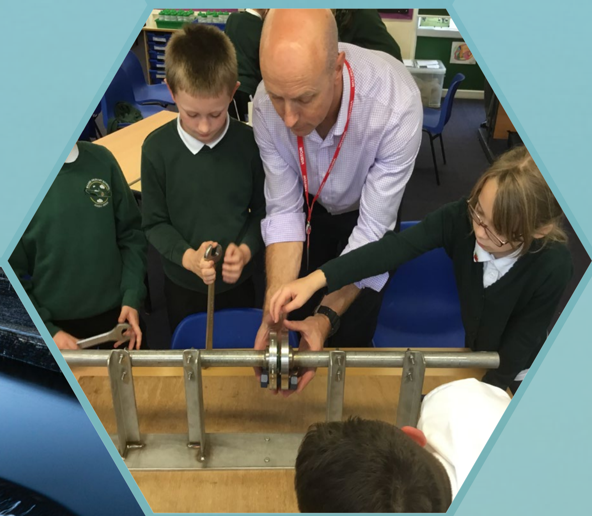
WATER FOR INDUSTRY

A science investigation pack for teachers of 9-11 year olds



CENTRE *for* INDUSTRY EDUCATION COLLABORATION

ExxonMobil

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Introduction

AGE RANGE

The material is aimed at 9 - 11 year olds, though the activities can be modified for use with other age groups and their associated learning objectives.

INTRODUCING THE ACTIVITY

This resource provides an opportunity of children to learn about the story of water as it travels from a reservoir, around an industrial site and back to a river.

Most of the water used on an industrial site is continuously recycled. An additional supply of water is piped from an external source (e.g. a reservoir) and then piped off site (e.g. to a river). This is done to maintain a balance of 'clean' water and chemicals that can otherwise become concentrated, and to replace water that has evaporated during heat exchange. It is this small percentage of water that provides the storyline for the following activities.

The activities are put into a context using Activity sheets 1 and 2. Activity sheet 1 is a letter from a fictitious oil company. In the letter, the site engineer describes some problems that the company are having, and asks the 'consultants' for help in these areas. This letter is intended to be used as a stimulus for class discussion, during which the teacher and children talk about the points that are raised. Statements from the letter can be enlarged to provide prompts for an open-ended approach to some of the activities. Terminology used in the letter can be discussed briefly during this introduction, and expanded upon before each relevant activity.

Activity sheet 2 provides a pictorial map of the path that the water takes from the reservoir, around the site and back to the river. Copies of these can be given to each child or group of children for reference, or displayed centrally. Children can add information to this sheet as an activity is completed. Once this context is established through discussion, the individual problems can be investigated through activities 1 to 5 below.

Writing letters is an interesting and often novel way for children to record the work they have carried out. Activity sheet 3 provides a stimulus for this task and can be used

at the end of selected activities or on completion of the package. Masters for button badges are given on Activity sheet 4, to encourage a positive image of science and for children to enjoy wearing once they have successfully completed one or more of the activities

The number of activities and order in which they are done can be varied. A description of each activity and the approximate duration is given overleaf.

ACTIVITY SUMMARY

Theme	Summary of activities
1. Pick a piece of pipe	Testing aluminium, steel and a plastic for rusting when exposed to water. The children test materials for their resistance to corrosion. Using this knowledge, they choose a material for constructing a pipeline for the water.
2. A leaky line	Investigating sealants to choose the most suitable for joining a pipeline that will carry water. The problem of sealing sections of pipeline is tackled. The children investigate the effectiveness of a variety of sealants to join 'pipes'.
3. Filter fun!	A challenge to find the most efficient filter(s) to treat a sample of 'reservoir' water. Before use on the industrial site the water must first be treated. Children use filtration techniques to obtain cleaner water.
4. That's cool!	Investigating the possibilities of heat exchange between hot and cold water. After treatment the water is used for cooling hot liquids, which may otherwise reach a dangerously high temperature. The children model an industrial heat exchanger and investigate the temperature changes that can occur during this heat transfer.
5. A neutral mixture	Classifying liquids using the pH scale, and neutralising and alkaline liquid. Finally, the water is treated before returning it to the river. One of these treatments is to neutralise the water, as it is alkaline when used on site. The children investigate the classification of liquids using the pH scale, and try to neutralise a sample of alkaline water.

SCOTT OIL REFINERY

Kelty Site
Kelty
Fife
KE1 NQ7

Dear Sir/Madam,

I believe your firm of consultants may be able to help us with some problems we are having with our water pipelines. I have sent you a plan of the site. It shows the path the water takes from the Kelty Reservoir to the site and back to the River Kel.

The problems are:

1. The pipeline is rusting badly, and we need advice about the materials to build a new pipeline.
2. Water has sometimes leaked through the joints in our pipeline, so we also want to find a good sealant.
3. When filtering the water from the reservoir, we find that the water is not clear enough.
4. The water is made 'neutral' before it is returned to the river and we need to know how to achieve this.

