OUTREACH

no. 86

IN THIS ISSUE: LEARNING-BY-DOING LEAFLETS ON PRESSURE & WATER TECHNOLOGIES

New York University UNEP TVE WWF

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Issue no. 86 CONTENTS

OUTREACH INFORMATION PACKS

(All are available in English, Those so marked are translated into **a** - Arabic, **f** - French, **p** - Portuguese, **s** - Spanish)

1 Water and Health (1)
2 Water and Health (2)
3 Water and Health (3)
4 Water treatment
5 Water supply
6 Ground water
7 A balanced diet
8 Nutrient deficiency (1)
9 Nutrient deficiency (2)
10 An introduction to insects (1)
11 An introduction to insects (2)
12 Water and sanitation (1)
13 Water and sanitation (2)
14 Water and sanitation (3)
15 Teeth (1)
16 Teeth (2)
17 Eyes and vision (1)
18 Eyes and vision (2)
19 Coral reefs (1)
20 Coral reefs (2)
21 Soil (1) **f**
22 Soil (2) **f**
23 Soil (3)
24 Population growth (1)
25 Population growth (2)
26 Population growth (3)
27 Trees and fuelwood (1) **f**
28 Trees and fuelwood (2) **f**
29 Trees and fuelwood (3)
30 Pests and pesticides (1) **p s**
31 Pests and pesticides (2) **p s**
32 Pests and pesticides (3) **p s**
33 Wetlands (1) **a s**
34 Wetlands (2) **a s**
35 Wetlands (3) **a s**
36 Immunization (1)
37 Immunization (2)
38 Women - health & environment (1)
39 Women - health & environment (2)
40 Women - health & environment (3)
41 Children's magazines on water
42 Children's magazines on trees
43 Children's magazines on health
44 Children's magazines on food
45 Children's magazines on people and their environment
46 Tropical rainforests (1) **p s**
47 Tropical rainforests (2) **p s**
48 Tropical rainforests (3) **p s**
49 The marine environment (1) **s**
50 The marine environment (2) **s**
51 The marine environment (3) **s**
52 AIDS (1)
53 AIDS (2)
54 AIDS (3)
55 Weather **s**
56 The changing atmosphere (1) the "Greenhouse effect" **s**
57 The changing atmosphere (2) the "Greenhouse effect" **s**
58 The changing atmosphere (3) the Ozone layer **s**
59 The changing atmosphere (4) acid rain and air pollution **s**
60 Endangered species (1) Introduction **a f p s**
61 Endangered species (2) Threats to survival **a p s**
62 Endangered species (3) Wildlife trade **a p s**
63 Endangered species (4) Saving wildlife **a p s**
64 Drugs (1) Medical drugs **p**
65 Drugs (2) Drug abuse **p**
66 Drugs (3) Herbal medicine **p**
67 Crops (1) Seeds and plants **a p s**
68 Crops (2) The garden environment **a p s**
69 Crops (3) Farm work **a p**
70 Crops (4) After the harvest **a p**
71 Crops (5) Farming issues **p**
72 Learning-by-Doing leaflets on gardening (1) **f p s**
73 Learning-by-Doing leaflets on gardening (2) **f p s**
74 Appropriate Technology (1) Introduction
75 Appropriate Technology (2) Education **a**
76 Appropriate Technology (3) Water **a**
77 Appropriate Technology (4) Health
78 Appropriate Technology (5) Shelter
79 Appropriate Technology (6) Food & Fisheries
80 Appropriate Technology (7) Solar energy
81 Appropriate Technology (8) Biomass Energy
82 Appropriate Technology (9) Wind and Water Energy
83 Appropriate Technology (10) Stoves
84 Appropriate Technology (11) Transportation
Special issue "About OUTREACH"
85 Learning-By-Doing leaflets on Inventing and Simple Machines

The materials in OUTREACH packs may be used for non-commercial, educational purposes in Third World countries. Use the material as you wish. **ADOPT, ADAPT** and **ADD**, but **PLEASE CREDIT SOURCE** where indicated. Otherwise please credit OUTREACH. We need feedback. How useful is this material? How can we make it better? Are there special topics you need? Please let us know. Write to:

Dr. James Connor, OUTREACH Director, Teaching & Learning Center,
200 East Building, 239 Greene Street, New York University, New York NY 10003, USA
or **Mr. Richard Lumbe, OUTREACH Co-ordinator, Information & Public Affairs, UNEP,**
P.O.Box 30552, Nairobi, KENYA

OUTREACH LEARNING-BY-DOING LEAFLETS

The OUTREACH Learning-By-Doing leaflets have been especially designed for middle and high school teachers in Low Income Countries. It has been recognised that good learning materials are scarce in many classrooms in the South. Textbooks are not always available. Those that are available are not always relevant to the most pressing problems in the Developing World, including health and environmental problems and sustainable development. The purpose of the Learning-By-Doing leaflets is to help fill the needs, at least in small part, of middle school and high school teachers in Low Income Countries by providing inexpensive, classroom-ready materials that will help to foster a scientific attitude in students. They are meant to supplement and enrich the science curriculum, not replace it, and they are meant to be used in any way that is most useful to the classroom teacher. In other words, they can be adapted, adopted or added to in order to meet local needs. They may be used, copyright-free, for any non-profit purpose in Low Income Countries. The Learning-By-Doing leaflets will be published for profit in the North, and profits will be used for the further development and publication of leaflets on other topics for use in the South.

Fostering a scientific attitude

The philosophy behind the science leaflets is that science teaching should not be telling students what to think and believe. Rather, science teaching should foster a scientific attitude - the attitude which appreciates the value of forming ideas based upon observations and reliably testing information, and being content to say, "I don't know" until the evidence is sufficient to answer the question. Science teaching should allow students to find out things for themselves through scientific inquiry. The Learning-By-Doing leaflets, as the name implies, include a variety of hands-on activities designed to foster a scientific attitude towards solving the most pressing health and environmental problems facing people all over the world. This scientific attitude can be useful in all areas and levels of inquiry in the classroom and for problem-solving in every day life as well.

Adaptable

Each leaflet is self-contained. Teachers can pick and choose the topics that they would like to cover to supplement their science programme and to help meet the curricular specifications of their local education ministries. In addition, each of the leaflets and accompanying teacher materials provide a number of suggestions for additional, more in-depth activities, so that the leaflets are adaptable to a wide range of classroom levels, from primary to high school.

The leaflets are adaptable in many different climatic and cultural situations, since their focus is on basic scientific principles and scientific inquiry. A particular technology may be appropriate in one area, but not in another. Therefore, the focus of the leaflets is not on providing information about specific technologies, such as how best to plant a specific crop. Rather, the leaflets provide some basic scientific information and tools of scientific inquiry which students can use to closely examine technologies being used in their own areas and to test and perhaps improve upon these technologies.

Inexpensive

The content of each Learning-By-Doing leaflet cover two sides of a sheet of paper. When folded down the middle, it becomes a four-page leaflet. The materials required in the activities are readily available, even in the most rural areas, and are not costly.

Relevant

When engaged in the tasks outlined in the leaflets, the students are in contact with their surroundings directly, through the senses, because they deal with concrete things in the world around them. Moreover, the leaflets cover very practical problems in the students' own lives, especially those related to health, the environment and sustainable development. The students learn through their own investigations of real problems, which is as sound a basis for education as one could desire.

Motivational

Children demonstrate a natural curiosity about the natural world around them. In their every day lives, children like to watch things grow and develop. They like to manipulate things and observe what happens. The Learning-By-Doing leaflets take advantage of the natural curiosity of children by focusing it towards learning how to solve practical environmental and health problems. Students are allowed to take an active learning role by actively constructing their own meanings in the classroom. When allowed to make discoveries on their own, students become excited about the learning process and are self-motivated to learn more on their own.

Inter-curricular

Teachers the world over complain that there is no time to teach science, since basic literacy is their main concern. The health and environmental problems that are the focus of the leaflets can be a suitable "unifying" subject in the classroom, as it has many links with other subjects. In the course of their investigations, students have many chances to practise their reading, writing and speaking skills. They are also encouraged to tap into and build upon the knowledge of their elders, and to bring home and make practical use of what they have learned in the classroom.

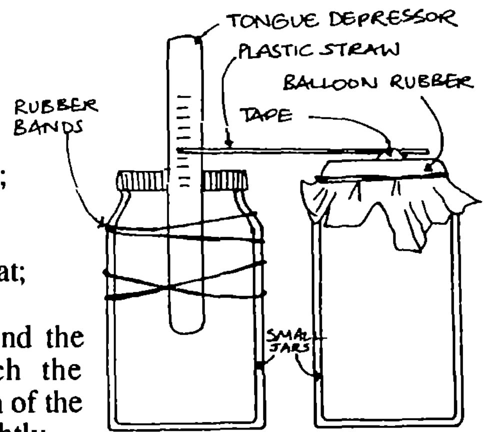
LEARNING-BY-DOING LEAFLETS IN ISSUE 86

In the first section on pressure, students learn some important principles about water and air pressure. They will need to know these principles in order to understand how different types of water pumps work. In the second section, students learn about different sources of water including ground water, which can be tapped into by wells, and run-off water, which can be collected in water tanks or behind dams. Then, they learn about various kinds of water-lifting devices, and finally, about various appropriate technologies for insuring safe water supplies.

Make your own barometer

Getting reliable information that predicts changes in weather conditions gives people like farmers an opportunity to prepare for what is going to happen. Air pressure affects the weather. Falling air pressure often means stormy weather is on the way. Rising air pressure usually means the skies will be clear.

The pressure of the air can be measured by an instrument called a **barometer**. Here is one way to make a simple barometer:



You will need:
* a piece of balloon rubber;
* two small jars;
* a plastic straw;
* a tongue depressor or card;
* 3 rubber bands;
* plastic tape;
* petroleum jelly or animal fat;
* scissors.

Put petroleum jelly around the mouth of one jar. Stretch the balloon rubber over the mouth of the jar. Pull taut, and secure it tightly with a rubber band to make sure it is airtight. Cut one end of the straw to make a point, and tape the other end to the middle of the balloon. Attach the tongue depressor to the second jar with 2 rubber bands. Place the jars as shown, and mark the tongue depressor where the straw hits. As the air pressure changes, the rubber will move and the straw pointer will record the movements Make a scale on the depressor, so that the pointer can indicate whether the pressure is up or down (see diagram).

DAY	READING ON BAROMETER	WEATHER CONDITIONS
AM		
PM		
AM		
PM		
AM		
PM		

You have made a simple barometer. It should be shielded from rain and wind in a place where the temperature is constant. Keep a daily record of its readings, and note the weather conditions each day (see chart at right). Work out what kind of weather to expect if the barometer level rises or falls.

OUTREACH pack 86 pp 3-4. Other Learning-By-Doing Leaflets and Information packs are available from Dr. James Connor, OUTREACH Director, Environmental Education Center, 200 East Building, New York University, New York NY 10003, U.S.A or Richard Lumbe, OUTREACH Coordinator, Information & Public Affairs, UNEP, P.O.Box 30552, Nairobi, KENYA

Under Pressure

What is pressure?

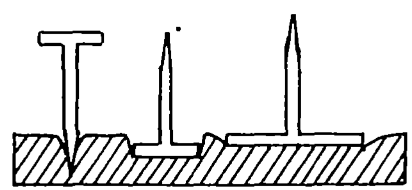
Two men of equal weight and height fall into quicksand. One man is standing upright. The other is lying flat on his stomach. Which one, do you think, will sink more quickly?

The man standing upright. Why? It's a matter of **pressure**. What do we mean by pressure? Here's an experiment that will help you understand what pressure is. You will need:
* some clay;
* a large nail;
* a large coin;
* a book.

Fashion the clay into a flat disc about 2 inches deep. Holding the nail upright, with its point resting on the surface of the clay, balance the book on top of the nail head. See how deep an impression the nail makes in the clay.

Remove the nail, turn it upside down, and rest the book on the nail point. (You will need to hold the book in place, but try not to apply any force on the nail.) See what impression the nail head makes in the clay.

Remove the nail once more. Place the coin on top of the clay. Then, hold the nail upright with the head on top of the coin. Balance the book on the nail, and see what impression the coin makes in the clay.



Compare the three impressions. Which one is the deepest? The shallowest? You can make a deeper mark in the clay by pushing harder. Describe another way to leave a deeper mark.

Pressure is a force applied over an area. The relationship between pressure, force and area is thus: **Pressure** $= \frac{\text{Force}}{\text{Area}}$

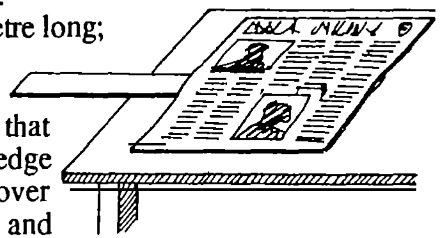
(a) State two ways to increase pressure.
(b) State two ways to decrease pressure.
(c) Now explain why you should lie flat on your stomach to keep from sinking in quicksand.

Air pressure

When you swim underwater, you can feel the pressure of the water on your body, especially in your ears. The deeper you go, the greater the pressure. Air exerts pressure, too. Hold your hand in front of your mouth and blow. You can feel the air pressing against your hand. That pressing of the air is **air pressure**.

Because air is invisible, we sometimes make the mistake of thinking that air isn't really there. The activity below shows air pressure in action. You will need:

* a ruler or flat stick about a metre long;
* a table;
* a sheet of newspaper.



Place the stick on the table so that about a third of it hangs over the edge of the table. Lay the newspaper over the end of the stick on the table, and smooth it down carefully.

Hit the other end of the stick (not too hard!) and try to make the paper fly in the air. What happens? Can you explain why?

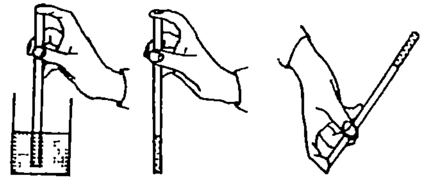
The air presses down on the sheet of paper. Because the paper has a large area, there is a lot of air pushing down on it, and this is enough to stop the paper and the ruler from moving.

Air is all around us. There is more than 14 pounds of air pressing on every square inch of your skin. The pressure is caused by a layer of air, called the atmosphere, which surrounds the Earth. Most of the air is concentrated about 3 miles (5 km.) above the surface of the Earth.

Pressing up, down and sideways

How can you remove some water from a jar using only a straw? Try it - but do not use your mouth or splash the water!

Place the straw in the jar of water, then seal the end with your finger. You can remove the straw from the jar while the water is trapped inside. Why? Air pressure, pushing up from the bottom, keeps water from running out of the straw.



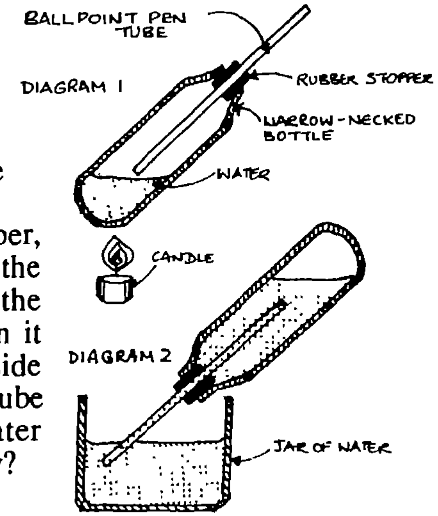
Keep you finger over the end of the straw, and tilt the straw in different directions - sideways, upside down and so on. What does this tell you about air pressure? Air pressure acts in all directions, and is inside the straw, too.

Lifting water with air pressure

Here are two experiments that show how air pressure causes liquids to rise in a tube:

(1) You will need:

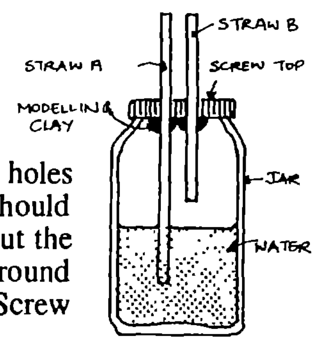
* a ballpoint pen tube
* a small narrow-necked bottle
* a rubber stopper to fit the bottle
* jar of water



Fix the tube through the stopper, and fit the stopper snugly onto the bottle. Drive out the air from the bottle by boiling a little water in it (diagram 1). Turn the bottle upside down with the open end of the tube under the surface of the water (diagram 2). What happens? Why?

(2) You will need:

* a jar with a screw top;
* two straws;
* some modelling or ordinary clay;
* some water;
* a nail.



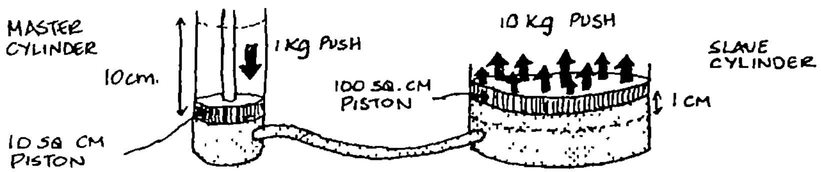
Fill the jar half full of water. Make two holes in the screw top with the nail. Each hole should be big enough to pass a straw through. Put the straws through the holes, and place clay around each hole to make the openings air tight. Screw the top onto the jar, as shown above.

Place a finger over the end of straw B, and try to drink through straw A. Then, remove the finger and try to drink through straw A. Which is easier to do? Why? Now ask a friend to blow through straw B while you try drinking through straw A. How easy is it to drink? Explain what is happening.

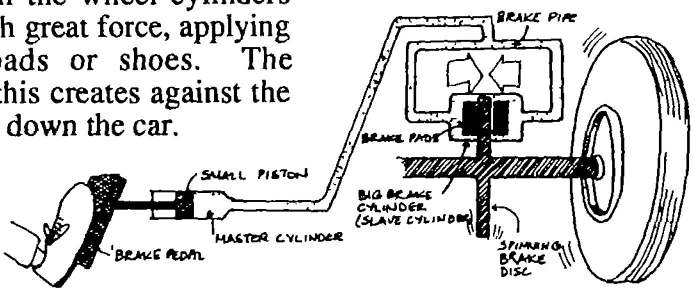
Hydraulic machines

A hydraulic machine makes use of the pressure exerted by a liquid, usually a type of oil. It does this with a set of two (or more) cylinders connected by pipes completely filled with some fluid. In each cylinder is a piston. To work the machine, force is applied to one piston in what is known as the "master" cylinder. This raises the pressure of the fluid throughout the system, and pistons in the other "slave" cylinders move and perform a useful function. (Any liquid could be used but water would cause the metal to rust so oil is usually used.)

Hydraulic machines work on the same principle as levers in that a small force applied over a large distance can be turned into a large force moving over a smaller distance. And vice versa. In the example below, the small piston pushing down over a large distance moves the large piston only a small distance. But the large piston has a surface ten times bigger than the other piston, so it gives ten times as much push:



This idea is used to work the foot brakes in a car . The brake pedal moves the piston in the master cylinder, raising the pressure of the brake fluid in the system. The high-pressure fluid then makes the pistons in the wheel cylinders move out with great force, applying the brake pads or shoes. The friction that this creates against the wheels slows down the car.



OUTREACH pack 86 pp 5-6. Other Learning-By-Doing Leaflets and Information packs are available from Dr. James Connor, OUTREACH Director, Environmental Education Center, 200 East Building, New York University, New York NY 10003, U.S A. or Richard Lumbe, OUTREACH Coordinator, Information & Public Affairs, UNEP, P.O.Box 30552, Nairobi, KENYA

OUTREACH

LEARNING-BY-DOING

HEALTH & ENVIRONMENTAL ACTIVITIES FOR YOUNG SCIENTISTS

LEAFLET NO. 38

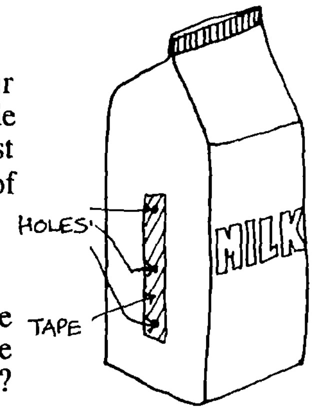
Getting Liquids to Work for You

Did you ever wonder how it is possible to stop a speeding car by simply stepping on the brakes? How does a car lift raise a car at the press of a button? The pressure exerted by liquids makes these things possible. These experiments will show you how.

Seeing water exert pressure

You will need:

* an empty milk carton or can;
* a piece of sticking tape the length of the carton;
* a nail;
* a hammer (if a metal can is being used).



1. Use the nail to punch three or four holes, one above the other, on one side of the carton. Make the top hole at least 1 1/2 inches (about 4 cm) from the top of the carton.
2. Cover the holes with the tape.
3. Fill the carton with water.
4. Put the carton in a sink or tub. Pull the strip of tape off quickly. Which hole produces the longest jet of water? Explain why.

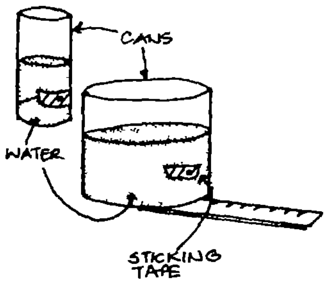
Now take another carton or tall can, and punch holes in all its sides near the base. Make sure the holes are the same distance from the bottom of the carton. Cover the holes with one vertical strip of tape, and fill the carton with water. Hold the carton over the sink, and strip off the tape quickly. See and compare the distance the streams shoot out from the holes all around the can. What does this tell you?

Water pressure in different sized containers

You have seen that the depth of water in a container makes the pressure greater. What about the size of the container? Here is an experiment that explores this question.

You will need:

* a can that is narrow (i.e. has a small diameter);
* a can that is wide (i.e. has a large diameter);
* a nail;
* sticking tape;
* metal or wooden ruler.



1. Punch a hole the *same* distance (2 - 3 cm or about 1 inch) from the bottom of each can.
2. Cover the holes with sticking tape.
3. Fill each can with water to the *same* depth, say 5 cm (2 inches). The larger can will need more water.
4. Put one can in a tub, placing it on the end of the ruler. Pull the tape off, and measure how far the water stream goes.
5. Repeat 4 using the other can. Which stream of water travels the furthest?

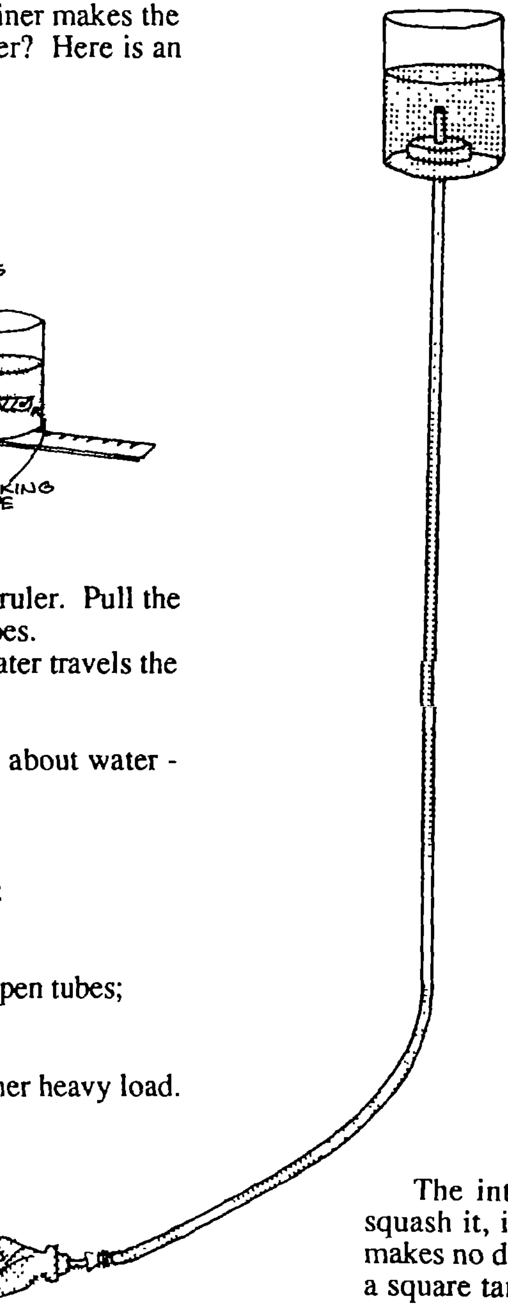
From the experiments above, what do you know about water - or liquid - pressure?

Raising heavy weights by water pressure

The next experiment shows the lifting power of water:

You will need:

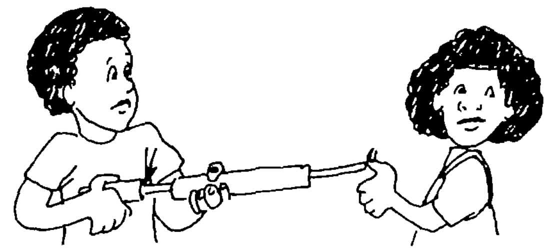
* a rubber hot-water bottle;
* a long length of plastic or rubber tubing -- at least 4 feet long (about 1.25 m);
* two one-hole stoppers: one should fit into the water bottle opening;
* a can;
* two ballpoint pen tubes;
* a nail;
* board;
* rocks or another heavy load.



1. Set up the equipment as shown in the diagram on the left. You may need a little help to get water-tight joints at the can and the hot-water bottle. Test for leaks by filling the can. Then empty out the water.
2. Place everything on the floor. Place some rocks or other heavy objects on the board.
3. Fill the can with water. Raise the can end of the tubing higher and higher. See what happens to the rocks. See how heavy a weight you can lift by raising the can as high above the floor as possible.

Pushing and squeezing with liquids

To find out if water can be squashed, try this experiment. Suck some water up into a bicycle pump. Then, ask a friend to block the end of the cylinder while you press the piston back. You are trying to squash the water inside. Keep pushing. Then, ask your friend to take his finger away from the hole. What happens? You now have a wet friend!



The interesting thing about a liquid is that when you try to squash it, it pushes back with the same force in all directions. It makes no difference if the liquid is in a pipe with lots of bends, or in a square tank or in a floppy plastic bag. The pressure spreads out evenly, so that every part of the container has the same force pressing upon it.

The amount of water in an underground reserve partly depends upon rainfall. During very wet spells, the water-table rises. During very dry spells, the water-table falls. But even during long dry spells, there is always some water deep below the surface of the Earth. For example, a great reservoir lies deep beneath the Sahara Desert.

The amount of water in an underground reserve does not change too much - unless the reserve is tapped. Water may stay for several years in the place where it first collected. But it may also travel deep below the surface, or move hundreds of miles from where it entered the ground.

Wells

A well is a hole sunk in the ground that reaches below the water-table. Water seeps out of the rocks into the well. Do people in your community draw water from wells? How is the water drawn to the surface?

Activity: Your community's water supply needs

Find out where your community's water supply comes from. Draw maps showing the location of rivers, streams, lakes, springs, reservoirs, and wells. (Do these give any clues to the presence of the water-table?)

Carry out a survey at each water collection point. Observe how much water is taken per day; who collects the water; the behaviour of water collectors (i.e. popular collection times; time spent collecting water; actions that might contaminate the water supply, etc.) Interview the water collectors to find out how they use the water and their opinions and complaints about the water supply. Use charts and diagrams to present your data. Can you draw any conclusions?

Make a water supply calendar: keep daily records of rainfall; note any fluctuations in water supplies during the course of the year (i.e. when streams or wells dry up, when rivers flood, etc.); record which water sources are used at different times of the year.

Carry out a survey to identify the water supply problems of your community. Talk to women, community leaders, health workers, farmers, pastoralists and children. Find out how people have tried to solve the problems, and why the actions worked/did not work.

Make proposals for solving your community's water supply problems. You and your classmates could discuss the issue, and draw up a plan to present to the community.

OUTREACH pack 86 pp 7-8. Other Learning-By-Doing Leaflets and Information packs are available from Dr. James Connor, OUTREACH Director, Environmental Education Center, 200 East Building, New York University, New York NY 10003, U.S.A or Richard Lumbe, OUTREACH Coordinator, Information & Public Affairs, UNEP, P.O.Box 30552, Nairobi, KENYA

OUTREACH
LEARNING-BY-DOING
HEALTH & ENVIRONMENTAL ACTIVITIES FOR YOUNG SCIENTISTS
LEAFLET NO. 39

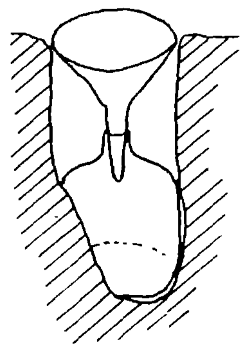
Your Community's Water Supply

Does your community have a safe and reliable water supply? In this leaflet, you will learn how to investigate your local water supplies, and how to make safe water more accessible to your community.

