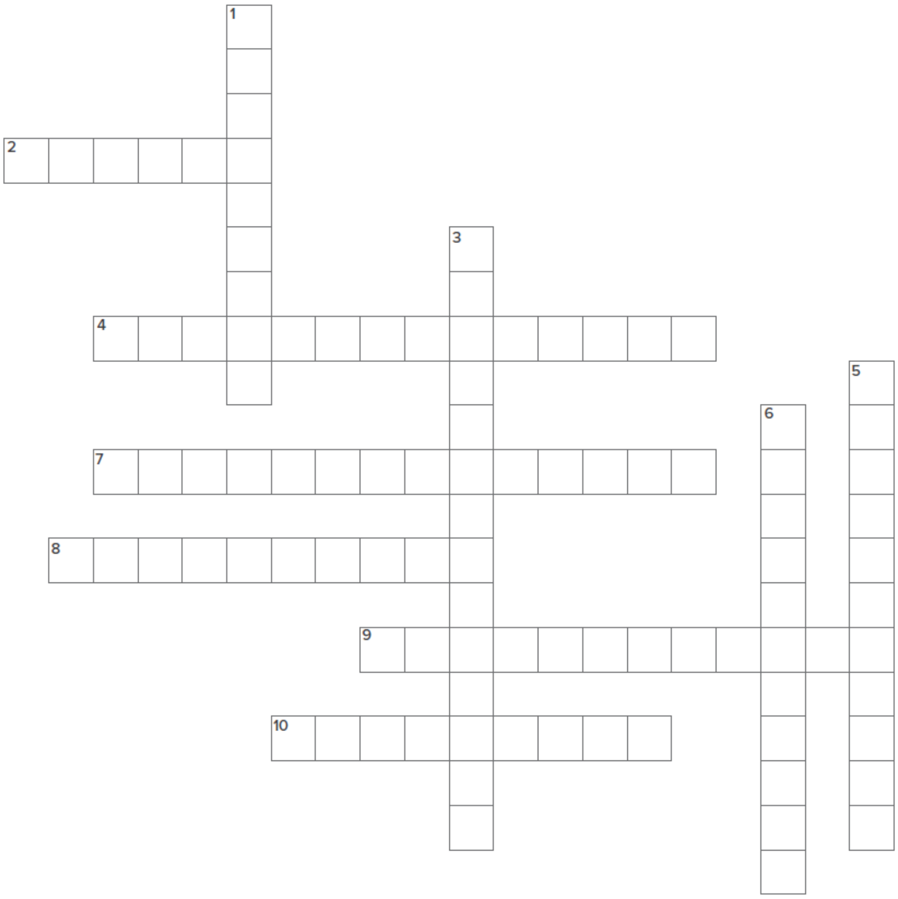
Steps:

1. Tell them to work on the crosswords using pencil, reading the chapter to get the answers
2. If necessary or if it is taking a long time, write additional clues on the board – e.g. the number of letters; first letter of each word (alternative handout on next page).

Answers:

Across	Down
2. policy	1. greywater
4. water footprint	3. water intensive
7. comsumptive use	5. maintenance
8. management	6. functioning
9. conservation	
10. committee	

Water Management Crossword (with letter clues)



Across

2. A procedure, protocol, or set of principles, often created by people in the government, that is used to guide decisions (6 letters)
4. The total amount of water directly and indirectly used by a person, or the total amount of water used to produce something (2 words, 5, 9 letters)
7. Use of a resource that lowers the amount that is available for use over time, such as removing
water from a lake or aquifer and not returning the same amount back (2 words, 11, 3 letters)
8. The activity of deciding and controlling how a resource like water is used (10 letters)
9. Prevention of wasteful use of a resource such as water (12 letters)
10. A small group of people selected by a larger group to represent them and do a set of tasks (9 letters)

Down

1. The wastewater from household activities like cooking and washing (9 letters)
3. A description of an industry that uses a lot of water (2 words, 5, 9 letters)
5. Activity that is done to keep something working or in good condition (11 letters)
6. Continuing at the same speed or amount without breakdown or depletion (11 letters)

Session 15: Who is Involved in Water Management?

Activity 1: Who is involved in water management? – 60 mins (p. 53-55 student booklet)

Steps:

1. Ask students to reflect and write down one or two sentence answer to the following question: Why is it necessary to manage water?
2. Read out the paragraph at the bottom of page 53 in the student booklet, and then ask the students to go back and edit their answers. Encourage them to use their own words to answer the question.
3. Ask students to read (or read out) the text under the heading 'Who makes decisions about how water is managed?' from half way down page 54 to page 55 and make a list of all the jobs and social groups that are mentioned in the text. At the end, get them to call out answers or compare lists, so that everyone has a complete list.

[POSSIBLE ANSWERS]

- Regulators, Voters, Government
- Scientists, Engineers, Management professionals
- Business people, People who work in industry
- Water management committee
- NGOs
- Community
- Mechanics (this is in the picture), Service providers

4. Think of a set of places that all the students can imagine – for example,
    a. a rural area with a few villages where people get their water from a river which is risky due to the waste from the many cattle kept in the area;
    b. the capital city of your country;
    c. the zone or district around your school.
5. Create handouts which describe each place and mentions what type of water supply they currently have and any particular problems with it (e.g. pollution, relying on surface water which may be contaminated with pathogens). The activity is for pupils to use the handouts to imagine that they are in the role of a decision-making committee who will choose how to spend a budget on improving water services for that area.
6. Put the students into groups and give out the handouts. The task of each group it to come up with a proposal for the budget allocations presented as a pie-chart and write a short justification for their decisions to be presented to the class after 10 minutes discussion and preparation. You may want to give the same scenario handout to more than one group to provoke debate.

7. Before announcing the start of group discussion or "water budget committee meetings", draw a circle on the board and check that everyone is ready and able to present proportions or percentages as a pie chart.

Questions for each Water Budget committee:

- If you were responsible for creating a budget for managing the drinking water supply in this area, how would you allocate your budget?
- What proportion of the money would you give to expanding the supply of safe water
- What proportion would you keep for maintaining equipment such as handpumps, pipes, and solar pumps?
- What proportion would you spend on treating the water?
- Can you think of any other costs that should be considered for managing drinking water supplies? [Answers might include: Paying for electricity and fuel for pumping the water; paying staff in the water treatment facility]

8. When the groups have finished creating their budget allocation pie charts and justifications, ask each group to present to the class. Firstly, they need to describe their area, then present their budget allocation decision to the whole class and explain why they think that is an appropriate way to spend the budget for their area.