Finally, although this is not at present a problem, we would like you to advise us on the most efficient way to cool our hot liquids.

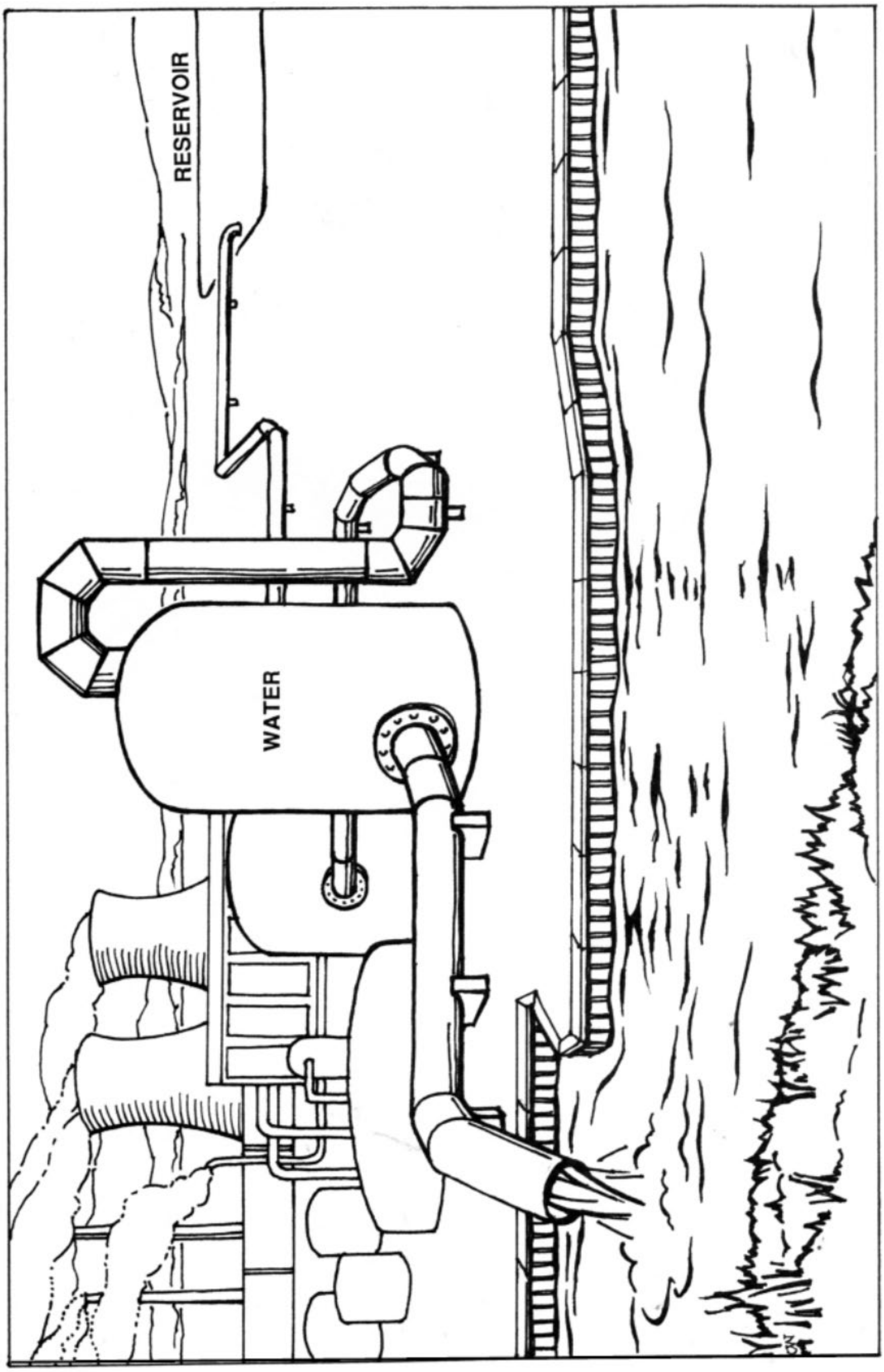
I look forward to hearing from you in the near future. I hope you can solve these problems, as you advice would be very valuable.