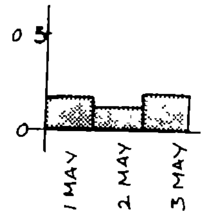
Sources of Water

The chief source of water is rainfall. (Can you think of other forms of precipitation?) Do you know how much rain falls in your region? Build a rain gauge to find out. You will need:

* a bottle with straight sides;
* 1 funnel, the mouth of which has the same diameter as the bottle;
* a measuring cylinder

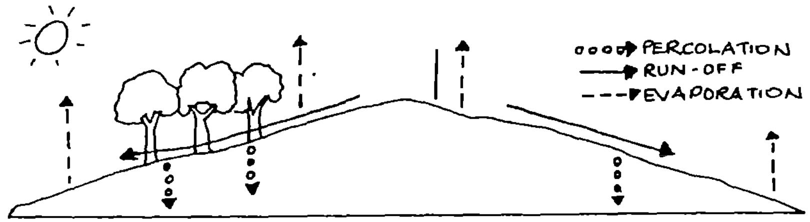


Choose a funnel with a very sharp vertical edge or a horizontal lip. This will prevent raindrops from bouncing out. The collecting jar should have the same diameter as the mouth of the funnel. Do you know why? Arrange the rain gauge as shown, and bury it a few centimetres above ground level in an open, undisturbed area. Each day, at the same time, empty the water collected into the measuring cylinder to find out the day's precipitation. (Is this an accurate reading of the day's precipitation? Can you think of any factors that may have affected your results?) Record your daily results in a bar chart like the one shown. After a month of data collection, can you work out the mean (average) daily rainfall? After a year, you can work out the mean weekly rainfall, and the mean monthly rainfall.



What happens to rain?

When rain falls, some of it runs on the surface forming streams and rivers, some of it evaporates directly, or indirectly via plants, and some of it soaks into the soil:



The amount of run-off, evaporation and percolation depends upon the nature of the rocks, the slope of the land and the climate. Choose words from the word bank to complete the sentences below:

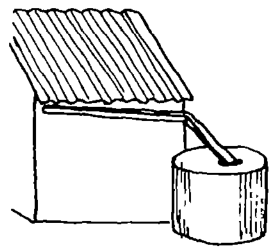
1. Run-off on ___ slopes is greater than _____ slopes.
2. Evaporation in ___ climates is greater than in ___ climates.
3. Water filters through ___ more easily than through ___.

Word Bank
clay; humid;
gentle; dry;
steep; sand.

Collecting rainfall and surface run-off

Can you think of ways to collect rainfall or surface run-off such as from rivers and streams? The picture shows one way.

What methods, if any, are used in your area for collecting rainwater or surface water?

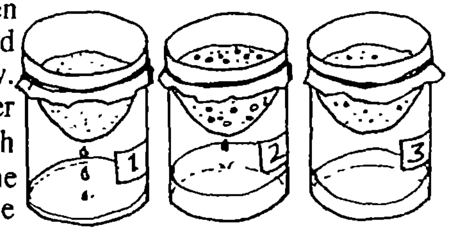


When water drains into the ground

What happens to water when it soaks into the ground? Find out by doing this experiment. You will need:

* three glass jars of equal size;
* three plastic bags of the same size;
* a sharp pointed pencil;
* a rubber band;
* bricks;
* a measuring cup;
* water;
* three samples of different soil types from different localities, preferably coarse, medium and fine grain soils;
* masking tape;
* a clock with a second hand.

Put your soils in a warm, dry place, and leave them to dry out. Once the soil is dry, place a different but equal amount of soil in each bag. Use the pencil to prick five small holes in each of the plastic bags. Put the bags in the cups, and secure in place with the rubber bands, as shown in the diagram below. Label the cups.



Guess what will happen when water is added to each soil. Record your guess on the chart below. Then, pour equal amounts of water (say, 125 ml. ($^1/_2$ cup) into each bag. Observe what happens to the water. Record, in each instance, the time it takes for the water to stop filtering through the soil. Compare the amounts of water collected under the cans. How much water did each soil hold? Note your results on the chart. Which is the best soil for good drainage? The best soil for holding water?

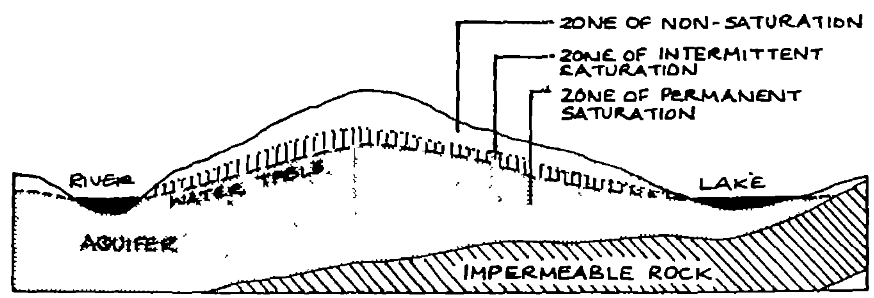
SOIL	1	2	3
GUESS			
WHAT HAPPENS			
AMOUNT OF WATER THAT SOIL HOLDS			

Groundwater

Water entering the ground moves downwards by gravity, through *permeable* soils and rocks. Permeable rocks allow water to pass through them; *impermeable* rocks do not. So when water comes to a layer of impermeable rock, its journey downward is halted. Where the permeable rock meets the impermeable bed, the groundwater may then emerge from the ground as a spring or line of springs. Does your community rely on water from natural springs?

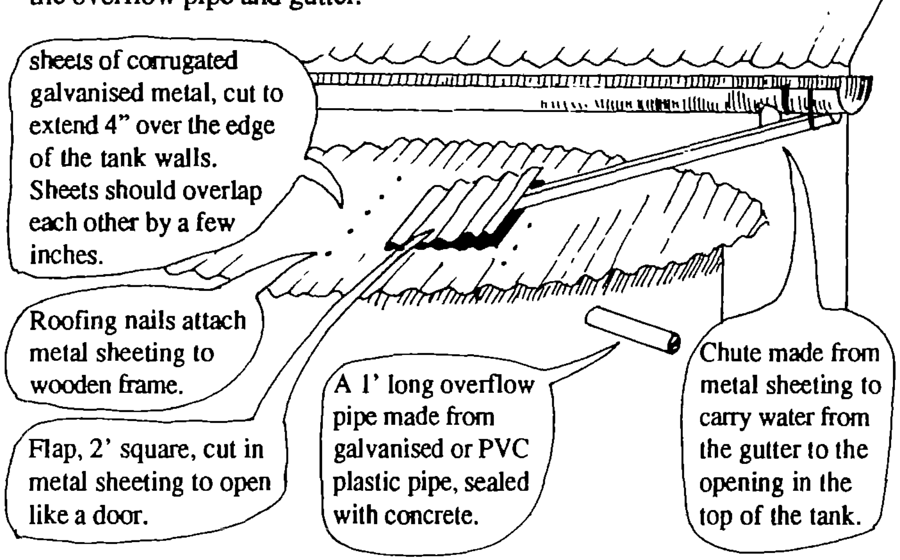
The water-table or level of saturation

Water collects in the ground above impermeable rock, forming underground reserves. The underground zone that holds groundwater is called an *aquifer* (said: AK-wuh-fur). The top of this saturated zone is called the *water-table.*



Roof, overflow pipe and gutter

The diagram below shows the roof construction and the installation of the overflow pipe and gutter.



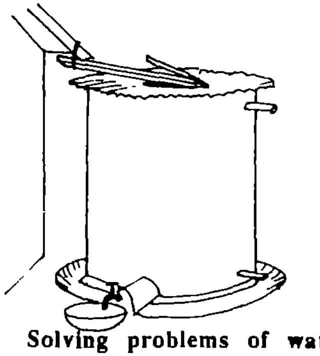
Finishing the tank

The outside wall of the tank may now be plastered. Dampen the wall with a thin mixture of cement and water to help the plaster stick to the wall.

Mix [3 buckets] sand; [1kg] cement and some water.

Cover the outside of the tank with a 1-inch layer of plaster. Fill all holes and spaces (including any gaps left between the top of the wall and the roof) with plaster. The final surface should be smooth. Put extra concrete around the drainpipe to hold it in place, and finish plastering the base.

The tank *must* be kept damp for the first week so that the concrete will dry out slowly and not crack later. Splash the outer wall with a lot of water every day for a week. Pour at least 3 barrels (400 litres) of water into the tank. Leave the water in the tank for a week, then drain it out and clean the tank. The tank is ready for use. This is what it will look like:



The information in this leaflet is based upon **Solving problems of water shortage at home**, *a World Neighbors in Action Newsletter. For more information, write to: World Neighbors International Headquarters, 5116 North Portland Avenue, Oklahoma City, OK 73112, U.S.A*

OUTREACH pack 86 pp 9-10 Other Learning-By-Doing Leaflets and Information packs are available from Dr. James Connor, OUTREACH Director, Environmental Education Center, 200 East Building, New York University, New York NY 10003, U.S.A. or Richard Lumbe, OUTREACH Coordinator, Information & Public Affairs, UNEP. P O.Box 30552, Nairobi, KENYA

OUTREACH

LEARNING-BY-DOING

HEALTH & ENVIRONMENTAL ACTIVITIES FOR YOUNG SCIENTISTS

LEAFLET NO. 40

Catch a Falling Raindrop

Is your water supply plentiful during the rainy season but scarce after the rains end? Do nearby ponds and streams dry up, and do you have to walk a long way to find clean drinking water?

You may be able to solve your water shortage by taking action close to home - by catching the rain that falls on your roof! Water that falls onto the roof can be carried by gutters into a tank where it can be stored until needed.

Rainwater provides good quality drinking water if it is collected from a suitable roof made of materials such as a galvanised iron, tiles or thatched shingles.

How big a tank?

Tanks of various sizes can be built. To determine how big a tank you need, you should consider your water needs and the amount of water that it is possible to collect from the roof-top.

Water needs depend upon such factors as the adequacy of your other safe drinking water supplies, the number of people using the water, and the type of usage.

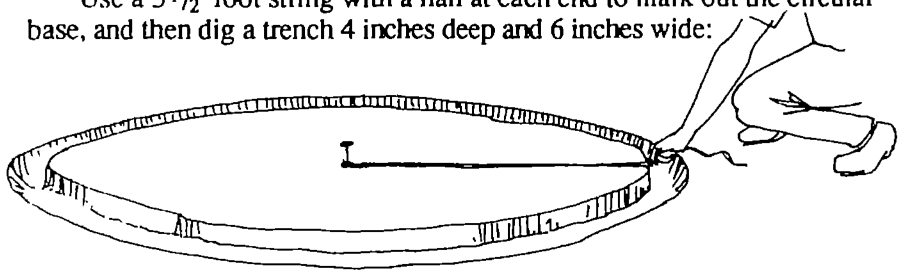
The amount of rainwater which can be guaranteed is hard to estimate. Daily rainfall records must have been kept for several years, say, over ten years. From these records, the driest monthly rainfall in that period can be identified. This monthly figure, when multiplied by the available roof area, gives you the amount of water that can be guaranteed to be collected.

This leaflet describes how to build a 1,700 gallon tank. To make a full-size tank, you will need the help of friends and grown-ups. As a classroom project, you could build a scale model of the tank, using clay or plaster rather than cement. The scale for your model could be, for example, 1" = 1', or the model could be one-quarter or one-half size.

The tank should be about 3 feet from the house. Round tanks are better to build than square ones: square tanks need reinforcing at the corners. This makes them more expensive. The diameter of the tank will be 7 feet, and it will stand 7 feet high. The top of the tank must be below the bottom edge of the house roof.

Tank preparation

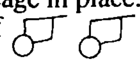
Use a $3^1/_2$ foot string with a nail at each end to mark out the circular base, and then dig a trench 4 inches deep and 6 inches wide:



The wall of the tank is to be made from a "skeleton" of wire mesh which will be plastered on both sides with a thin layer of concrete. This is called a ferrocement construction. Ferrocement tanks are both light weight and cheap to build.

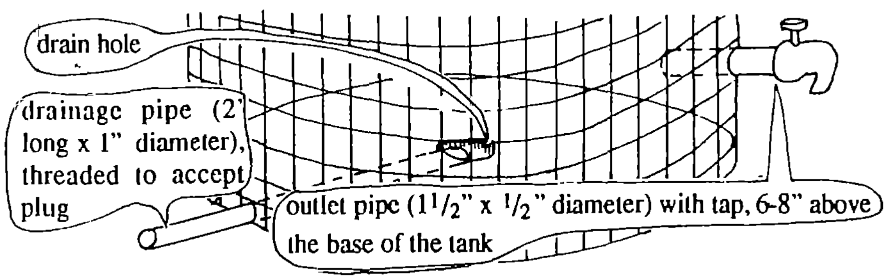
Join 10-gauge steel wire (welded in 2-inch squares) to form one piece 7 feet high and $22^1/_2$ feet long. Cover the inside of the wire mesh from top to bottom with 1-inch chicken wire. This will help hold the plaster in place. Join the chicken wire to the steel wire at about 18 inch intervals. Bring the ends of the steel wire together to form a cylinder that will fit into the trench. (Do not place it there yet.)

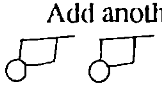
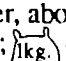
Building the base of the tank

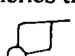
Inside the circle (but not in the trench) spread  (wheelbarrows) of small stones to form a layer at the bottom of the tank about 3 inches deep. Then put the steel wire "cage" into the trench. Add more stones around the bottom to hold the cage in place. Cover the stones with concrete. The concrete is a mixture of  sand; 

bag of cement and a little water.

A drainage pipe is needed for emptying the tank when it needs to be cleaned. An outlet pipe is also needed, see diagram below.



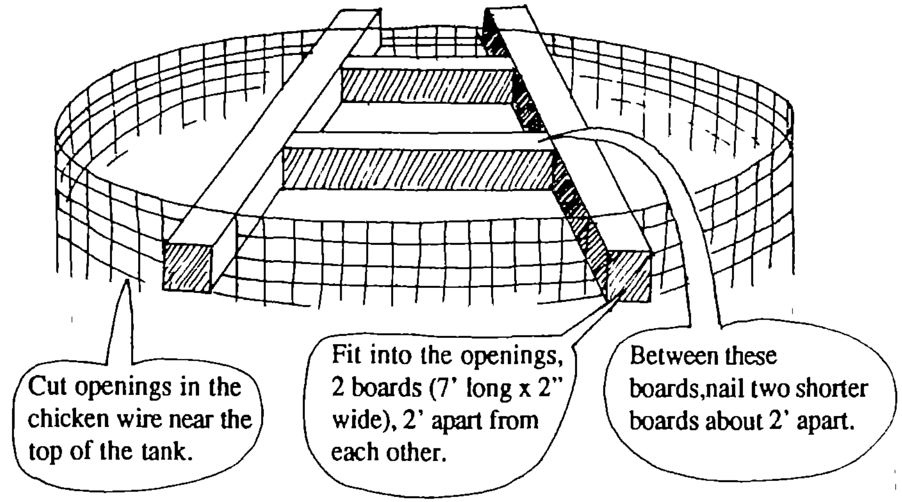
Add another layer, about 2-4 inches thick, that is a mixture of  sand; 

cement;  stones and some water. Spread evenly and tamp down firmly. Cover with chicken wire and plaster over. Check to see if the tank is level by using a carpenter's level, or a water level using a garden hose, or by using a ball (the ball should not roll when placed on a board put across the top).

CONVERSION TABLES Linear measures: 1inch = 2.54 centimetres; 2 inches = 5.1 cm.; 6 inches = 15.2 cm.; 1 feet (12 inches) = 0.31 metre; 2 feet = 0.61 m.; 7 feet = 2.17 m. **Square measures:** 1 foot square = 0.09 metres^2; 2 foot^2 = 0.37 m^2 **Weight:** 1 kilogram = 2.20 lb **Volume:** 1 litre = 0.22 Imperial gallons

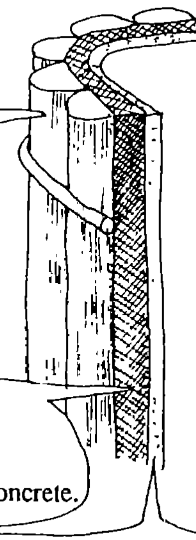
A wooden frame

A wooden frame is needed to support the roof and a small door:

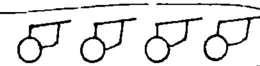
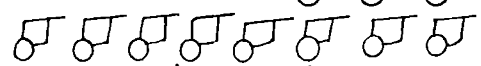
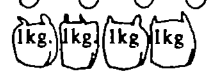


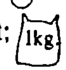
Plastering the inside of the tank

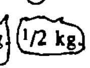
Below is a diagram of the cross-section of the tank walls, showing its various layers:



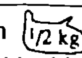
Sisal poles provide a temporary (and a reusable) support while the inside walls are plastered. 60 poles, 7' long are split lengthways to form 120 pieces. The flat sides are placed inwards. Rope is tied around the poles at the top, middle and bottom of the tank. Gaps are filled with pieces of wood or paper.

Inside plaster mixed from   sand; 

cement; 



waterproof cement; some water. Plaster the walls and floor with a 1" layer of concrete.

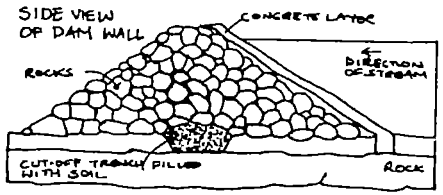
Waterproof coating made from 

cement and 

waterproof cement in a bucket of water. Spread this thin grey mixture smoothly over inside walls and floor. Let it dry overnight.

Remove sisal poles. Chip away loose plaster from the top of the tank and outside walls, and sweep dirt from the tank floor.

filled walls are stronger than earthen walls, it is not so important to build a spillway. After heavy rains, the water can flow over the dam wall without washing it away.



Experimenting with dams

As a class, try this experiment. You will need some sandy soil and some clay soil. Find some sloping ground outside where the soil is bare and where erosion has caused some gullies to begin to form. Build some model dams to test the effects of the following factors:

(a) a dam built from clay versus one built from sand
(b) a dam that has been dug out all the way up to the dam wall, versus one that has been dug out more than 1 foot (30 cm) back from the wall
(c) a dam with gently sloping walls versus one with nearly vertical walls
(d) a dam with a cut-off trench and a spillway versus a dam with neither.

Wait until a rainstorm, or if a hose will reach, sprinkle the ground above the dams with water from the hose. Observe how long it takes for each dam to break.

Next, hold a contest. See who can build the strongest dam. Then analyse what factors contributed to the success of the strongest dam.

After completing these experiments, take measures to try to stop the erosion on the slope, such as by damming gullies and planting a groundcover.

A dam for your community

Go for a walk along a nearby stream, and select three alternative sites for constructing a dam. Prepare a report on the pros and cons of building a dam at each site, (see "choosing a site").Also determine what materials should be used in the dam's construction, and how these materials might be obtained. Set out an implementation plan for dam construction and for its maintenance. Present your findings to the class.

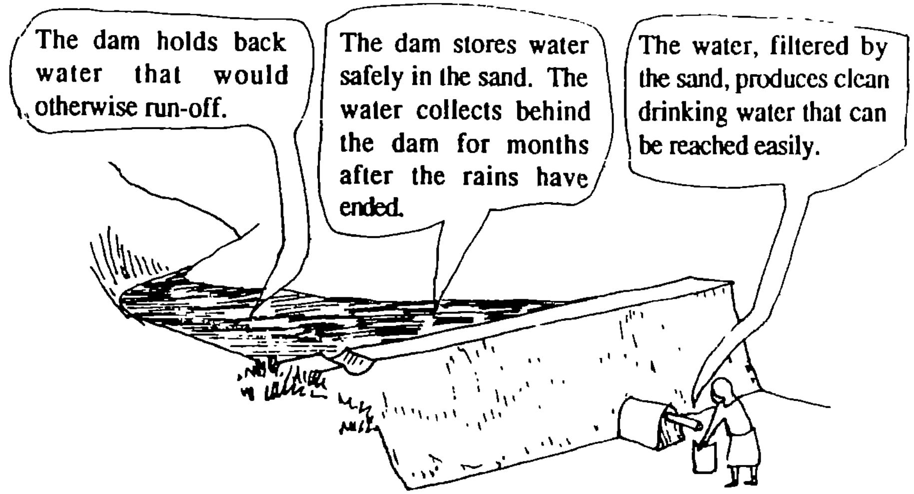
If your class as a whole determines that a dam would benefit the community, and that a suitable site has been identified, then the case for a new dam might be presented to the community at large.

OUTREACH pack 86 pp 11-12. Other Learning-By-Doing Leaflets and Information packs are available from Dr. James Connor, OUTREACH Director, Environmental Education Center, 200 East Building, New York University, New York NY 10003, U.S.A. or Richard Lumbe, OUTREACH Coordinator, Information & Public Affairs, UNEP, P.O.Box 30552, Nairobi, KENYA

Building Small Dams

Suppose your community does not have enough water throughout the year. Would a dam be a good idea? A small dam, built across a stream, may provide people with a clean and plentiful supply of water close to homes.

The picture below shows one type of small dam where the water is collected by drawing from a pipe set low down in the wall of the dam.:



Building a dam

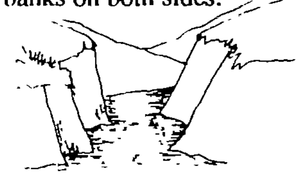
Building a dam is not easy. You have to build it in the right place that has the right soil. If a dam is not built well, it can be very dangerous. If a dam wall is washed away by floods, they can cause lots of damage to people, animals, and buildings.

Building a dam requires a lot of work. Everyone in the community needs to be involved. Before starting work, people should meet to discuss their needs as a community, and whether a dam is really what they need. It is important to think about the advantages and the disadvantages of constructing a dam. Can you think of any reasons why a dam should/should not be built in your community?

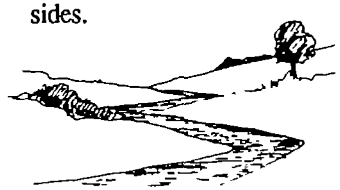
Choosing a site

It is important to find a good site for the dam. From each set of descriptions below choose one that would be a good feature for a dam site:

1.(a) A narrow valley with steep banks on both sides.

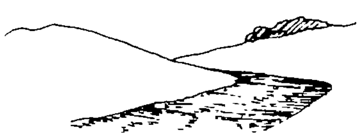


(b) A wide valley with gently-sloping sides.

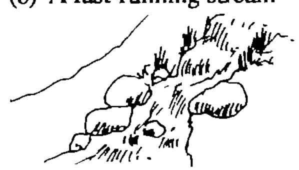


(HINT: How long a wall do you want to build?)

2.(a) A slow-running stream



(b) A fast-running stream



(HINT: Do you want a rapid build-up of silt and sand in the reservoir?)

3.(a) Ground that is a clay-silt soil. (b) Ground that is a sandy soil.
(HINT: You need a ground that will hold water)

4. The reservoir should cover
(a) a very large area. (b) a very small area. (c) an area that is not too large and not too small.
(HINT: Think about water needs and evaporation)

5. The storage site is (a) close to the users, below the village.
(b) far away from the users.
(c) close to the users, above the village.
(HINT: Think about convenience and health)

Can you think of any other criteria for selection of a dam site?

Preparing the site and building the wall

After finding a good site, it needs to be prepared. Clear away plants, roots and loose soil. Pack down the ground. A firm surface will provide a good foundation for the dam.

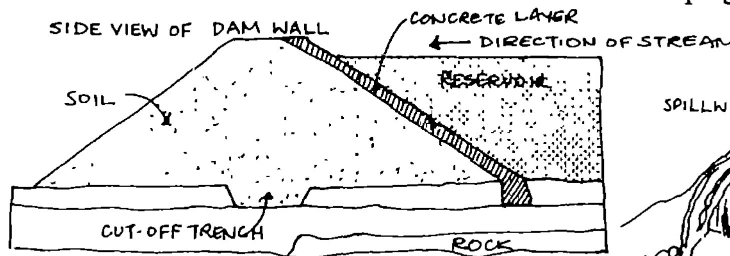
Dams can be built of earth, rocks and concrete. The material you choose depends upon what is readily available, and what you can afford.

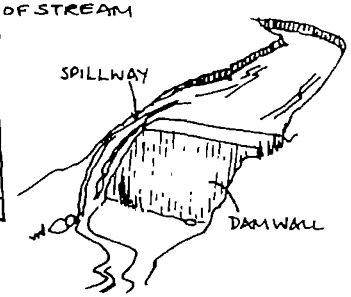
Earth Dams :

The best soil for earth dams is one with some clay in it, which helps to make the wall strong. Test the soil by rubbing a flat surface like a knife over a moist lump of soil. If the surface becomes smooth and shiny, then there is some clay in the soil. The soil should be dug out of the reservoir area to increase the amount of water stored by the dam. Do not dig closer than 5 to 10 metres from the dam wall because it could weaken the dam support.

The dam wall must be built on rock or clay soil. What would happen if the wall were built on sand? If the ground where you want to build the wall is not rock or clay, you have to dig a long trench. This trench, called the *cut-off trench*, must be in the middle of the dam wall. The cut-off trench is dug down to a layer of clay or rock. (If you cannot find rock or clay, ask an engineer how deep the trench must be.) The cut-off trench is filled with the same soil that will be used for building the dam wall, (that is, it should have some clay in it). The cut-off trench acts like an anchor and stops the dam from sliding down stream.

Build the dam wall in layers, putting on 10 to 15 cm of soil at a time. The soil must be damp, and each layer should be tamped down with earth compactors or trampled down by walking some oxen over it a few times. The dam wall must slope gently.

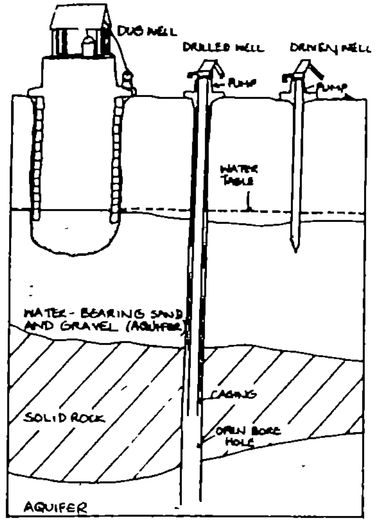




All earth dams should have a *spillway*. This is a place on the side of the dam wall that is a little lower than the rest of the wall. If the dam is full after heavy rains, excess water can run over the spillway without damaging the dam.

Rock dams:

Rock-filled dams are ones made from rocks with a layer of concrete or clay to stop water passing through the dam wall. Very big rocks should be used. Big rocks are difficult to build with, but if there are a lot of big rocks near where you want to build the dam, it may be worthwhile to make a rock-filled dam. Because rock-usually a shallow well built where the water-table is within 23 feet (7 metres) of the ground surface. It is made by driving a narrow pipe with a sharp driving point at the end of it into the ground. The pipe can be driven into the ground with a heavy hammer, or a special machine may be used which drops a heavy weight onto the pipe to drive it down. Sections of pipe are fastened together to make a long, unbroken lining for the well. A handpump may be used to draw water up from the ground.



3. A *drilled well*: In soil or sand, an auger (said: AW-ger) may be used to bore a well hole. This is a hollow instrument that is rammed into the ground and turned. It fills up with soil which is regularly emptied. A hard, steel bit is used to drill well holes through layers of solid rock. As the drill goes deeper into the ground, a pipe is placed in the hole as a lining. This pipe goes below the water-table. In many wells, the bottom section of pipe is capped with a heavy screen so that water can get into the pipe, but sand and gravel are kept out. Water is pumped to the surface. A drilled well is narrow. It may not provide enough water for a large group of people, but it could supply water to a family or small group of families.

Based upon the descriptions above, which type of well would you suggest should be sunk in each of the situations below. Give reasons:

1. A woman with five small children would like to have a well near her home. She has a little money to spend, but has no time to work on well-construction. She knows the land beneath her home is comprised of coarse sand with few rocks.

2. A family needs a supply of water. The family farm stands on solid rock, below which is water-bearing rock.

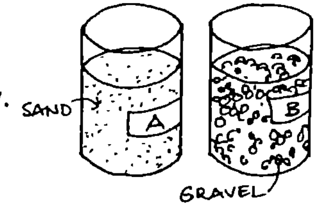
3. Villagers need a lot of water in the mornings and evenings, but they use little water at night, or in the heat of the day. The people have no money to spend on the well, but they are willing to spend a lot of time building one that can meet their needs.

OUTREACH pack 86 pp 13-14. Other Learning-By-Doing Leaflets and Information packs are available from Dr. James Connor, OUTREACH Director, Environmental Education Center, 200 East Building, New York University, New York NY 10003, U.S.A. or Richard Lumbe, OUTREACH Coordinator, Information & Public Affairs, UNEP, P.O.Box 30552, Nairobi, KENYA

Sinking Wells

Where does the water found underground come from? How does it get inside of wells? Here's an experiment that will explore these questions. You will need:

* 4 clean glass jars, all the same size;
* sand;
* gravel;
* water;
* a straw.