Activity 2: Planning for the future - 20 mins (p. 55 Maths / Geography; requires local prep)

Planning for the future is an important part of water management. In this activity, students are asked to imagine that they are a scientist trying to figure out how much water a city will need 20 years in the future.

Steps:

1. Ask students to list types of information they would need to figure out how much water a city will need in the future.
2. Provide students with some statistics on current and past population of a city in your region, and ask them to calculate the population growth rate. Ask does the population growth rate stay the same or vary? What factors affect the population growth rate?
3. If available, provide students with statistics on average water use per person per day in your country or region (noting that this varies a lot between rural and urban areas of the country) and ask them to work out an estimate for how much water the city currently needs and how much it will need in 20 years' time if the population growth rate stays the same.
4. Extra question for students to think about: Why might average water use per person be different in rural and urban areas? Are water services in rural areas the same as those available in the city?

Session 16: Water Footprints

Activity 1: Engaging water footprint information – 60 to 90 mins (p. 51-53 student booklet)

Teacher's Note:

The water footprint concept was first developed by Arjen Hoekstra, whilst working at the UNESCO-IHE Institute for Water Education. It is a term used to talk about all the water that is used when something is produced – for example, a crop such as rice, or a piece of clothing. The water footprint of an individual can be calculated by adding up the amount of water required to produce and transport everything that they eat and use every day. This can also be done at the scale of an entire country. When this number is divided by the total population of the country, it will give an average water footprint of that country's citizens. Of course this average does not reflect different levels of water use by different people.

Steps:

1. Ask a student to read the first paragraph on page 51 of the student booklet. Ask other students to read out the definitions of ABSTRACTION, RAINWATER, AND WASTEWATER footprints.
2. Turn to the Water Cycle diagram on page 52 and ask students to imagine that the factory in the diagram is producing cotton grown in the fields to the top right of the diagram. Ask students to look at the diagram and discuss where the ABSTRACTION water might come from and go on to and to think how it might be measured.
3. Repeat the question for the RAINFALL water, and the WASTE water.
4. Read the section on 'How much water do you use?' on pages 51 and 53 and ask students to choose one of the question below to discuss in pairs and then feed back to the class.
    - How many other water intensive industries can you think of?
    - What do you think is the most water-intensive industry in your country and why?
    - What do you think are the most water intensive crops grown in your country and why?
    - Look at the WASTEWATER footprint definition. Thinking back to the section about water quality, why is dilution sometimes a way to reduce the impact of pollution?

Optional additional activities for this or next session:

- If you are able to show this Youtube video, it will give good context to the activity on water use in cotton production (see also worksheet next page): https://youtu.be/Hfi4DUHDavQ
- Try out a personal water footprint calculator and learn more about this concept at the website: www.waterfootprint.org

Video Worksheet: A video about the cotton industry

The video is called Cotton and Water and looks at ways in which the global cotton industry is using new technology to reduce water use in cotton production and processing. Read the questions below. Then, when watching the video, note down the answers:

A) When it comes to cotton apparel (clothes), what is the third important link in the cotton chain?

1.) Textile processing

2.) Caring for the finished garment

3.) ____

Hint: If you need to see if again to hear the answer, ask to watch from 2:43 – 2:58 again.

B) Why and how do farmers in Texas, USA, irrigate their cotton crop?

Fill in the missing word*:* To ______________________ the yield.

C) Circle the correct word. When extra water is needed, the popular solution is precision:

(a) pipes,

(b) irrigation OR

(c) potatoes.

Hint: Irrigate means "add water to". Yield means "the amount of crop they produce". If you need to see it again to hear the answer, ask to watch 3:55 to 4:09 and 4:48 to 4:57.

D) How many gallons of water are saved by the water recycling system in the Chinese Central Textiles factory dying process?

Your answer: ___________________ gallons per day (1 large jerry can = around 5 gallons)

Hint: That's the factory run by Pat Nie Woo. If you need to see it again to hear the answer, ask to watch 9:26-9:44.

E) Having watched the film, make a list of the ways that water is used for producing a t-shirt.

Session 15: Water Conservation in the Cotton Industry

Activity 1: Can a t-shirt have a footprint? – 60 mins (p. 59-60 student booklet)

Introduction:

T-shirts are often made of cotton, which is a crop grown in many countries around the world. You can read about cotton production in India in the newspaper article: "***The cost of cotton in water-challenged India***" (read this on page 60 in the student booklet or on the following page in this educator guide).

"Blue" and "Green" water (see diagram on page 51 in the student booklet) is used for irrigation and also in the process of preparing and dying the final cotton textile used to make the t-shirt. The WASTEwater footprint of a t-shirt depends on how much pollution was caused by its production from the pesticides, dyes and any other chemicals used in the process. These uses of water can be added to estimate the total water footprint of a t-shirt.

Student Instructions:

If you can find a t-shirt with a label showing where the cotton was grown, you can use the information below to calculate the water footprint of that t-shirt. You will also need a weighing machine or use the average t-shirt weight of 0.25kg.

1. Check the label. Where was the t-shirt made? ______________________________

Country	Water footprint to produce 1 kg of cotton
USA	8,100 litres (L) of water
China	6000 L
Pakistan	9,600 L
Uzbekistan	9200 L
India	22,500 L
Global Average	10,000 L

Figures from "The Water Footprint of Modern Consumer Society" by Arjen Y. Hoekstra, Routledge, 2013; Cotton Harvest Kimberly Vardeman (CC BY 2.0)

2. How much does the t-shirt weigh? ____________________kg

   Hint: Remember 1 kilogram = 1,000 grams

3. What is the water footprint of the t-shirt?

   ______________L per kg X ___________kg = _______________L

   (water footprint of cotton) (T-shirt weight) (water footprint of t-shirt)

4. Why do the water footprints for cotton produced in different countries vary so much?

Extract from Guardian newspaper article from World Water Day 2015

The cost of cotton in water-challenged India by Stephen Leahy
Friday 20 March 2015 14.12 GMT

Severe water scarcity in India is exacerbated by the cotton industry. Concerns are high, but are businesses, consumers and government doing enough?