Yours faithfully

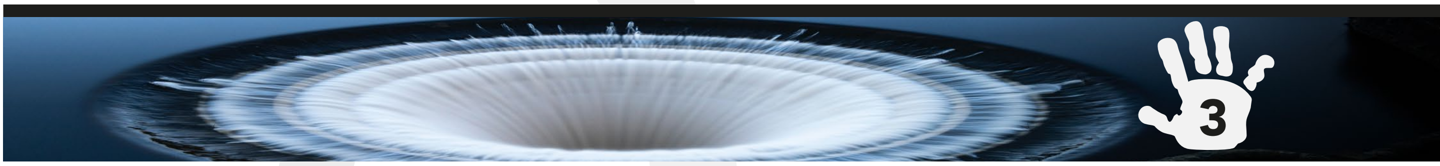
Lee Thompson

Lee Thompson
Site Engineer

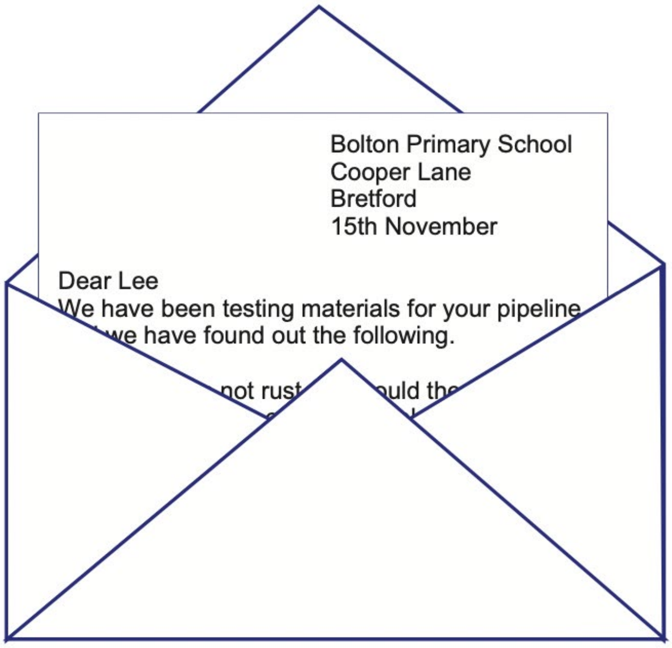
Activity Sheet 2

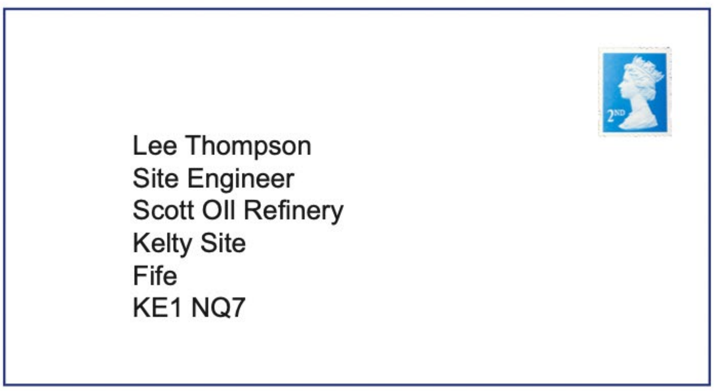


Activity Sheet 3

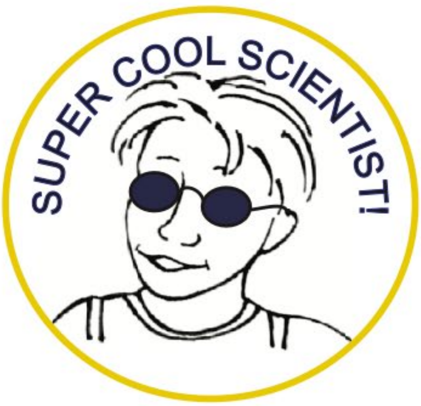


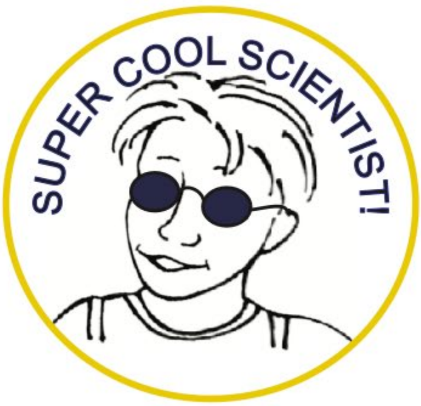
Write a letter to Scott Oil Refinery giving them you advice.
Don't forget to give them you reasons!





Activity Sheet 4





1. Pick a piece of pipes

1 hour *and* 10 mins a day for a week

Testing aluminium, steel and a plastic for rusting when exposed to water. Children test materials for their resistance to corrosion. Using this knowledge, they choose a material for constructing a pipeline for the water.

OBJECTIVES

- Give reasons, based on evidence from comparative and fair tests, for the particular uses of everyday materials, including metals, wood and plastic.
- Planning different types of scientific enquiries to answer questions, including recognising and controlling variables where necessary.

RESOURCES

(Per group of 4 children unless otherwise stated)

- Washing-up liquid bottle (cut into a 'plastic pipe')
- Food can[1] (cut into a 'tin-plated steel pipe – see safety note)
- Fizzy drinks can[1] (aluminium 'pipe')
- 3 x 2-litre plastic bottles, with tops cut away
- Rubber gloves
- Coarse sandpaper
- 1.2 litres tap water
- Activity sheets 5 and 6
- Activity sheet 7, copied onto an acetate sheet

Safety note

An adult uses a safety tin-opener (which leaves a smooth edge) to cut cans into 'pipes'. Sand, file or tape any slightly rough edges that remain. If this is not possible use the cans whole. The children should wear rubber gloves whenever they are handling the 'pipe', to prevent loosened rust being transferred to children's mouths via their fingers.