1. Label the jars A,B,C, and D.
2. Fill jar A $^{3}/_{4}$ full with sand. Fill jar B $^{3}/_{4}$ full with gravel.
3. Fill the other two jars full of water. Why doesn't water leak out from these jars? (The glass is impermeable - like some rocks under the ground.)
4. Add water from jar C to jar A until the sand is just covered. (This is like a rainfall.) Add water from the jar D to jar B until the gravel is just covered.
5. Compare water levels in jars C and D. What does this tell you about the water-holding capacity of sand in jar A and gravel in jar B? Based on your results, summarize where you would most likely find ground water.
6. Make a hole in the sand in jar A, and insert the straw until it reaches the bottom of the glass. Suck on the straw to draw water up it. Don't let the water reach you mouth. (This is how a well or pump works.)

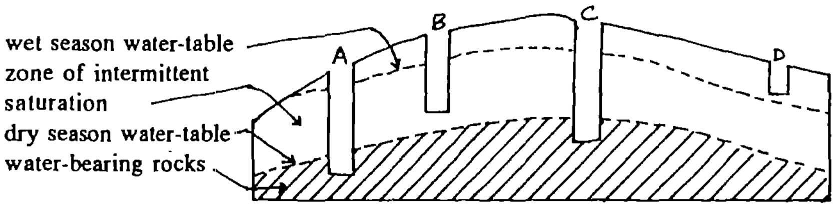
What is a well?

A well is a hole sunk in the ground to below the water-table. The water-table falls during long, dry spells. The lowest level of the water-table, reached at the end of the driest time of the year, is called the permanent water-table because below this level, there is water all the time. The well-hole must reach this level if people are to be able to get water all year round.

The well hole can be a few inches (centimetres) in diameter, or it may be much wider, perhaps, 6-7 feet (2 or 2$^{1}/_{3}$ metres) across. Water seeps out of the rocks into the well. The water in the hole may be drawn to the surface using pumps or buckets.

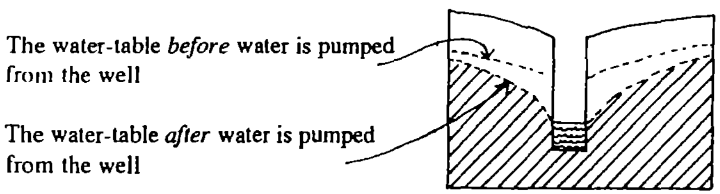
How deep should a well be?

The diagram below is a cross-section of a hill and valley. As you can see, four wells have been sunk into the ground. Which of these wells should always contain water?



Drawdown

A newly-drilled well may fill up with water a few feet (a metre or so) deep. But after some hard pumping, the well may become dry. Has the well failed? Was it dug in the wrong place? It is more likely that what has happened is *drawdown* - an effect every pumped well has on the water-table. Because water flows through the ground slowly, almost any well can be pumped dry for a little while, if it is pumped hard enough. Any pumping lowers the water-table around the well as shown:



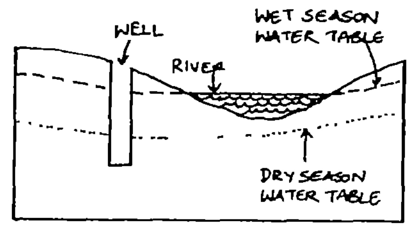
Drawdown becomes a serious problem only when normal pumping causes the drawdown to lower the water-table to below the level of the well.

Where to sink a well

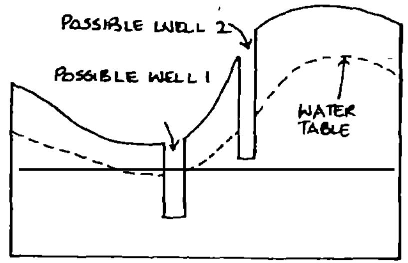
Choosing a good site for a well is not easy. Sometimes a well may be 'dry'. No matter how deep the hole, no water is found. Or water may flow very slowly into the well, or the well may dry up after a while. People who sink wells usually know the area they are drilling or digging. They know the kinds of rock in the ground. They know where other wells are sited, and how much water these produce.

Here are some well-digging puzzles for you to try.

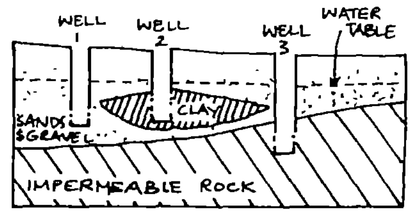
1. A village decides to sink a well near the river. This may seem strange when the river water is available. Can you think of two reasons why the decision makes sense? (HINTS: Which water would be cleaner? What could happen in the dry season?)



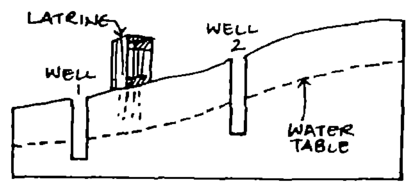
2. A farmer plans to sink a well. He has chosen two sites, see right. Which of these wells would you advise the farmer to sink? (HINT: Ground water, being a liquid, gathers in low areas.)



3. Here are three wells. Which one will provide all the water that is needed? (HINT: look at the types of rocks into which the wells are sunk.)



4. Which of these two well sites is likely to provide safer water? (HINT: Sometimes ground water has impurities that move with it.)

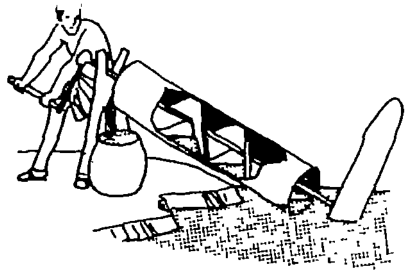


Types of wells

Here are three ways to sink a well:

1. A *dug well* is wide, 6-7 feet (2 - 2$^{1}/_{3}$ metres) across. It can also be deep. A deep or wide well allows a lot of water to seep into the hole, where it is stored, ready to be drawn up when needed. Digging a well is slow, hard work. It is dug by hand. Soil is removed, and the hole is lined with bricks or stones to keep the sides from caving in. Water from the dug wells is often drawn up by bucket.
2. A *driven well* is cheap and quick to make. It is narrow, best sunk in coarse sand, where there are not too many rocks. It is

Archimedes Screw



One ingenious water-lifting device was invented by the mathematician, Archimedes, over 2,200 years ago (see right). He designed this machine to lift fresh water from the hold of a ship. It had a watertight cylinder enclosing a spiral running from end to end. What does the spiral remind you of? The lower end of the cylinder was immersed in water. As the machine was turned by hand, the water collected in the rotating spiral blades and was lifted out of the ship's hold.

To better understand how the Archimedes screw works, try this activity. Make a tube out of paper to fit around a drill bit. Place a marble at one end of the tube. Turn the drill bit inside the tube. See how the marble is drawn to the other end of the tube.

Water-lifting machines in your community

Carry out a survey of water-lifting devices used in your community. For each machine, answer the following questions:

* Who uses the machine?
* Why is the machine needed; what is it used for?
* What is the source of water? (Describe the water: is it running or still; clean or dirty; available all or part of the year etc.)
* How much water is raised, and how high and how fast is it lifted?
* Are the machines made and repaired by local people?
* What materials are used in their construction?

Interview the users to find out if they are pleased with the methods of raising water. What improvements could be made?

Present all the information you gather in the form of charts, diagrams, pictures and text. Compare devices being used. Which machine is best suited for raising water at particular locations, for particular purposes, etc.? Can you help re-design one of the water-lifting devices being used to make it raise more water or to make it raise water faster?

Perhaps no water-lifting device exists in your community. Is there a need for one? Find out who might use one; what it might be used for and where it might be placed. Try using one - or a combination - of the following in your design: levers, wheels and axles, pulleys and screws.

Have a contest to see who can best re-design an existing water-lifting device, or design a brand new device for your community.

OUTREACH pack 86 pp 15-16. Other Learning-By-Doing Leaflets and Information packs are available from Dr. James Connor, OUTREACH Director, Environmental Education Center, 200 East Building, New York University, New York NY 10003, U.S A. or Richard Lumbe, OUTREACH Coordinator, Information & Public Affairs, UNEP, P.O.Box 30552, Nairobi, KENYA

OUTREACH

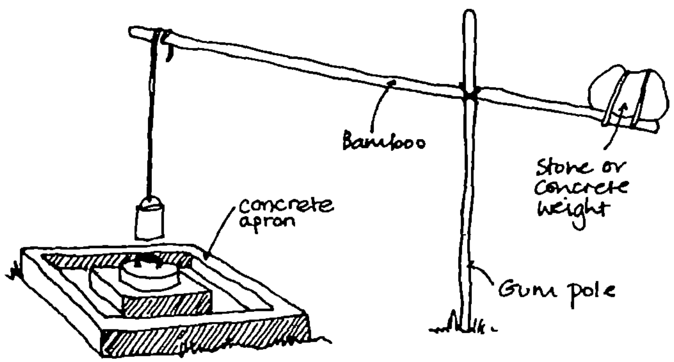
LEARNING-BY-DOING
HEALTH & ENVIRONMENTAL ACTIVITIES FOR YOUNG SCIENTISTS
LEAFLET NO. 43

Water-lifting Devices
(1) Using Simple Machines

Many people throughout the world rely on underground water supplies for clean drinking water. Also, in hot regions where rainfall is low or unreliable, water is often lifted from rivers and channelled into fields to water - or *irrigate* - the crops. Different devices have been invented over the ages to raise water to where it is needed. Many are still in use today.

The Shaduf

The shaduf is a simple water-lifting device that has been used for the past 4,500 years or so, and is still used in the Middle East. It is made of an upright post on which is balanced a long thin pole. A rope and bucket is fixed at one end, and a heavy counter-balanced weight is attached to the other end to balance the bucket. Then it is only necessary to pull on the rope to lower the bucket to the water. The weight can then lift up the full bucket.

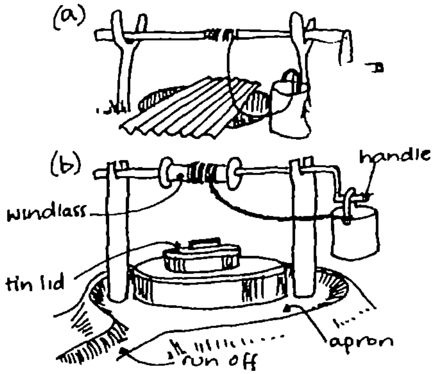


The shaduf is a lever-type machine. Can you label the load, effort and fulcrum? What are the advantages and disadvantages of this device? Design your own lever-type water-lifting machine.

Bucket and windlass

In many parts of Africa and the Middle East, the bucket and windlass device is widely used as a means of raising water from a well. This is a type of wheel and axle, (see Learning-By-Doing leaflet no. 33). Can you label the wheel and the axle?

On the right are diagrams of two bucket and windlass machines. Can you think how water drawn from the well in diagram (a) may get contaminated? Study the well in diagram (b) to discover ways to protect the water supply. Write a paragraph to summarize your observations.

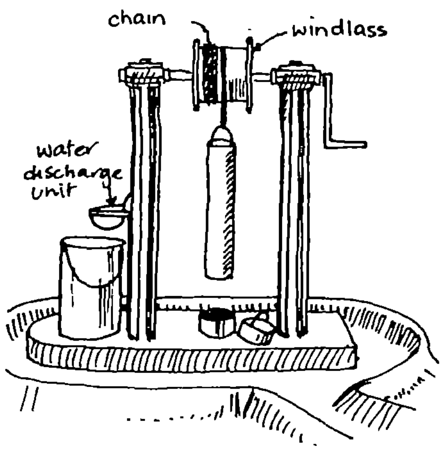


Bucket pump

The picture below shows the modern version of the bucket and windlass. This device is called the bucket pump.

There are three parts to the pump; the pump stand including footings and windlass; the bucket and chain, and the PVC (plastic) casing, which sits in the well.

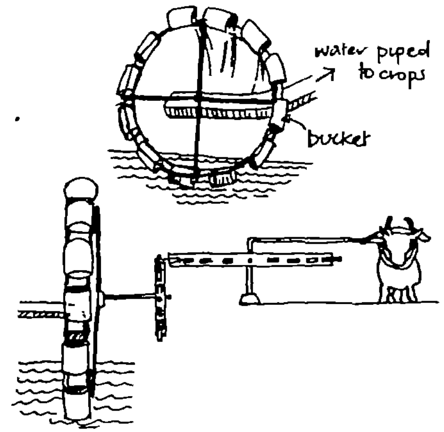
The bucket pump shown in the picture has a cylindrical steel bucket with a simple non-return valve at its base so that water can flow in, but not out. The bucket is connected to the windlass through a length of chain. The bucket is raised or lowered through a PVC casing which is either mounted in a hand-drilled tubewell or a wide diameter well. In most situations, the pump is fitted to wells and tubewells down to a maximum depth of 15 metres. Water can be delivered either by tipping up the bucket, or by placing it on the water discharge unit.



Suppose the bucket holds 5 litres of water, the well is 15 metres deep, and one bucket of water could be raised in a minute. How much water could be raised in an hour? Find out how much water your family uses in a day. Then, work out how many people a bucket pump could reasonably serve.

The Persian Wheel

Wheels and axles are used in other water-lifting machines. The Persian wheel is traditionally used in the Middle East and Asia to supply water to irrigation channels in fields. Buckets are fixed to the wheel, and as the wheel turns, water is lifted in the buckets from the stream and emptied into the channels. The wheel itself is turned by oxen, see the picture at right. (See Learning Leaflet no.34, Gears: wheels with a bite.)



The rope pump

The Persian wheel can raise water only to the height of the wheel. A rope pump may be used to raise water to greater heights. It can lift water from open waterholes, hand-dug wells and streams. Used as far back as Roman times, the rope pump is still one of the simplest and most effective pumps.

Shown here is a rope-washer pump made from materials which are widely available and cheap. It is used by farmers in many parts of Zimbabwe to irrigate crops. Study the picture closely, and then try to describe how the pump works.

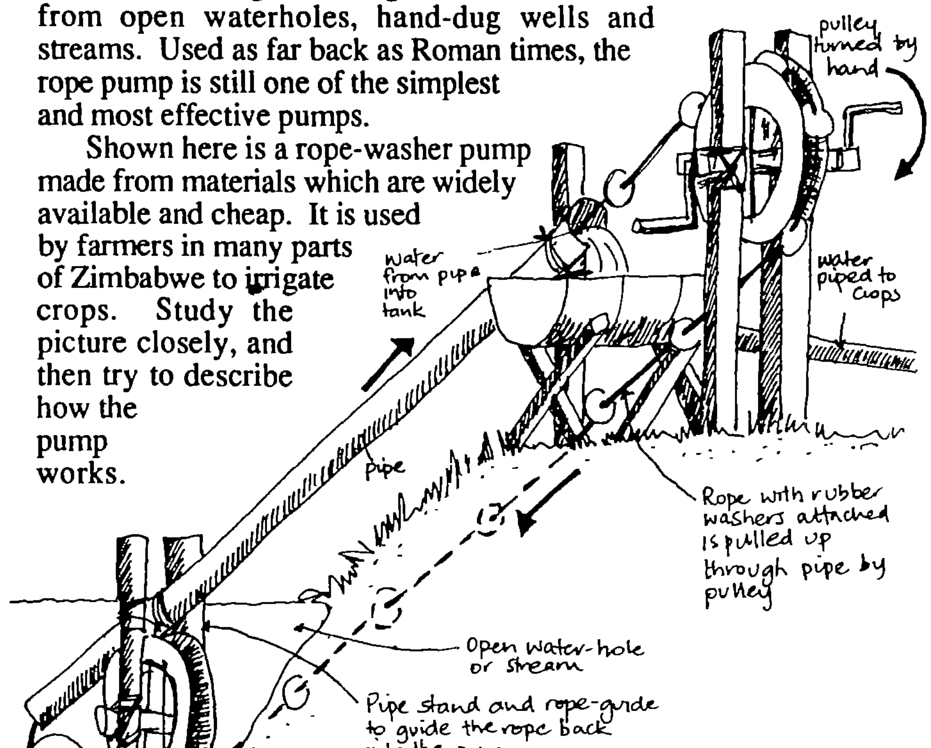
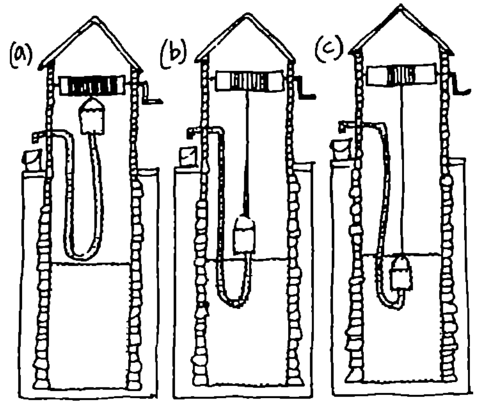


Illustration from Footsteps No 7 June 1991 published by Tear Fund, 100 Church Road, Teddington TW11 8QE, UK

started lowering the hose-bucket, the water in her own bucket started disappearing up the hose into the well again.
"Aggh!" she cried, "There's an evil spirit at work!"
What would you say and/or do (a) to help this woman understand that there wasn't an evil spirit at work, and (b) to make sure this didn't happen again?

2. If you close the discharge outlet with a cork before lowering the bucket what would happen?
3. Can you think of a way of modifying the hose and bucket pump so that it takes less time to raise the water?

Here are three pictures showing the hose and bucket pump in operation. Which picture shows the woman's bucket being filled with water?



Design a pump

A site has been chosen near your village where groundwater suitable for drinking is present at an easily accessible depth of 5 metres. A pump is to be installed so that the water is available to the whole village. The pump should meet as many of the following requirements as possible:

* The pump should not need an expensive form of energy (i.e. petrol, electricity)
* The pump should be cheap and made of locally-available materials.
* The pump should require little maintenance; if repairs are needed, it should be possible for members of the community to carry out repairs themselves.
* The building of the pump should be such that it will be impossible to contaminate the water supply.
* The pump must be able to meet the water requirements of the whole community.

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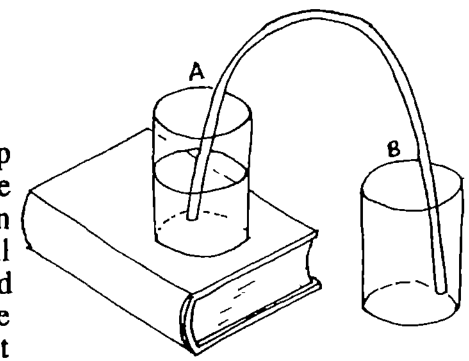
Water-lifting Devices (2) Siphons

Suppose you were washing some clothes in a tub. You want to fill the tub with water from a large rain bucket. How could you do this without having to lift either the rain bucket or the tub, and without having to bail the water out by hand? Hint: You do have a plastic tube available. You could siphon the water out with the tube. This experiment will show you how.

You will need:

* 2 jars
* a length of tubing
* a table
* a thick book



Fill jar A almost to the top with water and stand it on the book. Put the empty jar B on the table beside the book. Fill the tubing with water, and pinch the ends tightly so the water doesn't run out. Put one end of the tube underwater in jar A, and let it stay in the water. Put the other end of the tubing into jar B. Let go of the tubing and see what happens.

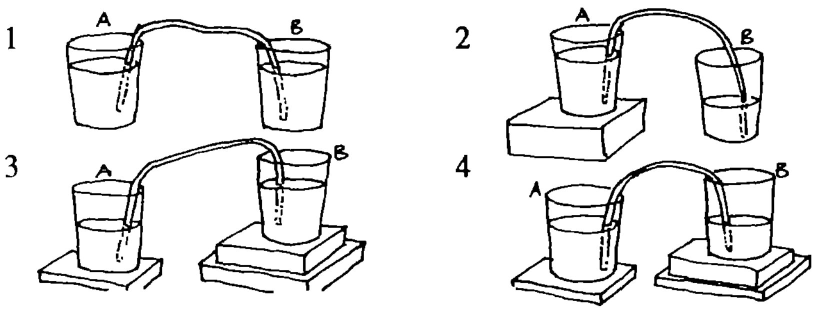
Try raising jar B, without letting the tubing come out of the water at either end. What happens? Which way does the water flow? Does the water stop flowing at some point? What happens if you raise jar B above jar A? Is there a way to make the water flow faster or more slowly? Is there a way to start the siphon without filling the tube with water to start with?

You may discover some important facts. Use the word bank below to complete the paragraph.

The water will not begin to flow if the tubing is full of ____. When the flow of water is starting, the end of the tubing has to be _____ the level of the water in jar A, or the water won't flow from jar A to jar B. Also, if you lift jar B ____ than jar A, the water will flow in the opposite direction. In siphoning, water moves ____, and will continue to do so until the container is empty or the water level in the two jars is the ____.

Word Bank:
higher
same
below
downwards
air
water

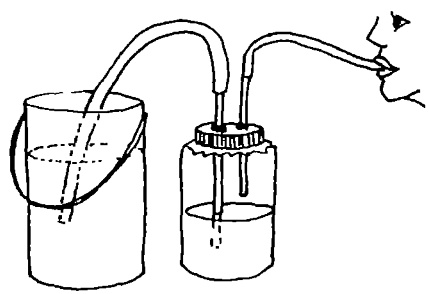
Here are some drawings of experiments you have tried. In which experiment will the water flow from jar B to jar A?



A Siphon Bottle

Here is another experiment in siphoning. You will need:

* a rubber stopper or a stopper made from a sponge rubber ball, cork, or plastic bag;
* a jar in whose opening the stopper snugly fits;
* 2 pieces of tubing;
* a ballpoint pen tube;
* bucket

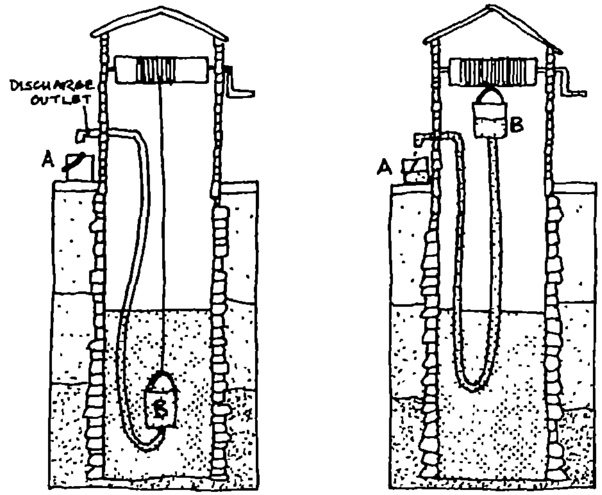


Use the materials to set up the apparatus at right. Try sucking on the shorter tubing to see if you can get water to come into the bottle from the bucket. Are there other ways to get water into or out of the bottle? Place the bottle in different positions, hold it upside down, on its side, high above and then lower than the bucket. See if and how the water flows. Record your results. Answer these questions:

* Can you get the water to flow into the bottle by itself without sucking all the time?
* Can you get the water to flow more quickly or more slowly out of the bottle?
* Can you stop and start the flow of water by closing off one of the tubes with your finger?

The Hose and Bucket Pump

The picture below shows a hose and bucket pump:



It works like a siphon. If bucket B is raised above the discharge outlet, the water will run out.

Can you make a model of the pump? The materials you use depends upon what you can find.

When you have made a model, put your finger against the discharge outlet. Then, lower bucket B. You will feel your finger being sucked into the hose. That is because the water in the hose flows downwards when you lower bucket B. If you put your finger against the discharge outlet, air cannot move into the hose to replace the water that has flowed down to bucket B. This creates a lower air pressure in the hose which sucks your finger.

What happens if you leave the hose in water in bucket A as you lower bucket B? Just as your finger was sucked into the hose when bucket B was lowered, so too will the water from bucket A be sucked into the hose and down to bucket B. When will this stop happening? When the hose in bucket A is no longer in water.

Questions on hose and bucket pumps:

1. A woman was using a hose and bucket pump. She filled her bucket, but left the end of the hose hanging in it. When she

Making your own suction water pump

You can make a model of a suction pump as shown in the pictures on the previous page. Use locally-available materials. What materials might you use for the tubes? For the piston rod and piston flaps? What can you use for the valve? Try different materials, and see which works best. Keep a record of the results. Here are some ways of testing your pump:

* How many downstrokes on the piston are required to get water flowing at first?
* How long does it take to pump, say, 10 litres of water with your model pump if you pump steadily?
* From what depth can your model pump up water? (Hint: put a bucket of water at the bottom of a flight of steps or hill slope and run a tube from the bucket to the suction pump which you are holding at the top of the steps.)

Think of how you could improve the pump so that you can raise water from a greater depth. Why is it not possible to pump water from a depth of more than 10 metres with a suction pump?

Over time, the pump is likely to become less efficient. The washers of the piston will wear out from being moved up and down along the well of the cylinder. If the washers are worn, air will enter the cylinder from above when the pressure in the cylinder drops below 1 atmosphere. This will stop water rising in the rising main. Can you think of a way to prevent air from entering the cylinder from above?

One way is to pour water on the piston which will press the flaps against the wall of the cylinder. What are the major disadvantages of using a water seal in a suction pump used to supply drinking water?

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OUTREACH

LEARNING-BY-DOING

HEALTH & ENVIRONMENTAL ACTIVITIES FOR YOUNG SCIENTISTS

LEAFLET NO. 45

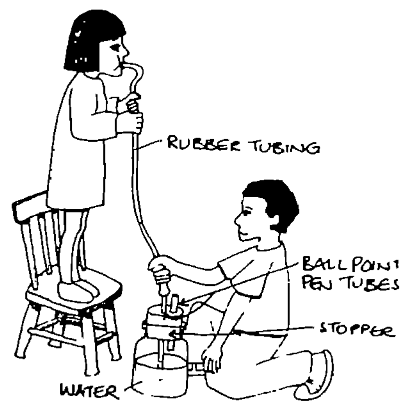
Water-lifting Devices (3) Suction Pumps

How can you lift a liquid by using a drinking straw? If you suck, you can pull up the liquid through the straw to your mouth. What you're doing is sucking air out of the straw. How do you do this? You expand your lungs so there is lower air pressure in them. Then air moves from the straw to your lungs. This makes the air pressure inside the straw less than the air pressure on the outside. The air pressing down on the liquid in the glass pushes the drink up the straw to balance the pressure again.

How high can you pull up water?

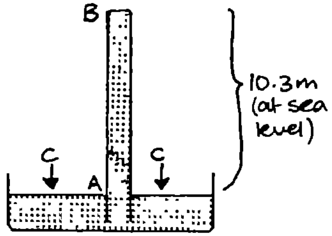
Could you pull water up a tube 2, 3, or 4 metres long? You could try this by adding a long tube to a siphon bottle, see below:

Stand on a chair or up some steps to see how high you can suck the water. When you suck on the tube, the air pressure inside the tube is lowered. Water moves up the tube to equalize air pressure inside and outside the tube. The weight of the water column is supported by atmospheric pressure acting on the surface of the water in the siphon bottle. Now close off the small tube, and make sure the stopper is airtight. Can you suck the water now? Why or why not?



Unblock the small tube, and then take your mouth away from the long tube. What happens? Once your mouth is removed, the atmosphere exerts equal pressure both inside and outside the tube. The water column, therefore collapses under its own weight.

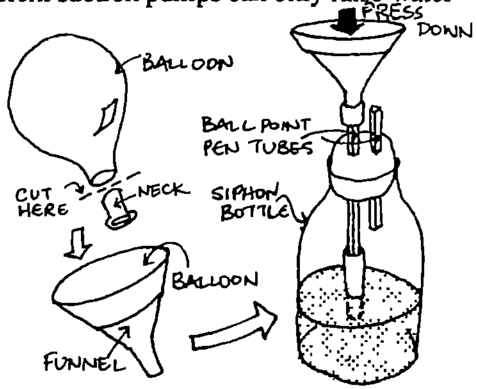
In theory, if you had enough sucking power, you could raise water about 34 feet (10.3 m) above the water level in the bottle, and no more. That's because the pressure of air is about 1 atmosphere, and this is equivalent to the pressure of 10 metres of water. In practice, because of friction and the effects of temperature, even the most efficient suction pumps can only raise water to 22-25 feet.



THE COLUMN OF WATER AB IS SUPPORTED BY ATMOSPHERIC PRESSURE AT C

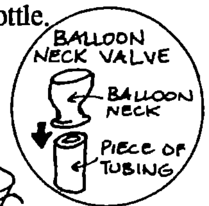
Ways to help you "suck"

Can you think of a way to help you pull water up a tube without having to suck it up yourself? One way is to use a piece of balloon and a funnel. Cut off the balloon neck, and stretch the balloon over the funnel. (Save the balloon neck for later.) Add the funnel to the siphon bottle as shown at right:

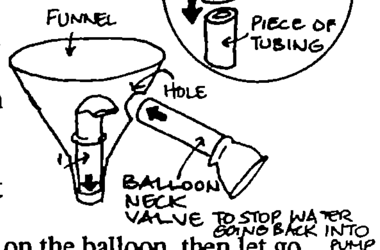


What happens when you press down on the balloon and then release it? You will find that the water in the tube moves up and down in the tubing. Can you explain why? When the balloon is pressed, there is less space inside the funnel, so the air pressure increases and some water and air move down the tube, into the jar to equalize air pressure inside and outside of the funnel. When air and water move into the bottle, air pressure inside the jar increases, so some of the air inside the jar moves out of the bottle through the small tube to equalize the air pressure inside and outside of the bottle. When the balloon is let go, air pressure inside the funnel decreases, so water moves up the tube from the bottle.