You might not realise it, but India exports enormous amounts of water when it exports raw materials such as cotton and products such as automobiles.

The water consumed to grow India's cotton exports in 2013 would be enough to supply 85% of the country's 1.24 billion people with 100 litres of water every day for a year. Meanwhile, more than 100 million people in India do not have access to safe water.

Virtual water:

Cotton is by no means India's largest export commodity – petroleum products followed by gems and jewellery follow closely behind. All of these exports require water to produce, and the quantities needed are staggering. Not only does it take water to grow anything, it also takes water to make anything: cars, furniture, books, electronics, buildings, jewellery, toys and even electricity. This water that goes largely unseen is called virtual water.

What's easy to forget is that virtual water is as real as the water you drink. Producing 1kg of cotton in India consumes 22,500 litres of water, on average, according to research done by the Water Footprint Network. In other words, this 22,500 litres of water cannot be used for anything else because it has either evaporated or is too contaminated for reuse.

By exporting more than 7.5m bales of cotton in 2013, India also exported about 38bn cubic metres of virtual water. Those 38bn cubic metres consumed in production of all that cotton weren't used for anything else. Yet, this amount of water would more than meet the daily needs of 85% of India's vast population for a year.

Doing things differently:

Cotton doesn't usually consume this much water. The global average water footprint for 1kg of cotton is 10,000 litres. Even with irrigation, US cotton uses just 8,000 litres per kg. The far higher water footprint for India's cotton is due to inefficient water use and high rates of water pollution — about 50% of all pesticides used in the country are in cotton production.

Most of India's cotton is grown in drier regions and the government subsidises the costs of farmers' electric pumps, placing no limits on the volumes of groundwater extracted at little or no cost. This has created a widespread pattern of unsustainable water use and strained electrical grids.

Recent reports show that India's water consumption is far too high. In 54% of the country 40 to 80% of annually available surface water is used. To be sustainable, consumption should be no more than 20% in humid zones and 5% in dry areas, to maintain the ecological function of rivers and wetlands, experts say.

India's extensive groundwater resources are also rapidly being depleted, with 58% of wells in the drier north-west India experiencing declining water levels.

Sessions 17-19: Research reports

Activity 1: Research projects – 4 sessions of 60 to 90 mins (p. 55-58 student booklet)

Allow 3 sessions for projects and 1 for final presentation/report preparation. Below are three ideas for group/individual projects. Make these outlines available to students and get them to choose a project to work on as individuals or in groups of 3 or 4. The initial source of information for the second and third project are on pages 55-58 of the student booklet. Students may require more assistance with the third project because they would need to have access to further reading material or an opportunity to speak to people with agricultural or horticultural knowledge.

Depending on your capacity to provide access to information on other project topics, you could also open this out by allowing students to select a topic of interest for research from another section of the Water Module.

A suggested timeframe for projects would be 4 weeks to prepare a research report to deliver to the group in the form of a poster or presentation. You could suggest that pupils create an outline of their report and discuss it with you before they start to work on the detail of their report. It might be exciting to invite other teachers and community members to a presentation session to see the results of the work.

RESEARCH REPORT IDEA 1: Water use in your school

Design a research plan to find out how much greywater is produced at your school per week. Research techniques you could use:

- Survey forms for staff and students
- Observation at waterpoints – taps, pumps etc.
- Direct measurement of your own use – e.g. Collect and measure water used when washing clothes, washing hands and brushing teeth.

RESEARCH REPORT IDEA 2: Greywater system design

Read about greywater on pages 56 and 58 of the student booklet. Questions you could try to answer:

- How is the greywater at your school used or thrown away?
- Why is it important to consider safety issues when designing a greywater system?
- Can you design a simple greywater system that would work at your school?

RESEARCH REPORT IDEA 3: Conservation Agriculture

Read pages 55 and 56 in the student booklet. Questions you could try to answer:

- Which food crop plants growing in your area use the most water and which ones use the least? Is there a gardener or farmer that you could ask about this or a source of information you could consult? Or can you think of a way to measure it directly*?
- Can you find out about some of the water-saving techniques that are used by farmers in your area?
- Are there any water-saving techniques that could be used in the gardens at your school? *Think back to the evapotranspiration experiment.

Additional sources of information:

The projects above would work with access to the student booklet but if possible, some of the following additional sources of information could be accessed via the Internet or downloaded/printed for students to read. You could also find locally based farmers, agricultural extension workers or scientists who might be willing to talk to students or answer written questions.

Greywater (RESEARCH REPORT 2)

Case study of SuSanA projects; Greywater tower, Arba Minch; Ethiopia; Wudneh Ayele Shewa (ROSA project), Bogale, SuSanA 2010. https://www.susana.org/en/knowledge-hub/resources-and-publications/case-studies/details/90

Sacher, N. and Gensch, R., Xavier University. How to build greywater towers. Published on SSWM. https://sswm.info/sswm-university-course/module-6-disaster-situations-planning-and-preparedness/further-resources/greywater-towers

Introduction to greywater management, EcoSanRes Factsheet 8, May 2008. www.ecosanres.org/pdf_files/ESR-factsheet-08.pdf

Rand Water in conjunction with Eliza van Staden (UNISA); greywater guidelines for home gardens in Gauteng, South Africa, RAND Waterwise. http://www.waterwise.co.za/export/sites/water-wise/gardening/water-your-garden/downloads/Greywater_pamphlet.pdf

Rodda, N., Salukazana, L., Jackson, S.A.F., Smith, M.T. 2011. Use of domestic greywater for smallscale irrigation of food crops: Effects on plants and soil. Physics and Chemistry of the Earth, 36: 1051–1062 Misra, R.K. and Sivongxay, A. 2009. https://www.researchgate.net/publication/225543837_Reuse_of_Domestic_Greywater_for_the_Irrigation_of_Food_Crops

Conservation agriculture (RESEARCH REPORT 3)

Conservation agriculture – what is conservation agriculture? African Conservation Tillage Network. www.act-africa.org/image/01INTRO.PDF

Mati, B.M. System of rice intensification – growing more rice while saving on water: Practical notes for SRI Farmers. http://sri.ciifad.cornell.edu/countries/kenya/extmats/Kenya_SRI_Manual2012.pdf

Harvesting water on the farm – Technical Manual on Soil and Water Conservation – Sustainet E.A. https://wocatpedia.net/images/1/18/Technical_Manual-_Soil_and_Water_Conservation.pdf

