THE WATER MODULE

EDUCATOR GUIDE

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 (Forms 1 to 4). 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 resource. Whilst the Water Module was originally designed for use in after-school clubs, this resource covers many concepts and skills that will be relevant to formal education, particularly in chemistry, biology, geography and PSHE. Teachers are welcome 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.

You will need to have a copy of the student resource to refer to when you use this guide. The topics covered in the booklet are the following:

1: The Water Cycle (aka The Hydrological Cycle)
2: Geology – Understanding Rocks and Minerals
3: Groundwater – Water in the ground
4: Water Quality – Keeping water safe
5: Water Conservation – Saving water

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 how each session could be run, the order in which they could take place and have included a register to keep track of student progress through the module. That said, of course you are most welcome to use this material in any way you like and any order you like. You could select topics or activities that fit with your school's scheme of work and use them with classes at different levels. To facilitate school decisions over using this material, we have indicated how the Water Module sub-topics and activities relate to the new Kenyan curriculum, referring to the new Basic Education Curriculum framework of 2017, and have provided a list s of materials and equipment needed for each activity.

Items listed in further reading sections can be accessed through the Water Module website 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

9	Activity 2: Background reading on sedimentation	36-37, article	20 mins
9A	Source protection fieldwork / Arrange an expert talk		90-180 mins
10	Activity 1: Comparing methods to speed up sedimentation	40-41	60 mins
10	Activity 2: Investigate how turbidity is measured	42	30 mins
11	Activity 1: Engaging with the information: Filtration	37	15 mins
11	Activity 2: Engaging with the information: Disinfection	38	15 mins
11	Activity 3: Safe storage	39	15 mins
11	Activity 4: Water Quality crossword	45	15 mins
12-13	Activity 1: Different water disinfection methods		20 mins
	Activity 2: Solar still design challenge	42-44	90 – 120 mins
	5: Water Conservation - Saving water		
14	Activity 1: Engaging with the information – Water footprints	46-48	60-90 mins
15	Activity 1: Can a t-shirt have a footprint?	49-51	60 mins
16-19	Activity 1: Choose a research report to work on Follow-up: Presentations and poster reports	50-51; 47, 48	60-90 mins x 3 60-90 mins
	Our Vision for Water		
20 onwards	Activity 1: The big picture	52	20 mins
20 onwards	Activity 2: Sharing our vision for water	52	40 – 70 mins plus ongoing

<u>Session 1:</u> Why learn about water

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

Materials

Students must be able to see page 2 of Water Module booklet

Pens and paper; calculator

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: (Maths: Reading graphs) – 10 mins (p. 2 Student resource)

3. Ask the class to look at the graph on the left. Ask them to estimate by eye the percentage of Kenyan people who took their drinking water from surface water sources in 2000? Ask: "Did more or less people take their drinking water from surface water in 2015?" (The answer is less).
4. Ask the class to read the definitions of the 4 types of drinking water (surface, unimproved, limited, basic) 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 and BASIC categories are 'IMPROVED' drinking water sources – these are drinking water sources that have been constructed or treated so as to be protected from contamination with substances that could cause disease. Improved sources include piped water supplies to households, public taps or standpipes, boreholes with pumps, protected wells and springs and rainwater collection.
5. Ask the class: "Do the graphs show that access to **improved** drinking water got better or got worse between 2000 and 2015?"

Activity 3 (Maths: Percentages) – 5 mins (p. 2 Student resource)

6. Write the population figures below and this question on the board: **How many more million Kenyans had access to BASIC Improved drinking water in 2015 compared to 2000?** Get the class to agree estimated % for BASIC drinking water access in 2000 and 2015, write these on the board and use the figures to calculate the answer. Give them the method if required.

   Total population of Kenya in 2000 = 31.45 million
   Total population of Kenya in 2015 = 47.24 million (Source: World Bank)
   % with BASIC drinking water access in 2000 = _______________
   % with BASIC drinking water access in 2015 = _______________

Method:
Population of Kenya in 2015 (million) x % with basic drinking water access in 2015 ÷ 100 = ________(a)
Population of Kenya in 2000 (million) x % with basic drinking water access in 2000 ÷ 100 = ________(b)

(a) – (b) = change in number of Kenyans with access to BASIC improved drinking water between 2000 and 2015 = _______________ (million)

Activity 4 – Bingo reading (20 mins) (pp. 3-4 Student resource)

Materials

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

discharge	water scarcity	run-off
condensation	reservoir	drought
interflow	precipitation	consumptive use
evapotranspiration	vapour	hydrology
transpiration	hyporheic zone	

- 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.
- 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)
- Tell the class to listen while you read out some text and to listen out for the words on the pieces of paper. 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.
- Read out the text on pages 3 and 4 and be ready to award and record points. Applaud the winning group for close listening!

Activity 5 – Water Cycle Crossword (15 mins) (p. 15 Student resource or below)
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 (in booklet page 15 or handout below)
- Tell them to work on the crosswords using pencil
- To start, tell them the answer to clue 6 is "interflow" and tell them to check the definition matches that in the glossary
- 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)
- If necessary or if it is taking a long time, write additional clues below on the board or use the handout below to provide first letter of each word; the number of letters.

Activity 6. Preparation for next session – The Water Cycle (10 mins) (p. 6 Student resource)

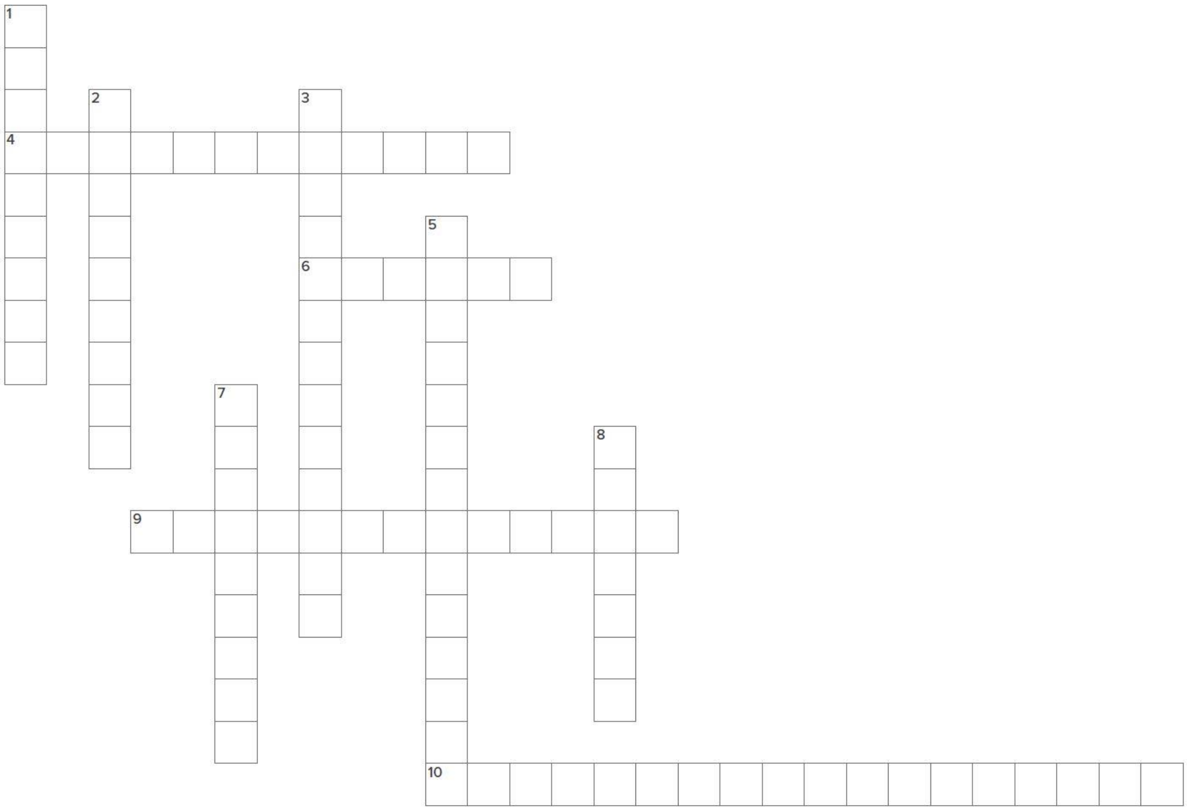
Materials

- Paper and pencil

Method

- Ask students to start making a list of the ways that people use water in your area during the rainy season
- If time, go round groups or individuals asking them to read out items from their list. Looking at the diagram of the water cycle including human activity on page 7, discuss whether the ways of using water on their list are included in the diagram.

Water Cycle Crossword



ACROSS: Clues for horizontal words

4 – The process by which vapour becomes a liquid often due to cooling (12 letters; first letter: c)

6 – Water that flows over land to surface streams, rivers and lakes and eventually to the ocean/sea (3 – 3 letters; first letter: r)

9 – Water falling out of the atmosphere in a liquid or solid state (13 letters; first letter: p)

10 – Movement of water vapour into the atmosphere due to both evaporation from soil and transpiration from plants (18 letters; first letter: e)

DOWN: Clues for vertical words

1 – Water flowing out; the opposite of recharge (9 letters; first letter: d)

2 – Water travelling horizontally through shallow ground during or soon after precipitation (Bonus clue answer: interflow)