Can you think of a way to keep the water in the funnel instead of flowing back into the bottle? You can add a valve. The balloon neck may be used as a valve, see diagram at right.



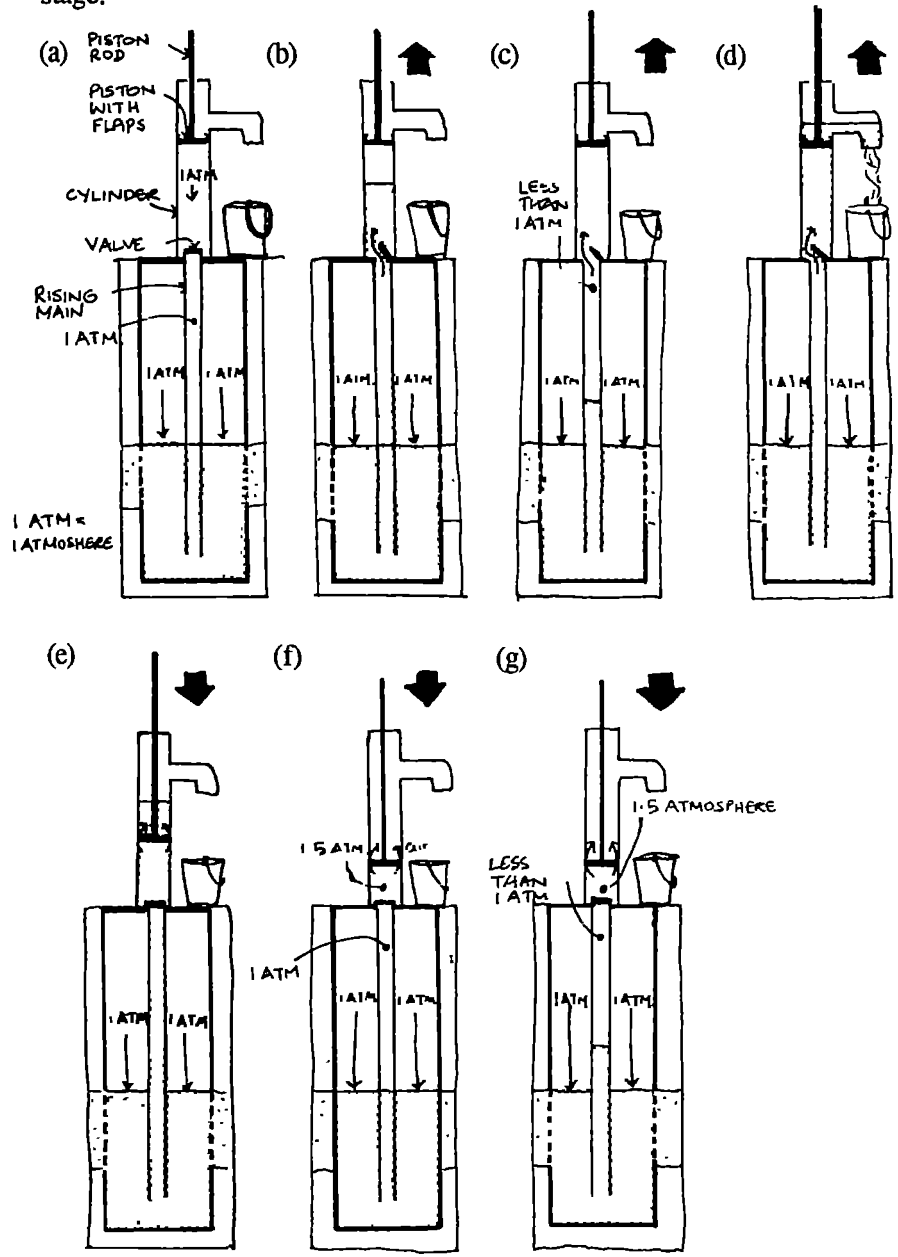
The valve helps water come into the funnel, but prevents it from returning to the bottle. With a few additions, the apparatus can be made into a *suction pump*. Make a hole in the funnel, place a tube in the hole, and add another balloon neck to the tube, see diagram at right. Now you have an outlet for the water.



To operate your suction pump, push down on the balloon, then let go. Repeat these strokes for a few times to get the water flowing out.

How a suction pump (lift pump) works

Below are 7 drawings that show different stages of a suction pump in action. However, the pictures are in the wrong order. Put them in the correct order, and then describe to other people what is happening at each stage.



Some water is forced around the piston, which has the advantage of lubricating the moving parts whilst they are in motion. For this reason, the piston and cylinder wear away remarkably slowly. For 6 metre lifts, the pump works with worn valves and leaky pistons. But for greater lifts, the valves cannot afford to leak. Explain.

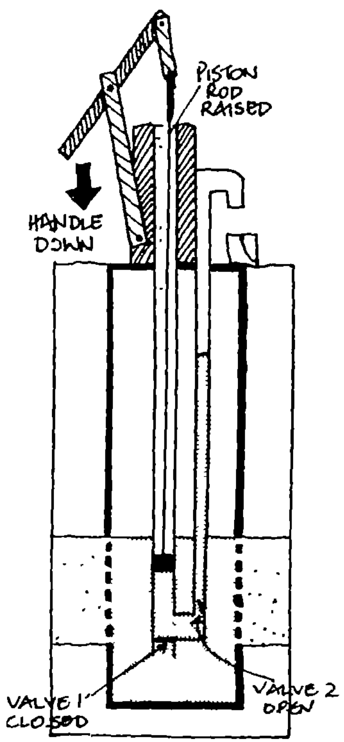
The Blair pump design uses less parts than other direct action pumps, and is therefore simpler and easier to make. Its delivery rate varies between 15 and 20 litres per minute.

Compare the Blair Pump, a direct action force pump and the displacement pump, a lever acting force pump, shown on page 1. Which do you think is easier to install, use and maintain? Explain.

Lift pump versus force pump

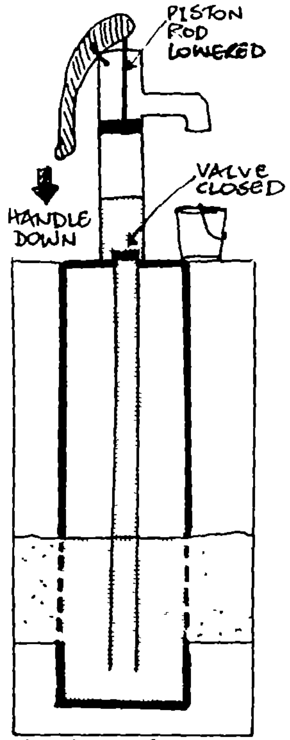
Here are pictures showing downstroke actions of a force pump and a lift pump, but there are two things wrong with each diagram. Can you spot what is wrong?

DISPLACEMENT PUMP



A LEVER-ACTING FORCE PUMP

SUCTION PUMP



A LEVER-ACTING LIFT PUMP

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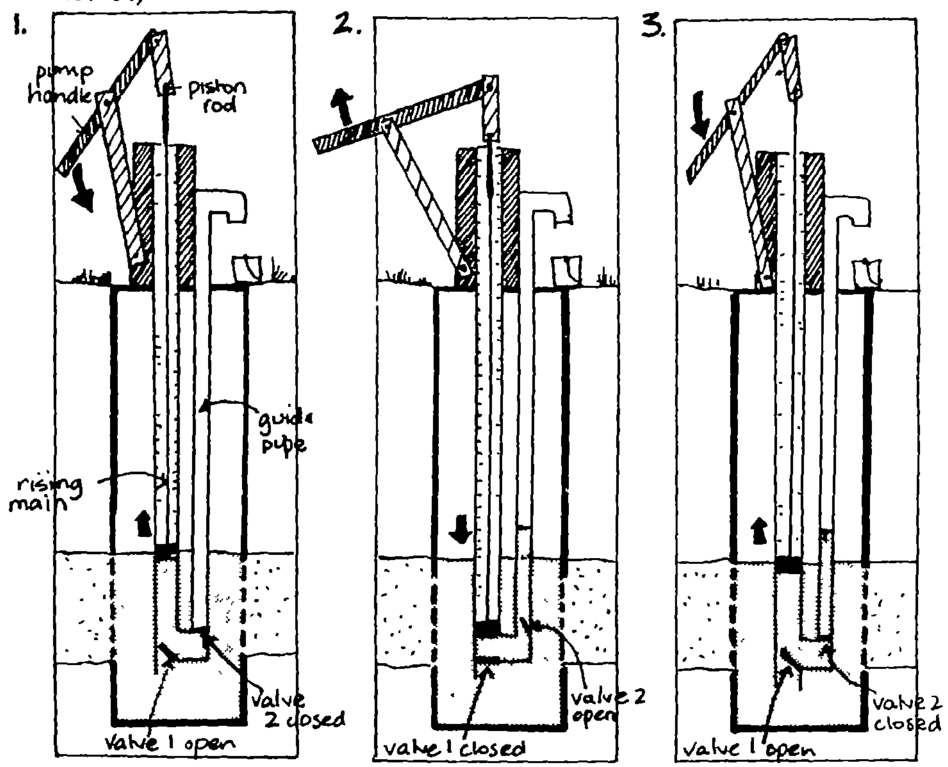
Water-lifting Devices (4) Force Pumps

The pictures below show how a *displacement pump* works. A displacement - or force - pump is a *reciprocating* pump. A reciprocating pump is one in which a part, such as a piston, moves to and fro. As you can see, with this force pump, the pumping mechanism is placed at or near the water level, and pushes the water up. (Compare this to the lift pump - another type of reciprocating pump - whose pumping mechanism is located at the top of the well and raises the water by suction, see L.L. no.45.)



Describe how this displacement pump works. Where is the pumping mechanism? What happens when the handle is pushed down? What happens when the handle is raised?

When the handle is pushed down (1), the piston moves up. The pressure of the water under the piston drops slightly, enough to open valve 1 and close valve 2. Water flows from the well through valve 1 into the cylinder.

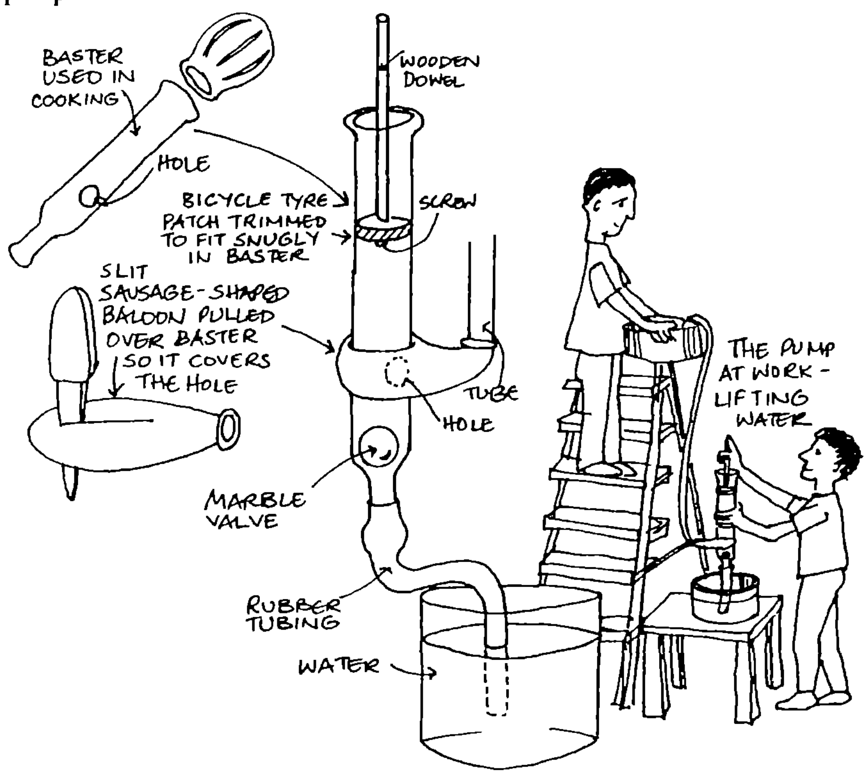
When the pump handle is raised (2), the piston is pushed downwards. Pressure causes valve 1 to close and valve 2 to open. The water in the cylinder is forced through valve 2 and into the guide pipe. After moving the handle several times (3 and so on) water flows out of the pump.

Here are some questions:

1. Do you think it would get harder and harder to pump water? Explain.
2. A good displacement pump can pump water up from a depth of 30 metres. The pressure that must be exerted on the water by the piston is quite considerable. Can you explain this?
3. Why is the piston rod in a displacement pump easily damaged?
4. Will there be any difference in the pressure on valve 1 in the wide rising main and on valve 2 in the narrow guide pipe? Explain.

Make a model force pump

You can make a model displacement pump from PVC tubes bought at a hardware shop. Or you can try making one from materials that are more readily available. The diagram below shows one way to make a force pump:



The model force pump shown is worked by *direct action*: Unlike the displacement pump, it does not have a lever that raises or lowers the piston rod.

Use your model pump to raise water. See how many times you must raise and lower the piston before water squirts out of the pump. See how many litres of water it raises in 1 minute. Pump steadily, don't hurry.

Add long tubing to the release valve of the pump in order to raise water from greater depths. Determine the maximum height to which water can be raised by your pump. How would you change your model in order to raise water from greater depths? Do you think it takes longer to pump water up from a depth of 1 metre than from depths of 2 and 5 metres? Try to find out.

Do you encounter any problems with your pump after continued use? Does it get harder to work the piston? Do the valves leak? What happens if and when they do?

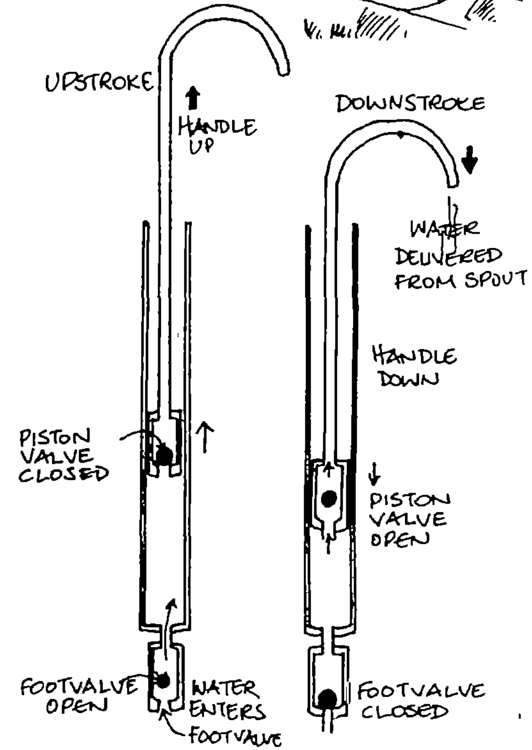
The Blair pump

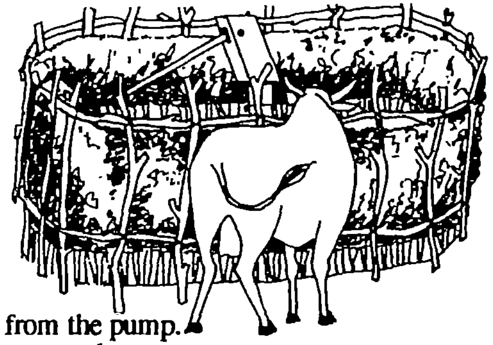
In the picture at right, a woman is using the Blair pump. The Blair pump is one type of direct action pump that uses the force pump principle.

The piston valve is linked to the pump rod, which is hollow and acts as a water spout and handle combined.

The diagrams below right illustrate how the Blair pump works.

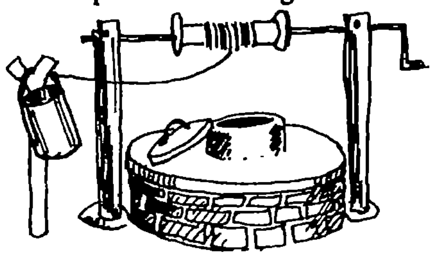
On the upstroke, water is drawn into the lower end of the cylinder through the footvalve. On the downstroke, the footvalve closes, the piston valve opens as it passes down through the cylinder. As the two valves come closer together, water is forced to find a way out, the easiest path being through the open piston valve, through the hollow pushrod to the surface and out of the handle.





* Keep rubbish away from the pump.
* Do not allow washing near the pump area.
* Keep animals out of the area by building a fence or growing a hedge.
* Encourage users to move the pump handle slowly and steadily so as not to break the pump..
* Learn all you can about the workings of the pump so that you may be able to help in the event of a break-down. Ask the repair person if there are any locally-available materials that can be collected and stored to use as substitutes when pump parts wear out.
* Report all cracks, leaks and break-downs immediately to the caretaker/mechanic.
* Keep a record of break-downs: when they occur, the cause, how long it takes for the repair to be fixed.
* If latrines or houses are to be built in the vicinity of the pump, advise that these should be constructed at least 30 metres from the pump and downhill.

Here are some extra duties relating to open wells:
* Clear away bush from around wells so that it does not fall into the water and rot there; it does not attract animals to come to the well; it does not house insects. After clearing the bush, plant short grass around the well extending from the concrete platform.
* Build a retaining wall around the well to prevent plant remains from being washed into the well by running surface rain water.
* Cover the well for protection against birds, animals and dust. The cover also inhibits the growth of green algae, which needs sunlight to grow. The cover should be movable to allow periodic cleaning of the well.
* Water should be obtained through an opening in the cover. Make sure only clean, uncontaminated vessels are used to draw water from the well. Keep the vessel hanging on a stick or hook near the well, and never let it touch the ground.



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Pump Probe and Patrol

This leaflet will help you to look critically at the hand pump in your community, and determine ways to keep the pump supplying you with clean, safe water. A pump is a "machine that raises a liquid". It may be a simple, traditional bucket and windlass or a reciprocating type.

Here are some questions about your local pump that you can ask yourself and other pump users. Your answers will help you work out the problems and potentials of your pump:

PUMP PROBE

General

1. How old is the pump?
2. Is the pump the only source of drinking water for your community? If not, what other water sources are available to the community?
3. What type of pump is it?
4. Who decided to have a pump installed?
5. Who paid for the pump?
6. Who owns the pumps?
7. Is the pump used throughout the year?
8. Is it used only in the dry season?

Pump make-up

9. How many parts make up the pump? (Ask a pump repair person to show you.)
10. What are the parts made of? (Draw a picture of the various parts and give labels that describe the materials used in their construction.)
11. Are all the parts locally-available? If not, where did they come from?
12. Was a skilled person needed to make the pump parts?
13. Who installed the pump?
14. How long did it take to install?
15. What is the cost of the pump?

Pump site

16. How far is the pump from houses and latrines? (You can draw a scale map of its location. Note surface waters, houses, latrines and vegetation on the map.)
17. From what type of well does it raise water?
18. From what depth does the pump raise water?

Pump usage

19. How many people does the pump serve?
20. How fast is water raised by the pump? (in litres/minute)
21. Does it take a lot of effort or a little effort to raise water? (Can a child operate the pump?)
22. What are the uses for pump water? (When are the peak demands on the pump?)
23. What do people say about the amount and quality of the water provided by the pump? (Do they think the pump is an improvement to water supplies prior to the pump installation?)

Pump maintenance

24. Who maintains the pump?
25. How does the community pay for pump maintenance? (Time? Money?)
26. What do people say about how well the pump and pump area are kept clean and in good working order?

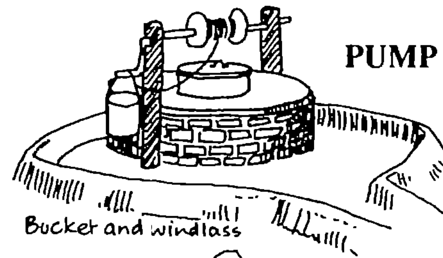
Pump repairs (You may need to ask the repair person these questions.)

27. When was the last time the pump broke down?
28. Who repaired it?
29. Does the repair person need to be a skilled mechanic?
30. How far away from the pump does the repair person live, and how often does the mechanic visit the pump?
31. How long did it take to fix the pump when it last broke down?
32. What needed fixing?
33. What is the most common reason for the pump to break down?

Pump improvements

34. What are the good points about using the pump?
35. What are the bad points about using the pump?
36. Ask pump users what improvements they would like to see.

What improvements would you make to the pump and its usage? You might decide the design needs modifications. Or the pump area simply needs to be kept clean to improve hygiene. Or maybe you want to work out a way to keep this pump and others in the region in good repair. Whatever your thoughts, *try to put them into action!*

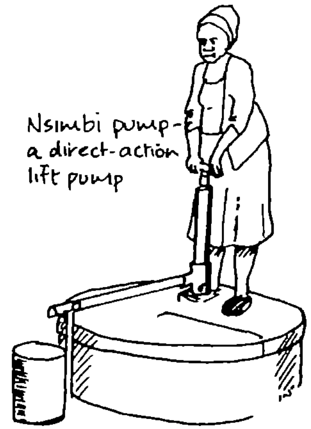


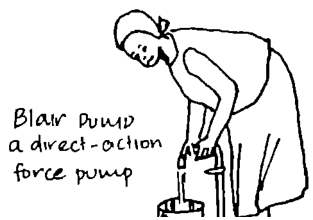
PUMP MONITOR

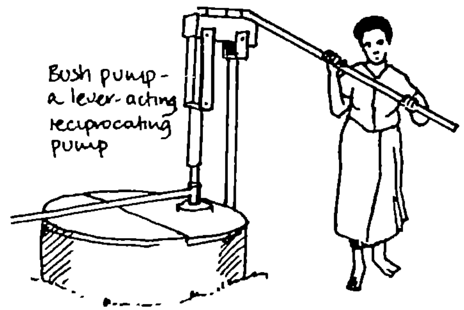
If there is no-one who is responsible for the up-keep of your pump, then you and your friends may wish to become pump monitors. Even if there is a pump caretaker, he or she may welcome help from the community.

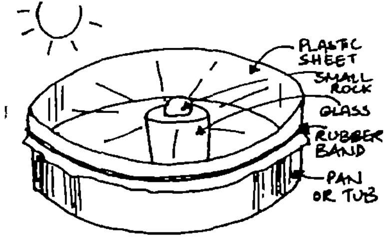
Ask permission to be in charge of looking after the pump and its surroundings. Here are some of the jobs you and your friend can do. These suggestions may apply to shallow wells (which do not usually go below 6 metres) and deep wells or boreholes (where water is tapped from a depth of 30 to 100 metres):

* Build a concrete platform around the pump to prevent water from soaking into the well from the soil immediately around it. Slant the platform gently away from the well to keep the surroundings dry and easy to keep clean. The chances of the well becoming contaminated by the well-users defecating or urinating near it are also reduced.
* Keep the platform clean and swept, and the drainage clear.









1. Fill the pan to a depth of 5 cm (2 inches) with muddy water.
2. Stand the pan in a place where the sun will shine on it all day.
3. Put the glass right-side up in the centre of the pan.
4. Put a loose covering of the plastic sheet over the top of the pan. Fix it securely with the tape or rubber band.
5. Place the pebble on the plastic sheet, over the centre of the glass. Don't let the rock touch the glass.
6. Leave in the sunshine for at least four hours.

Do you see any droplets of water forming on the bottom of the plastic sheet? How do you think the water got there? What colour is the water collecting in the glass? What has happened to the water and the impurities that were dissolved in the pan?

The water in the glass has been distilled. Can you think of an example of distillation taking place in nature?

Advantages: Distillation removes all dissolved impurities from water. It can make sea water fit for drinking.

Disadvantages: The process takes a long time, and it uses a lot of fuel (although sometimes free energy from the sun can be tapped).

SUNLIGHT

Sunlight - especially ultraviolet rays - can kill most germs in water. To try this method, you will need:

* clear glass or plastic containers of small volume (1-3 litres)
* relatively clear water from a well or river
* strong sunlight

Pour water into the containers, cap them, turn them on their sides and expose them directly to the sun, when it is at its brightest. Leave for 5 hours.

Advantages: This method uses solar energy which is free, plentiful, renewable and can do the job without human intervention. This method has been tested successfully in Poona, India to prevent the transmission of cholera in particular. The Red Cross has obtained the same positive results from tests carried out in Yemen.

Disadvantages: This method works for relatively clear water, but it is not an efficient way to treat waste water. The rainy season presents a major obstacle to its use in tropical countries. Some bacteria can develop a resistance to the destructive effects of ultraviolet rays.

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OUTREACH

LEARNING-BY-DOING
HEALTH & ENVIRONMENTAL ACTIVITIES FOR YOUNG SCIENTISTS
LEAFLET NO. 48

Purifying Water with Heat

Water is the source of all life. Without it, you would die. Yet water which is dirty may also make you very sick. Even water which looks clean may still contain microscopic germs or harmful chemicals. Diseases such as bilharzia, cholera, typhoid and gastro-enteritis are all caused by germs in water. To make sure water does not have these germs, it must be cleaned before you can drink it or wash with it.

In this leaflet you will look at several ways to purify water with heat. Try out these methods, and decide which works best for you.

BOILING WATER

Boiling water is one of the best ways to destroy germs that carry disease. Boiling is a physical change of a liquid to a gas. If liquid water is heated sufficiently, it boils to form a gas known as water vapour. Water vapour, like other gases in the air, is invisible. When water vapour cools, it becomes water again. Steam and clouds are tiny drops of liquid water which have condensed from water vapour in the air. Where else have you seen condensed water?

The temperature at which a liquid turns to a gas is called its *boiling point.* Not all substances have the same boiling point.

What is the boiling point of water?

Read all these instructions carefully before you begin, and carry out this experiment only under adult supervision.

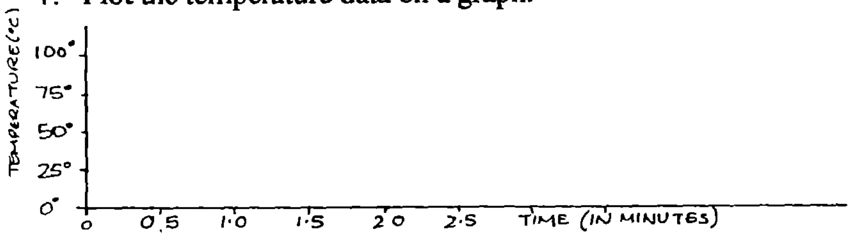
You will need:

* a small, deep pot;
* water;
* a ruler;
* a thermometer;
* a source of heat (i.e. stove);
* a clock with a second hand.

1. Copy the chart and record what you observe.

TIME (MINUTES)	0	0.5	1.0	1.5	2.0	2.5
TEMPERATURE OF WATER (°C)						
APPEARANCE OF WATER						

2. Fill the pan to a depth of 2 inches (or 5 cm) with cold water. Place the pot over the stove. Record the time you begin the observe steam and bubbles on the water surface.
3. Measure the temperature of the water every 30 seconds from the time you start heating it. To measure the water temperature, hold the thermometer with the bulb just under the water. Keep measuring until 10 minutes after the water starts to boil. *Be careful when you are near boiling water.*
4. Plot the temperature data on a graph:



Then answer these questions:
(a) At what temperature did the water begin to boil?
(b) Did the temperature increase after the water began boiling?
(c) Do you observe steam before the water is hot enough to boil? When does the change from water to water vapour happen most rapidly?

Here are some more things to try:

* When the water begins to boil, is there any change in the thermometer reading if it touches the bottom of the pot? Explain.
* After the water has boiled for 10 minutes and cooled, measure the water depth. Explain what has happened.
* Do you think the time taken for water to boil will vary depending upon (a) the amount of water being heated; (b) if the water is being brought to the boil at sea level or high in the mountains? If possible, try to find out for yourself.
* Add different substances - such as salt, sugar, or dirt - to the cold water, and then boil the water. Find out if these substances are still present in the boiled water once it has cooled.

How boiling affects living things

We can study how boiling affects tiny living things such as harmful bacteria in a simple way. The white of an egg is known to be chemically very similar to the substance that makes up the bodies of living bacteria. So heat some water to boiling, and then add a few drops of egg white in the boiling water. Observe what happens.

The egg white is changed completely. It becomes like egg white in a boiled egg or fried egg. We say it has *coagulated.* This is probably what happens to the living tissue of harmful bacteria when water containing them is boiled.

To make water safe by boiling

Here's what to do to make sure water is boiled properly:

1. Wait until the water begins to boil, then let it boil for 10 minutes. If you live high in the mountains, let it boil longer - 15 to 20 minutes.
2. If you have to boil a lot of water, you can make a boiler out of an oil drum. Make a fireplace under the oil drum turned on its side. Screw a tap into the bottom opening, and make an opening in the top for steam to come out. (What would happen if you didn't have this opening?)
3. After boiling, taste the water. It will taste flat. Let it stand a while to redissolve air. If you can, store the water in the container it was boiled in. Or make sure the container you store it in is clean. Keep it covered, too, to keep dust and insects out. Unless water is carefully stored, it can easily get dirty again.