Drought tolerant varieties: Are drought-resistant crops in Africa the tech fix they're cracked up to be? Newspaper article by Oliver Balch. https://www.theguardian.com/sustainable-business/2016/sep/02/drought-resistant-crops-gm-africa-monsanto-syngenta-dupont

Drip irrigation Irrigation method that helps farmers grow more crops using less water, Kenyan Standard Digital Edition News Article by Grace Mureithi. http://www.standardmedia.co.ke/business/article/2000189088/irrigation-method-that-helps-farmers-grow-more-crops-using-less-water

KnowledgePoint QandA Forum for Shared Knowledge in Humanitarian Development – How well does drip irrigation work for small farmers? https://knowledgepoint.org/en/question/3386/micro-irrigation/

Session 20: Our Vision for Water

Activity 1: The big picture – 20 mins (p. 62 student booklet)

Steps:

1. Get students into pairs or small groups.
2. Write the questions below on the board or refer to page 62 of the student booklet.
3. Instruct each pair of students to select and discuss two questions.

Discussion questions:

- Who is responsible for making water safe to drink?
- Who is responsible for making sure there is enough water for everyone?
- How much water is enough water for drinking and household activities?
- How much water do people in your school use every day? Do you think the water footprint of your school should be reduced or increased? If so, how would you do that?
- How can commercial users of water like agriculture, factories or mines conserve water and protect supplies?
- What are the main risks of drinking unsafe water and what can be done to reduce the risks?
- Why is groundwater from a handpump usually safer to drink than water collected from a lake, river or open well?

Activity 2: Sharing our vision – 40 to 70 mins and ongoing (p. 62 student booklet)

Steps:

1. Have a class discussion on the two questions below.
   - What do you think everyone should know about water?
   - What are the best ways to share important messages about water?

2. As a final activity, set students the challenge of making a poster, writing a school newsletter or creating an awareness campaign on the theme of OUR VISION FOR WATER aimed at the school or wider community. Students could continue to develop these in further sessions and they could be presented as part of a whole school assembly on Water or at another club or class event to mark the end of the module.

Activity 3: Hold a debate – preparation 60 mins and event 60 mins (p. 62 student booklet)

Organise a debate with a water management theme. Some examples of debate topics are:

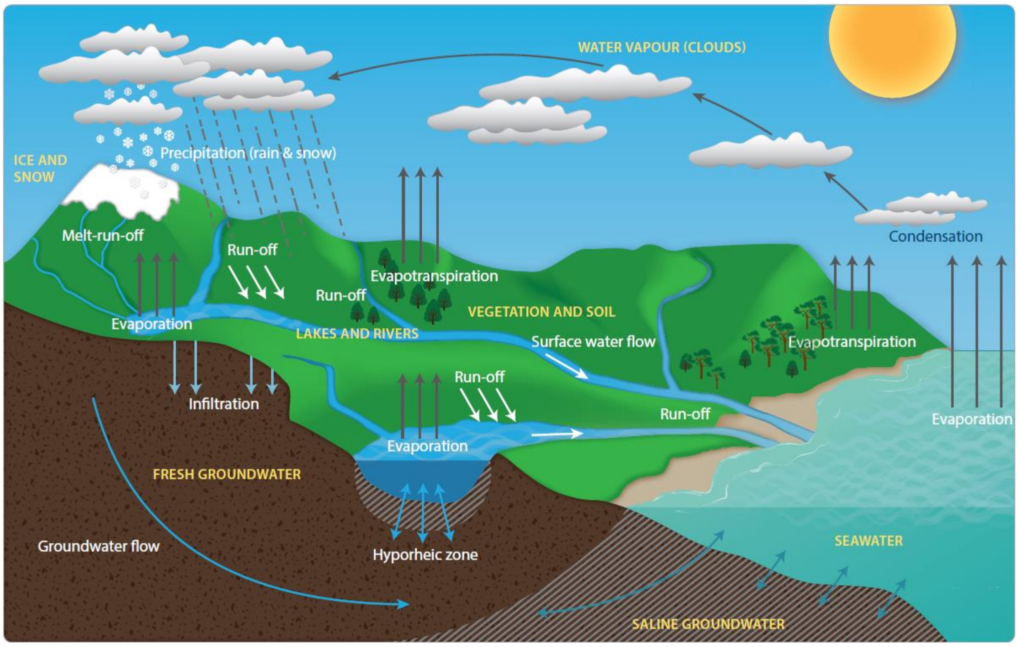
Team 1		Team 2
We believe that greywater should be used in agriculture and gardening because it is a form of water recycling that helps to conserve water.	vs.	We believe that greywater should not be used in agriculture and gardening because it contains soap, other chemicals, and possibly pathogens from household activities that could be harmful.
We believe that paleowater in old aquifers should be abstracted and used because it can provide supply for drinking, growing food, and economic production. It is not useful for anything if it stays in the ground.	vs.	We believe that paleowater in old aquifers should not be abstracted because it is a non-renewable supply and when it is depleted it will be difficult for people to find another water supply and there will be water scarcity.

How the Water Module Links to the Curriculum

Learning about water has relevance to the Sustainable Development Goal Target 6.1: By 2030, achieve universal and equitable access to safe and affordable drinking water for all, which most countries have signed up to. The topic of water is therefore critical to **Education for Sustainable Development** (ESD) and practical activities suggested in this booklet could help students develop relevant knowledge and skills.

Many of the activities in this booklet have been designed to allow students to practice their communication skills and can be extended to give students the opportunity to utilise information and communication technology across varied contexts. There are also many opportunities for practising critical thinking and apply learning to real contexts.

Teachers will be able to assess ways in which the activities in this module can be mapped to different school subjects in particular geography, science, as well as Personal Social and Health Education, and mathematics. The relevance of the materials to class learning will vary depending on local and national curriculum requirements.



CERTIFICATE

This is to certify that:

Name:_______________________________________

School:______________________________________

has successfully completed the Water Module.