1 Prior to the lesson, rub the fizzy drinks and food cans along their length with sandpaper, to remove the paint and tin respectively. Section of the cans are left intact, so a comparison between the protected and unprotected surfaces can be made.

BACKGROUND INFORMATION

Metals corrode in the presence of air and water, therefore the corrosion occurs most on the metal surface at the air/water boundary. The metal reacts with the oxygen in the air to form a metal oxide. The steel pipe corrodes quickly. Aluminium corrodes relatively slowly in water to form a white powder (i.e. it looks tarnished). The time taken for the aluminium to corrode is far greater than the children's testing time, therefore they are unlikely to see any corrosion.

'Rusting' is the term given to the corrosion of metals which contain iron, e.g. steel.

It is impossible to stop corrosion, but it can be controlled. In the case of steel, a layer of zinc can be added to the steel. This process is call **galvanising**. The zinc corrodes to form an oxide layer, which provides a protective coating against further corrosion. To control corrosion of food cans the thin steel plate is coated with tin, and if the contents are acidic a layer of lacquer may provide added protection against corrosion. Mild steel corrodes relatively quickly and therefore requires a protective coating.

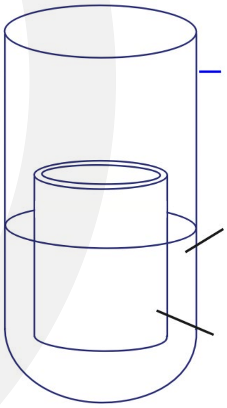
Pipelines exposed to the atmosphere are usually painted to provide protection, and are inspected regularly. Pipelines are designed with a safety factor (increased thickness), so that in the worst possible cases of corrosion leakage should not occur.

Pipelines running underground may have zinc blocks attached to their interior, so that the zinc will corrode before the pipeline does. Zinc-based chemicals are also added to the water to prevent oxygen attack to the pipeline. Bactericides are added to the water to prevent the growth of bacteria, as chemicals produced by the bacteria can cause corrosion.

Cooling water is typically carried around an industrial site in pipes made from galvanised steel or mild steel. These can be lined with glass or certain types of plastic to prevent corrosion. Stainless steel may also be used to carry cooling water, as this does not corrode, but is much more expensive than mild or galvanised steel. Aluminium is not used because it is a mechanically weak metal. Plastics are a relatively new group of materials and therefore have been considered for use in recent years.

With the advances in polymer (plastics) technology, new pipelines can be made from uPVC (Unplasticised polyvinyl chloride) and other plastics, as their mechanical strength has gradually been improved. Plasticised PVC has added flexibility which is an undesirable property for a pipeline. Plastics do no corrode and they also provide a lightweight pipeline which requires less support from the ground than metal pipelines (which therefore reduces costs).

CARRYING OUT THE ACTIVITY



A class discussion of everyday items made from plastic, aluminium and steel puts the materials into a context for the children, for example; aluminium tent poles and pans; steel exhaust pipes and nails; plastic yogurt pots and rulers. The children also discuss the meaning of 'rusting# and where they may have seen rusting occur, e.g. car bodies and exhaust systems, nails, screws, metal gates, etc. They could carry out a 'rust hunt' around the school, listing the rusting objects and (possibly) what they are made from. This will aid the process of making predictions about which materials may rust, based on their knowledge of everyday objects. Children may not be aware that some metals do not rust. This does not require detailed explanation at this stage, as the children can discover this through the following activity.

The activity is then presented with Activity sheet 5, which poses the question; How will you choose the best material for the pipeline?

The resources that the children are asked to use are the plastic bottle, aluminium can and steel can. These should have been opened into pipes by the teacher before the lesson. Spaces are provided on Activity sheet 13 for children to write the material that each 'pipe' is made from. The first letter of each material has also been given. The children plan their test and choose additional resources needed to carry it out. They may require prompting by the teacher to limit the variables to one (the pipe material), to maintain fair test conditions. This may need further discussion, if the children's previous experience of carrying out fair tests is limited. Variables to consider include the quantity of water used each time; the position of the pipe in the water; and the method of measuring the amount of rusting.

One method of carrying out the test is outlined below. This method can be used by those children who have difficulty in planning their own test.

The children set up the test by pouring 400 ml of water into each plastic bottle. This quantity of water allows the top half of the pipes to be exposed to

the air and the bottom half to be submerged. The pipes are cleaned using warm water containing a little detergent, and rinsed. The children place a pipe in each bottle (is using whole fizzy drinks cans, the children must make sure that some of the water is poured into the can, to hold it in position on the bottom of the bottle).