Advantages: Boiling water kills most germs.
Disadvantages: Boiling water doesn't make the water look clean. It also takes a long time, and uses up a lot of fuel. Boiling water does not get rid of harmful chemicals.

DISTILLATION

Distilled water is the only kind of water that is completely chemically pure. To distill water, it must be heated until it changes into a gas, and *evaporates* into (gets into) the air. Then, the gas must be cooled so that the water *condenses* , and changes back into a liquid. You can see what happens when water is distilled. You will need:

* a large pan or tub; * a pebble; * some muddy water.
* a heavy glass cup (shorter than the pan is deep)
* a clear plastic sheet big enough to fit loosely over the pan;
* adhesive tape or large rubber band;

8. Present your findings in a chart similar to the one below:

		TIME TAKEN TO TREAT	AMOUNT OF WATER TREATED	CLARITY OF WATER
FINE SAND	4 inches			
	8 inches			
SOIL	4 inches			
	8 inches			

What can you conclude from this experiment?

Experiment further by building filters of layers of different materials. Determine which kind of filter will work most effectively.

Then, instead of filtering muddy water, see what happens when you try to filter salt from water. You will first have to stir some salt into water until it disappears. The salty water is called a *solution*. Now find an answer to this question: Can filtration purify water mixed with vinegar?

Filtration is a natural way of making water pure. When water passes through the sand, it not only becomes clear, but also free of some disease organisms. Harmful bacteria do not find either sand or soil a good medium in which to multiply. They tend to die off. This explains why water taken from adequately protected wells and tubewells excavated in the soil yield water with very few bacteria in it.

Build a water filter of your own

You can create your own small scale "water purification" system in a simple pot containing graded layers of stones, gravel, sand and broken charcoal, see the diagram at right.

① WATER ② FINE STONE ③ ROUGH PEBBLES & SAND ④ FINE SAND ⑤ ROUGH PEBBLES & SAND ⑥ FINE CHARCOAL ⑦ ROUGH PEBBLES & SAND ⑧ FINE STONE ⑨ ROUGH STONE

Advantages: Passing water through very fine sand is a good way to make water safe if boiling is too difficult, and it can get rid of most disease organisms including those that spread bilharzia.

Disadvantages: Unlike the distillation process, filtration cannot separate substances such as salt that are dissolved in water. For water that might contain serious diseases such as cholera, typhoid and gastro-enteritis, filtration is not enough. Water must be treated further either by boiling or by adding chemicals.

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Purifying Water with Filters

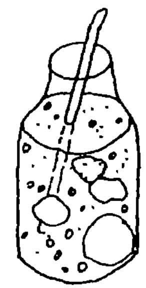
Is the water you use for drinking and washing muddy? These experiments will show some ways to purify it.

SETTLING

Try this experiment. You will need:

* a gallon glass jar or transparent plastic container;
* equal amounts of soil, clay, sand, gravel, and pebbles;
* water.

Put the soil, sand, pebbles, etc. in the jar, and add enough water so that it is almost full. Carefully shake or stir the mixture very thoroughly. Can you predict the order in which the materials will be deposited (settle out) in the jar?



Record your predictions on the chart below:

	PREDICTIONS	RESULTS
MATERIAL THAT SETTLED FIRST		
MATERIAL THAT SETTLED LAST		

Stop stirring and let the mixture stand. Observe and record the order with which the sediment settles to the bottom of the container. Which material settles out first? Can you infer why? Which material settles out last. Why? Compare your observations with your predictions. Can you prepare a list of factors that would control the rate at which sediments settle? What if you use salt water instead of well water or hot water instead of cold water? Will you get the same order and rate of deposition for those sediments?

To make water safer by settling

If your water supply is muddy or dirty, it can be stored for at least two days. During this time most of the dirt in the water will sink to the bottom, and many of the germs that can make people sick will die. So the stored water will be much safer to drink.

Many people who purify their water in this way, use what is called the "three-pot method". Two big pots are used for fetching the water and storing it. The third pot is smaller, and is used for the clean drinking water. The diagrams on the right show how to use the three-pot method.

Advantages: Water that has been allowed to stand for 48 hours is safer to drink than water you just fetch from a river or lake. Dirt has been removed and harmful organisms in the water, such as blood flukes, are dead. No fuel is required for this process.

Disadvantages: The water is not as clean as boiled water.

FILTERING

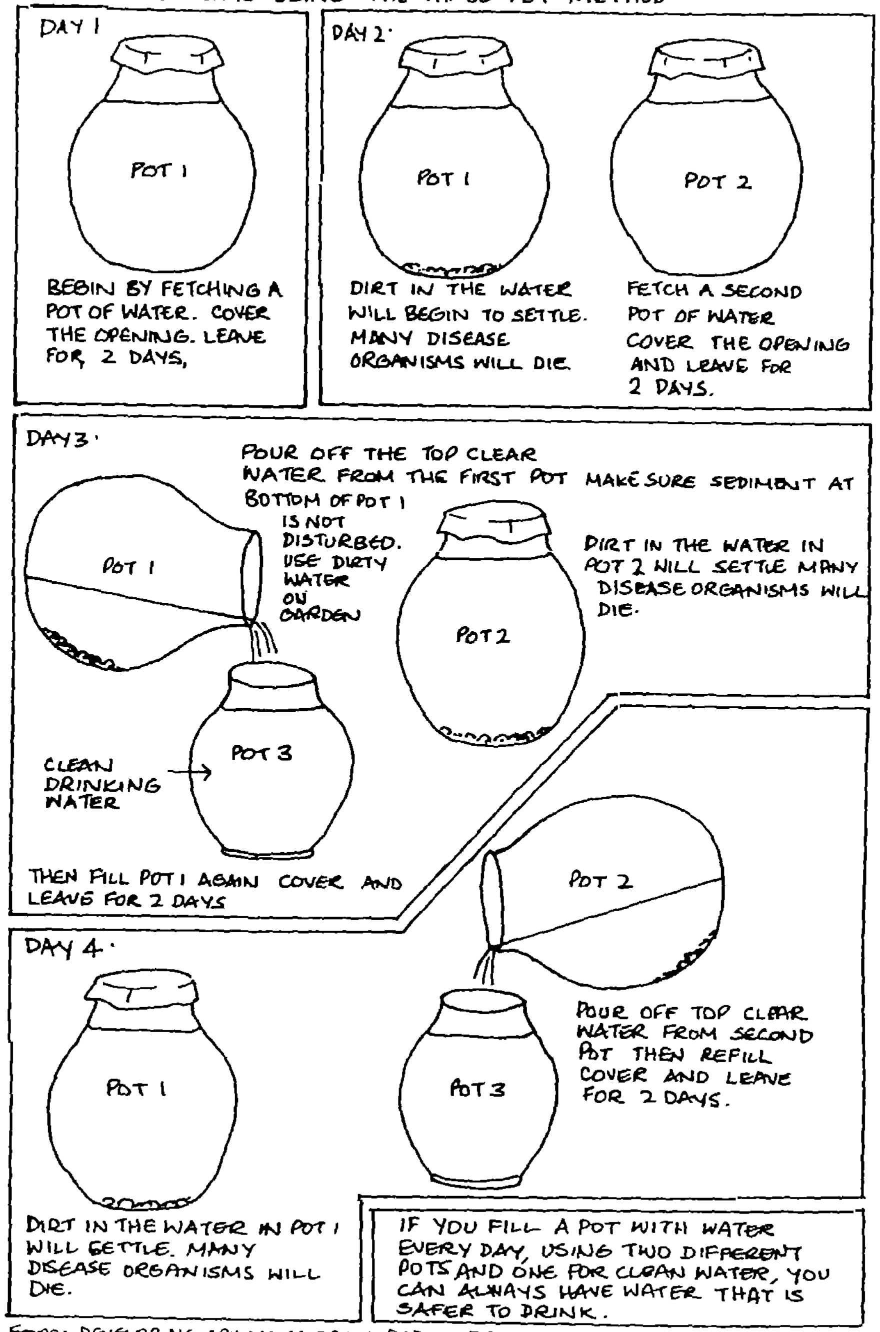
Passing water through layer(s) of material to free the water from suspended impurities is called *filtration*. Here is a filtration experiment to try. You will need:

* 8 large tin cans, all of the same diameter;
* 8 collecting jars;
* stones about 1/2 inch in diameter;
* gravel about 1/8 inch in diameter;
* fine sand;
* broken charcoal;
* some soil
* a large pot (that holds at least 3 litres);
* a clock.

1. Punch the same number of holes in the base of each can.
2. Fill one can with stones up to a depth of 4 inches, and fill another can with stones to a depth of 8 inches. Hang each can over a collecting jar.
3. Use the rest of the cans to repeat (2) but fill with gravel, broken charcoal, fine sand. (The two cans filled with fine sand will need lining with a fine mesh to prevent the sand from leaking from the holes.)
4. Pour 3 litres of water into the pot and stir in some soil until the water is turbid.
5. Pour 1/2 litre of water into each can, and note how long it takes for the dirty water to drain through each filter.
7. Measure the amount of water that has drained through each can. Compare the appearance of the treated waters.

"THREE-POT METHOD"

IF YOU CAN'T BOIL YOUR WATER BECAUSE OF A SHORTAGE OF FIREWOOD OR FOR SOME OTHER REASON YOU CAN MAKE IT SAFER TO DRINK BY LETTING IT STAND FOR 2 DAYS USING THE 'THREE POT METHOD'



From: DEVELOPING COUNTRIES FARM RADIO NETWORK PACKAGE 14 ITEM 6 for 24 hours. Although a significant percentage of indigenous bacteria are removed through treatment, scientific studies suggest treated water should be further purified by filtration, chorination or boiling. To achieve uniform results, equipment needs to be standardised; appropriate training given; daily water treatment activities monitored. The treated water must be left undisturbed for at least one hour for purification to be effective. Favourable growing conditions are needed to produce the seeds, although the tree does seem to thrive in impossible places: near the sea, in bad soil and dry areas. Cultivation requirements vary according to environmental conditions.

Try this: If growing conditions are appropriate, set up a nursery for the seeds.

ADDING CHEMICALS

Another way to disinfect water is to buy special chemicals, which when added to water, will kill all harmful organisms. Often people add chemicals after it has been filtered to make sure it is completely safe. The most common chemical for disinfecting water is chlorine. You may have come across chlorine because it is found in bleaching powder.

Chlorine kills germs chemically, but you would have to go to a biology laboratory to perform experiments proving this. You would grow *cultures* (colonies grown in a test tube) of harmful bacteria and then kill them with chlorine. Both these things would be too dangerous to try at home. Furthermore, chlorine, in sufficient amounts, is a poisonous gas and is very dangerous to work with.

For disinfecting a large water supply, chlorine is put into the water as a gas. For small communities, it is best to use chlorine tablets. When added to water, the tablets dissolve and the chlorine kills the germs. It always takes time for the chlorine to work. If you try this, allow at least 30 minutes for the chlorine to take effect.

In whatever form the chlorine is used, the dosage of available chlorine must be carefully measured. For example, the eggs of worms and organisms that cause bilharzia need very strong doses of chlorine solution to kill them. However, these organisms can be filtered out before a chlorine solution is added so that less chlorine is needed to kill other disease organisms.

Advantages: Chemicals, when added to water, kill all harmful germs.

Disadvantages: Chemicals are expensive and probably must be imported. They are difficult to handle, and sometimes require a trained operator.

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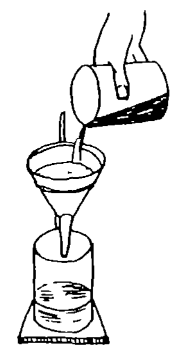
Purifying Water with Chemicals

Does your water contain harmful germs? It can be purified by adding various chemicals to it. After learning about all these techniques, try them for yourself, compare the results, and decide which works best for you.

COAGULATION

Filters can remove small particles that are suspended in water, but some particles are too small to be filtered out. If a chemical called potassium aluminium sulphate is added to water, it makes tiny particles group themselves together or *coagulate*. When the water is then filtered, these grouped particles are large enough to be removed from the water. You can observe coagulation by trying the following experiment. You will need:



* powdered potassium aluminium sulphate $(Al_2(SO_4)_3.K_2SO_4)$
* a small amount of clay;
* some sand;
* 2 funnels;
* filter paper;
* 2 upright stands and 2 ring supports;
* 4 pint jars.

Arrange the stands, ring supports and funnels lined with filter paper as shown in the diagram at right.

Put about 1 inch of sand in each of the funnels. Mix ⅔ of a cupful of water and 2 teaspoonfuls of clay in one jar. Make a similar mixture in another jar, but also add 2 teaspoonfuls of potassium aluminium sulphate. Stir both mixtures. Pour each mixture through a different funnel into clean pint jars. Compare the liquids you catch in the pint jars. Which one holds the cleanest water?

Advantages: *Coagulation* is a process that can be used to filter out very tiny particles of clay. It can also remove remains of germs that have been killed by other means but which are too small to be filtered out by means of sand and gravel alone.

Disadvantages: This process cannot remove dissolved industrial wastes. It cannot purify liquid sewage or germ-polluted water either. The liquid sewage contains dissolved impurities, and germs are usually too small to be filtered out in this particular way. Coagulation must be done in association with filtration or settlement. Use of chemical coagulants may require trained personnel.

USING MORINGA OLEIFERA SEEDS

Native to Northern India, the multipurpose *Moringa oleifera* trees is widespread in semi-arid subtropical countries, and are known by many different names, for example, malunggay (the Philippines) and benzolive tree (Haiti). The fast-growing tree, is a source of fruit, leafy vegetable, fodder, herbal medicine, nectar for bees, natural fences, fuel and raw materials for paper mills. The idea of using *Moringa* tree seeds to clear water came from Sudan, where women use the seeds to clarify muddy water from the Nile River in large earthenware jars. The crushed seeds coagulate particles suspended in the water including types of disease organisms. Agglomerates which form fall to the bottom of the jars where they can be collected.

How to purify water using Moringa oleifera seeds.

You need:

* 1 litre of turbid water (not drawn after sudden heavy rains or sandstorms as these will increase the amount of coagulant needed);
* some clean (clarified) water;
* a small bottle or cup;
* a mortar and pestle
* a clean cotton cloth or fine mesh tea strainer;
* a ladle;
* a container (with well-fitting lid) that can hold a litre of water.
* a *Moringa oleifera* seed;
* a stirring spoon;
* a small cup;
* spoon;
* 2 glass jars for samples;

1. Remove wings and brown coat of the seed; discard any seed kernels (cotyledons) that have dark spots or other signs of damage.
2. In a mortar, crush the seed into a fine powder.
3. Put the powder into a small bottle, and add clean water by a measured spoon (or use a home-made graduated bottle) to make a 2% suspension.
4. Stir or shake vigorously for 5 minutes to obtain a watery extract of the coagulant.
5. Filter the suspension through a clean cotton cloth into a small cup.
6. Put a litre of turbid (muddy) water into a container. Stir the water fast, and after a few seconds, while still stirring, add the milky suspension. Continue stirring for 30 - 60 seconds.
7. Continue stirring slowly and steadily (about 20 rotations per minute) for 5 minutes. You can control the stirring movement by chanting phrases to maintain a rhythm.
8. Cover the container with a lid, and allow the floc (solid matter) to settle. Leave undisturbed, and then take water samples using a ladle after (a) 1 hour (b) 2 hours.
9. Put the samples into glass jars. Assess the result with the naked eye. Record your observations in a chart similar to the one below.

Source of Water	Turbidity	Capacity of raw Water	No of moringa seeds used	Time clarified water left to settle	Result

Extension: Experiment further by varying the following:

(i) the quantity of moringa seed powder used (for example, use (a) $^1/_4$ seed (b) $^1/_2$ seed (c) 2 seeds (d) 3 seeds per litre of raw water);

(ii) the time and intensity of the stirring of the raw water and the milky solution.

What happens if, after stirring, the treated water is disturbed and not allowed to settle for at least an hour?

Compare the required treatment of waters of different turbidity. For example, treat water taken from a river before and just after a sudden rainstorm.

Advantages: It is a simple, cheap way to obtain clear water. It improves the physical, chemical and microbiological quality of the water. The method uses equipment found locally. No side effects to health have been associated with the use of *Moringa oleifera* seeds. Using locally-grown seeds means a country no longer needs to import alum (aluminium sulphate) to purify water.

Disadvantages: Often unaware of how much the amount of suspended matter in raw water fluctuates, people may use random dosage and unsuitable application methods. If "clarified" water appears whitish, not clear, its quality may be little better than if it had simply been left to settle

TEACHER'S NOTES FOR LEARNING-BY-DOING LEAFLETS ON PRESSURE AND WATER TECHNOLOGIES

The Learning-By-Doing leaflets in this pack are divided into two setions (I) Pressure and (II) Water Technologies. The latter covers the following topics: water supply; water-lifting devices and water treatment.

TEACHER'S NOTES FOR (I) PRESSURE

LEAFLET NO. 37: UNDER PRESSURE

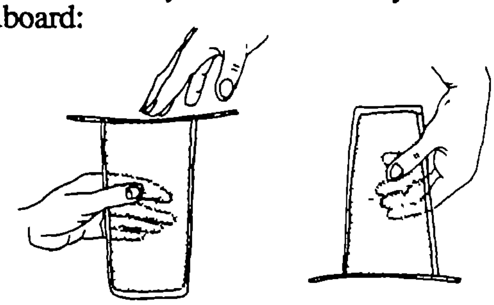
TEACHER'S TIPS

Air pressure activities

There are many more air pressure activities you and your students can try. Here are some examples, but your students may be able to think up other air pressure "tricks" to amaze people:

(1) The magic glass
You will need:
* a glass;
* some water;
* a piece of cardboard.

Fill the glass to the brim with water. Place the cardboard over the glass. Hold the cardboard against the glass, and turn the glass upside down. Take your hand away from the cardboard:



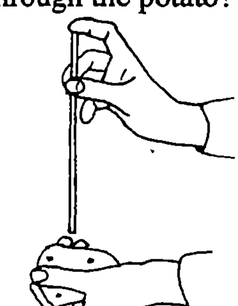
What happens? If you have done everything properly, the card will stay in place.
Conclusion: The pressure of the outside air acts against the card, and forces it against the glass, because it is stronger than the pressure of the water. (If it doesn't work the first time, keep trying!)

(2) Blowing strips
You will need:
* 2 long strips of paper

Hold the two strips of paper a few centimetres (about 2 inches) apart, dangle them in front of you. Ask your friends what they think will happen if you blow steadily between the strips. They may say "The paper will be blown apart," but in fact, the strips move together. Why? Because as you blow, the pressure of air between the strips is lowered, and the pressure of air on the outside of the strips becomes greater than the air between the strips, so the pieces are pushed together.

(3) Jabbing a potato
You will need:
* a drinking straw;
* a potato.

Hold the straw on its sides. Try jabbing it into the potato. Then place the index finger over one end of the straw. Rapidly jab the straw through the potato, being careful to hit the potato squarely with the straw. How can a straw go through the potato?



By sealing the top end of the straw with a finger, the air in the straw is trapped when the other end strikes the potato. Air exerts considerable pressure under normal conditions. But when it is compressed, the pressure is increased. The compressed air in the straw gives the straw strength enough to prevent its bending. The fragile straw will easily go through the potato.

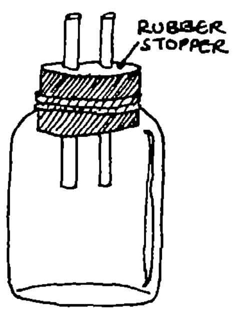
Learning by trial and error

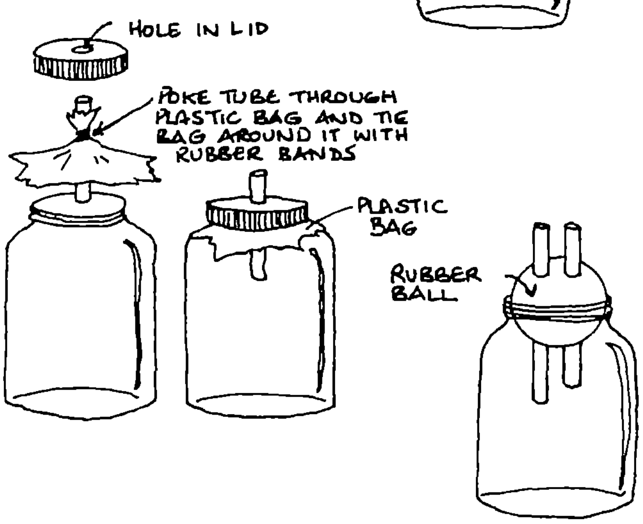
The students may have some difficulty

getting the activities to work. This is an excellent opportunity for them to act like science detectives and try and track down that small detail that means the difference between success and failure in the experiment. For example, if students have trouble with the magic glass activity above, which involves holding a piece of cardboard under a glass of water, it may be because of the cardboard. As long as the cardboard does not sag or get soggy, it will stay in place by itself. If the cardboard is not firm and flat to begin with, it will let air in and water out, so the experiment will not work.

Stoppers

In the experiment "Lifting water with air pressure", a stopper is needed as part of the experiment equipment. Stoppers can be made from a variety of things, such as a sponge rubber ball, a cork, a rubber stopper or a plastic bag:



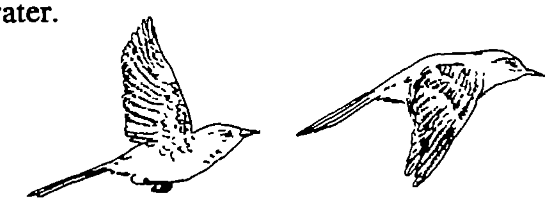


Air pressure in action

Find examples in your local environment that demonstrate air pressure in action. Here are two possibilities:

(1) Birds' flight: Have you ever wondered how birds fly? They flap their wings, but how does this keep them up in the air? They don't come crashing down because they push on the air with each wing-beat, and the air pushes back. The force of the wing-beat makes more pressure in the air underneath the wing, and this extra pressure pushes the bird up.

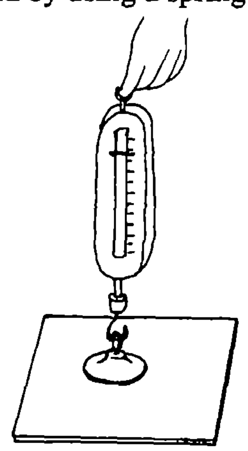
Ask the students to watch a bird in flight. See how the wing going up does not push as hard against the air as when the wing goes down. It's similar to the way people tread water.



(2) Bicycle pumps: If you squash air, or any other gas, into a smaller space, it pushes back. It is trying to spread out again and fill the space it used to have before you compressed it. This pushing back is very useful because it makes the air act like a spring. If you block the end of a bicycle pump with your finger, then push the handle hard, you will feel the springiness of the compressed air inside the pump.

Measuring air pressure

Atmospheric pressure can be measured with a rubber suction cup. The force required to pull the sucker away from a smooth surface can be found by using a spring balance:



The area on which the atmospheric pressure is acting can be measured by pressing the sucker on a piece of squared paper. It is best to use a sucker which has a hook attachment. If one of this sort is not available, tie some copper wire firmly around the neck of the sucker to form a loop. If possible try this experiment using different sized suckers.

EXPERIMENTAL RESULTS

What is pressure?

This activity is adapted from *TOPS*

LEARNING SYSTEMS TASK ORIENTED PHYSICAL SCIENCE: PRESSURE by Ron Marson. TOPS Learning Systems materials are available from 10970S Mulino Road, Canby OR 97013 U.S.A.

All three impressions were made with approximately the same amount of force (i.e. the book). The deepest imprint is made by the nail point impression. The shallowest imprint is made by the coin. You can make a deeper imprint by distributing the force of the push over a smaller area.

(a) To increase pressure either increase the applied force or decrease the area over which the force is applied.

(b) To decrease pressure, decrease the applied force or increase the area over which the force is applied.

(c) By lying flat on his stomach, the man is spreading the force over a large area.

Lifting water with air pressure

(1) As the air inside the jar cools, a partial vacuum is created inside the jar. Since air pressure outside the jar is greater than that inside the jar, water is sucked into the jar.

(2) When straw B is blocked, air cannot get into the jar to replace the liquid being sucked out. It will be difficult to suck on straw A since there will be less air pressure inside the jar than outside it. If air is blown into straw B, the air pressure inside the jar will become greater than that outside the jar. Thus, it will be easier to suck liquid through straw A.

Variation on this activity: Fill a soda bottle completely with water. Put a straw in the soda bottle, and seal with modelling clay, cotton, or wet paper. Challenge a friend to drink the water from the bottle. If air is completely excluded from the bottle, your friend will not be able to do it.

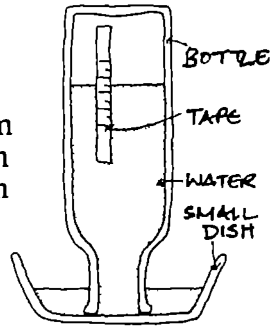
Make your own barometer

A barometer is a simple instrument to read. As the air pressure changes, a needle moves around a dial which is marked Rain, Showers etc. so that we can read out the changes in weather. The learning leaflet describes how to make one simple type of barometer. Here is another way to make a barometer:

You will need:

* a bottle;
* a small dish;
* a piece of white tape;
* some water.

Fill the bottle full of water. Cover the bottle with a dish, hold the dish and bottle tightly and invert them so the bottle stands upside down in the dish of water. Changes in air pressure will affect the level of water in the bottle. Stick a small piece of tape on the outside of the bottle, and mark the water level each day.



The students could make both types of barometers, and keep daily records of readings from each one. Then, the students can determine which barometer works best.

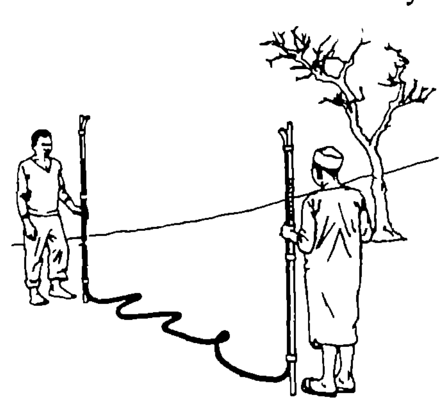
GOING FURTHER

Activity: Making a hosepipe water level

To reduce soil erosion, land should be farmed across the hillside, not up and down the slope. Better still, barriers such as hedges or stone lines running level with the **contours** can help slow run-off and increase the amount of rainwater that soaks into the ground. Here is one device that can be used to mark out contour lines on a slope. You will need:

* 2 stakes, about 5 feet (or 1.5m) tall, marked half-way up with a series of lines 1/10 inch (or 0.25cm) apart;
* a narrow transparent hosepipe, 30-60 feet (or 10-20m) long;
* water;
* string.

Each end of the hosepipe is attached by string to a stake. The hosepipe is filled with water. Water is added or tipped out until the water level lies between the marked lines on the stakes. Provided all air bubbles are expelled, whenever the bottoms of the two stakes are level, the water at each end of the hosepipe should come up to the same mark on each of the stakes. Now the device is ready to be used.



LEAFLET NO. 38: GETTING LIQUID TO WORK FOR YOU

TEACHER'S TIPS

Experimental Results

The experiments described in the student leaflet use very simple equipment to demonstrate water pressure at work.

Seeing Water Exert Pressure

The pressure of water above the holes causes the jets of water to flow from the holes. The water near the bottom of the carton has the force of all the water above it pushing it out, and so the water shoots out further from this hole. The water coming out near the top of the carton has very little water - and therefore pressure - above it.

Water pressure in different sized containers

Pressure is not affected by the size or shape of the vessel: it only depends upon the depth of the liquid.

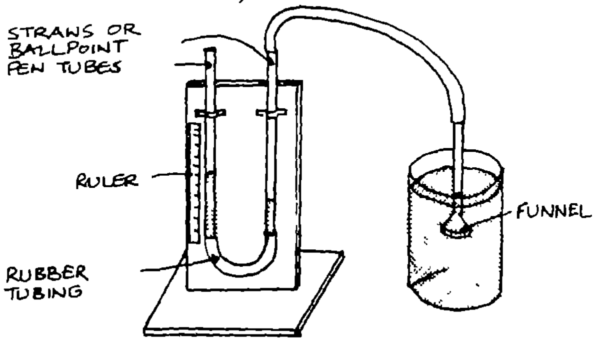
Note: The water may squirt out the same distance at first, but the water level will drop more quickly in the narrower container, so the water will not continue to squirt out as far as that in the wider container.

The following experiments using more elaborate equipment may be tried in class:

You will need:

* two lengths of rubber tubing, one long (30 cm) and one short;
* two ballpoint pen tubes or two transparent plastic drinking straws;
* food colouring
* a funnel;
* two pieces of board;
* some thin rubber - perhaps, from an inner tube
* string;
* clips;
* ruler;
* a bucket of water.

1. Connect the drinking straws to the short length of tubing, and attach them to an upright board, as shown in the diagram that follows.
2. Put some water in the tube to a depth of 6-8cm., and add one or two drops of food colouring so that the water is clearly seen. Tape a ruler next to the open straw. This is your pressure gauge or *manometer* (said: man- OM-eter).