Signed: ________________________________

Date: ________________________

STUDENT REGISTER

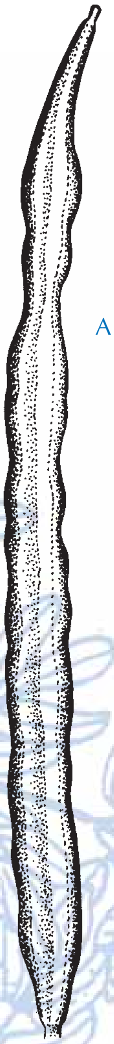
Session	Section/Activity Title																					
1: The Water Cycle																						
1	Activity 1: The Sustainable Development Goal for water																					
	Activity 2: (Maths: Reading graphs)																					
	Activity 3 (Maths: Percentages)																					
	Activity 4 – Bingo reading																					
	Activity 5 – Water Cycle Crossword																					
	Activity 6 - The "natural" water cycle where I live																					
2	Activity 1: Measuring evapotranspiration																					
3	Activity 1: Measuring precipitation																					
2: Geology																						
4	Activity 1: Engaging with the information																					
	Activity 1A/Homework – Water use in mining																					
	Activity 2./Homework Crossword																					
5	Activity 1: Using geology to understand water flow in the distant past																					
3: Groundwater																						
6	Activity 1: Infiltration Experiment																					
	Activity 2: Saturation Experiment																					
7A	Activity 1: How do scientists study groundwater?																					
	Activity 2: How do people access groundwater?																					
	Activity 3: Sustainable use of groundwater																					
	Activity 4: Crossword																					
7B	Groundwater where I live (optional field visit)																					

4: Water Quality																						
8	Activity 1: Source protection quiz																					
	Activity 2: Teaching groundwater protection																					
9A	Activity 1: Doing a sanitary inspection of a water supply																					
	Activity 2: Background reading on sedimentation																					
9B	Extension ideas: Source protection/sanitary inspection fieldwork / Arrange an expert talk																					
10	Activity 1: Sedimentation practical																					
	Activity 2: Investigate how turbidity is measured																					
11	Activity 1: Engaging with the information: Filtration																					
	Activity 2: Engaging with the information: Disinfection																					
	Activity 3: Safe storage																					
	Activity 4: Water Quality crossword																					
12-13	Activity 1: Different water disinfection methods																					
	Activity 2: Solar still design challenge																					
5: Water management																						
14	Activity 1: The water cycle with human activity																					
	Activity 2: Water management crossword																					
15	Activity 1: Who is involved in water management?																					
	Activity 2: Planning for the future																					
16	Activity 1: Engaging with the information – Water footprints																					
	Activity 2: Can a t-shirt have a footprint?																					
17-19	Activity 1: Choose a research report to work on Follow-up: Presentations and poster reports																					
Our Vision for Water																						
20	Activity 1: The big picture																					
	Activity 2: Sharing our vision for water																					
	Activity 3: Host a debate																					

Moringa: the science behind the miracle tree

Moringas have long been known as miracle trees. Now scientists are investigating their properties in depth, as **Sue Nelson** and **Marlene Rau** report.

A flower from a moringa tree



A moringa pod

Moringa leaves

In the foothills of the Himalayas grow trees, five to ten metres tall, with clusters of small oval leaves and delicately perfumed cream-coloured flowers. These are *Moringa oleifera* – the most widely cultivated of the 14 species of the genus *Moringa*, known as 'miracle trees'.

"It is called a miracle tree because every part of the tree has benefits," says Balbir Mathur, president of Trees for Life International[w1], a US-based non-profit organisation that provides developmental aid through planting fruit trees, moringas among them. "The roots, leaves, bark, parts of the fruits and seeds – everything. The list is endless."

Reports in the press about the miraculous nature of the tree may be exaggerated, but it does have some truly impressive properties. Native to northern India but now found widely in Asia, Africa and Latin America, moringas have been used in villages in developing countries for hundreds of years, their uses ranging from traditional medicine, food and cooking oil, to natural pesticide, domestic cleaning agent, and – the latest addition – biofuel.

Moringas are extremely hardy, known in parts of Africa as nebedies, meaning 'never-die trees', because they grow on marginal soils, regrow after being chopped down, and are one of the few trees that produce fruit during a drought.

It is yet another useful property of *Moringa oleifera*, though, that is exciting scientists: when crushed, moringa seeds can help purify dirty water. This could save lives: the World Health Organization estimates that unsafe water, poor sanitation and inadequate hygiene cause about 1.6 million deaths a year globally.

Water purification is mainly a two-step process: initially, water is clarified, removing particles such as minerals, plant residues and bacteria. However, since not all particles readily sink to the bottom, coagulating agents are added to help clump the particles together; these clumps can then be removed by filters or sedimentation. The second step is disinfection, to kill those pathogens that still remain, using chlorine compounds, ozone, hydrogen or ultraviolet light.

Moringa oleifera can help with the first purification step – not only in the developing world but also in the developed world. In industrial water treatment plants, the most prevalent coagulating agents used today are aluminium salts. Most particles that need to be removed from water are charged, so coagulating agents are usually ions; because the coagulating efficiency increases with the square of the coagulating agent's ionic charge, polyvalent ions such as aluminium are very efficient. However, there is concern – albeit controversial – that long-term exposure to aluminium may be associated with the develop-

The *M. oleifera* tree

REVIEW

- **Biology**
- **Chemistry**
- **Biochemistry**
- **Physics**
- **Personal, social and health education**
- **Ages 7-18**

This is a thought-provoking article that uses theoretical science (binding abilities of ions, neutron reflection techniques) to explain a real-life situation (using seeds to purify water).

Ideas from this article could be used with students of all ages to carry out some innovative practical work, with appropriate risk assessments. *M. oleifera* seeds can be bought via the Internet, if you are not lucky enough to have them grow locally, and their effects on clarifying water can be compared to those of other seeds. Are *M. oleifera* seeds really much better? Younger students could have a lot of fun grinding up different seeds and coming up with different ways of measuring how clear their dirty water becomes.

Older students could take this further and carry out investigations linked to using different parts of the seeds and relating this to seed biochemistry, or compare seeds treated in different ways, e.g. dried versus fresh. Researching the scientific basis of the seed-driven clarification process would certainly be challenging for the most able students.

The article fits well into a number of curricular topics: biology of seeds / biochemistry of extracts; chemistry of water purification / physical behaviour of the salts; physics – perhaps something to do with investigating density of layers – and looking at alternative methods. The idea could form the basis of a cross-curricular project with social science lessons, because of the good links with sustainability and renewable resources.