The children are now given the opportunity to make predictions about what they think will happen to the different pipes in the water. These predictions can be recorded on Activity sheet 6.

Each day the children remove the pipes to assess any rusting that has taken place. This can be measured or described. The results of their observations can be recorded on Activity sheet 6. The children either record an area of rusting, or use short phrases to describe the state of the pipes.

One method of measuring the rusting is to hold a square grid (on an acetate sheet or tracing paper) next to the pipe, and count the number of squares through which rusting is visible. A square grid is cut from Activity sheet 7 for this purpose.

N.B. Care should be taken not to remove the rust formed when the pipe is lifted out of the water.

The children can mark the material for the pipeline on a copy of Activity sheet 2, using arrows to show the flow of water through the pipeline from the reservoir to the site.

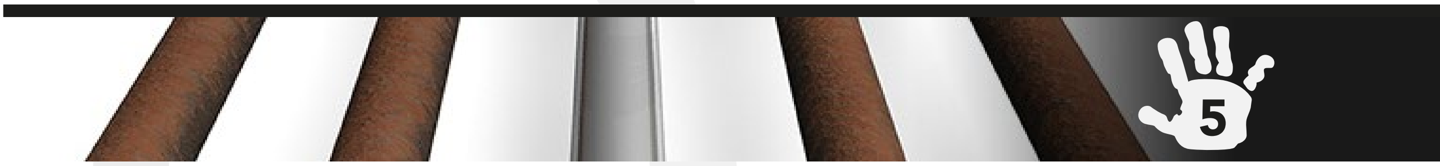
DISCUSSION QUESTIONS

- Which pieces of pipe rusted?
- Which parts of the pipe rusted? Why?
- Which material would you choose from your pipeline? Why?

EXTENSION ACTIVITY

The children explore the effectiveness of a variety of coatings on the pipe that has rusted. They could use Vaseline, cling-film, water-based paints, oil-based paints, etc.

Activity Sheet 5



How will you choose the best material for the pipeline?

You need:

Washing-up bottle

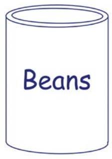
p ....

Drinks can

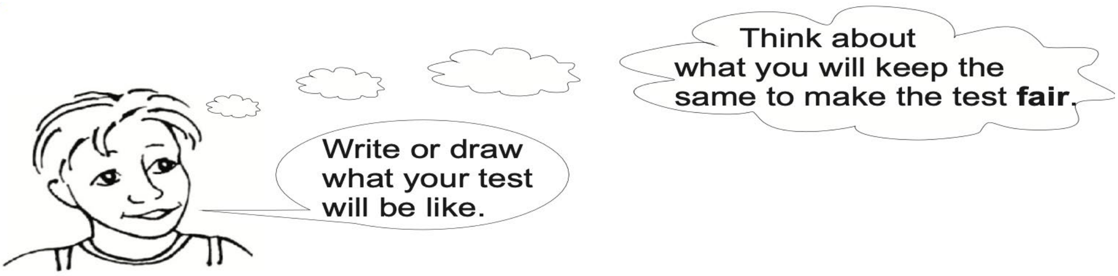
a ....

Food can

s ....



Decide what else you need for your test. List of draw these things here:



Activity Sheet 6: Pipe pieces

Pipe 1

Pipe 2

Pipe 3

Pipe 1

Pipe 2

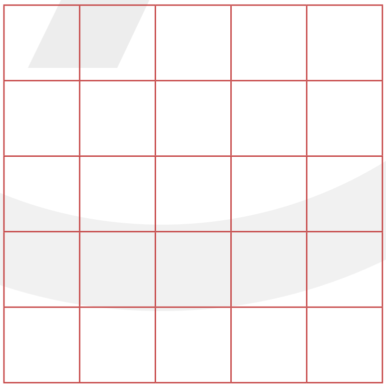
Pipe 3

Pipe material	Rusting of pipes					
	Day____	Day____	Day____	Day____	Day____	Day____

How close was your prediction to your results?

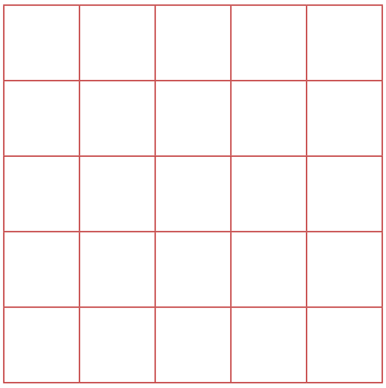
Grids for area measurement

Rust grid



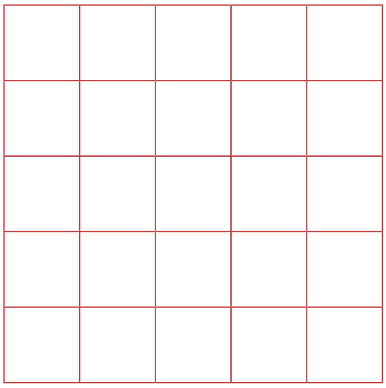
Each square has an area of one square centimetre.