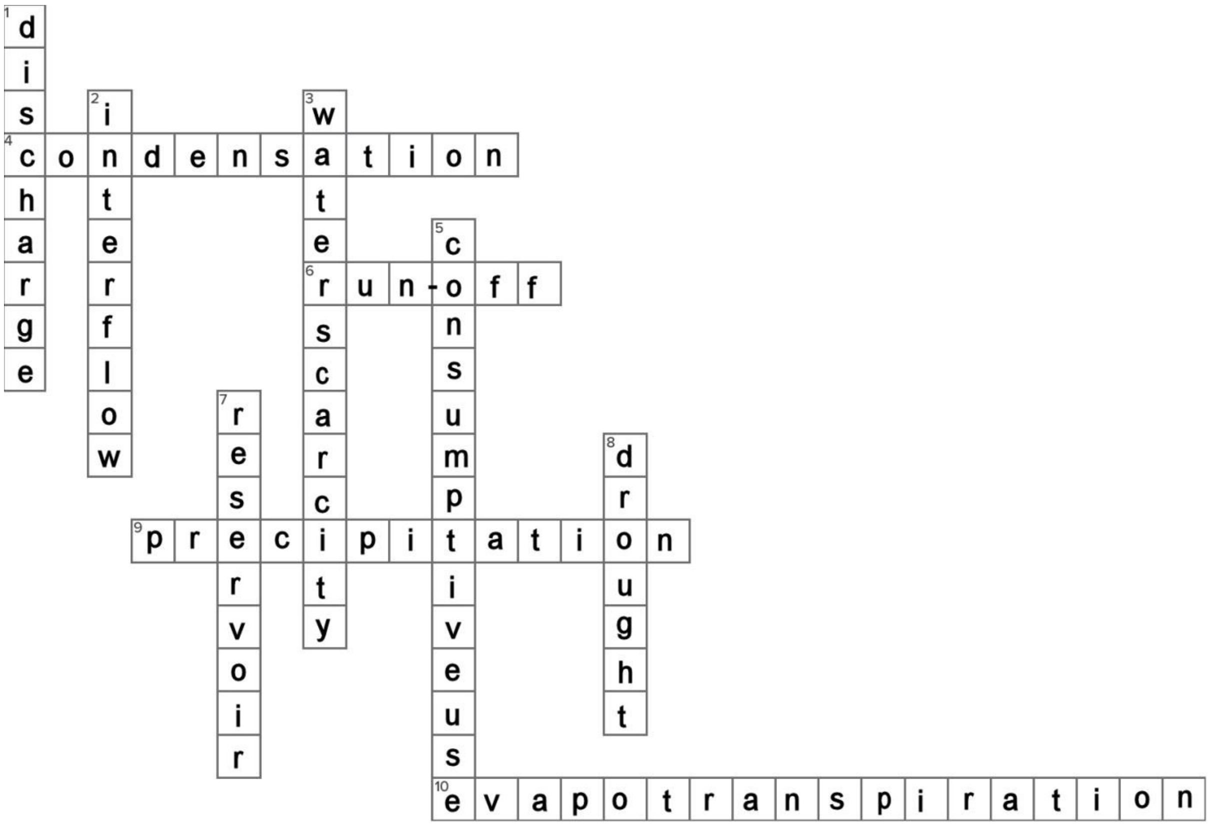
3 – When there is not enough water to satisfy the needs of people, animals and the environment in a region (5 letters, 8 letters (two words); first letters: w, s)

5 – Use of a resource that reduces the supply, such as removing water from a river, lake or aquifer without returning the same amount (11 letters, 3 letters (2 words); first letters: c, u)

7 – A body of water that forms behind a dam (9 letters; first letter: r)

8 – An extended period of less than normal precipitation that often affects availability of water supplies - a natural hazard caused by climate variability (7 letters; first letter: d)

Water Cycle Crossword Answers



<u>Session 2</u>: The Water Cycle Where I Live

Activity 1: Thinking about the water cycle (pp. 6-8 Student resource)

Materials

A4 Paper, A3 or A2 sheets of paper, pencils, pens, ruler, scissors

Diagram of the **Water Cycle including some human activity** (page 7 of booklet/poster)

This activity can be done individually or in groups of 2 – 4. If working in groups, pause at each * to get feedback from each group; if individually, ask students to turn to their neighbour and discuss. The aim of sharing at each stage is so that each group or individual can use what other people came up with to add to their lists and tables.

1. Instruct students to revisit or continue to prepare a list of ways people use water in your area (e.g. drinking, washing, livestock etc.)
2. Instruct students to look at the diagram of the water cycle including some human activity. Are the items on your first list included in the diagram? ***** Add any additional items to the list.
3. Instruct students to make a list of places where people in your area get water from.
4. Instruct students to look at the diagram of the water cycle including human activity. Are the items on your second list included in the diagram? ***** Add any additional items to the list.
5. Give out handouts copied from below/use the booklet/write on the board the following labels from the water cycle diagram on page 7. Ask students to look at each of the labels and circle those which show the ways in which water moves around the cycle. (Clue: You should circle 11 of them).

Condensation	Precipitation	Evapotranspiration	
Surface water flow	Hyporheic zone	Groundwater abstraction	
Saline groundwater	Melt-runoff	Evaporation	
Groundwater flow	Runoff	Dam	Reservoir
Infiltration	Borehole	Agricultural water use and runoff	
Industrial water use and disposal	Domestic water use and disposal		

Answer to (5) above.

Condensation	Precipitation	Evapotranspiration
Surface water flow	Hyporheic zone	Groundwater abstraction
Saline groundwater	Melt-runoff	Evaporation
Groundwater flow	Runoff	Dam Reservoir
Infiltration	Borehole	Agricultural water use and runoff
Industrial water use and disposal		Domestic water use and disposal

6. Ask students to copy out the table below and put 11 rows after the title row. Add each of your circled words to the first column on table, and then fill in the other columns.

As an example...

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
Groundwater abstraction	*Yes*	*Handpump that takes water from a borehole into the ground*
Domestic water use and disposal	Yes	*Water taken from river, thrown onto ground*
...*		

7. Do the 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 coloured pens or more paper to make arrows to show the flow of water around your diagram.

Discuss as a group: 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?

This activity was based on ideas from: Go with the Flow – Mapthink Toolkit series - http://www.takingspace.org/go-with-the-flow-investigate-your-water-system/

Preparation for the next session: If appropriate, ask students to help gather materials for the evapotranspiration practical.

Session 3: A small sip of hydrology (1)

Hands-on learning activity for Integrated Science Pathway

Activity 1: Evapotranspiration experiment (60 to 90 mins) (pp. 9-10 Student resource)

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 a few 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 an 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)
- Graph paper

Teacher's Notes

This activity was adapted with permission from: https://www.teachengineering.org/activities/view/usf_stormwater_lesson02_activity1 by Ryan Locicero, Maya Trotz, Krysta Porteus, Jennifer Butler, William Zeman, Brigith Soto © 2014 by Regents of the University of Colorado; original copyright 2013 University of South Florida, Water Awareness Research and Education (WARE) Research Experience for Teachers (RET), University of South Florida, Tampa, United States of America

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 does not travel through the plant and out 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 and plot data, determine transpiration rates and answer comprehension questions. To gauge comprehension, review their worksheet predictions, data, calculations, graph and answers.

Method

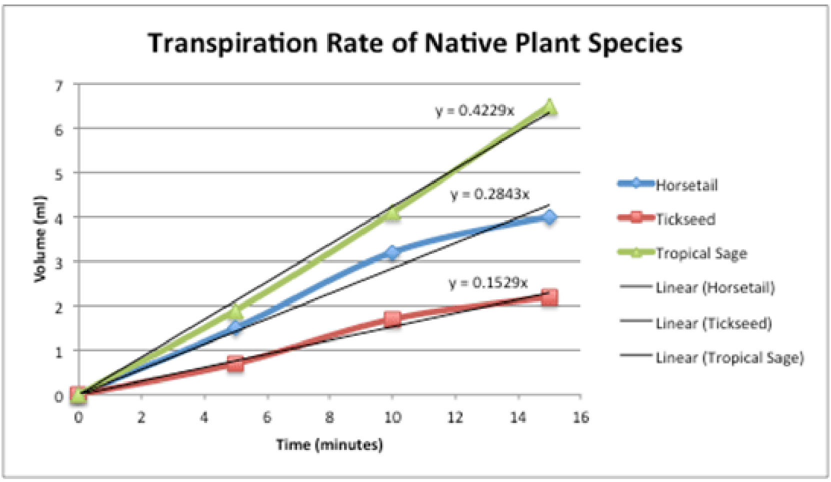
1. Get groups ready and set up with materials (a plant and a plastic bottle) and worksheets/instructions. This activity works best conducted outside on a sunny day.
2. Look again at the Water Cycle diagram on page 6 and explain that we are zooming in on the phase of the water cycle called Evapotranspiration. 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.
4. Ask students to fill in the first section of the worksheet answering the questions: "What do you predict that you will see accumulate on the bottle(/bag)?"; and filling in the section which asks them to predict the colour of water as it evaporates from the plant. If they need clarification, this means: "What colour will the water be as it evaporates from the plant and collects on the 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 the bottles after weighing to remove the water between each 5 minute trial.

Student instructions

- Use the food colouring to colour the water in the jug
- Water the plant with the coloured water. Record the weather and fill in your predictions.
- Weigh the cut bottle and record its weight to the nearest 0.1gram
- Place the bottle over the plant.
- Set the stopwatch or timer for 5 minutes
- When 5 minutes is up, carefully remove the bottle without letting any of the water inside it out.
- Weigh the cut bottle and record its weight below
- Put the bottle back and time again for 5 minutes (***after shaking to empty out the water***). Weigh again and record.
- Put the bottle back and time again for 5 minutes. Weigh again and record.

6. When everyone has finished recording results, ask students to use the table on the worksheet to work out the transpiration rate measured during each five minute period. Show students or get them to use weighing machine to discover that 1 ml weighs 1 g. Share the results and draw up a table on the board to allow calculation of the class average is for each plant species.
7. Tell students to plot their results on a graph, using cumulative amounts (given that the condensed water was emptied out every five minutes - i.e. plot the volume for trial 1 at 5 minutes, the volume for trial 1 + trial 2 at 10 mins; and for trial 1 + 2 + 3 at 15 minutes. Draw a line of best fit and determine the slope which corresponds to the evapotranspiration rate.

8. If other groups have conducted the same experiment using different species of plant, get the class to plot all their results on one graph using different colours for each plant species. 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. Discuss as a class: What was the colour of the water that condensed on the inside of the bottle and why? If you found a dead plant exactly the same size as your living plant, how would you design an experiment to measure evaporation and transpiration separately?



Example graph from experiment comparing evapotranspiration rates of different plant species
Source: **https://www.teachengineering.org/activities/view/usf_stormwater_lesson02_activity1**

Student Worksheet: Evapotranspiration

Time of Day ______________________ **Weather conditions** ____

Predictions

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

____

Predict the colour of water as it evaporates from the plant.

____

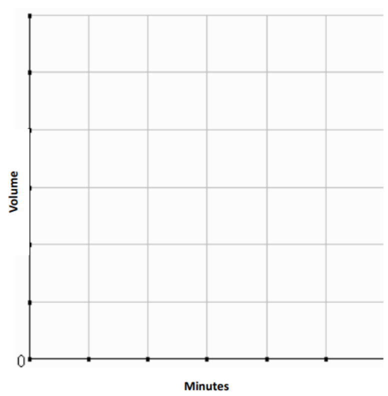
Results

<table>
<tr><td colspan="3">Plant ID # ________
Common name: Scientific name:</td></tr>
<tr><th>Time (minutes)</th><th>Weight (g)</th><th>Observations (What do you see?)</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

Determine the amount of transpiration:

<table>
<tr><td>Trial 1 weight</td><td></td><td>Trial 2 weight</td><td></td><td>Trial 3 weight</td><td></td></tr>
<tr><td colspan="2">minus</td><td colspan="2">minus</td><td colspan="2">minus</td></tr>
<tr><td>Initial weight</td><td></td><td>Initial weight</td><td></td><td>Initial weight</td><td></td></tr>
<tr><td colspan="2">equals</td><td colspan="2">equals</td><td colspan="2">equals</td></tr>
<tr><td>Trial 1 transpiration mass (g)</td><td></td><td>Trial 2 transpiration mass (g)</td><td></td><td>Trial 3 transpiration mass (g)</td><td></td></tr>
<tr><td>Trial 1 transpiration rate</td><td></td><td>Trial 2 transpiration rate</td><td></td><td>Trial 3 transpiration rate</td><td></td></tr>
<tr><td colspan="5">Average transpiration rate (1 g=1 ml)</td><td>ml/min</td></tr>
</table>

Graph



Plot the transpiration rate data as volume over time. The slope of the line is the evapotranspiration rate.