The article is suitable as a comprehension exercise for students aged 16 and older. Possible questions to ask in a biology lesson include:

- *Moringa oleifera* is just one of 14 species of the 'miracle tree'. Which part of the scientific name gives the genus, and which the species?
  (Answer: genus: *Moringa*; species: *Moringa oleifera*)
- In this article, a variety of uses are given for the moringa, including medicine, food, and cooking oil. Suggest which parts of the tree might be used for which of the given uses in the article. (Answers need not be correct, as students are not expected to know, but they should be reasonable suggestions, e.g. oil from seeds; medicine from any part; food from fruit; pesticide from leaves; cleaning agent from roots.)
- Moringas 'regrow after being chopped down' and are also described as being 'one of the few trees that will produce fruit during a drought.' Suggest what adaptations these trees might possess in order to do this.
  (Answer: again, students would not be expected to know the answer, but could come up with possible ideas such as new trees growing from seeds that were dispersed before the tree was cut down, or the chopping down acting as a kind of coppicing, causing more branches to grow. Being able to produce fruit during a drought could be due to an extensive root system (deep and / or wide, like those of cacti), to leaves that reduce the transpiration rate, or to mechanisms for absorbing dew, such as shallow roots.)

The article can also form the basis of discussion. Possible topics include:

- The evidence for / against aluminium being implicated in neurodegenerative diseases
- The more unusual uses of plants
- The role of the media in scaremongering the public on flimsy scientific basis (such as the drop in sales of aluminium saucepans, after it was proposed that they may be harmful)
- Citizenship topics and / or theme days based on water availability around the world.

Sue Howarth, UK

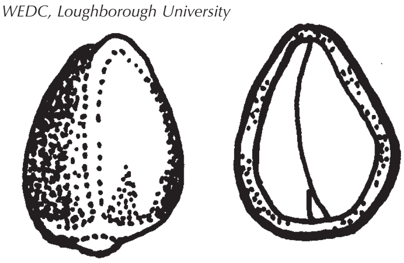
ment of neurodegenerative diseases. Iron salts are an alternative, but they are more difficult to use, as their solubility changes with pH.

Further kinds of coagulating agents include synthetic polymers, but, as with the other coagulants, the sludge formed in the clarification process needs to be disposed of: so even though synthetic polymers solve the problem of the putative link to neurodegenerative diseases, their lack of biodegradability is an issue.

Since *M. oleifera* is both non-toxic and biodegradable, and reported reductions in the cloudiness, clay and bacterial content of water after the application of *M. oleifera* seeds rival the efficiency of aluminium salts (see Ghebremichael et al., 2005), it seems to be a viable alternative.

In certain rural areas of Sudan, women already use *M. oleifera* to purify water: when collecting water from the River Nile, they place the pow-

© WEDC, Loughborough University



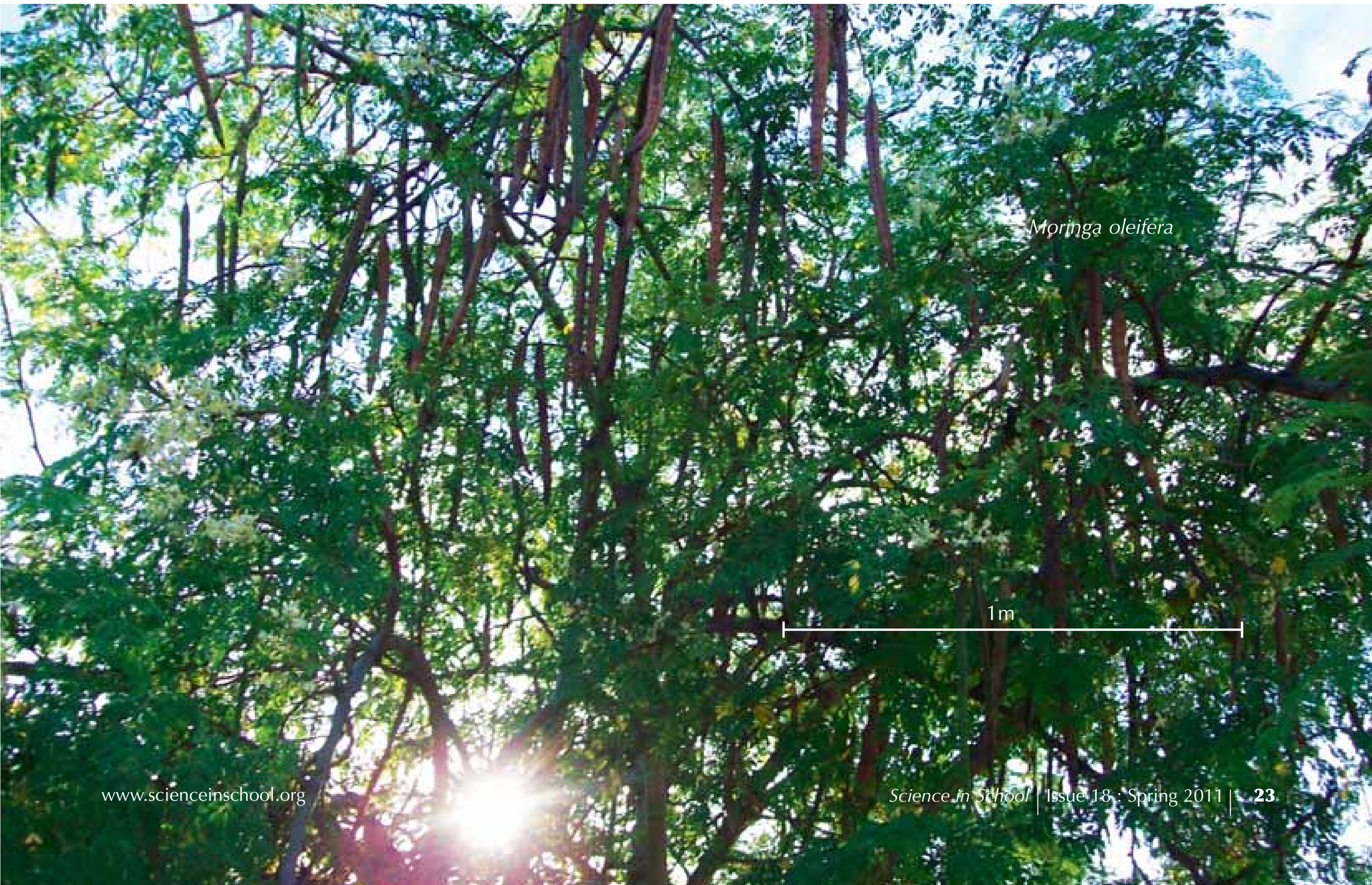
Moringa seeds: whole (left) and cut open (right)

dered seeds in a small cloth bag with a thread attached. This is then swirled around in the bucket of turbid water, until the fine particles and bacteria clump together with *M. oleifera* powder, sinking and settling to the bottom. For drinking water though, the water needs to be purified further – by boiling, filtering through sand or placing it in direct sunlight in a clear bottle for a couple of hours (solarising; see Folkard et al., 1999). You can try a similar technique yourself in class (see box on page 24).