Rust grid



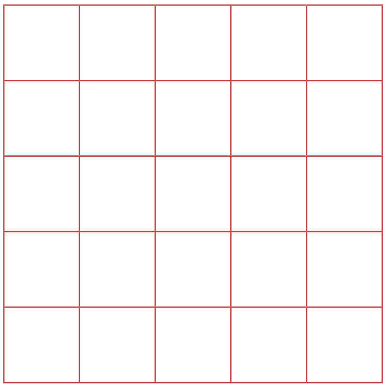
Each square has an area of one square centimetre.

Rust grid



Each square has an area of one square centimetre.

Rust grid



Each square has an area of one square centimetre.

2. A leaky line

1 - 2 hours

Investigating sealants to choose the most suitable for joining a pipeline that will carry water. The problem of sealing sections of pipeline is tackled. Children investigate the effectiveness of a variety of sealants to join 'pipes'.

OBJECTIVES

- Give reasons, based on evidence from comparative and fair tests, for the particular uses of everyday materials, including metals, wood and plastic.
- Taking measurements, using a range of scientific equipment, with increasing accuracy and precision, taking repeat readings when appropriate.

RESOURCES

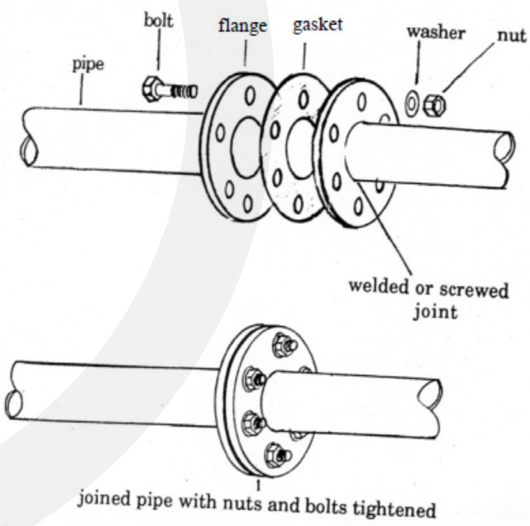
(Per group of 4 children unless otherwise stated)

- Food can, with both ends removed to form a tube.
- Food can, with one end removed.
- 2 x 1-litre plastic measuring jugs
- Range of adhesives, e.g. Blu-tack, Sellotape, PVA glue, insulating tape, glue gun
- Safety tin-opener
- Activity sheets 8 and 9

Safety note

Certain adhesives, such as glue from a glue gun, may need to be applied by an adult. Check your education authority policy and safety warnings on the adhesive's packaging.

BACKGROUND INFORMATION



A good sealant needs to stick successfully to the surface of the pipe material and remain attached with added water pressure, be water-resistant, and leave no air gaps when joining the two surfaces.

Blu-tack and PVA glue do not often provide air-tight seals. Blu-tack tends to be 'pushed away' from the surface of the pipe by the water pressure. PVA glue can take over an hour to dry. Sellotape is not very resistant to water, but provides a good seal if several layers are used. Insulating tape seals the pipe well. Glue from a glue gun forms a strong, water-resistant seal if a thick layer is applied.

In industry pipes are usually sealed using flanges and gaskets to prevent leaks. The gasket is often an open circle of asbestos, plastic or rubber, which is compressed between the flanges, which are also open circles. The thickness of the flange depends on how much pressure there will be inside the pipe.

The joints are then either threaded so they screw onto the pipeline, or they are welded to the pipeline. The welded join can be explained as similar to the join using a glue gun, using molten metal instead of molten glue.

Sections of pipe for cooling water in industry can be 6-12 metres long, e.g. as long as 4-8 children lying end-to-end.

CARRYING OUT THE ACTIVITY

To help the children choose the sealants they are going to test, the class brain-storm methods of joining two items. The list could include paper-clips, pins, needle and thread, glue, Sellotape, etc. This could be a competition, or a challenge to the class to make the longest list possible. Once completed, the children pick the feasible methods to join the pipeline. From this reduced list, groups of children choose four sealants to test, filling in the names of these sealants on Activity sheet 8.

N.B. The teacher should allow discussion of feasible methods for joining a pipeline that children suggest but cannot investigate in the classroom, e.g. screw- fitting or soldering.

The cans are joined using one of the chosen sealants. The children then place the cans in the measuring jug, being careful not to break the seal.

Before pouring water in to each 'pipeline', the children predict how suitable the sealant will be. The teacher encourages the children to think of reasons to substantiate their predictions where possible.