<u>Session 4</u>: A small sip of hydrology (2)

Hands-on learning activity for Integrated Science Pathway

Activity 1 – Collect your own rainfall data – 60-90 mins to set up (ongoing data collection and analysis in later sessions) (pp. 11-14 Student resource)

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).

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. 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). Tell students to read the information on page 11. Write these sums on the board and help them use the information to work out the answers.

How many litres of rain have fallen in one square metre if the height of rain was fifty millimetres? *[Answer: 50L]*

Estimate the area of your school roof. How many litres of rain have fallen on the school roof if the height of rain was two millimetres?

[Answer: Area of roof in m^2 x 2mm = amount you can collect in Litres (excluding evaporation)]

2. Discuss the following questions as a class:

Do you think 100 mm rain **in 24 hours** would be a shower or a heavy storm?

[Answer: This would be heavy rain though it depends on the rate at which is fell]

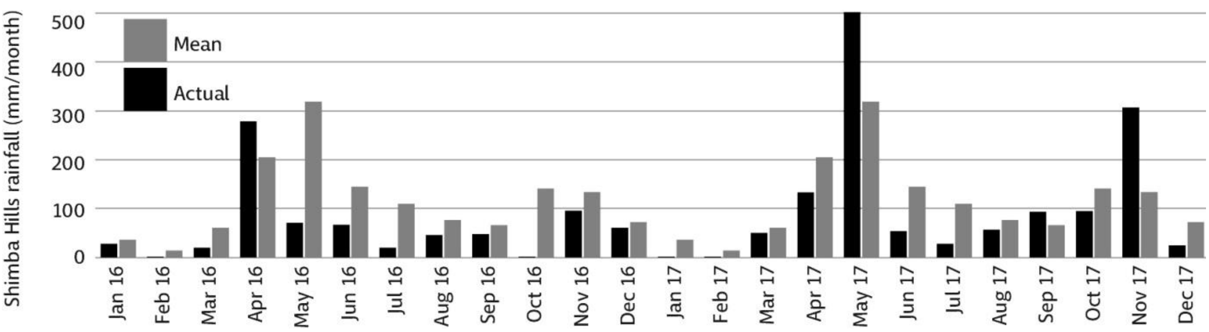
Slight rain:	Less than 0.5 mm per hour.
Moderate rain:	Greater than 0.5 mm per hour, but less than 4.0 mm per hour.
Heavy rain:	Greater than 4 mm per hour, but less than 8 mm per hour.
Very heavy rain:	Greater than 8 mm per hour.
Slight shower:	Less than 2 mm per hour.
Moderate shower:	Greater than 2 mm, but less than 10 mm per hour.
Heavy shower:	Greater than 10 mm per hour, but less than 50 mm per hour.
Violent shower:	Greater than 50 mm per hour.

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

How often does it rain where you live?

Does anyone collect rainwater from roofs?

Using the graph from Shimba Hills (in Kwale County, Kenya), which was the wettest month in 2016? Which month is usually the wettest? Do you think it is likely that Shimba Hills regularly receives more than 50mm rainfall a day? *[Answers: April, May, No]*



Data source: Base Titanium 2018

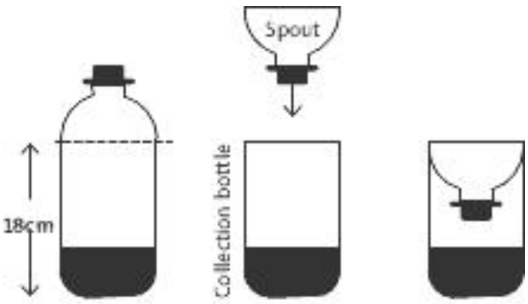
3. Construction of raingauge(s)

Tell students that we are going to make our own raingauge(s) to measure the volume of rainwater collected in a plastic bottle and use an equation to convert it into millimetres of precipitation.

Work in groups or if you are only making one raingauge, by selecting volunteers to do different stages.

- Remove cap and lid from bottle and rinse out with water.
- 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.
- 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. Preparation of data collection notebook

Select or seek volunteers for one student to prepare the data collection notebook for each gauge. Write the table headings on the board and give them the notebook and ask them to copy the table into the notebook.

Table to copy into data collection notebook

Time	Date	Volume (ml)	Precipitation (mm)

5. Practice converting measurements into precipitation (mm) for the final column of the data table

Referring to the instructions on page 14, ask everyone to practice converting volume of rain collected into a measurement of precipitation in mm by following steps to convert the volume collected into the height of precipitation in mm to fill in the final column of the table. Tell them to imagine they have just collected 10mm in the gauge and 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)

6. 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?

7. Set up the raingauge(s)

Tell students to read the information on page 13 and use it to suggest a good place for the raingauge(s) to be set up on the school grounds

- Away from any buildings or trees. If you estimate the height of any buildings or trees in the area, then the raingauge should be at least 2 and ideally 4 times that distance away from the obstruction.

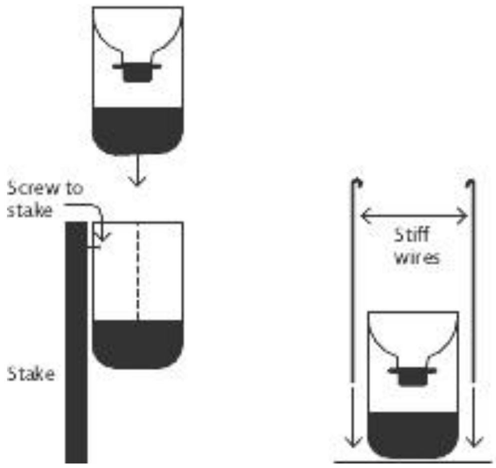
- Away from places where it will be disturbed by people or animals

- Fixing the raingauge 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. A raingauge fixed too high up would be likely to be affected by the wind.

Having chosen the site for your raingauge, fix it in place using the instructions on page 13, keeping the base horizontal.

- 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 raingauge. 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.

Add a small drop of non-toxic oil to the bottle to reduce evaporation.



Ways to fix raingauge

Return to the classroom or meeting place.

8. Work as a team to plan how to take regular measurements of precipitation using the raingauge(s)

Each day, ideally at the same time, the gauge or gauges should be visited to take a reading. This will involve removing the gauge and tapping the bottle to dislodge any droplets that have formed from evaporation on the inside bottle walls. The water from the raingauge is then poured into a measuring cylinder and the volume is recorded in millilitres. When you read your measurement, read along the bottom of the liquid surface and not the meniscus which will be slightly higher up where the water touches the edge of the cylinder. Empty the gauge after each measurement and add a small drop of oil.

Plan who will collect the rainfall data, at what time, and how often.

Extension into later sessions

Data collection should be repeated over a month or for as long as possible until you have built up your own rainfall dataset.

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?

<u>Session 5</u>: Geology – Understanding rocks

Activity 1: Engaging with the information (50 mins) (pp. 16-19 Student resource)

Materials: Access to be able to read through pages 16-19 in Water Module booklet; rock samples and/or additional photographs if possible; pens, A3 paper for presentations if you want

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)
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)
Tell the students they have 5 minutes to read through pages 16 and 17 of the booklet. They can start looking for the elements in page 18 if they finish early.

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 or a poster version in the class, 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

To introduce the information on page 19, 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	**Score out of ten for how clearly was the formation of the rock type communicated to the audience**	**Score out of ten for originality/creativity of the way in which the group explained the formation of the rock type**	**Score out of ten for how well was the whole group involved in giving the explanation**	**Total score (out of 30)**

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 round 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.

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 (perhaps some rocks?!)

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

Activity 2: Geology News (5 min intro) (p. 20 Student resource)
Note: This could be given as homework or added to another session

Ask student to read the Geology News article on page 20, noting that this is real information but from a pretend magazine. Ask them to consider: Would the rocks formed from the clay and sand carried by the rivers be classified as igneous, metamorphic or sedimentary?

Activity 3: Crossword (5 min intro for homework or another session) (p. 21 or print below)
Note: This could be given as homework or added to another session.

Materials

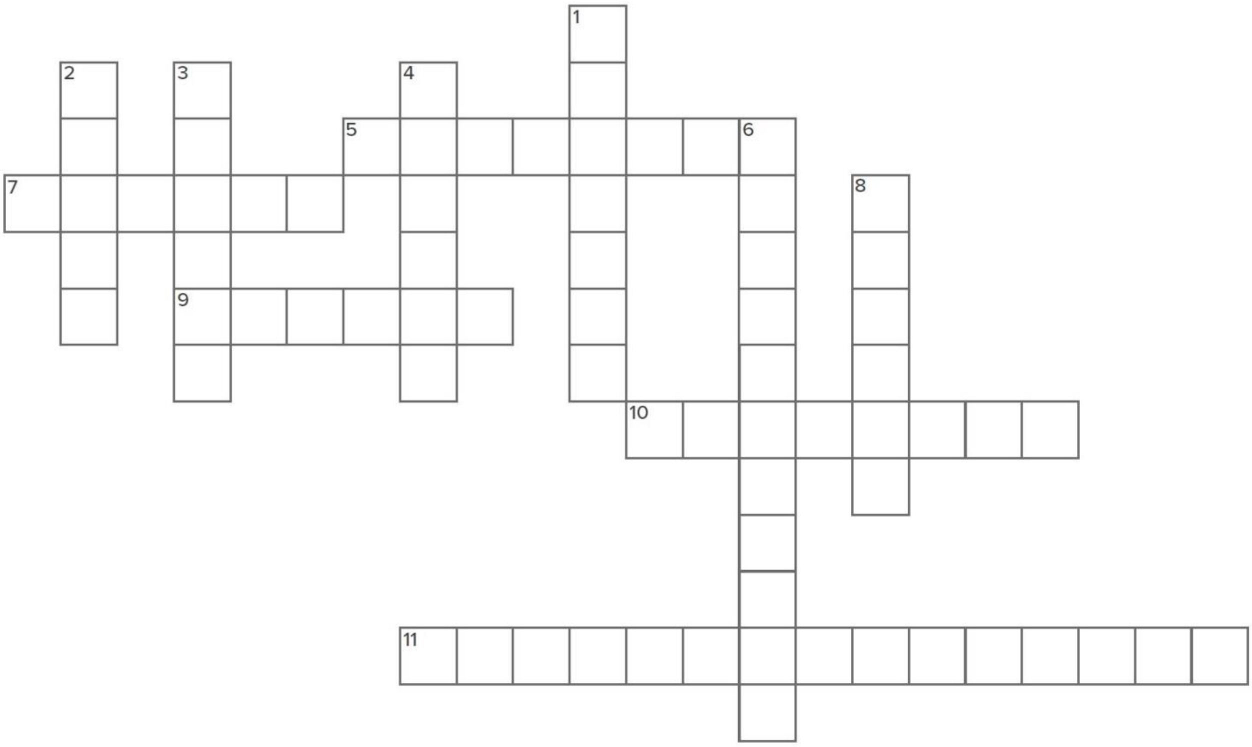
Enough copies of the crosswords for individuals, pairs or groups to fill in together and access to the text in Chapter 2 Geology, and the glossary in the Water Module booklet.