Although a successful pilot study was performed at Thyolo water treatment works in Malawi in 1989-1994 (see Folkard & Sutherland, 2002), developing future industrial treatment methods from *M. oleifera* relies on knowing exactly what processes take place during the purification. Researchers already know that the active ingredient in the seeds is protein, which accounts for 30-40% of the seeds' weight. There are at least two proteins that may be active: they are water-soluble and quite small, about 6-16 kDa, so they can readily diffuse out of the cloth bags. At higher concentrations, they aggregate even in solution due to their substantial hydrophobic regions. The protein adsorbs on to contaminant particles, which then clump together and can be separated and extracted.

But how exactly does this clumping work? Scientists from the University of Uppsala, Sweden, and the

Image courtesy of Dr Majority Kwaambwa, University of Botswana



M. oleifera seeds are ground to a powder before use

University of Botswana in Gaborone, Botswana, set out to investigate further (see Kwaambwa et al., 2010). They produced a purified extract of all the water-soluble protein from the seeds to study how the protein adsorbs onto an interface between water and silica (silicon dioxide, SiO_2) as a model for the interface between water and mineral particles.

The team used a neutron beam at the Institut Laue Langevin[w2] in Grenoble, France, in a technique called neutron reflectometry, to measure the thickness, density and coarseness of the forming protein layer.

Dried *Moringa oleifera* seeds

Image courtesy of Dr Majority Kwaambwa

How does this technique work? When you see a layer of petrol on a puddle, you can see a variety of iridescent colours: light bounces off both the top and bottom of the petrol layer. The reflected light waves will be slightly out of phase, and depending on the thickness of the petrol layer, will either add up or cancel each other out, resulting in different colours. Many more materials are

CLASSROOM ACTIVITY

Cleaning water with moringa seeds

Seeds of the *Moringa oleifera* tree are cheaply available online, as the tree is grown for decorative purposes.

Water will require different amounts of *M. oleifera* powder to purify it, depending on the impurities present. Around 50-150 mg of ground seeds treat one litre of water: as a rule of thumb, powder from one seed will be sufficient for one litre of very turbid or two litres of slightly turbid water. Experimenting with small amounts of water in a jar will help you work out the correct amount of powder and the optimal stirring times.

You may want to compare the water quality achieved with *M. oleifera* seeds to that achieved with other methods (see Mitchell et al., 2008, for an example of a different water purification method), and run a competition for the most efficient method of water purification.

1. Remove the seeds from the dried pods, if still present, and shell them, leaving a whitish kernel. Discard any kernels with dark spots or other signs of damage.
2. Crush the seed kernels to a fine powder and sieve them (0.8 mm mesh or similar).
3. Add the powder (approximately 2 g) to one cup of clean water, pour into a bottle and shake for 5 minutes.
4. Filter the mixture through a clean cloth into a bucket of dirty water that is to be treated.
5. Stir the water quickly for 2 minutes and slowly for 10-15 minutes (do not use metal implements, since this may re-introduce unwanted metal ions removed by *M. oleifera*). During the slow mixing, the fine particles and bacteria will begin to clump together and sink and settle to the bottom of the bucket.
6. Cover the bucket and leave it undisturbed until the water becomes clear and the impurities have sunk to the bottom. This may take up to an hour.
7. The clean water may be siphoned or poured off the top of the bucket or filtered through a clean cloth. The process removes at least 90% of the bacteria and other impurities that cause turbidity.

Notes:

Both the seeds and the seed powder can be stored, but the paste (made in step 4) should be freshly made every time water is to be purified.

For safety reasons, water purified in class must not be used as drinking water.

Images courtesy of Dr Majority Kwaambwa, University of Botswana

The mother of moringa researcher Dr Kwaambwa demonstrates how the seeds are treated for water purification

transparent to neutrons than to light, and neutron wavelengths are also about one thousand times shorter (0.2-2 nm) than those of light (about 0.5 μm), which is why a neutron beam can be used to measure layers of protein a single molecule thick.

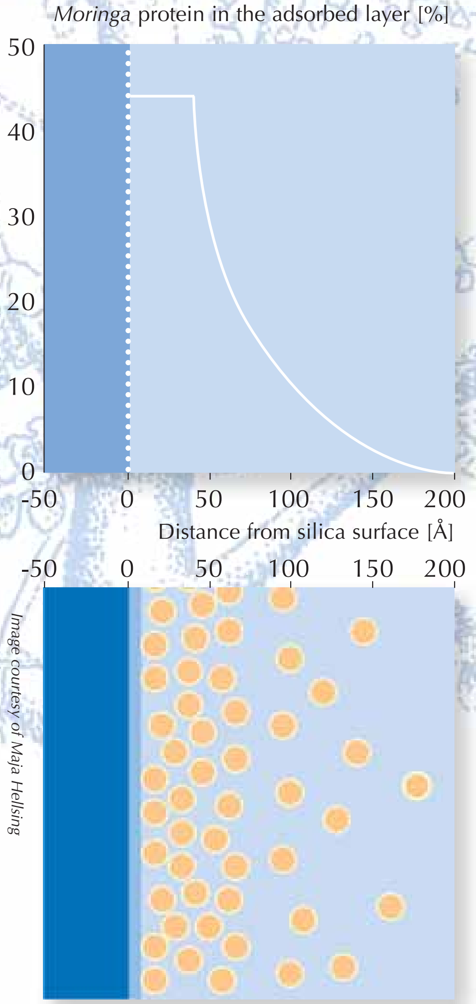
The 'white' neutron beam is shone onto the sample, and reflectivity is measured as a function of neutron 'colour' (i.e. wavelength), telling scientists how many molecules thick the layer is, how densely packed the molecules are, and how rough the surface of the layer is.