An appropriate quantity (say 800 ml) of water is poured into the cans, ensuring that the water level is above that of the sealant, whilst maintaining 'fair' conditions. The cans are then left for 10 minutes before observing for leakage. The amount of water that has collected in the jug can be measured and recorded on Activity sheet 9. How the children measure the volume of water will depend upon their ability. Some may simply mark the water level on each picture. Others may use non-standard measures such as egg-cups, and the more able children may measure in millilitres.

The cans are dried thoroughly and the procedure repeated for each sealant being tested.

N.B. A thick layer of glue from a glue gun is required to produce a good seal.

On Activity sheet 2, children can show where sealants are needed to join pipes.

DISCUSSION QUESTIONS

- What must a good sealant be like?
- Which sealants were good?
- Would any of these be used in real water pipes? Why?
- What else might factories use to seal their pipes together?
- How long do you think each piece of pipeline would be ?

EXTENSION ACTIVITY

The children investigate changing the thickness of the sealant layer on the effectiveness of the seal, i.e. using 1, 2, 3, etc. layers of Sellotape; 1, 2, 3, etc. spatulas of PVA glue.

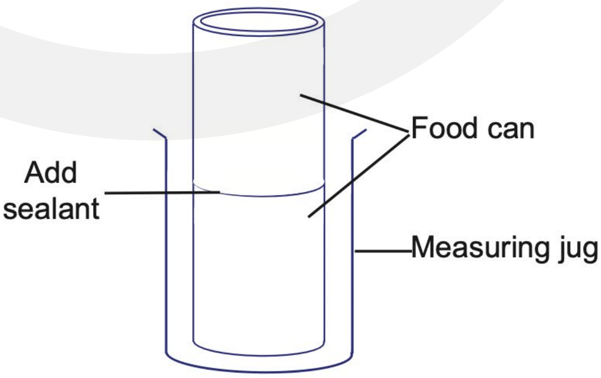
The ambassador can initiate these activities and act as an advisor/consultant if present for the practical sessions. The ambassador may also play the part of a judge and provide detailed information for the latter stages of the activities, such as marketing aspects.

Activity Sheet 8: A leaky line

Can you stop a pipeline leaking?

Something that seals two things together is called a sealant.

Test some pipeline sealants. Collect these things:



List the sealants you are testing.

___

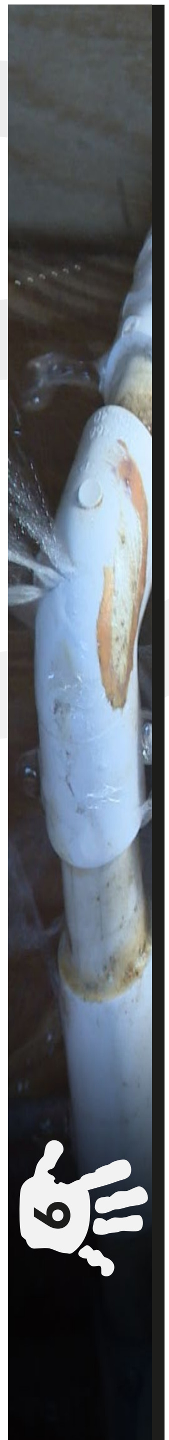
___

What do you think will happen when you fill each 'pipe' with water? **Why?**

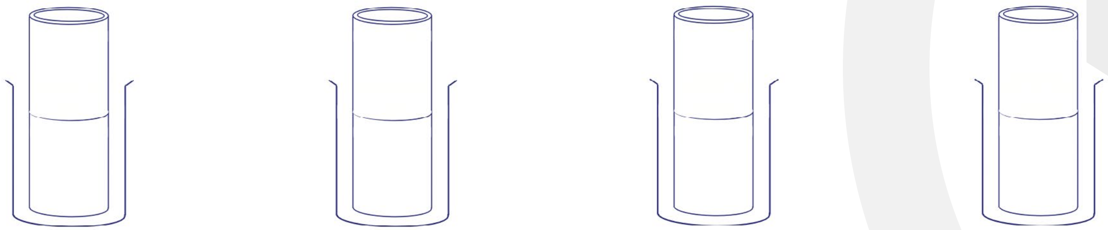
Fill each 'pipe' and leave them for 10 minutes.

Now record what you have found out.

Activity Sheet 9: How much leaked?



1	2	3	4



Leakage: ____________________

← Which sealants will you recommend?

Which sealants should Scott Oil **not** use? →

3. Filter fun!

2 - 3 hours

A challenge to find the most efficient filter(s) to treat a sample of 'reservoir' water. Before use on the industrial site the water must first be treated. Children use filtration techniques to obtain cleaner water.

OBJECTIVES

- Use knowledge of solids, liquids and gases to decide how mixtures might be separated, including through filtering, sieving and evaporating.
- Taking measurements, using a range of scientific equipment, with increasing accuracy and precision, taking repeat readings when appropriate.