- Tell them to work on the crosswords using pencil reading back through the chapter to get the answers
- 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)

Optional homework/extra: Student involvement in preparation for experiments in next session

Ask students to find 1 litre plastic bottles and collect the sand, soil, different sized gravel for the experiment described in the next session.

Geology Crossword



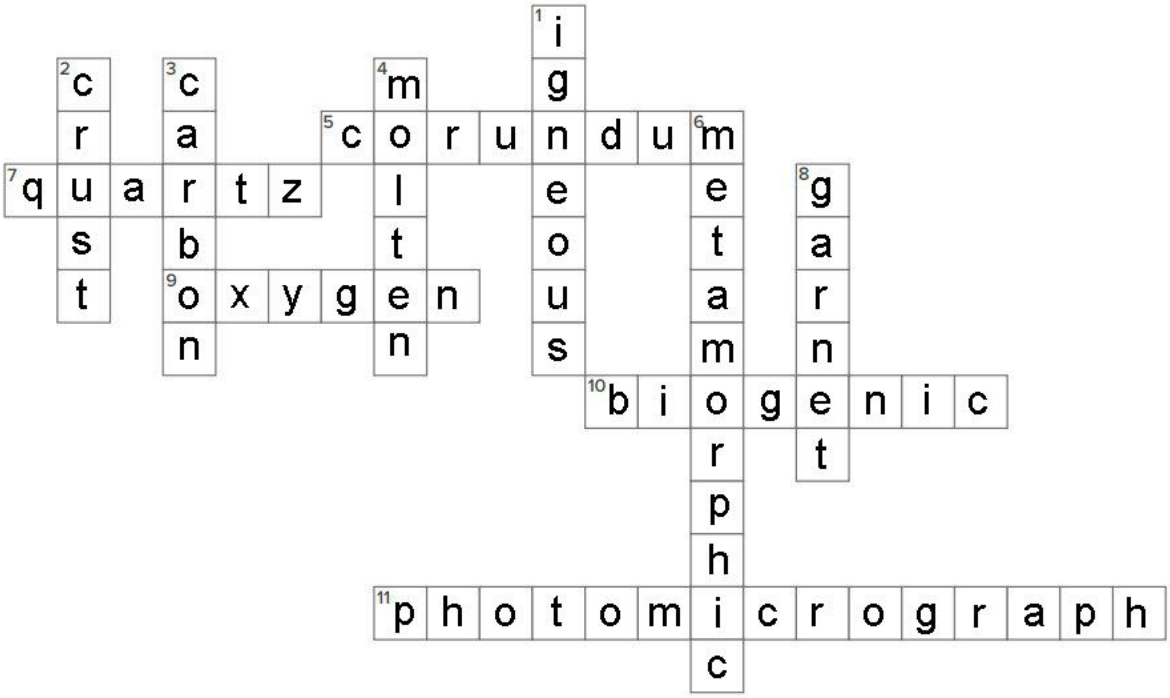
ACROSS: Clues for horizontal words:

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: Clues for vertical words:

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 in Kenya that is less valuable than ruby (6 letters; first letter: g)

Geology Crossword Answers



<u>Session 6</u>: Infiltration and Saturation Experiments

Activity 1: Infiltration Experiment (40 to 60 mins) (pp. 23; 29-30 Student resource)

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.

Materials:

Each group will need:

- A worksheet to fill in (page 30 in Water Module 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 23 in Water Module Booklet
- 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)

Each group could work independently with 4 bottles and 4 different 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.

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

Introduction:

Ask students to think about the following questions: If you dig into the ground where you live, what do you find? Soil? Sand? Pieces of gravel? Rock? Does this vary depending on exactly where you dig?

Read out or give students 5 minutes to read the sections about permeability and porosity section on page 23 of the student resource.

Tell students that they will be experimenting with different materials to compare their permeability and porosity. Tell them to follow the instructions on page 29 in the Water Module 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 nec.).

Method

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.
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.
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).

Activity 2: Saturation Experiment (20 to 50 mins) (pp. 22, 31 Student resource)

If this is completed within the session, continue to the saturation experiment (worksheet below). 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 22.

Optional extension/development: You could add a clay or other impermeable layer in the bottles or further develop this experiment to model how groundwater and pollutants travel through different layers within a subsurface aquifer as described on this webpage:
https://kingwedemaji.wordpress.com/2017/07/17/all-about-aquifers/

Infiltration Experiment Worksheet

Draw a picture or diagram to show how the experiment is set up:

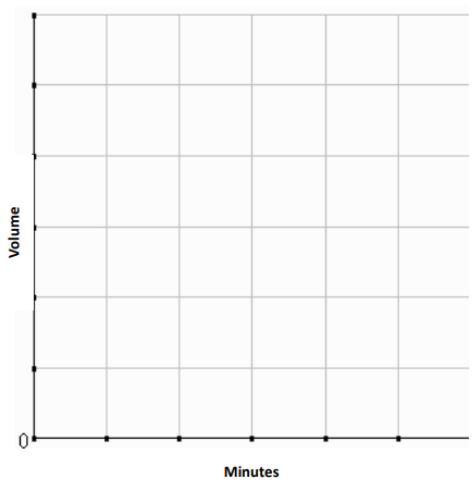
Make a prediction: Which material do you think will have the fastest infiltration rate and why?

____

____

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?

____

____

Saturation Experiment Worksheet

After 30 minutes put the lids back on each of the bottles. Had all 250 ml 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?

	Soil	Sand	Gravel
Volume left in bottle after 30 mins (ml) [A] (250 ml minus volume recorded in previous table)			
Volume poured into the bottle before it cannot hold any more (ml) [B] (1000 ml 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 LARGE GRAVEL SMALL GRAVEL SAND

Most porous

Most permeable

Least porous

Least permeable

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

<u>Session 7</u>: Finding out about groundwater

*****Practising critical thinking*****

Activity 1: How do scientists study groundwater? (30 mins) (pp. 20, 26, 25 Student resource)

Materials:

- Pencils and Paper
- Access to reading on pages 20 and 26 of Water Module Booklet or printed handout below

Ask students to get into small groups and read the article on pages 20 and 26 of the Water Module booklet. Write these questions on the board and give groups 5 minutes to discuss before leading class discussion with contributions from each group.

1. What methods did the geologists use to find out about the geological structures and rock types of Kwale County?
2. How is groundwater stored in rocks?
3. How is the groundwater stored in the palaeochannels being accessed?
4. If you had the opportunity to meet one of the geologists involved in this research, what would you ask?

Write the questions suggested in (4) on the board. Assign different groups the following readings and give them another 5 minutes to see whether these readings help answer their questions:

- page 25 and 26 (How is groundwater detected and assessed?)
- page 22 (How does water get into the ground?)
- page 24 (What is an aquifer?)

Revisit the questions on the board – What additional answers can the different groups suggest following the reading? What questions remain? How could the remaining questions be researched?

Activity 2: How do people access groundwater? (5-10 mins) (Chapter 3 Student Resource)

Swap groups around if need be. Ask students flick through the Water Module section 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). 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. If a field trip is planned (see 7A below), talk about it with the students and tell them what they need to prepare.

Activity 3: Sustainable use of groundwater (10 mins) (p. 28 Student resource)

Materials:

Water Module booklet page 28 and glossary

Ask a student to read the definition of "sustainable" from the glossary of the Water Module booklet. Ask them to discuss in groups: Do you think this word "sustainable" can relate to groundwater use? Can groundwater be used sustainably?

Following any discussion, explain that there is ancient groundwater beneath the Sahara Desert in North Africa from a million years ago when more rain fell there. Tell students to look at the pictures on page 28 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).

Write on the board:

Rate of recharge (rainfall and runoff) into Sahara Desert aquifer = $\boxed{}$ km^3 per year

Rate of abstraction out of Sahara Desert aquifer = $\boxed{}$ km^3 per year

Ask students to read the large paragraph on page 28 and to put their hands up when they have the numbers to fill in the boxes on the board.

When these 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:

- Do these figures suggest that the groundwater in the aquifer under the Sahara Desert is being used sustainably?
- Why was the groundwater in this area called fossil water?
- What is it being used for?
- What do you think should be done by the people and governments of the North African countries involved?

Activity 4: Crossword (10 mins and homework/optional) (p. 32 Student resource)

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 Water Module booklet.

- Tell them to work on the crosswords using pencil

- To start, tell them the answer to clue 6 Across is "paleowater" and the last clue across (12) is "seepage" and tell them to check the definitions match those in the glossary – explain that that scientists from the UK spell "paleo" as "palaeo" as in the glossary – you could use this to discuss whether they know of any other examples of English language words that are spelt differently in different countries.

- Get them to do the rest of the crossword or complete as homework – they will need to re-read the chapter to find all the words. If necessary or preferred, write additional clues below on the board or provide the clues below – e.g. first letter of each word; the number of letters

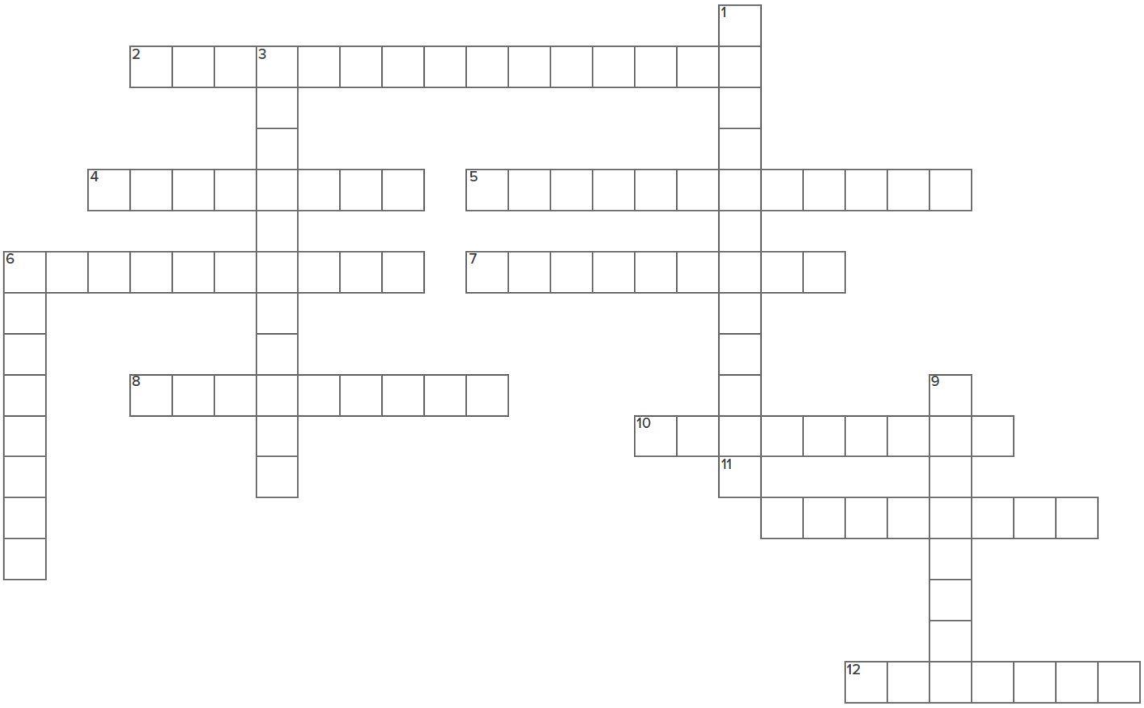
Session 7A: Optional extra session for field visit (1 - 3 hours)

If there are safe-to-visit boreholes, wells or handpumps accessing groundwater 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?