3. Stretch a piece of thin rubber tightly over the funnel and secure with some string. Fix the funnel to the manometer with the 30 cm length of rubber tubing.
4. Push the funnel into the bucket of water. What happens? As the inverted funnel goes deeper into the water, the manometer liquid level changes.

Conclusion: Water pressure forces the air in the funnel and manometer tube to move the manometer liquid.

5. Measure the water pressure when the funnel is held just below the surface of the water. Then, move the funnel down to the bottom of the bucket. How does the pressure change with depth?

Extensions:

(A) Try this experiment using different sized funnels.

(B) Fill a jar of small diameter and a jar of large diameter with water to the same depth. Measure the pressure at the bottom of each jar. How do they compare?

(C) Take two jars of the same size and fill one with water and one with a less dense liquid such as rubbing alcohol. Make sure the depths of the liquids are the same. Using the funnel and manometer as described in 1-4 above, measure the pressure at the bottom of the water jar and then at the bottom of the alcohol jar. How do they compare?

Hydraulic machines

A garage and a construction site are two good places to see hydraulic machines at work. Visits to such places require the owner's (and parents') permission, and should be undertaken only when students can be well supervised.

An hydraulic lift in a garage easily raises the great weight of a car for inspection. Although it contains only one piston, it does work by hydraulics. Ask the garage owner if it is possible for your students to see the hydraulic lift in action. It may also be possible to study how a car's hydraulic brakes work.

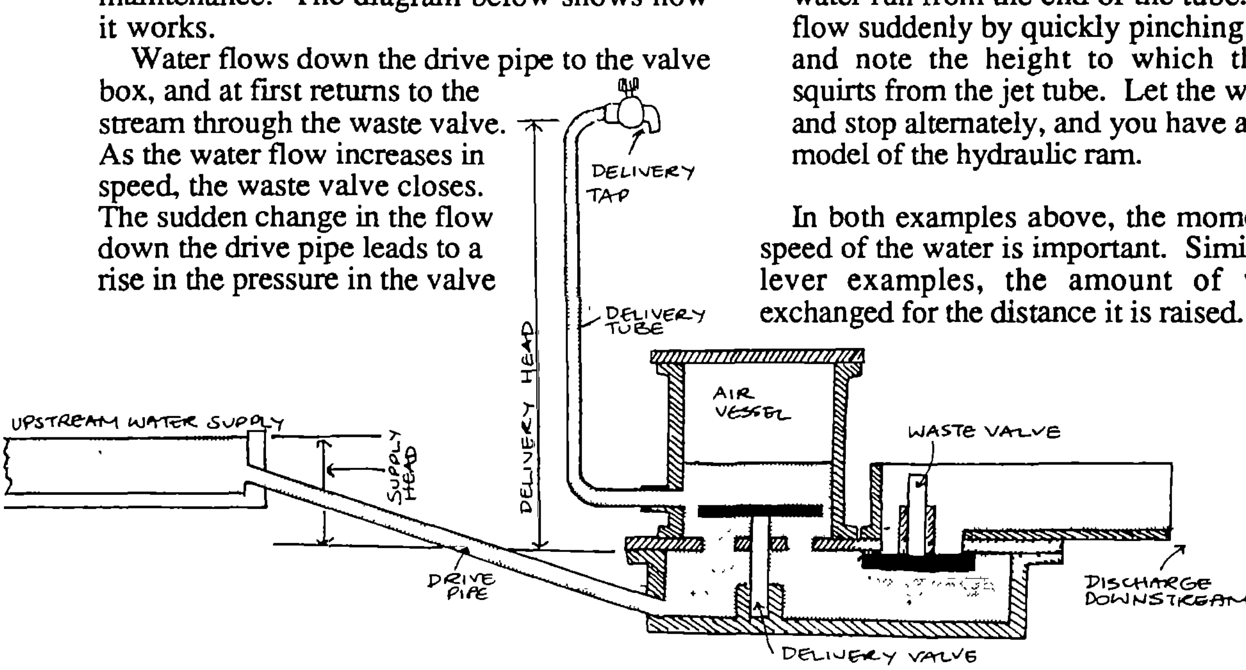
Machines such as bulldozers, work with hydraulic rams. Each ram consists of a piston in a cylinder connected by pipes to a central reservoir of hydraulic fluid. By having two-way valves in the hydraulic cylinder, the piston can be made to push in either direction. That is how the powerful rams on a bulldozer can gently lift and lower its huge steel blade.

Hydraulic Ram

A hydraulic ram is a machine which pumps water up to a height of 100 metres or more. It can be used to pump water from a river in the valley to a village in the mountains.

The pump uses no motor and is easy to repair, but it does not work in all places. It needs falling water, so it cannot work in areas which are very flat and it cannot pump water from a well. The falling water forces a small amount to a height greater than the source. At least 7-14 times as much water is needed to work the pump that is raised. A small amount of water with plenty of fall can pump as much water as a greater amount with only a little fall. The water source needs to be at least one metre above the pump. Plenty of water must be available. It is one of the cheapest methods of raising water and it needs only a little maintenance. The diagram below shows how it works.

Water flows down the drive pipe to the valve box, and at first returns to the stream through the waste valve. As the water flow increases in speed, the waste valve closes. The sudden change in the flow down the drive pipe leads to a rise in the pressure in the valve box. The delivery valve opens and water is forced up into the air vessel and to the delivery pipe.



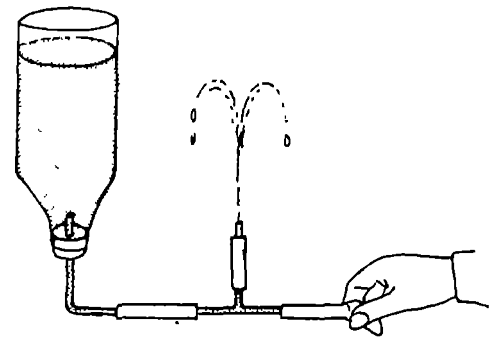
A model Hydraulic Ram (Taken from *p. 132, New UNESCO sourcebook for science teaching*):

Here is one way to make a model hydraulic ram.

You will need:

* a large plastic bottle from which the bottom has been removed;
* a ball point pen tube;
* a one-hole stopper which fits the bottle top, and through which the ballpoint pen tube fits;
* a metal T-tube;
* three pieces of rubber tubing of various lengths.

1. Set up the apparatus as shown:



2. Fill the bottle with water. (This reservoir will act as a natural stream flowing downhill.) Pinch the tube at the end. Let the water run from the end of the tube. Stop the flow suddenly by quickly pinching the tube, and note the height to which the water squirts from the jet tube. Let the water flow and stop alternately, and you have a working model of the hydraulic ram.

In both examples above, the momentum or speed of the water is important. Similar to the lever examples, the amount of water is exchanged for the distance it is raised.

GOING FURTHER

Making a hydraulic ram

A hydraulic ram is sometimes used to raise water from a low level to a higher level. It is operated by a flowing stream of water, and it pumps a fraction of this flow to a greater height.

Can your students design a hydraulic ram? They may use an actual small fall in a natural stream to pump a much smaller flow of water to a greater height. Or they could create their own artificial water reservoir. How can the flow of water be controlled?

TEACHER'S NOTES FOR (II) WATER TECHNOLOGIES

LEAFLET NO. 39: YOUR COMMUNITY'S WATER SUPPLY

TEACHER'S TIPS

Introduction

This leaflet brings together several school subject areas: geography, mathematics, science, and English. It encourages students to develop skills of observation, map-reading, data-collection and analysis, interviewing techniques, etc.

The project can involve as much as a year-long commitment on the part of students if they are to complete the activity on community water supply needs, see notes below. In this case it may be necessary to introduce the topic at the start of the year, and then see what interest there is in pursuing the practical activity towards the end of the school year. If you wish to complete the topic in one session, then the activity suggestion could be modified accordingly.

A discussion about the water cycle, and on water sources that exist in your region might serve as an introduction to the leaflet.

The water-table or level of saturation

When the students are studying the diagram showing the water-table, point out to them that the water-table is not level. It tends to have high spots and low spots that match the valleys and hills of the earth's surface. It is usually arched under hills, but beneath plains it generally lies close to the surface. Oases, swamps and lakes can be found where the water-table is at the surface of the ground. Ask students what must happen to the water-table if rivers and lakes dry up after a long dry spell.

For more on water-tables, and the effect of wells on underground water supplies, see Learning-By-Doing Leaflet no. 42 SINKING WELLS.

EXPERIMENTAL RESULTS

Sources of water

To get accurate rainfall readings, make sure the diameter of the mouth of the funnel is the same as the diameter of the collecting jar. If the funnel mouth has a smaller diameter, the readings will be too small; if the mouth has a larger diameter, the readings will be too large. Help students find suitable locations for their rain gauges. Try to find open areas because locations sheltered by tree canopies, for example, will affect results. Ask the students to consider what other topographical features might affect the results. (You could, in fact, start the exercise by positioning the rain gauges in a variety of locations to see if the topographical features do dramatically affect rainwater collection.)

If daily rainfall is recorded for a long period of time, total rainfall may be divided by the appropriate number of days to determine the average weekly, monthly rainfalls. These results can be plotted on bar charts for further discussion.

When water drains into the ground

Ask students to think about when it rains really hard, and puddles form. Can they suggest which locations have puddles that take a long time to disappear? What kind of soil is found at these locations?

If possible, have the students collect samples that have high sand or high clay content. Have the students study the samples and describe the colour, texture, particle size of each soil before water is added. This may help them make predictions.

Soil samples may dry overnight, or they may take a few days to dry out. Wait until all the samples are dry. A speedier way to dry soils out is to heat them in an oven at a temperature of 105-120°C until they are thoroughly dry.

Discuss the results. Sandy soils are porous, composed of coarse particles with little organic matter, and tend to hold less water. When water soaks through sand and gravel, it can move downwards and sideways as fast as several metres a day. Crumbly, organic soils and sticky, clay soils are less porous and absorb more water. Water moving through clayey soils may move only at a rate of a centimetre or so every 24 hours.

To find out how much water each soil holds, first help students measure how much water drained out of each sample. To find out how much (approximately) stayed in each soil, subtract the amount that drained out from the amount they poured in.

Going further: The students should examine the water after it has drained through the soils. Is any of the water discoloured? Discuss with the students how substances can be washed through the soil as water drains. This presents a problem in the cases of chemical wastes and the leaching of nutrients valuable for plant growth. Students could repeat the exercise but mix some soil in the water before it is poured on the soil samples. They should examine the water after it has drained through the samples. Is it as dirty as before? The soils may have acted as a filter, helping to clean the water. Which soil proves to be the best filter?

ANSWERS TO QUESTIONS

What happens to rain?

1. Run-off on *steep* slopes is greater than on *gentle* slopes.
2. Evaporation in *dry* climates is greater than in *humid* climates.
3. Water percolates into *sands* more easily than into *clay*.

Try experiment 1 in Learning-By-Doing leaflet no. 8 SAVING SOIL ON A SLOPE to discover how the steepness of a slope affects the amount of surface run-off.

Collecting rainfall and surface run-off

Dams may be used to impound water from rivers and streams. Try to show students pictures of dams. Discuss the effects of building small and large dams upon the environment and local inhabitants. For more information on dams, see Learning-By-Doing Leaflet no. 41 BUILDING SMALL DAMS.

An individual household can collect rainwater that falls on the house roof. For more on this topic, see Learning-By-Doing Leaflet no. 40 CATCH A FALLING RAINDROP.

Activity: Your Community's Water Supply Needs

The students should be encouraged to record all data onto charts or diagrams. This activity is ideal for developing mapwork skills, whether it be studying topographical maps and geological maps (if they are available) or making scaled plans and maps of the locality. The students can also practice their surveying skills. Have students develop a list of questions to ask before actually beginning to interview people.

This project obviously demands a year-round commitment. The project can be divided into two main study periods. At the beginning of the year, students could be introduced to the topic, and the initial data could be collected (including setting up rain gauges, drawing maps and doing initial surveys at water collection points). The second period of study, at the end of the year, could comprise problem identification and exploration of solutions. The intervening period would require the up-keep of the rainfall record and doing the community-wide survey. Solutions will vary depending upon the community need and the creativity of the students involved. For example, students might advocate behavioural changes on the part of water collectors, or construct water-collecting technologies that could supplement existing supplies.

LEAFLET NO. 40: CATCH A FALLING RAIN DROP

TEACHER'S TIPS

Introduction

Introduce the topic by discussing water supply in your region. Students could first try the activities in the Learning-By-Doing Leaflet no. 39 YOUR COMMUNITY'S WATER SUPPLY.

If some households already collect water in drums, students may inspect the condition of the containers. Frequently, storage containers are rusty and leaking: the life of a well-constructed galvanised tank on a tropical island, for example, can be as short as two years because of the corrosive salty atmosphere.

(It is possible to use an old corrugated iron tank which has rusted through as the supporting frame for a ferrocement tank. The method is exactly the same as for constructing one with wire mesh. The tank must be brushed clean of rust and holes must be punched all over the tank. The tie wire is passed through these holes to fasten the inner layer of chicken wire to the outside.)

Water and Health issues

In discussing water catchment from roof-tops, there are several water and health issues you may wish to raise. For example, students may talk about the health benefits of having water close by to the house.

Ask the students why a cover for the tank is necessary. It is to keep out mosquitoes. Without a cover, the stored water could become a breeding ground for these insects. Discuss what other measures should be taken to keep the stored water clean. Here are some suggestions:

* Clean your roof and gutter regularly;
* Make the gutters slope smoothly towards the tank. Sometimes there are bends and bumps in the gutters. Pools of water can collect there after the rains, and these provide a breeding ground for mosquitoes;
* Put wire mesh over the entrance pipe into the tank so that no insects can get into the tank;
* Make sure that there is a proper drain away from the drainage pipe, or make a concrete channel so that it is not always muddy around the tap.

Another issue concerns the type of roof used to collect the water. Galvanised iron, tiles or thatched shingles are suitable materials for roofs, but freshly-treated wooden shingles may contaminate the water with the treatment chemicals such as copper, chromium and arsenic, all of which are poisonous. Rainwater from thatched roofs tends to contain a lot of dirt and other suspended matter.

Skill Development

This leaflet helps students develop some mathematical skill and building skills such as carpentry, metalwork and plastering.

Mathematics: This topic on water tanks provides a practical application for the study of capacity (i.e. the amount of space inside a container, expressed in liquid measure, for example, litres) and volume (i.e. the amount of space taken up by an object, expressed in cubic feet/cubic metres etc.,). Students can estimate the capacity and volume of containers of various shapes and sizes as a prelude to this exercise. Set various problems for the students to solve. For example, what size tank would be needed to provide 100 students with 1 litre of water per day for a week?

Students can also practise describing circles using the string and nail technique shown in the leaflet. Construction of the tank involves more measurement work, including the mixing of ingredients to make concrete and construction of the roof frame. Constructing a scale model of a tank will give students practice in figuring out ratios.

Building skills: Students can practice the skills they will need to make a full-size tank by building their model tanks. Ideally, adults with the various building skills required should give the students demonstrations - and tips - before the students undertake the building of a full-size tank. These craftspeople may be prepared to supervise the work and lend specialised tools for this project.

Obtaining materials

Building a ferrocement cement water storage tank requires supplies of cement, steel wire mesh and corrugated galvanised metal sheets, as well as sand, water and sisal poles.

If through discussion and preliminary studies of the community's water supply, students determine that a storage tank would benefit the school/community, then supplies have to be acquired. Involve the students in the material collection process. The students may simply need to write letters to local industries asking for donated materials. Or, perhaps they will have to organise fund-raising activities. The students should form their own fund-raising committee and determine for themselves what action is necessary.

EXPERIMENT SUGGESTIONS

Depending upon the time and material resources available, this project may be simply one of tank construction or it may be expanded to include experiments on water-holding structures. Students should set hypotheses (e.g. round tanks are better than square tanks) and then set up experiments to test their hypotheses. Here are some suggestions:

Experimenting with different materials: Students may construct small model tanks from different locally-available materials and devise means of comparing the tanks' water-retention capacities and their suitability for local climatic conditions. For example, students may build bamboo, not wire, ferrocement structures. Do the types of materials used limit the shape and size of the tank?

Experimenting with different shaped tanks: Students may try out different shaped tanks. For example, do they find round ones work better than square ones? (Round ones are better to build than square ones. Square tanks need reinforcing at the corners which makes them more expensive.)

Experimenting with different consistencies of concrete: Vary the mix of ingredients (sand, water, cement) to discover which mix can be applied the most easily; which proves to be the most water-proof, and which is strongest.

OTHER RESOURCES

Developing Countries Farm Radio Network package no.6 items 9A and 9B explain how to make a bamboo roof and eavestrough. These can be constructed for directing the rain water into the storage tank. Contact DCFRN, 595 Bay Street, 9th Floor, Toronto, Ontario M5G 2C3 Canada

For more information on storage tanks, see

Liklik Buk, a sourcebook for development workers in Papua New Guinea (1986) published by Liklik Buk Information Centre, ATDI, Unitech, P.M.B., Lae, Papua New Guinea

People's Workbook (1981) published by the Environment and Development Agency (EDA) Box 62054, Marshalltown, 2017 Johannesburg, South Africa

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LEAFLET NO. 41: BUILDING SMALL DAMS

TEACHER'S TIPS

Uses of dams

Discuss why people build dams: for a water supply; for hydroelectric power; for irrigation. Use local examples to discuss the consequences of building dams. Consider the effect on people, land and wildlife upstream from the dam and downstream from the reservoir. Interview people living near a dam to find out their views on whether the dam should/should not have been built.

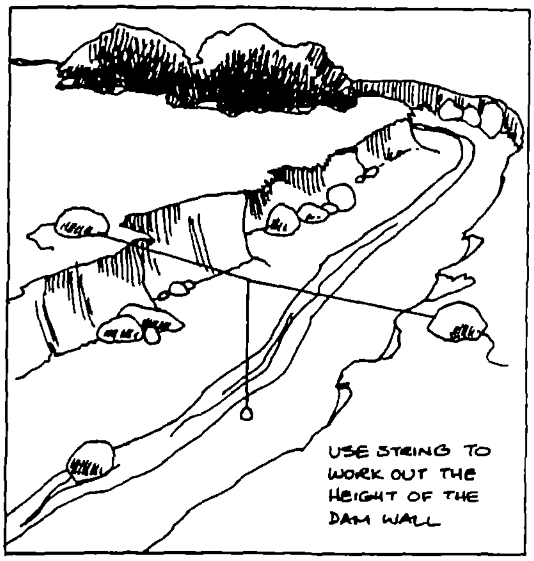
A dam for your community

Have students brainstorm benefits and disadvantages of building a new dam in your community. For example, some of the advantages could include a source of safe drinking water and water for irrigation year-round. Some of the disadvantages could include the spread of certain diseases, such as bilharzia and destruction of natural habitats. Which people would benefit most/least? The topic could be discussed in a class debate, with students voting on the issue.

How big is a dam?

The students can apply their mathematical knowledge of capacity and volume to a practical exercise where they work out how much water can be held by a dam on a nearby stream. Here's what they should do:

1.Select a site on the stream where a dam could be built.
2.Stretch a string across the place where the top of the dam wall would be. Hang another string from the middle of this string. This will show the height of the dam wall, see picture. It should be no higher than 2 metres, otherwise the dam can become dry or fill up with sand too quickly.
3.To find out how much water the dam will hold, use a spirit level or water level (see learning leaflet no. 37 UNDER PRESSURE) to find the place where the stream is level with the top of the wall. Measure the distance between this place and the dam wall. Then, the amount of water the dam will hold in cubic feet/metres is approximately 1/6 x this distance x the length of the wall x the height of the wall, see picture below:



ANSWERS TO QUESTIONS

Choosing a site
1.A narrow valley with steep banks on both sides. This will reduce the length of the dam wall or dike;
2.The stream-bed should have a gentle incline. A slow-running stream is less likely to cause excessive build-up of sand and silt.
3.The ground should be a clay-silt soil mixture that will hold water.
4.The reservoir area should be large enough to hold enough water but not too large. If it is too large, too much water will evaporate.
5.The storage site should be close to the users. It is better to build above a village than below it. Then, people will wash in the stream coming out of the dam, not in the stream going into the dam. This will help to keep the dam water clean. Another criterion is that materials for construction should be nearby. Materials required depends upon the type of dam to be built. Dams may be made from rocks, earth and concrete.

Preparing the site and building the wall
Earthen dams: If the wall was built on sand or silt, the water will slowly empty out from under the wall. A solid foundation is vital in order to prevent the collapse of the dam wall.

Collecting water from a dam
You may wish to discuss with students how water should be collected from a dam. The person collecting water from the reservoir itself is more likely to contaminate the supply. (For example, germs may enter the water from the water container.) To safeguard the water supply, a covered well may be dug behind the dam. A dam will raise the groundwater level closer to the surface. Therefore, the well would not have to be as deep. In the case of a concrete and stone dam, piping can collect water from the sand behind the dam wall, and channel it through the wall to a tap on the other side of the dam. The sand upstream from the dam stores the water and filters it as it travels to the pipe and through the dam. The water that comes out of the pipe is clean.

The water held by a dam can bring many benefits to a village, but it can also create problems if people are not aware of the dangers of waterborne diseases. Discuss such diseases with your students and explain how the spread of these diseases can be prevented. See learning leaflets on PURIFYING WATER. Animals and people can pollute the reservoir water by entering it to swim, bathe or wash their clothes and dishes. All of these activities pose possible health problems to others who drink water from the reservoir.

LEAFLET NO. 42: SINKING WELLS

TEACHER'S TIPS

This leaflet is concerned with ways of recovering water from underground. People who live in lands where there is little surface water in the form of rivers and lakes have to find and use the reservoirs of water held underground. Such people know that there may be water close to the surface near a dry river bed or hollow in the land which contains water only a few hours or days during the rainy season. The type of vegetation growing is another indication that there may be water underground. Many people dig, by hand, 50 or 60 metres before finding water. Mechanical drills can obviously do the job much quicker, but they are more expensive.

This leaflet encourages students to consider factors that might influence the siting and type of wells required. Students develop skills in comprehension and logic.

EXPERIMENTAL RESULTS

Collecting water underground
This experiment can be used to show students what a water-bearing strata looks like, what the water-table is, and how pumps draw water up from underground. Water-bearing strata is usually sandy soil surrounded by impermeable rock.

ANSWERS TO QUESTIONS

How deep should a well be?

Wells which are sunk far below the permanent water-table (wells A and C) should have a constant supply of water because there is water all the time. Well B has been sunk into the zone of intermittent saturation (see Learning-By-Doing Leaflet no. 39 YOUR COMMUNITY'S WATER SUPPLY). This well will have water after rains have fallen, but will go dry in periods of drought when the water-table falls. If a well does not reach the water-table (well D), it will be dry.

Where to sink a well

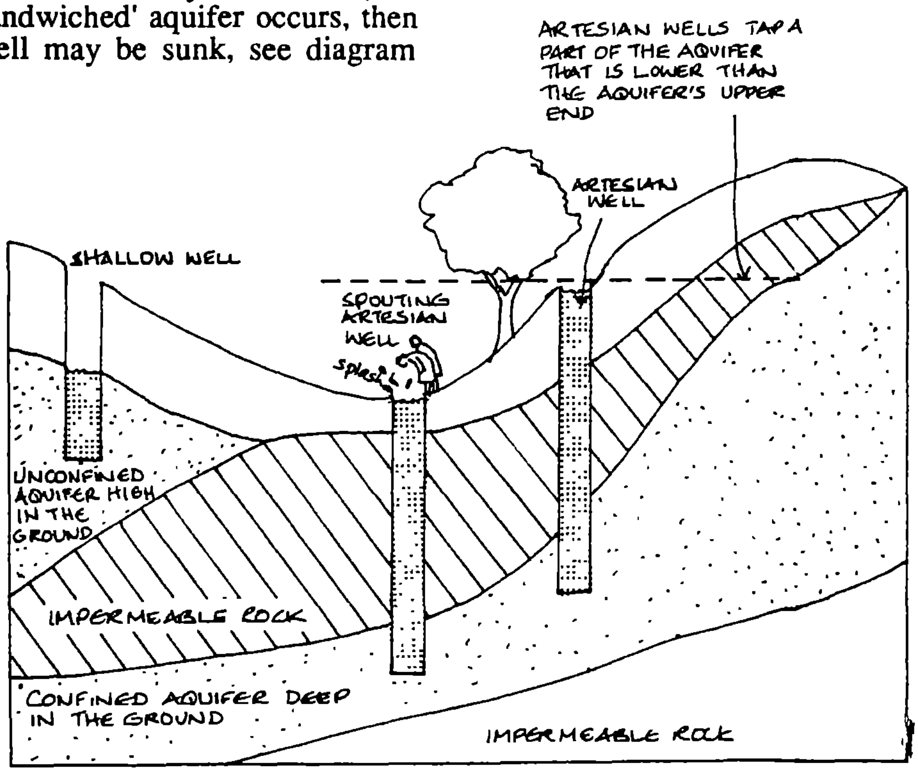
1. Digging wells near rivers or lakes may seem strange if river or lake water is available. But soil acts as a filter, and well water is usually cleaner , and more free of bacteria than river or lake water. A well may also provide water during the dry season when the water-table has fallen and the nearby river has dried up.
2. Ground water, being a liquid, gathers in low areas. So the lowest ground, say a valley, is generally the best place to dig or drill a well.
3. Some types of rock can hold a lot of ground water, and some hold no water at all. If a well is sunk into gravel or sand, you may draw all the water you need (well 1). Wells sunk into a layer of clay (well 2) will be dry because the ground water soaks through clay very, very slowly. (If well 2 were dug deeper, it would not be dry.) Hard impermeable rocks such as shale or granite cannot hold ground water at all, so well 3 would be dry.
4. Sometimes ground water has impurities that move with it. For example, harmful wastes from a latrine may get into ground water, and stay with it as the water trickles through the ground, and seeps into wells. (Another example is saline water from oceans getting into wells that are located near oceans.) A well should be uphill from a latrine and be some distance (65 feet/20 metres) away from it. Well 2 is likely to provide safer water than well 1.

Types of well
1. a driven well
2. a drilled well
3. a dug well

GOING FURTHER

Artesian wells You might want to explain *artesian wells* to your students. This is one type of well in which water reaches nearly to the surface of the ground. It may even spout up into the air like a fountain!

To understand how an artesian well works, there are several things to realise. The first thing is that aquifers do not always lie flat below the surface of the ground. They may be slanted, or inclined. Second, aquifers may also be sandwiched with a solid layer of rock above and below it. This is a *confined aquifer*. (An unconfined aquifer is one which is not sandwiched between solid layers of rocks.) If an inclined 'sandwiched' aquifer occurs, then an artesian well may be sunk, see diagram below.



An artesian well is always located 'downhill' from the top of an inclined aquifer. This means that the well taps part of the aquifer that is lower than the aquifer's upper end. Since water seeks its own level, the pressure from the water in the upper end of the aquifer forces water up the well hole, see learning leaflet no. 38 GETTING LIQUIDS TO WORK FOR YOU. Because the aquifer is surrounded by solid rock, water cannot move from the aquifer except up through the well. If the pressure of the water is great, water may spout up out of the well like a fountain.

Artesian wells will stay full if the ground water supply is recharged by rainfall in the area at the upper end of the aquifer.

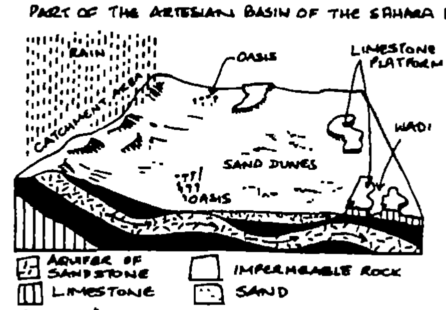
When a confined aquifer has the form of a syncline (said: SIN-kline) (i.e dipping towards a certain point), an *Artesian basin* results. Rain water enters the permeable layer at its exposed end(s). This layer becomes saturated with water. The Sahara Desert is underlain by an extensive artesian basin. The diagram at right shows a section of it.

In places, the aquifer bends up towards the surface, and wind erosion sometimes exposes it. When this happens, pools of water occur and these are called *oases*. If the aquifer is near to the surface, wells can be - and are often - sunk.

For more information on ground water, see OUTREACH issue no.6.

For more information on methods of raising water from wells, see Learning-By-Doing Leaflets on WATER-LIFTING DEVICES.

PART OF THE ARTESIAN BASIN OF THE SAHARA DESERT



SOURCE: "CLEAN WATER - A RIGHT FOR ALL" published by UNICEF UK 19[illegible]

LEAFLET NO. 43: WATER-LIFTING DEVICES (1) USING SIMPLE MACHINES

TEACHER'S TIPS

Before students begin these activities, make sure they have completed the series of learning leaflets on simple machines so that they can apply the mechanics principles they have learned.