In the *M. oleifera* experiment, the scientists found that the seed protein forms dense layers thicker than a single molecule even at concentrations as low as 0.025 wt% – so the binding is very efficient. The surface of the layers is remarkably smooth, but the array of *M. oleifera* protein is not uniform: further away from the silica surface, the number of water molecules among the protein increases, which can be seen as a change in density, as measured by neutron reflection (see diagram, left).

This suggests that the clumping is so efficient because *M. oleifera* protein has a strong tendency to bind both to mineral surfaces and to other *M. oleifera* protein molecules, even at very low protein concentrations, due to hydrophobic regions and to the fact that, even when the overall protein is electrically neutral, different subgroups of opposite charge will be ionised.

Work on *M. oleifera* proteins continues to develop a non-toxic, biodegradable water purification treatment for which materials are available locally and at a much lower cost than aluminium salts. Questions being addressed include how much seed protein is needed, whether other proteins or biopolymers are suitable, and if other impurities in water, such as natural detergents, affect the action of the process.

Mathur welcomes the scientific scrutiny. "We feel that the moringa tree is very important and needs to be brought to the attention of scientists who can do further research," he says. "It is not widely known in the Western world yet because it doesn't grow there." In the future, the miracle tree could live up to its name. "The moringa could save millions of lives around the world for years to come," states Mathur. "I cannot emphasise enough how important it is."



Closest to the silica surface, *M. oleifera* protein is packed very densely, in a layer about two molecules thick (50 Å). Then, with increasing distance from the silica surface, the concentration of adsorbed protein decreases rapidly

References

Folkard G, Sutherland J (2002) Development of a naturally derived coagulant for water and wastewater treatment. *Water Science and Technology: Water Supply* **2(5-6)**: 89-94

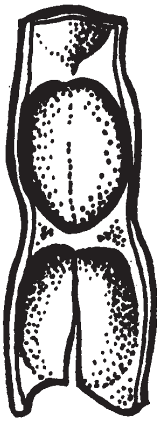
Folkard G, Sutherland J, Shaw R (1999) Water clarification using *Moringa oleifera* seed coagulant. In Shaw, RJ (ed) *Running Water: More Technical Briefs on Health, Water and Sanitation* pp 109-112. Rugby, UK: IT Publications. ISBN: 9781853394508

Ghebremichael KA et al. (2005) A simple purification and activity assay of the coagulant protein from *Moringa oleifera* seed. *Water Research* **39**: 2338-2344. doi: 10.1016/j.watres.2005.04.012

Kwaambwa HM, Hellsing M, Rennie AR (2010) Adsorption of a water treatment protein from *Moringa oleifera* seeds to a silicon oxide surface studied by neutron reflection. *Langmuir* **26(6)**: 3902-3910. doi: 10.1021/la9031046

Mitchell WA et al. (2008) Science for the Next Generation: activities for primary school. *Science in School* **10**: 64-69. www.scienceinschool.org/2008/issue10/nextgeneration

The *M. oleifera* tree


© WEDC, Loughborough University

Section of a moringa pod

Web references

w1 – Trees for Life International provides an international forum on beneficial trees and plants, and has been promoting the moringa tree for many years, sending literature and information to universities, embassies and heads of state, as well as producing educational material for schools. See: www.treesforlife.org

w2 – To learn more about the Institut Laue-Langevin, see: www.ill.eu

Resources

If you enjoyed reading this article, take a look at other *Science in School* articles about research done at ILL. See: www.scienceinschool.org/ill

---

Sue Nelson is an award-winning UK science broadcaster and writer. A physics graduate, Sue also studied space science and astronomy at the University of Michigan as a Knight Wallace journalism fellow in 2002 and recently completed a one-year Nesta Dream Time fellowship writing science-based dramas. Her reports have appeared on all the BBC's national TV and radio news bulletins. Co-author of the popular science book *How to Clone the Perfect Blonde*, Sue has written for *The Sunday Times*, *The Observer*, *The Guardian* and *The Independent* and has contributed opinion columns on science for *The Times*.

Dr Marlene Rau was born in Germany and grew up in Spain. After obtaining a PhD in developmental biology at the European Molecular Biology Laboratory in Heidelberg, Germany, she studied journalism and went into science communication. Since 2008, she has been one of the editors of *Science in School*.

To learn how to use this code, see page 1.

© WEDC, Loughborough University

The first edition of the Water Module was created and tested in Kenya by Saskia Nowicki, Nancy Gladstone, Jacob Katuva, Heloise Greeff and Dr Achut Manandhar (University of Oxford), Geofrey Wekesa and Geofrey Mwania (Base Titanium Environmental Education Programme) with input from teachers and students at Kingwede Girls Secondary School, Shimba Hills Secondary School and Mivumoni Secondary School in Kwale County, Kenya and assistance from Calvince Wara, Fauzia Mumbua Swaleh and Willy Sasaka (Rural Focus Ltd.). It was reviewed and improved upon by Dr Georgina Jones (Base Titanium), Prof. Dan Olago (University of Nairobi), Prof. Bancy Mati and Prof. John Gathenya (Jomo Kenyatta University of Agriculture and Technology), Mike Thomas and Mike Lane (Rural Focus Ltd.), Dr Albert Folch and Nuria Ferrer Ramos (Universitat Politècnica de Catalunya), Prof. Rob Hope, Patrick Thomson and Dr Caitlin McElroy (University of Oxford).

In 2020-2021, it was revised for wider use by Saskia and Nancy with input from teachers from PCSS Mfou and Baptist High School in Yaoundé, Cameroon, Fred Njobati and Lucy Diffang (In Service Teacher Training Programme, Cameroon), Penny Fraser (Education and Training Africa), and Berinyuy Verye Marius (National Secretariat for Catholic Education (SENECA), Yaounde).

This resource was originally an output from the Gro for GooD project, an UPGro consortium project funded through the UK Government via NERC, ESRC and FCDO (formerly DFID) (Grant: NE/ M008894/1) with additional funding from an Inspiration Grant from the School of Geography and the Environment, University of Oxford and the University of Oxford’s ESRC Impact Acceleration Account. The information contained in it is not necessarily endorsed by the FCDO or the other institutions named above, which can accept no responsibility for such information or for any reliance placed upon them.