Groundwater crossword



ACROSS: Clues for horizontal words

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 separation in a rock that divides it into two or more pieces (8 letters; first letter: f)

5 The study of groundwater and the 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: Clues for vertical words

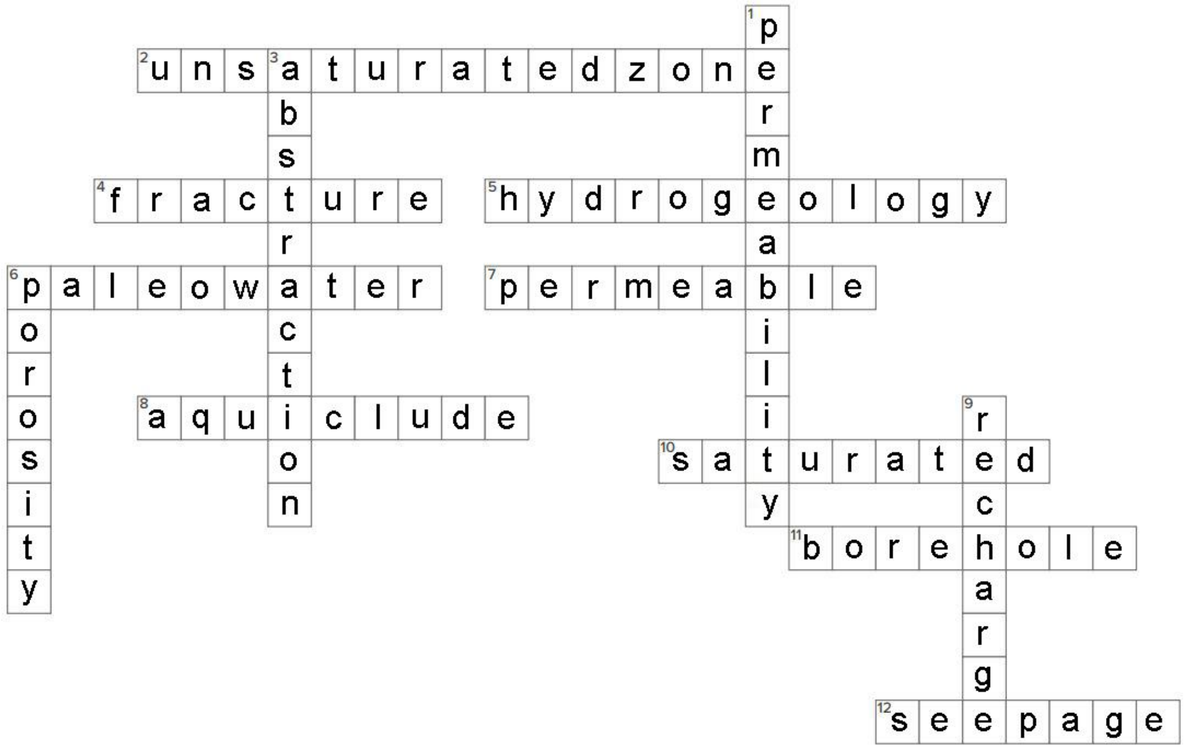
1 A measure of the connectivity of void spaces in the ground (12 letters; first letter: p)

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)

Groundwater Crossword – Answer Sheet



Geology News Article (pages 20 and 26)

GEOLOGISTS MAP ANCIENT RIVERBEDS IN KWALE COUNTY

Geological study of Kenya reveals new groundwater resources

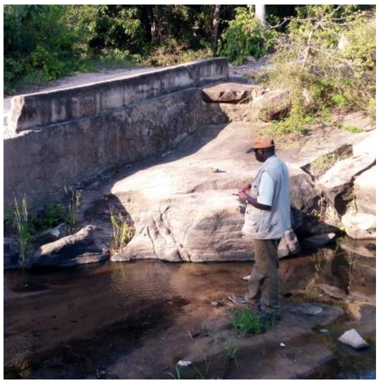
Millions of years ago, a network of rivers and their tributaries flowed across the land that is now known as Kwale County, Kenya. The water in the rivers carried particles of clay and sand washed down as eroded materials from the hills and mountains. As the rivers came closer to the ocean the land became less steep and the water spread out and slowed down. Near the coast the water flowed slowly enough for the clay and sand in the river water to settle, sinking down to rest onthe bottom of the river, layer upon layer, year after year. These coastal rivers flowed for millions of years, but about 5 million years ago sea level increased and the coastal plain with its river channels was buried by more sediments, including rubble from the coral reefs which fringed the coast. As sea level fell again, gradually the landscape came to look as it does today.

How did geologists figure out what took place on the coast of Kenya over the course of millions of years?

By studying the rock beneath the ground, geologists are able to piece together the processes by which the rocks and landforms of an area were formed. In 2017, geologists from the University of Nairobi used a variety of techniques to map some of Kwale County's ancient riverbeds, giving us more information on their evolution in the distant past. Their findings are very interesting and lead on to many more questions: For example, what did these rivers look like?

What creatures lived in and around them? More importantly perhaps, this new geological research may have practical significance for the county…

The geologists working in Kwale County used geophysical methods, fieldwork mapping of rocks, and studies of rock samples from boreholes drilled into the ground to build up a picture of the geological structures and rock types which lie beneath Kwale County and find out where groundwater is stored.



Many of the sandstone and coral rock formations found in the area are great sources of groundwater, supplying thousands of people for their daily needs. However, surveys suggest that the ancient river-beds located by the University of Nairobi geologists have the potential to form another useful groundwater resource. The ancient sediments found in the palaeochannels (palaeo = ancient) store groundwater in their interconnected pores – small spaces between the particles forming the rocks.

Boreholes drilled into the channels are providing a new source of water for people, industry and agriculture in the county.

<u>Session 8</u>: Water Quality – Source protection

Activity 1. Source Protection Quiz (20 mins) (p. 34 Student resource)

Materials: Access to reading on pages 34 to 36 of the Water Module booklet

Read the information as a group and then read out the quiz questions. Each person writes their answers on a sheet of paper. Alternatively, give everyone 5 minutes to read from (1) Source protection to half way down page 35 (before the heading "Protecting groundwater from pollution") and then tell them to turn over their paper. Mark each other's answer sheets as you read out the right answer. Ask people who got the right answer to point out which sentence in the text gave them the answer.

If you needed to collect water near to where people are washing clothes should you go upstream or downstream to collect the water?

A. Upstream | B. Downstream | (ANSWER: A. UPSTREAM)

Pollution that got into groundwater down a well or borehole has travelled along:

A. an aquifer pathway | B. a localised pathway | (ANSWER B: A LOCALISED PATHWAY)

Which is usually cleaner? Groundwater or surface water?

A. Groundwater | B. Surface water | (ANSWER: A. GROUNDWATER)

If the ground above an aquifer is permeable, pollution is:

A. More likely | B. Less likely | (ANSWER: A. MORE LIKELY)

Activity 2. Teaching groundwater protection (40 mins) (pp. 35-36 Student resource)

Materials: Access to information on page 35: Protecting groundwater from pollution

Imagine you want to teach ways to protect groundwater from pollution to someone who cannot read. Draw simple pictures or pairs of pictures to communicate each of the 8 steps that a community could take.

Session 9: Water Quality – Source protection

Activity 1: Protecting a water source (40 mins) (p. 40 Student resource)

1. Ask the whole group to identify a water source used by people near school.
2. Arrange students into small groups.
3. Ask each group to make a list of all possible ways that this water source may be at risk of pollution.
4. Get groups to feedback one item and write up the ideas on the board. Discuss what category of pollution the items fall into – e.g. biological like bacteria from human or livestock faeces; or chemical caused by improper use or disposal of pesticides
5. Ask each group to make a list of all possible ways the water source can be protected from the pollution risks noted.
6. Get each group to feedback one item and write up ideas on the board, until there are no more items to add
7. Go through the list of actions and discuss the questions 1) 'What are some of the challenges you would face if you tried to put this idea into action to protect the water source?' 2) Who should be informed of problems with wells or handpumps?

Activity 2: Background reading on sedimentation (20 mins and homework)

Materials: Page 36-37 of water module booklet; Moringa article from Science in School website

Ask students to read the section on sedimentation on page 36 and 37 of water module 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 9A (Optional): EXTENSION IDEAS

If feasible in your area, source protection 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, if there is a sanitation expert or toilet construction project in your area, you could arrange for them to give a talk to students about design and siting of latrines.

Session 10: Sedimentation practical

Activity 1: Comparing methods to speed up sedimentation (60-90 mins) (p. 40-41 Student resource)

Materials:

- 2 litre sample of murky water from a muddy place or a water sample made by mixing dirt and water
- 3 x 2 plastic bottles cut in half
- 1 tablespoon of Alum (potassium aluminium sulfate)
- Small pestle and mortar
- Moringa seed (1 seed per litre of water; choose good quality seed)
- 2 x tablespoon
- 3 x metal spoon or stirrer
- Funnel
- Timer/Clock
- Instructions (page 40 of booklet) / Student observation sheet

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

Introduction: 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.

Tell students to get their materials ready, follow the method and record their observations on the student observation sheet.

Method

1. Grind moringa seed into a powder

2. Put lid on original water sample and shake it

3. Use a funnel to pour the same amount of water into each bottle

4. Add ground moringa seed to one bottle and a tablespoon of alum powder to another; Stir all three bottles for 5 minutes.