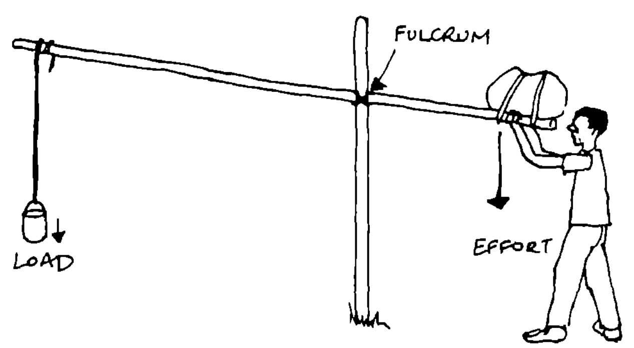
Invite the students to compare all the water-lifting devices illustrated in the student leaflet. Which do they think is the easiest to make? (Consider availability and cost of materials, labour resources and skill required). Which do they think is easiest to operate? Which raises water the fastest? The slowest? Which uses the cheapest, most reliable equipment that is easy to maintain? Which method is the best, in their view, for raising drinking water? Why? Which is the best method for raising water for a large population? Which method is the best for raising irrigation water? Why? Students should also consider health factors such as prevention of water contamination.

When students try designing their own water-lifting machines, encourage them to make models of the machines. Have they considered why the water is being raised, how much and how high it needs to be raised, what materials are locally-available?

ANSWERS TO QUESTIONS

The Shaduf

The diagram below indicates where the load, effort and fulcrum are on a shaduf:



Bucket and windlass

The answer is 300 litres. The bucket pump will serve a limited number of people: ideally this should be between 30 and 60 individuals. Where large numbers of people or cattle require water, or where water is required for irrigation, then the water delivery rate is inadequate. The bucket pump is primarily designed for providing water for domestic use only.

ADDITIONAL NOTES

Persian Wheel

The Persian wheel lifts water faster than the shaduf, and it doesn't require such hard work. While it doesn't work as fast as a diesel or electric pump, it can be made and repaired by local craftspeople using locally-available materials. It is an example of both an *appropriate technology* and an *intermediate technology*.

The rope-washer pump

The picture shows one of the pumps for garden irrigation that was developed under a research project funded by the Overseas Development Administration (U.K.) and based at Loughborough University of Technology in England and the University of Zimbabwe.

This simple pump is based upon a very old principle having been used in Roman times, but it has been adapted to use materials which are now widely available and cheap. For example, in Zimbabwe, with all the materials bought at shop prices, the cost of the material amounts to about Z$70.00 (about UK £15.00). Some farmers have made the pump for less than Z$20.00 (UK£4.00) by using materials on their own.

How it works: The pump consists of a continuous rope, with rubber washers attached, which is pulled up through a pipe by means of a pulley-wheel. The rubber washers are slightly bigger than the inside of the pipe. When the bottom of the pipe is inserted in water, the rubber washers, moving upwards, draw water with them. As they emerge at the top of the pipe, the water falls into a collecting tank. An old 200 litre drum is ideal as a tank. The water must then be taken to the crops. Plastic hose piping is a very effective way of doing this.

What materials are needed: Pipe, rope and an old tyre are the most important materials.

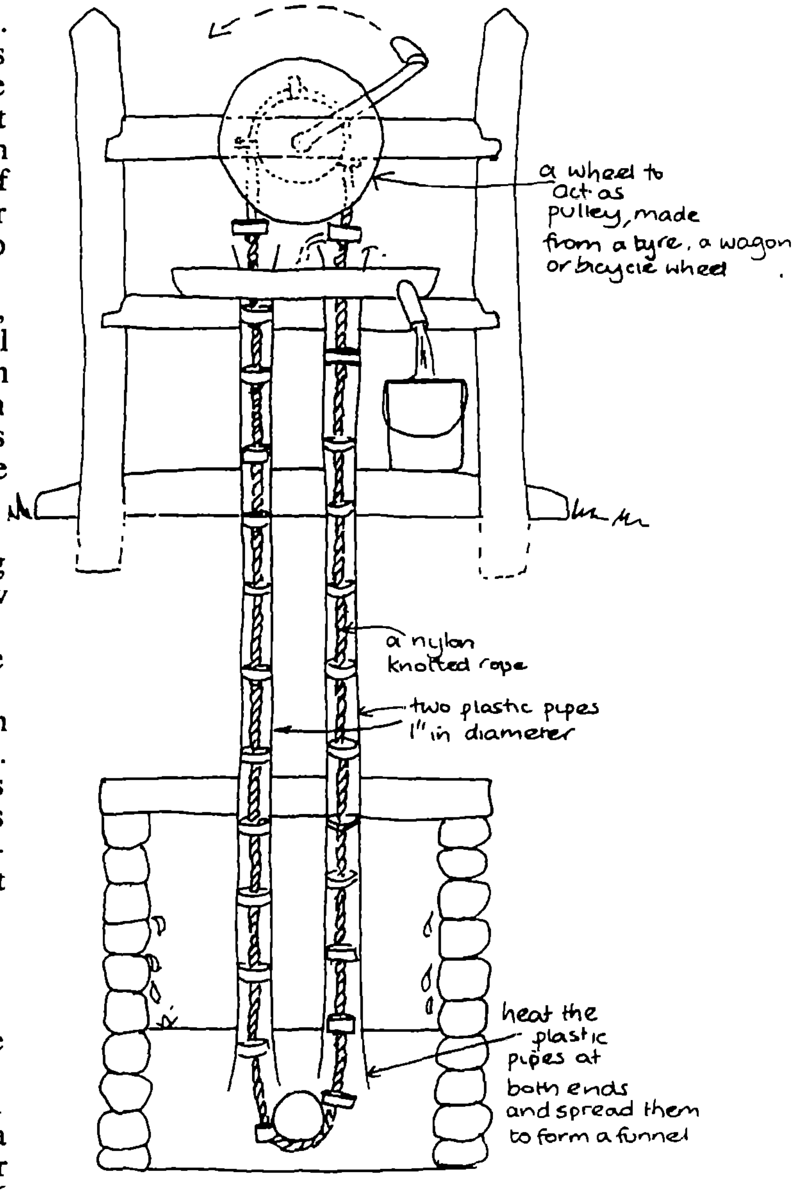
Where available, strong PVC pipe is ideal. Steel pipe may also be used. If piping is unavailable, then a square pipe may be made from wooden boards. Strong water-resistant rope, such as nylon braid, is the best, although ropes made of sisal, manila or even strips of car tyre may be used. Steel bars, strip of inner tube, some poles, wire and nails are also required.

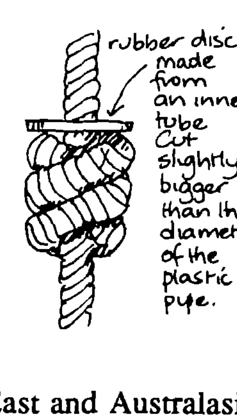
Tools needed are a sharp knife, a hammer, a pair of pliers, a wood-saw and wood chisel and a hack-saw. Basic welding facilities can improve the quality of the handle. An experienced pump-maker, with all the materials ready, can make and install the pump in one day.

The rope-washer pump can:

* lift water from open waterholes, hand-dug wells and streams but not from narrow machine-drilled boreholes.
* pump water quickly when water is near the surface.
* lift water from deep wells. Water has been lifted from depths of more than 20 metres. However, in deeper wells, water flows from the pump more slowly because it is harder to work. A variation of the rope-washer pump is shown in the picture at right. This pump is used in Peru.
* lift water into overhead tanks.
* be operated by one or two people at a time.
* cope easily with mud, weeds, etc.
* be easily understood and repaired by the farmer when something goes wrong.
* it saves time. To irrigate a garden of 0.1 hectares (a little over 30m x 30m) using a rope-washer pump (if pumping up water from a 5 -deep well) would take about 6 hours per week, or a little over an hour a day. To water the same sized garden using a watering-can would take at least 4 hours each day.

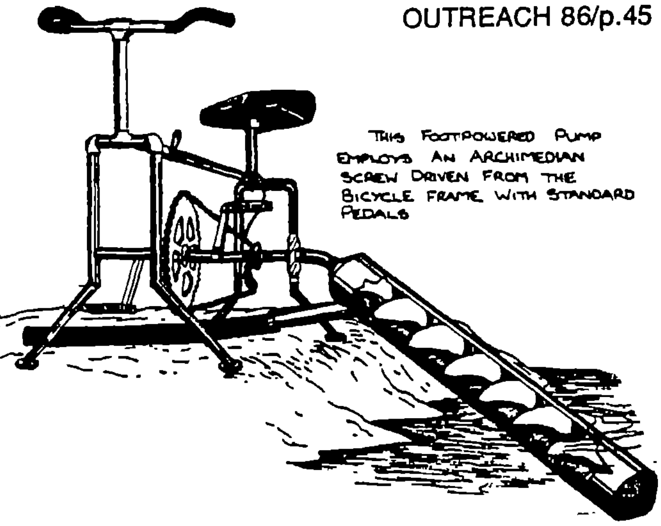
In order to make this technology widely available, good training is required. A detailed manual has been published in English, on the construction of the rope-washer pump. A 20-minute video (with no narrative) is also available showing the main steps in making the pump. The manual and video are available from Intermediate Technology Publications, 103 Southampton Row, London, WC1 4HH, UK. The manual costs £4.95 incl. air speed postage (£5.55 to the Far East and Australasia). The video costs £19.95 incl. postage (£22.25





to the Far East and Australasia). Training in the construction of the pump is only the first step. Training in garden irrigation for farmers, and in business methods for pump-makers, are

also available. For further details of such courses and for additional information on the rope washer pump and other irrigation pumps, please write to: Robert Lambert, School of Development Studies, University of East Anglia, Norwich NR4 7TJ, UK
Source: "Technology for Garden Irrigation" by Robert Lambert, Footsteps (No.7 June 1991) Footsteps is a quarterly paper published by the Tear Fund, linking health and development workers worldwide.



Archimedes Screw
The spiral is a screw shape. Above is a diagram showing an archimedean screw being driven by a foot-powered pump from a bicycle frame with standard pedals. Perhaps, the students can devise another way of powering an archimedean screw.

LEAFLET NO. 44: WATER-LIFTING DEVICES (2) SIPHONS

TEACHER'S TIPS

Siphons

How does the siphon work? Gravity pulls the water down on the lower side of the tube. At the same time, air pressure pushes the water through on the higher side. Together, they create the flow of water through the siphon. When the water is at the same level in both jars, gravity is exerting the same pull on both sides of the tube and the flow stops. Why does the tube have to be full of water first for the experiment to work? Try the experiment without the tube full of water. When it has air only in it, water is prevented from rising to the top of the high side. You can start a siphon working by putting one end in the jar of water, then sucking on the other end of the tubing until the water is almost all the way through the tube. Take the tube quickly out of your mouth and hold it, pointing down, at any point lower than the level of water in the full jar. As long as the free end of the tubing is lower than the water level in the jar, water will continue to drain. You could experiment with tubing of different lengths, too.

Siphon bottle
You can extend the work using the siphon bottle by doing the following with your students:

* With the siphon bottle, instead of blowing hard to move water up, try making devices that when squeezed, will push the water out of the bottle for you. Try a blown-up balloon or a bicycle pump. In the case of the latter, don't pump too hard: the siphon bottle could break. Ask the students what these devices resemble. (e.g. a fire extinguisher).
* See if heating the water in the bottle affects the way the water behaves. The students can use their hands or place the siphon bottle in a bucket of very warm water. If the long tube is held upright, measure how far the water from the siphon bottle rises. This is like an air thermometer. This experiment explores what happens when air pressure in the bottle increases.

Hose and bucket pump

For more on hose and bucket pumps, read "Clean Water for Elemit - a letter from the village health worker" OUTREACH issue 73.

One of the disadvantages of the hose and bucket pump is that not all the water in the bucket inside the well can be discharged. There is always water in the pump that cannot be pumped out.

EXPERIMENTAL RESULTS

A Siphon Bottle
Through the experiments, students will

discover that water will flow from one container to another only when the air is being sucked out of the bottle or when the two water levels are different. In a closed container like the siphon bottle, air has to go out in order for water to come back into the bottle, and when water goes back out, air comes in.

ANSWERS TO QUESTIONS

Siphons

Completing the paragraph: air; below; higher; downwards; same. *Experiments*: (3). There would be no water flow in (1) and (4) because the water levels are the same. In (2) the water would flow from jar A to jar B.

Hose and bucket pump

(1) It is important to convince the woman that there is no evil spirit at work - just gravity. The water is being sucked back into the hose as the bucket attached to the hose moves to a lower level. Let the woman feel that the hose "sucks" when the bucket is lowered: she would feel it quite distinctly if she put her finger just inside the hose. One way to make sure this doesn't happen is to fix the hose so it cannot be left in a collecting bucket.

(2) If the discharge outlet is plugged with a cork before lowering the bucket, the water in the hose won't run back into the bucket as it's lowered.

(3) Use a larger bucket, raise the support or use a more efficient windlass, perhaps one operated by a windmill.

Picture (a) shows water running into the bucket. (b) shows water being sucked back into the hose and bucket. (c) shows the hose bucket hasn't reached a level where the flow will take place yet.

Design a pump

The project may begin with a class discussion of existing water supplies: what is the rainfall in your region; where community members obtain their water over the course of the year (the source may vary depending upon the season); how adequate existing supplies are for meeting the needs of the local community; what the quality of the water supply is; what local residents know - and do - about preventing water supplies from becoming contaminated; even the taste preference of local water supplies (e.g. underground supplies may have a different taste and appearance to surface water.)

It is important to discuss your community situation with the students, because the choice of design depends upon local conditions:

* Consider what sources of energy are available. For example, would a wind pump be suitable? Are there draught animals (oxen, donkeys etc.) available?
* What materials are available - wood, clay, stones, straw, leather? Some industrial products such as oil drums, car tyres, buckets, gas pipes, plastic tubing may or may not be easy to obtain. What about cement, nuts and bolts, metals?
* Who can maintain the pump? Are there mechanics living in the community? Who should be responsible for the maintenance?
* Point out the cheapest pump is not necessarily the best pump, and the cleanest pump may not be the cheapest. Who will pay for the installation of the pump and its maintenance?
* How many people live in the community, and will use the pump? What uses will the water be put to? When in the day will most people use the pump? Are the water demands constant throughout the day/year?

Ask the students to examine the design criteria, and decide for themselves which are the most important, and which are the least important. (Priorities may be determined after class discussion, or after they have talked to members of the local community about their water needs.)

RESOURCES

A useful publication for work on pumps is *Water for Tanzania* published in 1983 by The Physics Curriculum Development Group (PLON) in Holland for 14-15 year olds. This is an imaginative resource both for science and other subject areas. Photos and text give background to Tanzanian water problems and needs and show in detail (diagrams, photos) how different types of pumps work. It includes questions for activities and discussions. It is available for £3.60 from Centre for World Development Education, Regent's College, Inner Circle, Regent's Park, London NW1 4NS ENGLAND or the book may be ordered from NIB publishers, P.O.Box 144, 3700 AC Zeist, THE NETHERLANDS.

LEAFLET NO. 45: WATER-LIFTING DEVICES (3) SUCTION PUMPS

TEACHER'S TIPS

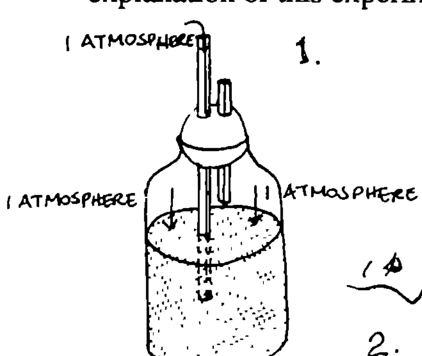
Resources

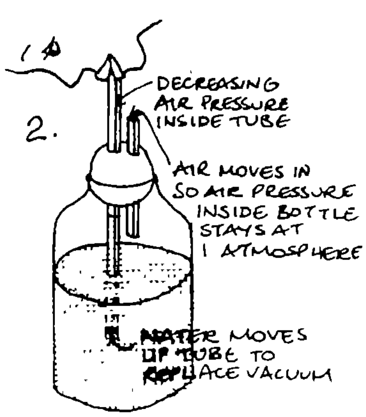
Much of the information for this leaflet is adapted from: *Water for Tanzania* published in 1983 by The Physics Curriculum Development Group (PLON) in Holland for 14-15 year olds. This is an imaginative resource both for science and other subject areas. Photos and text give background to Tanzanian water problems and needs and show in detail (diagrams, photos) how different types of pumps work. It includes questions for activities and discussions. It is available for £3.60 from Centre for World Development Education, Regent's College, Inner Circle, Regent's Park, London NW1 4NS ENGLAND or the book may be ordered from NIB Publishers, P.O.Box 144, 3700 AC Zeist, The Netherlands.

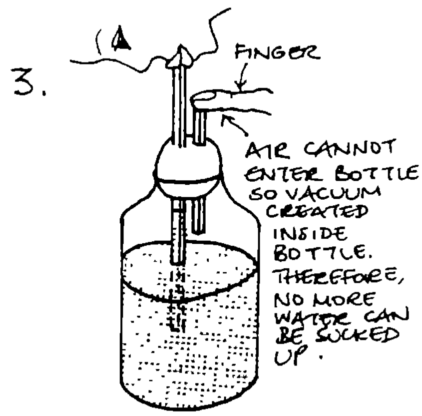
Another useful resource is *Messing Around with Water Pumps and Syphons: A Children's Museum Activity Book* by Bernie Zubrowski, published in 1981 by Little, Brown and Company (ISBN 0-316-98877-4 (pbk.) This book encourages children to play around with water and common materials in order for them to begin to understand how liquids move from one point to another and how such things as pumps, fire extinguishers and air thermometers work.

How high can you pull up water?

The following diagrams provide further explanation of this experiment:





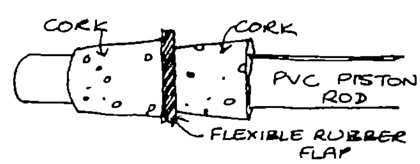


Galileo discovered how high water could be 'pulled up' when he tried to construct a pump to suck water out of a cr 'ne. Since the pump could only suck wa about 20 feet and no further, he had to u ree pumps in succession to pump the water all the way out of the mine.

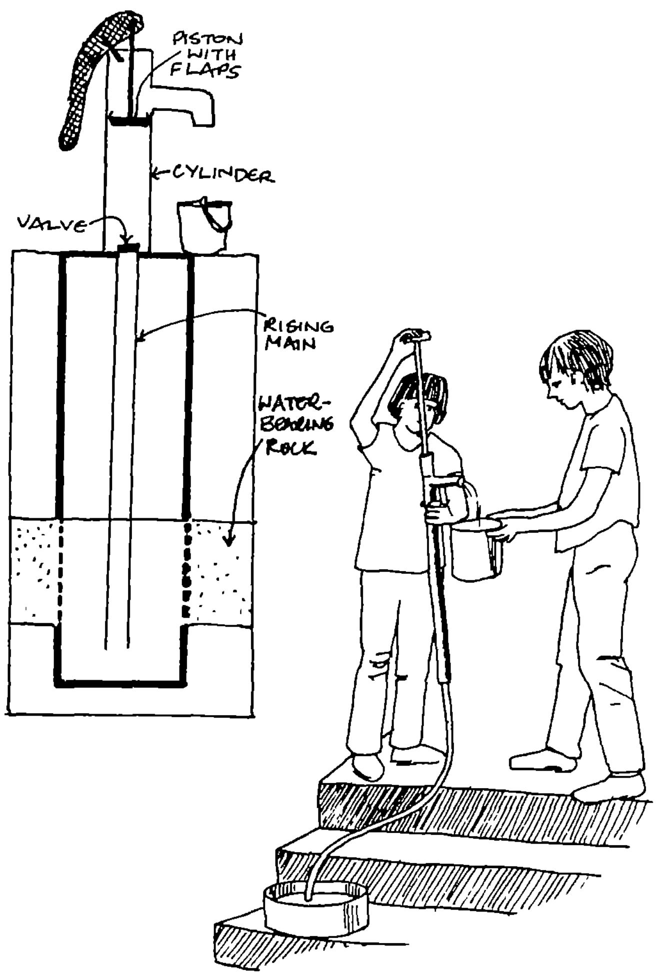
You can expand this section to include work on barometers. If a mercury barometer is available, show it to your class. Measure the height of the mercury column supported by air pressure (76cm or 30 ins. at sea level). As mercury is 13.6 times as dense as water, get the students to calculate how high air pressure would force water up a vacuum tube (10.3m or 34 feet at sea level).

Making a suction pump

When making a suction pump, students may be able to use such things as marbles for valves; squeezable bottles instead of a balloon and funnel. In real-life suction pumps, PVC tubes are used: you could try these or hollow bamboo tubes. The piston could be made from corks, a flexible rubber flap cut from the inner tube of a bicycle tyre, and a pole. The flap must be placed into the tube with its edges curled upwards:



Here is a diagram of a suction pump, and a sketch of one made by some students:



ANSWERS TO QUESTIONS

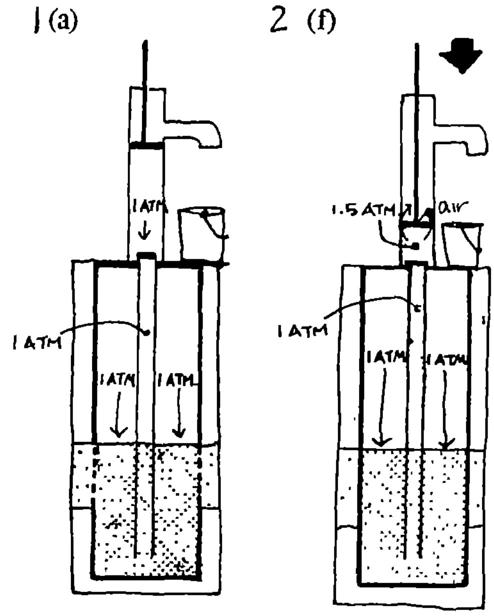
How a suction pump works

The information below is taken from: *Water for Tanzania* by the Physics Curriculum Development Project (PLON), see above reference.

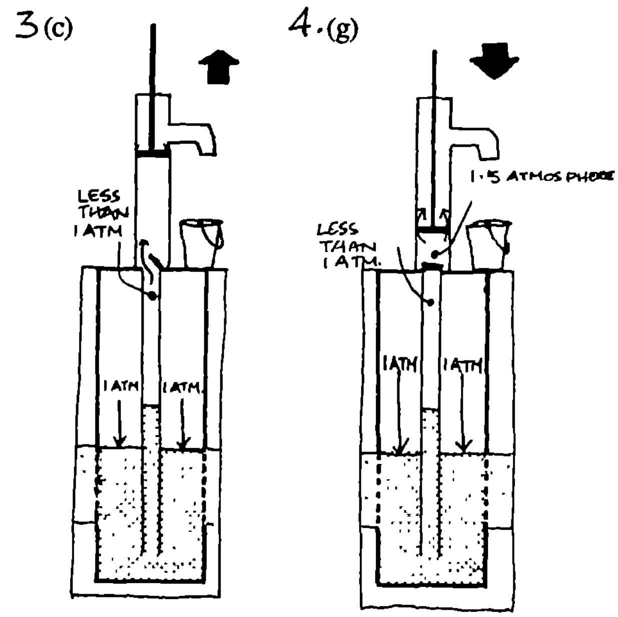
The order of the pictures should be:

1(a); 2(f); 3(c); 4(g); 5(b); 6(e); 7(d)

The students could create a poster showing the different stages in order, and then the class could discuss what's happens at each stage. The different stages are explained as follows. (Please note the handle has been omitted from the drawings. The diagrams indicate the air pressure at the various stages) :



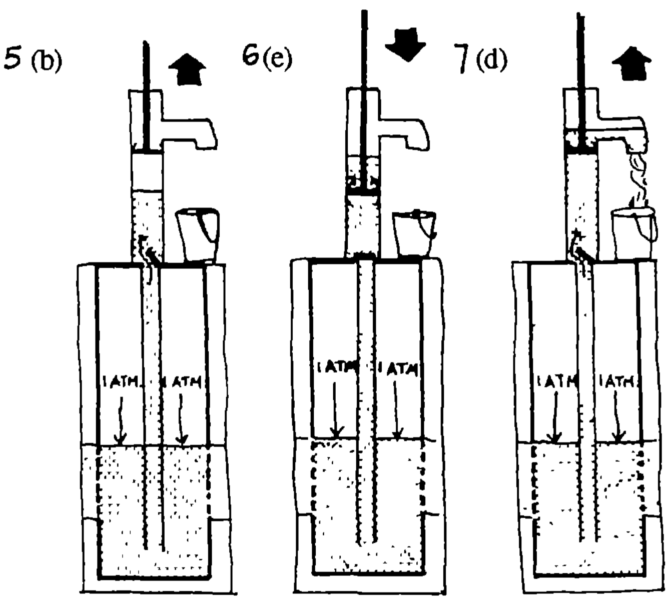
1. The piston and valve are above ground. Air is below the piston. The piston is at the highest position. The water level in the suction pipe is at the same level as the water in the well.
2. The piston is forced down. The pressure of air underneath the piston increases. The valve stays closed. The piston is prevented from being pressed down as far as the valve because of the air underneath. If the pressure is too high, the air pushes the flaps on the piston upwards and escapes upwards.



3. When the piston is raised to its highest point, the pressure of air trapped between

the piston and the valve is less than the pressure of air in the rising main so the valve is pushed open. The air from the rising main flows into the cylinder. The pressure of air in the pump is less than the air pressing down on the water in the well, so the water is "sucked" up the rising main a little way.

4. When the piston descends again, the air pressure in the cylinder is increased, so the valve shuts. The water in the rising main stays at the same level and air is forced out of the cylinder past the piston. This is repeated, with the result that the water in the rising main rises higher with each stroke.



5. After several strokes of the pump, the water rises so high that it passes the valve and enters the cylinder. The last of the air is forced out of the cylinder.
6. When the piston is pushed down again, water is forced past the flaps, and rises above the piston.
7. The water above the piston flows out of the pump when the piston is moved upwards. New water under the piston is sucked upwards through the valve by the pressure of the air on the water in the well. If pumping continues, water will continue to flow out of the discharge outlet - as long as the rising main stays under water.

Making your own suction water pump

In theory, a suction pump could raise a column of water 10.3 m (34') at sea level.

In practice, however, even the most efficient suction pump can create a negative pressure of only one atmosphere. Because of friction losses and the effect of temperature, a suction pump at sea level can actually lift water only 6.7m to 7.6m (22' to 25'). To explore more on the effect of altitude and water temperatures on the effectiveness of a suction pump, see *Village Technology Handbook* published by Volunteers in Technical Assistance (VITA) (revised edition printed 1970) 80 South Early St., Alexandria, Virginia 22304, USA.

The water seal might prevent air leaking when the piston is worn, but some drops of water will leak pass the flaps, and this water can contaminate the drinking supply.

LEAFLET NO. 46: WATER-LIFTING DEVICES (4) FORCE PUMP

ANSWERS TO QUESTIONS

How the displacement pump works

The questions posed are taken from *Water for Tanzania*:

1. Yes. The water begins to rise in the rising main. The higher it rises, the more difficult it becomes to force it further upwards. Greater effort is needed to pump, especially to push the handle up. The valve will begin to leak as the pressure of the water at the bottom of the rising main becomes greater, so that water will also be forced past the piston. The height to which water can be pumped is determined by the degree to which the valves leak.

2. The water wants to be at the same level, so raising the water takes work (force x distance). The higher the volume of water has to be lifted, the same volume of water thus is in the pipe. The weight of the water gets heavier the deeper the well, (not like a bucket in a well whose water has the same weight in deep wells as in shallow wells).

3. The weight of the water in the rising main

places lots of strain on the piston rod.
4. Yes. Pressure is Force/Area. If force applied to the valve is the same, then the pressure on the smaller area of valve 2 in the narrow guide pipe is greater than the pressure applied to valve 1 in the wider rising main.
Lift pump versus force pump: Force pump - valve 1 should be open, and valve 2 should be closed. Lift pump - piston rod should be raised, and the valve should be open.

GOING FURTHER

Here is an exercise that can help determine your students' understanding of how force and lift pumps work:

Lift pumps versus force pumps

Here are some statements that describe force pumps and/or lift pumps. Put a 'T' next to those statements that are true, and a 'F' next to those statments that are false:

1. With the lift pump, the pumping mechanism is located at the top of the well, and raises water by suction.
2. With the force pump, the pumping mechanism is placed at or near the water level, and pushes water up.
3. The force pump raises water on the upstroke, and the lift pump raises water on the downstroke.
4. The force pump relies on atmospheric pressure.
5. Most lift pumps raise water from shallow wells, while force pumps are generally used to raise water from deep wells or boreholes.

Answers: 1 T; 2 T; 3 F; 4 F; 5 T.

LEAFLET NO. 47: PUMP PROBE AND PATROL

TEACHER'S TIPS

This leaflet can serve as a way of concluding work on pumps by inviting students to apply their newly-gained knowledge to practical work in their own community. Alternatively, the ideas in this leaflet may be used by students who do not have time for an in-depth look at the workings of pumps.