5. Record your observations of the appearance of each bottle at the start, and then at 5 minute intervals.

Student observations

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. 42 Student resource)

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.

Materials:

• A flashlight
• Four flat-bottomed drinking glass
• Samples of 1) unfiltered water (the original untreated water), 2) water after sedimentation with alum, 3) water after sedimentation with moringa, and 4) bottled drinking water (ie. clear)

Method

1. Pour equal volumes of unfiltered, treated and bottled drinking water into the flat-bottomed transparent drinking glasses.
2. Move the glasses of water into a dark room and place them on a flat surface.
3. Place the flashlight against the side of each container and shine a beam of light through each of the samples. Look at the path of the flashlight beam.
4. How does the path of the flashlight beam through the different water samples?
5 Now pour half of the unfiltered water out and replace it with the clear bottled drinking 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 the filtered water and the bottled water?

Discussion:

Why does the path of the flashlight tell us anything about the turbidity?

Ask students to read the explanation on page 42 and then answer the question, 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 = Greek for cloud; Metric = Greek for measure)

Safety glasses should be worn at all times 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.

<u>Session 11:</u> Filtration, Disinfection and Safe Storage

Activity 1: Engaging with the information: Filtration (15 mins) (p. 37 Student booklet)

If possible, obtain or visit a water filter to show students.

Get students into groups. Ask the students to read section 3 on page 37 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.

Number the definitions and read them out in order twice, telling students to note the number of the definition which they prefer.

Get students to cast votes for the definition they prefer.

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?

Ask the students to use what they have learnt to explain the word filtration to a child of 7 years old.

Activity 2: Engaging with the information: Disinfection (15 mins) (p. 33, 38, 55 Student resource)

Write the word PATHOGEN on the board. Ask students to find this word in the booklet on page 33, 38 and 55 and use the information to answer the following questions:

1. What is a pathogen?

2. How might pathogens get into drinking water?

3. How can you kill pathogens in drinking water?

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.

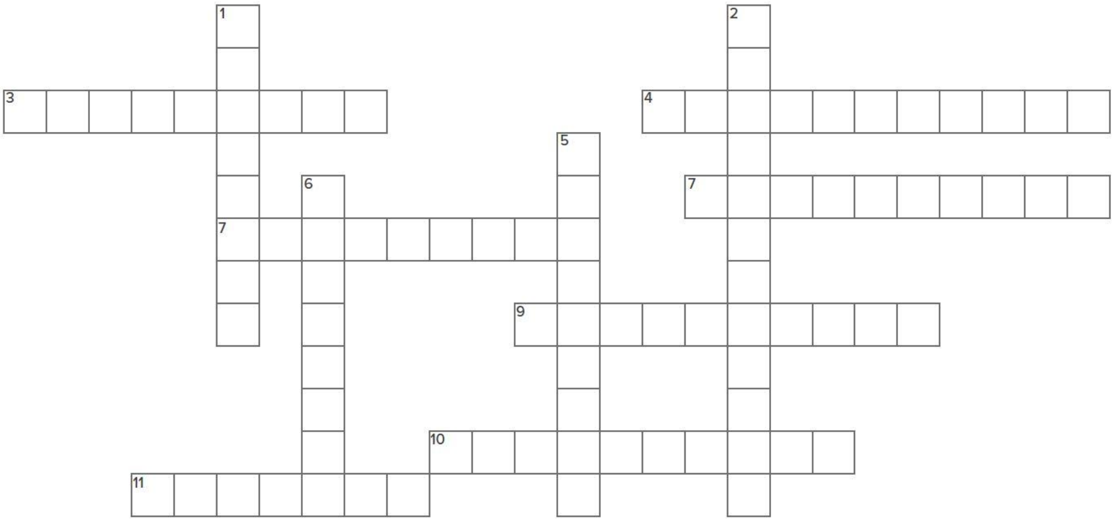
Activity 3: Safe storage (15 mins) (p. 39 Student resource)

Discuss: Why do you think that the booklet says that the most important thing is to keep your hands out of stored clean water?

Choose one of these as a group or individual activity, or give the choice to the students:

- Choose one or more of the points about safe water storage and design a poster to share the message
- Draw a design for a storage container that could protect treated water from pollution

Activity 4. Water Quality Crossword (15 mins) (p. 45 Student resource)



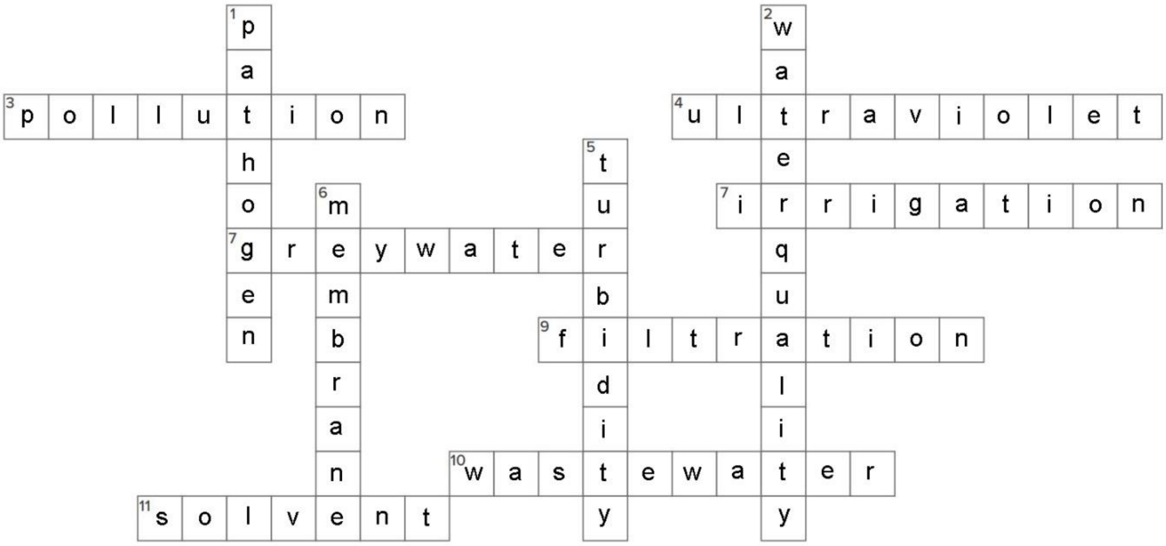
ACROSS – Clues for horizontal words:

3. Changing the physical, chemical or biological properties of water by introducing any substance that makes the water harmful to use
4. Radiation that comes from the sun and has a wavelength shorter than visible light
7. Controlled application of water to agricultural fields (Hint: look back to the end of section 3)
8. Wastewater from household use
9. The action of passing water through a device / material to remove unwanted substances
10. Water that contains unwanted materials from homes, businesses and industries
11. Something that can dissolve other substances

DOWN – Clues for vertical words:

1. A biological organism (often bacteria or viruses) that causes disease
2. The chemical, physical and biological characteristics of water with respect to its suitability for a particular use
5. A measure of the cloudiness/haziness of water due to suspended particles
6. A flexible sheet-like material that acts as a boundary so that some substances are blocked from moving through it

Water quality crossword answers



Session 12 and 13: Solar still design project

Activity 1: Different water disinfection methods (20 mins) (Student resource p. 38)

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)

Following any demonstration or videos, tell students to use the information on page 38 to produce a table of advantages and disadvantages for each method that is described in the book. 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)* (pp. 42-44 Student resource)

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.

Hints for making the solar still work well Part A:

- 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.

Arranging the design challenge Part B:

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 % 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

How the Still Works

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.

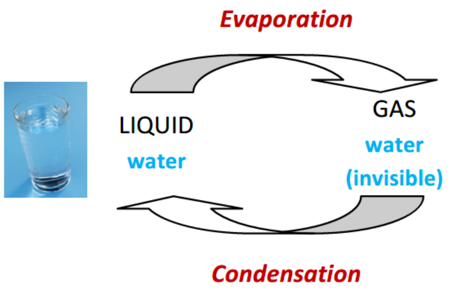
A deeper level of explanation is available if the students have been introduced to the particle nature of matter and the concept of energy:

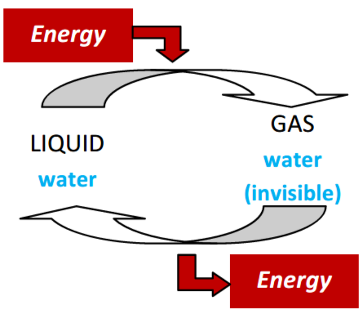
The sunlight entering the still is absorbed by the water and the container. The result is that the molecules and ions absorb the energy. Some of the water molecules absorb enough energy to break free from the liquid water and become gaseous molecules flying about inside the container. Some of these flying 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

Solar Still Design Challenge - Student Instructions

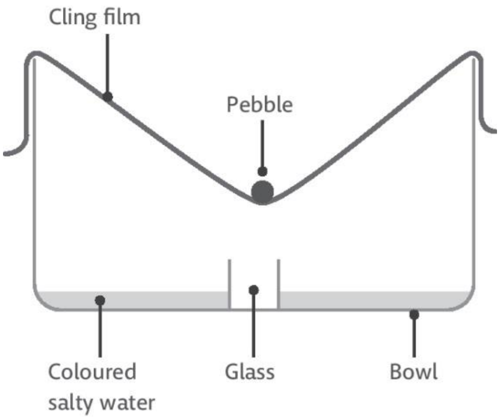
In this activity you will build a solar still and find out how it can purify water. You will be challenged to use your knowledge to build a more efficient solar still.

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)
- 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.
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:

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

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.

13. 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.
14. Discuss your ideas with your teacher and get his/her permission to carry out the experiment.
15. Carry out the experiment recording the volume of water you start with and the volume you purify.
16. Calculate the % water purified and record it on the Results Table.
17. If you have time, you can develop your design further. Make sure you get permission from your teacher for each experiment you carry out.
18. Draw a diagram of your most efficient still showing why it is more efficient than your first still.

Solar Still Design Challenge – Student Result Sheet

Copy this results sheet into your notebook or use one provided by your teacher.

Trial	Volume of water added	Volume of water collected	% water purified
Part A – First still			

Part A:

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

Part B:

2. Write down one way in which you could make your still work better.

3. 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.

4. Try the new still and record results in the table.

Trial	Volume of water added (ml)	Volume of water collected (ml)	% water purified
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.

Sample 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

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

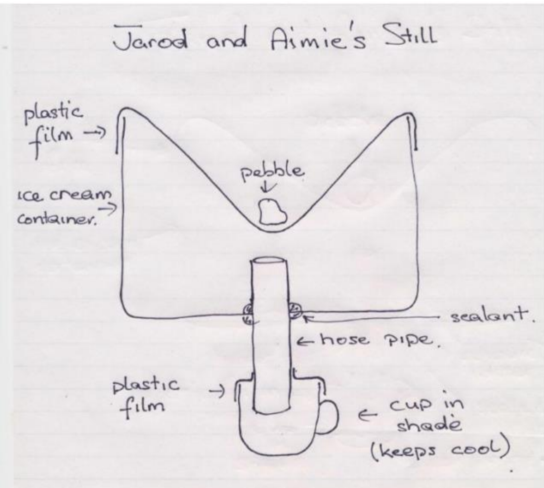
The still works by letting the Sun's rays warm the water. Some of the water goes into the air but you can't see it because it is gas not liquid. The water turns back into liquid when it touches the plastic and you can see the drops turn down to the pebble and fall into the cup.

1. 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.

Part B

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.

2. Draw a diagram to show how your new still works.

We used two chairs and put the still on them with the pipe between the chairs. We put the cup on a pile of books.

<u>Session 14</u>: Water Conservation – Saving water

Activity 1: Engaging with the information – Water Footprints *(60 – 90 mins)* (p. 46-48 Student resource)

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 worked out 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, but of course this average figure does not reflect different levels of water use by people across the country.

Ask a student to read the first paragraph of chapter 5 on page 46 of the Water Module. Ask other students to read out the definitions of BLUE, GREEN AND WASTE water which contribute to making up the water footprint. Turn back to the Water Cycle diagram on page 7 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 BLUE water might come from and go to and to think how it might be measured. Repeat the question for the GREEN water, and the WASTE water.

Read the second paragraph on page 46 and ask students to choose one of the question below to discuss in pairs and then ask for students to feed back to the class.

What are some possible reasons why the global average water footprint is bigger than the average footprint for a Kenyan citizen?

Within Kenya, how do you think the water footprint of a person living in Nairobi would compare to the water footprint of a person living in a small village? How do you think it would compare with your own footprint? What would be some reasons for the differences?

Is a big water footprint good or bad? Why?

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: **<u>A video about the cotton industry</u>**

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. <u>Read the questions below</u>. 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.) ____

If you need to see if again to hear the answer, ask to watch 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.

Circle the right word, (a), (b) or (c): When extra water is needed, the popular solution is precision (a) pipes, (b) irrigation, OR (c) potatoes.

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.

C) 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)
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.

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

<u>Session 15</u>: Water Conservation in the Cotton Industry

Activity 1: Can a t-shirt have a footprint? *(60 mins)* (pp. 49 – 51 Student resource)
This activity is on page 50 of the Water Module booklet. Additional optional activities are suggested above.

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***". "Blue " and "Green" water (see diagram on page 46) 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. All these elements can be put together to estimate the total water footprint of a t-shirt.

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.

Where was it made? (Check the label)

Country	Water footprint to produce 1 kilogram (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)

How much does the t-shirt weigh (in kg)? ________________________________
[Remember 1 kilogram = 1,000 grams]

What is the water footprint of the t-shirt?

____________________________in L per kg **X** ________________in kg **=** _____________________in L
(water footprint of cotton) (T-shirt weight) (water footprint of t-shirt)

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

The cost of cotton in water-challenged India

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.

<u>Sessions 16-19</u>: Research reports

Activity 1: Research projects *(3 x 60 – 90 mins)* (pp. 50 – 51, 47, 48 Student resource)

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 47 and 48 of the water module booklet. Students may require more assistance with the third project as it would be useful they could access to further reading material or an opportunity to speak to people with agricultural or horticultural knowledge would be needed. 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. Invite other teachers and community members to the final session to see the results of the work.

1. RESEARCH REPORT: 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.

2. RESEARCH REPORT: Greywater system design

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?

3. RESEARCH REPORT: Conservation Agriculture

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

The projects above would work with access to pages 47 and 48 in the Water Module 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 prepared to talk to students or answer written questions.

Additional sources of information:

Greywater (RESEARCH REPORT 2)

Case study of SuSanA projects; Greywater tower, Arba Minch; Ethiopia; Wudneh Ayele Shewa (ROSA project), Bogale, SuSanA 2010. www.susana.org/_resources/documents/default/2- 90-en-susana-cs-ethiopia-arba-minch-greywater-tower-2010.pdf

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

Mogaka Alphas Ombese, 2008. Design of an improved grey water recycling system, Department of Environmental and Biosystems Engineering, University of Nairobi. http://ebe.uonbi.ac.ke/sites/default/files/cae/engineering/ebe/FINAL%20PROJECT%20Alphas.pdf

Rand Water in conjunction with Eliza van Staden (UNISA); greywater guidelines for home gardens in Gauteng, South Africa, RAND Waterwise. 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. www.sustainabilityxchange.info/filesagri/Technical_Manual-_Soil_and_Water_Conservation_0.pdf

Practical composting; mulching – PACE Action Sheets based on VSO Agricultural Science Teacher's Handbook by Peter Taylor, and the Garden Organic Tropical Advisory Service. www.paceproject.net/soil

Drought tolerant varieties: Are drought-resistant crops in Africa the tech fix they're cracked up to be? Newspaper article by Oliver Balch. www.theguardian.com/sustainablebusiness/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 onwards: Our vision for water

Activity 1: The big picture *(20 mins)* (p. 52 Student resource)

Get students into pairs or small groups. Write the questions below on the board or refer to page 52 of the Water Module. Each pair to select and discuss two questions.

Discussion points

- 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?
- What do you think everyone should know about water?
- What are the best ways to share important messages about water?

Activity 2: Sharing our vision *(40 – 70 mins plus ongoing)* (p. 52 Student resource)

Focus on the final two questions above for a class discussion.

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.

How the Water Module links to Kenya's Basic Education Curriculum Framework (TBC)

As Kenya is a water scarce country, the topic of water could be said to be a key **pertinent and contemporary issue** of relevance to the Basic Education 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. Improved water and sanitation is also a key section in the Social Pillar of Kenya's Vision 2030 Development Strategy. The topic of water is therefore critical to **Education for Sustainable Development** (ESD) and practical activities suggested in this booklet could help students develop knowledge and skills relevant to learning outcomes 7 and 8 for senior school: **(Protect, preserve and improve the environment for sustainability / Demonstrate active local and global citizenship for harmonious co-existence).** Most 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. Further ways in which this module can be mapped to the BECF can be found in the table below:

	Activities suggested in this module relating to	Social studies Pathway	Integrated science Pathway	Maths applicable to real life situations	Core competency: Critical thinking and problem solving	Hands-on Learning Activities
	Section/Activity Title					
	Why learn about water					
1	Activity 1: The Sustainable Development Goals for Water	x			x	
1	Activity 2: (Maths: Reading graphs)			x		
1	Activity 3 (Maths: Percentages)			x		
	1: The Water Cycle					
1	Activity 4 – Bingo reading					
1	Activity 5 – Water Cycle Crossword					
1	Activity 6 - The Water Cycle where I live (prep)	x	x		x	
2	Activity 1: Thinking about the water cycle	x	x		x	
3	Activity 1: Evapotranspiration experiment		x	x	x	x
4	Activity 1: Collect your own rainfall data		x	x	x	x
	2: Geology – Understanding rocks and minerals					
5	Activity 1: Engaging with the information		x			
5	Activity 2: Geology News				x	
5	Activity 3: Crossword					

	Activities suggested in this module relating to:	Social studies Pathway	Integrated science Pathway	Maths applicable to real life situations	Core competency: Critical thinking and problem solving	Hands-on Learning Activities
6	Activity 1: Infiltration Experiment		x	x		x
6	Activity 2: Saturation Experiment		x	x		x
7	Activity 1: How do scientists study groundwater?				x	
7	Activity 2: How do people access groundwater?				x	
7	Activity 3: Sustainable use of groundwater	x	x	x	x	
7	Activity 4: Crossword					
7A	Groundwater where I live/optional	x	x		x	x
	4: Water Quality - Keeping water safe					
8	Activity 1: Source protection quiz					
8	Activity 2: Teaching groundwater protection				x	x
9	Activity 1: Protecting a water source				x	
9	Activity 2: Background reading on sedimentation					
9A	Source protection fieldwork / Arrange an expert talk	x	x		x	x
10	Activity 1: Comparing methods to speed up sedimentation		x	x		x
10	Activity 2: Investigate how turbidity is measured		x			x
11	Activity 1: Engaging with the information: Filtration		x		x	
11	Activity 2: Engaging with the information: Disinfection		x			
11	Activity 3: Safe storage				x	x
11	Activity 4: Water Quality crossword					
12-13	Activity: Solar still design challenge		x		x	x
	5: Water Conservation - Saving water					
14	Activity 1: Engaging with the information: Water footprints				x	
15	Activity 1: Can a t-shirt have a footprint?			x		
16-19	Activity 1: Choose a research report Follow-up: Presentations/posters	x	x		x	x
	Our Vision for Water					
20	Activity 1: The big picture				x	
20 +	Activity 2: Sharing our vision for water				x	x

Water Module topics are also directly relevant to Geography and Biology taught in Forms 1 to 4 as for example in this extract from the KNEC syllabus taught at Kingwede Secondary School, Kwale County (thanks to Mr Joseph Kimtai for providing this information):

Section	Level and KNEC Syllabus topics
Geology	FORM 1 1. THE EARTH AND THE SOLAR SYSTEM Structure of the earth 3. MINERALS AND ROCKS 1. Definition of minerals, rocks 2. Characteristics of minerals 3. Classification of rock according to mode of formation 4. Characteristics of rocks 6. Significance of rocks in Kenya 4. MINING AND WATER USE 1. Definition of mining 2. Factors influencing the occurrence of minerals and their exploitation 4. Distribution of major minerals in Kenya 5. Significance of minerals in Kenya FORM 2 2. Types of movements horizontal and vertical
The Water Cycle: **Thinking about the water cycle** **Collect your own rainfall data**	FORM 1 2. WEATHER 1. definition of weather 2. elements of weather 3. factors for siting weather station 4. instrument for measuring elements of weather condition 5. recording and calculating weather condition FORM 3: HYDROLOGICAL CYCLE 1. Definition 2. Process 3. Significance

Student record

– Enter student name in each column and tick activities as completed

	NAME																	
	Section/Activity Title																	
1	**Why learn about water**																	
1	Activity 1: The Sustainable Development Goals for Water																	
1	Activity 2: (Maths: Reading graphs)																	
	Activity 3 (Maths: Percentages)																	
1	**1: The Water Cycle**																	
1	Activity 4 – Bingo reading																	
1	Activity 5 – Water Cycle Crossword																	
2	Activity 6 - The Water Cycle where I live (prep)																	
3	Activity 1: Thinking about the water cycle																	
4	Activity 1: Evapotranspiration experiment																	
4	Activity 1: Collect your own rainfall data																	
5	**2: Geology – Understanding rocks and minerals**																	
5	Activity 1: Engaging with the information																	
5	Activity 2: Geology News																	
5	Activity 3: Crossword																	
6	**3: Groundwater - Water in the ground**																	
6	Activity 1: Infiltration Experiment																	
7	Activity 2: Saturation Experiment																	
7	Activity 1: How do scientists study groundwater?																	