The leaflet attempts to make students realise that an acceptance of new technologies by a community depends upon more than people understanding the nuts and bolts of the technology. Cultural, social and health factors should also be considered. For example, there seems to be little doubt that the encouragement of community participation in a new technology pays off in many ways. Installations which are put in place with active community support are much more likely to survive than those in which villagers have neither been consulted nor involved.

Pump Probe

This survey encourages the students to take part in a problem-solving activity: pump problems are identified, and students come up with creative solutions. Through this project, students can develop skills in observation, gathering data, prediction, communication, mapwork, and mathematics.

The data collected may be useful to the community at large. Through the survey, factors determining the success or failure of a community pump might be identified. The survey's results may also be beneficial to policy-makers at the national level who are concerned about introducing specific pump technologies. Perhaps, a national project could be established - a PUMP PARTICIPATION scheme - in which students from schools in different parts of the country can make recommendations on national pump design policies and on national pump maintenance policies based upon data they have collected in the survey.

The questions outlined in this investigation are meant to be suggestions: you may wish to add, or adapt this survey to suit local conditions.

General

If the pump is not old, or there are alternative sources of drinking water, you may wish to conduct a comparative study of pumps and other water supplies. For example, if a windlass and bucket has been recently replaced by a reciprocating pump, you may wish students to examine the pros and cons of both, basing their findings on the recent memories of water users.

Use the illustrations on page 3 of the Leaflet, and what the students have learned about pumps, to determine the pump type. Here is some additional information on reciprocating pumps to guide you:

Direct action reciprocating pumps include the Tara Pump (Bangladesh), Mark V (Malawi), Madzi (Malawi), Blair (Zimbabwe), Nsimbi (Zimbabwe), Rower (Bangladesh), Waterloo (IDREC), Wavin (Netherlands), Nira AF 85 (Finland), Ethiopia BP50 (Ethiopia), and many others.

Lever acting reciprocating pumps include the India Mark II (India), Maldev (Malawi), Afridev (Kenya), Nira AF76 (Finland), SWN 80/81 and Volanta (Holland), Petro (Sweden), Abi Vergnet (Ivory Coast), Swedpump (Sweden), Consellan and Climax (United Kingdom), National (RSA) and Bush Pump (Zimbabwe).

(from: *Rural Water Supplies and Sanitation* by Peter Morgan, Blair Research Laboratory, Ministry of Health, Harare, Zimbabwe published by Macmillan Publishers, London 1990)

Who's decision it was to install the pump has implications for the pump's acceptance and usage.

Who paid for and owns the pump has implications for pump accessibility.

Pump make-up

This section is concerned with the appropriateness of the technology, (for example, are the materials locally-available and affordable? How much involvement can the community have in the construction and repair of the pump?) The students may have to ask the pump repair person to explain the materials used. The following additional information might help:

Most direct action reciprocating pumps use PVC materials below ground, and steel components above ground and are used exclusively on shallow wells down to about 12 metres in depth.

Lever acting reciprocating pumps are certainly more complex than direct action pumps and thus are generally more difficult to maintain. However, they are more robust and are essential for all deep wells and heavy duty settings, see chart below. Lever acting reciprocating pumps use steel assemblies, which support lever mechanisms. The type of lever mechanism varies considerably, but generally is based upon a steel member rotating on roller or ball bearings. More recent bearings are made of hard-wearing plastics. The Bush Pump uses a hardwood lever mechanism and a teak block as a lever and bearing surface, and this has proved very successful.

In almost all cases, pump rods are made of mild or stainless steel. The rising mains are made of galvanised or black iron or PVC. Polyethylene is used in some cases. Most cylinders are made of brass, although some are stainless steel. (from: *Rural Water Supplies and Sanitation* by Peter Morgan, Blair Research Laboratory, Ministry of Health, Harare, Zimbabwe published by Macmillan Publishers, London 1990)

Recommended settings for Handpumps

(taken from *Rural Water Supplies and Sanitation* by Peter Morgan, Blair Research Laboratory, Ministry of Health, Harare, Zimbabwe, published by Macmillan Publishers, London 1990)

PUMP SYSTEM	DEPTH RANGE	MAX NO. USERS	IDEAL SETTING
Bucket and windlass on well	1-15 metre	20	Family
Bucket Pump	1-15 metre	60	Small community
Bush Pump	1-100 metre	250	Large community
Blair Pump	1-12 metre	60	Family/small community
Nsimbi Pump	1-12 metre	60	Family/small community

NOTE: In Zimbabwe, the bucket and windlass, Bucket Pump and Bush Pump are used in programmes sponsored by the Government. The Bush Pump is used most.

Pump site

This section encourages students to explore the geographical factors relating to water supply, namely the geology of the area, surface drainage, vegetation, and human settlement. Mapwork can be an integral part of the project.

Pump usage

Social skills may be developed through interviews. Students can create their own interview surveys and determine for themselves the effectiveness of different interviewing techniques, (e.g. open versus closed questionnaires).

Pump maintenance

The students may be able to draw some conclusions about the effectiveness of the maintenance system adopted in their community. For instance, there is evidence that where handpumps are essential for survival, in areas where water-tables are deep and there are no alternatives, communities are far more willing to contribute time and even their money to keep pumps working, since a higher value is placed on water. Where pumps are placed in areas having alternative sources of water close by, then the same principles may not apply: the users are less inclined to contribute to community maintenance, preferring to take their water from the nearest unprotected source, usually a water-hole or river, if the pump breaks down. In areas where family wells are common, these are often used in preference to communal supplies, since they are usually closer.

Encourage students to think about effective ways for the community/region to maintain its pump(s). See OUTREACH issue 76, page 15 "The barefoot mechanic".

Pump repairs

Ask students to find out about the current procedure for getting repairs done. Is the community reliant upon outside help or is someone in the community responsible for repairs? The students may be able to suggest ways of reducing breakdowns.

Pump improvements

Invite the students to ask others about the pros and cons of the pump. The advantages and disadvantages of pumps may not be just concerned with the design, (e.g. the pump doesn't supply water fast enough; frequent breakdowns) There could be health benefits and problems (e.g. less water-related diseases; poor hygiene as a result of sloppy pump maintenance) and social benefits and problems (e.g. the pump becomes a meeting place; time-saving way to get water; too many people trying to use pump water; the villagers are not used to - and do not like the taste or colour of groundwater). Data can be presented in bar charts and pie diagrams for analysis by students who can discover the most popular benefits and problems associated with the pump. Once identified, the students can work out ways to make improvements on the pump. Actions may vary from setting a schedule for water collection to suggestions for improving pump design.

MISCELLANEOUS ACTIVITIES

Hand pump options for a nation

In some countries, a dozen or more different handpumps may be used, each supported by their respective donors. Discuss this issue with your students. What are the problems and potentials of having many/ a few/ only one pump design available in a country? Who should decide how many pump designs are available? What criteria are important for determining pump options? Consider such issues as maintenance and availability of spare parts, donor dependency, etc.)

Bucket and windlass versus reciprocating pumps

Ask your students to read this passage and then answer the questions that follow:

In Zimbabwe (1988), there are about 15,000 reciprocating handpumps in regular use, and over 50,000 bucket and windlasses. The former raises water of higher quality, but, if poorly maintained, ends up as scrap and of little use to the community it was intended to serve. The bucket and windlass is easily maintained by the community, but it often delivers water of poor quality.

1. In Zimbabwe, how many more bucket and windlasses are there than reciprocating pumps?
2. Name an advantage of a reciprocating pump over a bucket and windlass.
3. Name an advantage of a bucket and windlass over a reciprocating pump.
4. *In many places of the world, the bucket and*

windlass remains the most successful water-lifting device ever designed. And yet this simple method has been cast aside, as being unsanitary and unsuitable for official use in most rural development programmes throughout the world. Discuss.

A pump for the village: a role playing exercise

Set up a role-playing exercise to determine which pump is to be selected for the village. Divide the class into small groups. One group is to act as a panel of local decision-makers who must decide which pump option the village should use. This group must determine the criteria on which to judge different pump designs. Here are some suggestions, taken from *Water for Tanzania* by PLON:

1. The operation of the pump must not require an expensive source of energy (petroleum, electricity)
2. The pump must be made of materials obtainable locally as far as possible.
3. The pump must require as little maintenance as possible.
4. The pump must be as cheap as possible.
5. The construction must be such that it will be impossible to pollute the water in or near the well.
6. The capacity of the pump must be sufficient to supply the needs of the village.

Each of the other groups studies a type of handpump in detail. The group must be familiar with the workings of the pump, the situations for which it is best suited; the materials used in its construction, and where they may be obtained; the maintenance required. Each group makes a presentation to the whole class. Then, the panel selects one pump, giving reasons for its decision.

Repairs to the Bush pump

The Zimbabwe Bush Pump is a lever acting reciprocating handpump that has been in service for over fifty years, and is still the handpump of choice in Zimbabwe (1989). There are about 15,000 Bush Pumps operating in the country.

Operating on the lift pump mechanism, the Bush Pump can lift water as high as 100 metres, but most are installed to depths of 30 and 40 metres. The pump also can be used on shallow wells.

The Bush Pump is maintained by the District Development Fund (DDF) of the Ministry of Local Government, Rural and Urban Development. The DDF operate at district level where pump fitting gangs, under the supervision of a District Field Officer, are equipped with special tools to maintain the Bush Pump and other water installations. (More recently, Pump Minders have been employed at Ward level in some areas to maintain handpumps, but this system is still being evaluated (1989).) Villagers and pump caretakers are also responsible for keeping nuts and bolts tight, greasing parts and for keeping the apron and run-off channel.

Below is a chart that shows some of the main Bush Pump repairs required in Zimbabwe (1987 - 1988):

TYPE OF REPAIR	NO. OF REPAIRS	PERCENTAGE OF TOTAL REPAIRS
Leather seals	1055	25%
Rising mains	635	15%
Rods	486	11%
Others	2101	49%
Total	4277	100%

(from: *Rural Water Supplies and Sanitation* by Peter Morgan, Blair Research Laboratory, Ministry of Health, Harare, Zimbabwe published by Macmillan Publishers, London 1990)

LEAFLETS ON WATER PURIFICATION: NO. 48: PURIFYING WATER WITH HEAT; NO. 49: PURIFYING WATER WITH FILTERS NO. 50: PURIFYING WATER WITH CHEMICALS

TEACHER'S TIPS

The World Health Organization (WHO) estimates that 1.2 billion people drink untreated water at considerable health risk. Eighty percent live in small rural communities, where present-day treatment units require investments far beyond their means. The Learning-By-Doing Leaflets on water purification describe some simple methods that might be applied at household or community levels.

The leaflets on water treatment are a practical way of helping students to understand various chemical processes. For example, the existence of impurities in water is a good starting point for any discussion and work on mixtures, solutions and suspensions, and experiments demonstrate how components of mixtures may be separated.

Other treatment techniques cover various other physical and chemical processes. For example, oxidisation takes place when chlorine is added to water. Physical changes (i.e. changes of state) are explored when students are experimenting with boiling water.

In the experiments using *Moringa oleifera* seeds, it would be best to divide the class into groups. Each group could use different quantities of *Moringa* seed powder, and simultaneously perform tests on water from the same source. In this way, water clarity could be compared at the same time.

EXPERIMENTAL RESULTS

Boiling

Pure water boils at 100°C (212°F). The temperature does not increase after the water begins boiling. The water starts to change to water vapour before it is hot enough to boil, but the change from water to water vapour happens most rapidly at the boiling point. The amount of water being brought to a boil affects the time it takes to heat water to the boiling point. Air pressure does affect the boiling point: the higher the air pressure, the higher the boiling point .

Explain what happens to the molecules of water when it reaches the boiling point: as the molecules move faster, they move to the surface of the liquid. At the boiling point, the molecules escape from the surface of the liquid, and the liquid becomes a gas.

Distillation

The sun's warmth heats the water in the bowl, making it *evaporate*, that is, turn into water vapour. When the vapour touches the cooler plastic sheet, it *condenses* back into water droplets. The water has been purified through this process, which is called distillation. The dirt and other substances that make up the mud evaporate at a much higher temperature than water does. So when the water vaporises, it leaves the particles of mud behind. This makes distillation an easy way to separate solid contaminants from water. The water collected in the glass has very few impurities and is clear. Distillation is often used when the substances in a mixture have to be separated. For instance, it's one way of making fresh water out of salt water, see *GOING FURTHER*.

The distilled water is absolutely pure. It can be used for drinking. It can also be used in medical prescriptions, in batteries, and in other instances where 100% chemically pure water is required.

Sunlight

The best results are obtained using water with few suspended particles and low bacterial density.

Settlement

Ask the students to think about the size, shape and density of the sediments when determining the rates they settle out. The materials that settle first are the larger, denser materials.

Filtration

Different amounts of mud come through the filters. Gravel, which permits most mud to get through, is the least effective filter. If the soil used as a filter contains clay, then the mud not only passes through but it also drags some clay with it. The sand does the best job of filtering out the solid particles. Sand cannot filter out dissolved solids such as salt and vinegar.

The effects of sand on water are complex, and involve many different mechanisms. Many bacteria are consumed by the skin on the surface of the sand. Called 'schutzdecke', this surface is made of algae, diatoms, protozoa and other organisms. When water passes between the sand grains, a process of adsorption takes place on the surface, caused by electrical and chemical bonding and mass attraction. Each cubic metre of sand provides 15,000 square metres of surface area for the adsorption of bacteria to take place. In addition, the pores or open spaces between grains occupy 40% by volume of the sand. Water flowing through these spaces slows down and sediments settle out. As the depth from the surface increases, the quantity of organic matter decreases, and the struggle between various organisms becomes fiercer. The harmful germs cannot compete with other organisms more suited to these conditions. In such an environment, disease-carrying germs perish.

Sand filters can be made in various sizes, from a family unit in a 200-litre drum or cement water jar to very large units designed for small communities.

Whilst sand removes bacteria effectively from water, it cannot easily remove large volumes of sediment which may be present in the water. Ideally, water should be added to a filter when it is mechanically clean, and this may involve pre-treatment, such as sedimentation or passing through a gravel filter first. If the water contains a lot of sediment, and this is not removed, the surface of the filter will become rapidly clogged.

OUTREACH issue 76, page 37 describes how to make a gravity sand filter for purifying water.

Coagulation

In the experiment, the potassium aluminium sulphate makes the small particles of clay stick together so that they filter out as if they were much larger. The particles in the liquid without the potassium aluminium sulphate get through the filter much more easily.

Using *Moringa oleifera* seeds

In various parts of the world, water coagulation is used to treat turbid and polluted natural waters because it does not just result in a fast removal of turbidity but also a fast removal of different types of microbes.

Studies using *Moringa oleifera* seeds to clarify the Nile water [Dr. Samia Al Azharia Jahn with the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) in Germany] have found that they can "clarify Nile water of any degree of visible turbidity" At high turbidity, their action was almost as fast as alum, but at medium and low turbidities, it was slower. The doses required did not exceed 250 mg./l. Coagulating the solid matter in water so that it can easily be removed can remove a good portion of the suspended bacteria.

Powdered seeds of the *Moringa oleifera* tree can clarify not only highly turbid muddy water but also waters of medium and low turbidity which appear milky and opaque or sometimes yellowish or greyish. During the cool season complete clarification, which takes only one hour in hot water, may take two hours unless water is left in the sun for some time to raise its temperature.

In the case of the Blue Nile, it was found that water of low turbidity in the initial and final flood season needed doses of crushed moringa seeds equivalent to about one quarter of a seed per litre, water of medium turbidities needed half a seed per litre and at high turbidities, the dose should be 1-1.5 seeds per litre. Water from a different river will require different quantities of clarifier because of variable characteristics of suspended material. Simple experiments in jars will determine the best dose for the untreated water collected by the class.

Try to obtain seeds of the *Moringa oleifera* plant for students to study, to use to purify water, and to grow to obtain more seeds. If *Moringa oleifera* seeds are not available, try *Moringa stenopetala* seeds.

Adding chemicals

Oxidation occurs when other elements react chemically with oxygen. When chlorine is added to the water, it combines with the hydrogen in the water, liberating free oxygen. This oxygen rapidly oxidises matter such as bacteria which is present in the water. The amount of oxidisable matter present in the water is important, since chlorine may be used up in the oxidisation of organic matter other than bacteria. Ask the students if they think unclear water would require more or less chlorine to treat it than properly sedimented and filtered water.

ANSWERS TO QUESTIONS

Distillation

In nature, the water cycle illustrates how evaporation and distillation take place. Energy from the sun causes water molecules from oceans, lakes, rivers and streams to *evaporate*. Up in the atmosphere, where temperatures are cooler, the water molecules slow down, get closer together and *condense* into tiny droplets of liquid, forming clouds. As more water molecules condense, the drops of water get bigger and bigger until they fall to earth as rain.

Sometimes, when enough water molecules are in the air and the temperature near the ground is cool enough, the water molecules condense to form dew. If the temperature drops below the freezing point (0°C or 32°F), the water in the air can change directly to ice, forming frost.

Using *Moringa oleifera* seeds

After stirring, the treated water should be covered and left to settle for at least an hour. If moved or shaken before this, then clarification will take much longer or fail to reach completion.

GOING FURTHER

Counting the calories

The students can explore how much energy is needed to treat water with heat. For example, the class can learn about calories.

Temperature is a measure of how hot something is. To raise the temperature, you need to add heat. Nothing can get hotter unless more heat is added to it. We measure heat in calories. To raise 1ml.. of water 1°C requires 1 calorie.

(a) How many calories are needed to raise 20ml.. of water 1°C? (Answer: 20 calories)
(b) How many calories are needed to raise a litre of water from 22°C to 100°C? (Answer: 78,000 calories)

This exercise can lead to a discussion about how much energy is needed to boil water for drinking.

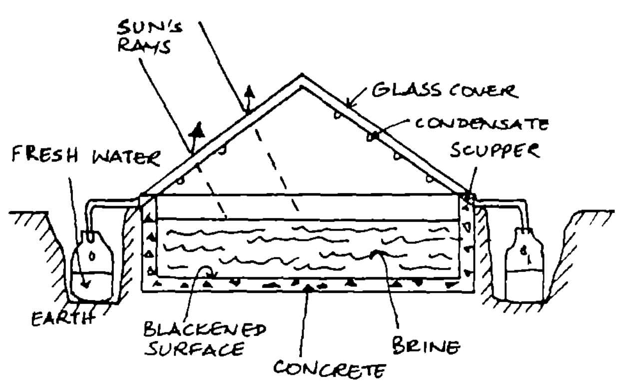
Distillation

The following notes on distillation are taken from Third World Science Project unit "Distillation" (produced by School of Education, University of North Wales, Bangor, UK, 1982):

(a) Solar distillation

Using a simple device as shown in the following illustration, controlled evaporation can produce fresh portable water from salt or brackish sources. A water-tight compartment, made of wood or concrete, is painted black to absorb the solar radiation which enters through the glass roof of the still. Salt or brackish water, or even sewage effluent, is allowed to flow into the channel or box to a depth of 60-100 cm. The incoming solar radiation heats the water, causing some of it to evaporate and this condenses on the inner surface of the glass roof.

GLASS COVERED SOLAR STILL



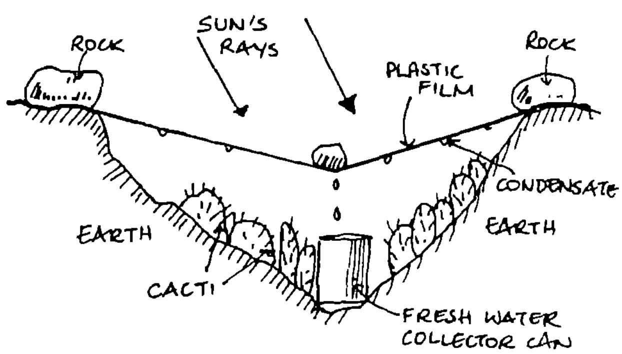
Since water will 'wet' clean glass, the condensation takes place in the form of a very thin film which flows down by gravity into the scupper which leads the condensate off to a suitable container. The water channel is insulated by the earth. After some of the water has been distilled, the brine which is left is flushed out at intervals. This prevents the concentration of salt from building up to the point when it will cover the bottom of the still with reflective white crystals.

The product of such a still is distilled water which can be used for drinking, for filling storage batteries or for any other purpose for which pure water is needed.

(b) Surviving in the desert

The diagram below is a desert survival still. The kit includes only a sheet of transparent plastic and a tin can, since the other needed materials can be found in the desert:

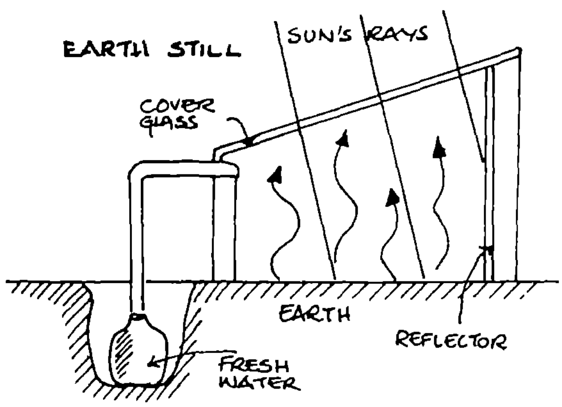
DESERT SURVIVAL SOLAR STILL



Even in the driest earth, there is always some moisture and it can be distilled out by creating a heat trap as shown. By using the transparent plastic cover, a rock to weigh the cover down in its centre, and a can to catch the droplets of moisture as they trickle down the inner surface of the plastic, water can be distilled. This water is suitable for drinking.

Dr. M. Kobayashi of Tokyo proved that water can be extracted from virtually any kind of soil by the still shown below:

EARTH STILL



He used a typical still construction, complete with a cover glass and reflector to increase the amount of solar radiation reaching the earth. He has tested his still at the top of Mount Fujiyama where the soil is volcanic ash and in arid deserts of Pakistan, and he has never failed to produce water which is pure and palatable.

Invite the students to construct a still for collecting water from a variety of soils in the locality. Which soil type/location/weather condition produces the most abundant water supply?

Using plants as primary coagulants

The notes above cite one water treatment study using *Moringa* seeds, (Dr. Jahn *et al*.) Another study is mentioned in *CERES* (134: March/April 1992) published by the Food and Agriculture Organization. Researchers from the Dept. of Environmental Technology at Leicester University (U.K.) have set up a unit at Thyolo in Southern Malawi to treat 48 cubic metres of water a day using *Moringa* seeds. The programme is being carried out in collaboration with local authorities, supported by the British Overseas Development Administration (ODA).

In Malawi, the pods, flowers and leaves of the tree, known locally as the *Chamwamba*, are the basic ingredients of the traditional local dish *Ndiwo*.

Moringa seeds have both economic and ecological advantages over chemicals. Malawi not only could save US$460 million a year if it no longer needed to import alum (aluminium sulphate) to purify its water, but might also be able to start cash-crop production of the seeds to stimulate the local economy. Planting the trees would help stabilise soil and contribute to the fight against deforestation.

The *Moringa* tree is highly resistant to drought and needs little care. It is fast-growing, produces its first seeds at 18 months and lives for an average 50 years. Each tree can produce approximately 10 000 seeds a year, and one hectare of *Moringas* spaced two metres apart would provide enough seeds to clarify 250 cubic metres of water every day of the year.

Working on artificially polluted water in the laboratory and then on small volumes of water taken from three rivers in Malawi, the British research team estimated the quantity of seeds needed depending upon the turbidity of the water and the volume being treated. They found that 100 milligrams of crushed seed can clear one litre of very turbid water. The study found that further disinfection (by boiling at home, or by slow filtration or chlorination at treatment sites) is still needed after treatment using *Moringa* seeds before the water is fit for human consumption.

The small experimental unit built at Thyolo will be the first attempt in Malawi to treat water with *Moringa* on an industrial scale. If the experiment is successful, similar projects will be launched in other developing countries.

For further information, write to John Sutherland, Bill Grant, Geoff Folkard or Paul William, University of Leicester, Dept. of Engineering, University Road, Leicester LE1 7RH, ENGLAND. Tel. (44) 533-522594.

Moringa oleifera seed is one of the more well known water coagulants. In certain environments, *Moringa oleifera* could be replaced as a "coagulant crop" by other *Moringaceae* (the most promising is *Moringa stenopetala* which has been shown to contain similar efficient primary coagulants. (Jahn 1986 and 1988). Other plant materials that are used to clarify include "Nirmali seeds" from *Strychnos potatorum*, sap from "tunas" (*Opuntia ficus indica* and other *Opuntia* sp.) If any of the plants are available, the students can compare their effectiveness as water coagulants. Other local available plant seeds can also be tested: the class may even discover a new coagulant!

Which water purification method is best for you?

Use this exercise to draw conclusions about water treatment techniques.

From the knowledge you have gained in the Learning-By-Doing leaflets on water purification, make up a chart similar to the one at right and complete it as best you can.

Design a water treatment plant for your community. Use some of the treatment methods described in these leaflets.

You could ask questions similar to those outlined below:

* What can be used to remove floating solids such as wood or leaves? (e.g. screening)
* How can large, non-floating solids be separated from water? (e.g. settling tanks)
* What can be used to remove suspended solids? (e.g. filtration)
* Name a way of separating dissolved chemicals. (e.g. alum)
* Which method kills all germs? (e.g. chlorine)
* Which treatment methods work well together to make water safe to drink? (Different answers, but one might be settlement, sand filtration, and chlorine or boiling)

	BOILING	DISTILLATION	SUNLIGHT	SETTLEMENT	FILTRATION	COAGULATION	USING *MORINGA* SEEDS	ADDING CHEMICALS
Results:								
makes water look clean								
makes water smell clean								
makes water taste good								
kills no germs								
kills some germs								
kills all germs								
Cost:								
no cost								
low cost								
high cost								
Speed of process:								
quick								
slow								
Construction:								
self-built								
artisan-built								
factory-built								
Power source:								
animal/manual								
renewable								
non-renewable								
scarce								
plentiful								
Maintenance:								
simple								
training needed								
specialist needed								

Encourage the students to apply what they have learned in these experiments to their own local conditions. They should consider which water treatment methods would suit their community bearing in mind the source of their water supply,the resources that are available and the water usage.

What do people think about water quality?

In many villages in developing countries, villagers may not seem concerned about the condition of the water they consume. Accordingly, they do not treat the water either. In such a situation it would be useless to try and disseminate water treatment technology because the people do not see the need for it.

Ask your students to find out what local people think about the quality of their water supply. Here are some possible questions. (Your students can perhaps think of others.)

* Do the people think the water they consume is dirty?
* Do they want cleaner water?
* Do they know the danger of drinking polluted water?
* Have they ever tried to treat the water they consume, and if so, how?
* Do they know of any ways to treat water?

If the survey shows few of the local people realise the danger in consuming polluted water, than invite the students to develop ways to change people's perceptions of dirty water and to make them realise its dangers. Through booklets, plays, posters and meetings etc., the students can also tell the community members about the advantages of consuming clean or treated water.

RESOURCES

Organisations:

Educational Concerns for Hunger Organisation (ECHO), 17430 Durrance Road, North Fort Myers, FL. 33917, U.S.A.

ECHO's seed bank and information network help Third World farmers to farm better with the skill, tools, and condition they have to work with. If you are planning to start a nursery for *Moringa* seeds, write to ECHO requesting information. In particular, ECHO Technical Note A-5 describes the uses and cultivation of *Moringa oleifera*. Explain in your letter the reason for your inquiry and ECHO may be able to provide some seeds, too.

Publications:

A publication that may be of interest is *Traditional Water Purification in Tropical Developing Countries* by Samia Al Azharia Jahn, 117 GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit) Eschborn, Germany, 1981. This manual deals with a scientific appraisal of indigenous technologies in the tropics for the improvement of water quality.

GATE No.1/1989 includes information on water purification using *Moringa oleifera* seeds. GATE is produced by Deutsche Zentrum für Entwicklungstechnologien, Dag-Hammarskjold-Weg 1, D-6236 Eschborn 1, Germany.

WATERLINES, Vol.3, No.4, April 1985 (published by IT Publications, 103-105 Southampton Row, London WC1B 4HH UK) also has an article on water purification using *Moringa oleifera* seeds. The article describes how Dian Desa, an Indonesian NGO, has used *Moringa oleifera* seeds in water purification projects in rural areas. Villagers' perceptions about water treatment are discussed, as are the ways Dian Desa changed these perceptions and encouraged the use of *Moringa oleifera* (known as *kelor* in Indonesia). A method of treating the water is also described:

Two clay jars are used. The settling occurs in one and the clarified water is stored in the second. Jars are modified slightly by the addition of an outlet to siphon the treated water. This is because the protein in dissolved kelor *seeds will start to ferment and small after about 12 hours.*

(1) Turbid water poured into the first pot for treatment.

(2) Bung removed from outlet of first pot. Clarified water stored in the second. The lower outlet is used to drain the jar.

For more information, contact Dian Desa, Jalan Kaliurang KM 7, P.O.Box 19, Bulaksumur, Yogyakarta, Indonesia.