7	Activity 2: How do people access groundwater?																	
7	Activity 3: Sustainable use of groundwater																	
7A	Activity 4: Crossword																	
7B	Groundwater where I live (optional field visit)																	
8	**4: Water Quality - Keeping water safe**																	
8	Activity 1: Source protection quiz																	
9	Activity 2: Teaching groundwater protection																	
9	Activity 1: Protecting a water source																	
9A	Activity 2: Background reading on sedimentation																	
10	Source protection fieldwork / Arrange an expert talk																	
10	Activity 1: Comparing methods to speed up sedimentation																	
11	Activity 2: Investigate how turbidity is measured																	
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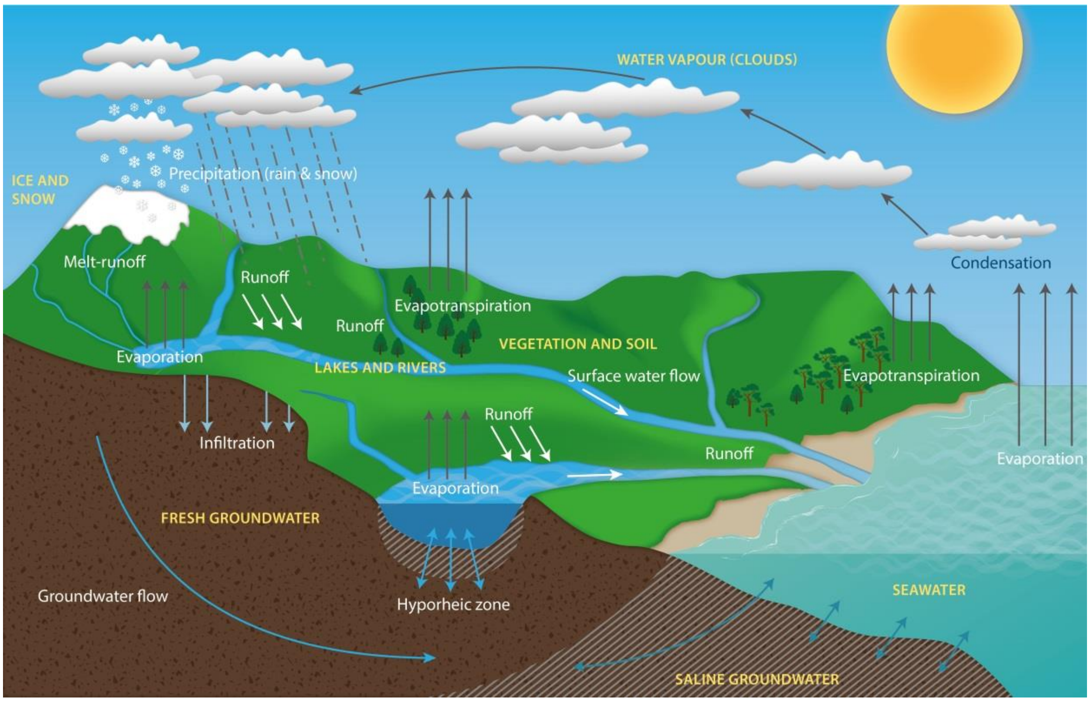
11	Activity 3: Safe storage																	
12-13	Activity 4: Water Quality crossword																	
	Activity: Solar still design challenge																	
14	**5: Water Conservation - Saving water**																	
15	Activity 1: Engaging with the information – Water footprints																	
1619	Activity 1: Can a t-shirt have a footprint?																	
19	Activity 1: Choose a research report to work on Follow-up: Presentations and poster reports																	
20	**Our Vision for Water**																	
20+	Activity 1: The big picture																	
20+	Activity 2: Sharing our vision for water																	



CERTIFICATE

This is to certify that:

*Name:*____________________________________

*School:*___________________________________

has successfully completed the Water Module.

*Signed:*____________________________

*Date:*_____________________

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), Dr Rob Hope, Patrick Thomson and Dr Caitlin McElroy (University of Oxford).

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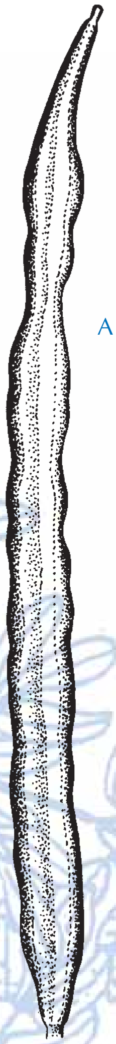
Moringa: the science behind the miracle tree

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-

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

The *M. oleifera* tree

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

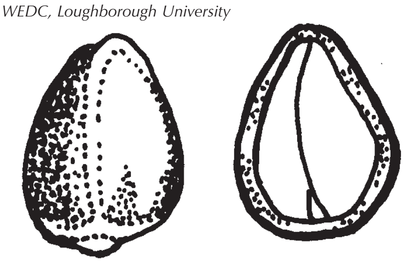
REVIEW

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 powdered 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).

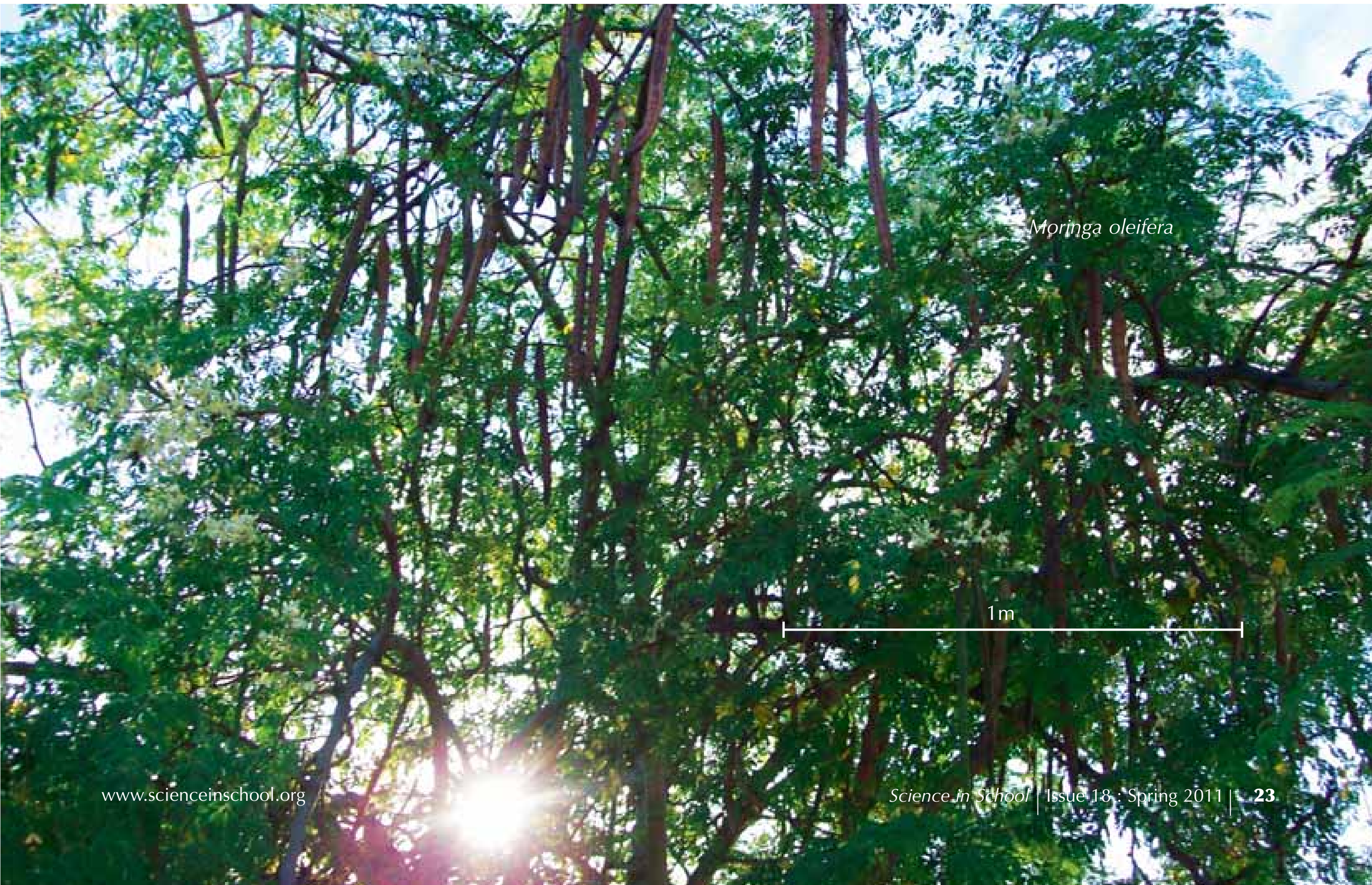


Moringa seeds: whole (left) and cut open (right)

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



Moringa oleifera

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."

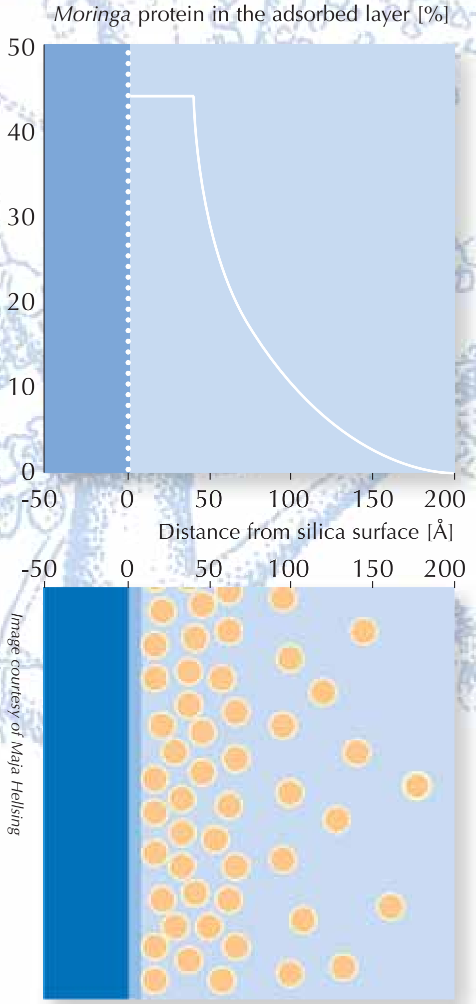


Image courtesy of Maja Hellsing

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

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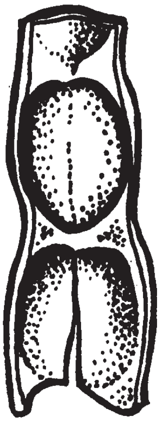

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Section of a moringa pod

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

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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*.

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

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