RESOURCES

(Per group of 4 children unless otherwise stated)

- 3-litre transparent plastic bottle
- Stopclock, watch, or egg-timer
- Funnel (or top of plastic bottle,with a smoothed or taped edge)
- Filters, e.g. colander, sieve, fishing net, tea-strainer, nylon tights, socks, muslin, paper towels, tissues, cotton-wool, filter paper
- 5-6 x samples of 'reservoir' water containing:
- 100 ml water' 1-2 leaves', 1-2 twigs/stones, 12 teaspoon each of gravel, commercial compost and sand
- Torch
- 2 x A4 card
- 10-20 sheets plain paper or tissue paper
- 5-6 transparent containers (e.g. mini pop bottles)
- Activity sheets 10 and 11

Safety note

Garden soil must not be used in this activity, as harmful microbes can grow in this soil. Sterilised commercial compost provides a suitable alternative.

BACKGROUND INFORMATION

A filter is chosen according to the size of the solid particles to be separated. Filters will separate anything that has a larger particle size than the size of its holes. Whether a filter is 'good' or 'bad' at separating the solids depends on the particle size in relation to the filter-hole size. Therefore, a colander is suitable for separating stones and gravel, but not sand and fine soil. Filter paper has very small holes and so will separate the fine soil particles from the water.

Filtering the water used for cooling in industry is important to prevent the pipes from getting blocked or scaled-up, and to remove substances that can cause corrosion.

The water is not fit to drink after filtering, as there will be many other things in the water, including microbes and dissolved chemicals, which cannot be seen.

If a filter is blocked in industry there are several ways of dealing with this. When the flow of fluid through a pipe or vessel has stopped, the filter can be taken out and cleaned. Another method is to 'backflush' the filter by reversing the flow of water. This carries any debris out of the filter to a destination of the operator's choice. If the flow of the fluid is rarely stopped and the filter becomes blocked, the fluid is re-directed along another branch of the pipeline in which there is a fresh filter. The blocked filter is then cleaned or replaced ready for use when the water is re-directed again.

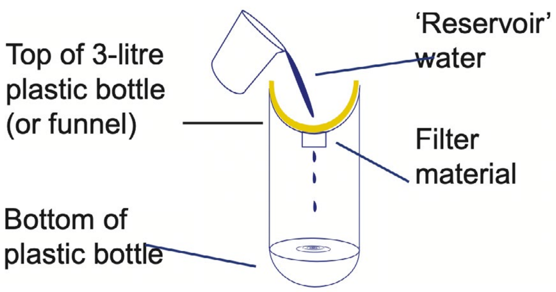
Filter mesh sizes vary from a few millimetres to a few micrometers (a micrometer is a thousand times smaller than a millimetre). Like flanges, filters have seals or gaskets to prevent leaks.

CARRYING OUT THE ACTIVITY

To introduce this activity the children brain-storm filtering or separating techniques that affect their daily lives. For example: tea-bags, coffee filters, vacuum cleaners, tumble driers, fishing or pond-dipping nets, strainers in plug-holes, etc.

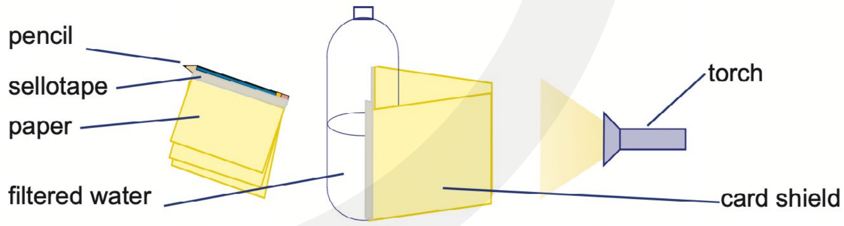
Activity sheet Sheet 10 presents the children with the problem of removing solids from a water sample, mixed to simulate water from a reservoir. They must obtain the clearest sample of water in the shortest possible time, thus creating an efficient filtration system. Each group chooses or is given 3-4 filtering materials with which to experiment.

One method of setting up the test equipment is shown opposite. The children begin to time the filtration as soon as they begin to pour the water sample. They decide when to stop timing, in order to make the test fair, i.e. when water is no longer dripping through the filter, or when the drips are a specific number of seconds apart. Timings are recorded on Activity sheet 11.



N.B. As filtration can take 40-60 minutes for some filters, it is advisable for children to be engaged in other tasks, such as recording the clarity of one water sample whilst another one is filtering.

One method of assessing the water clarity is to transfer the filtered water into a clean, transparent container. The children then shine a torch through the water sample, and gradually 'block out' the light with paper (tissue or writing paper, according to the brightness of the torch). The number of pieces of paper required is then recorded on Activity sheet 11. As a comparison, tap water and unfiltered water can also be assessed in this way. Each sample is then left for 15 minutes and the depth of sediment is measured and recorded. Alternatively, the children may simply rank the water samples using descriptive language, such as 'murky', 'dark brown', 'light brown', 'clear', etc.

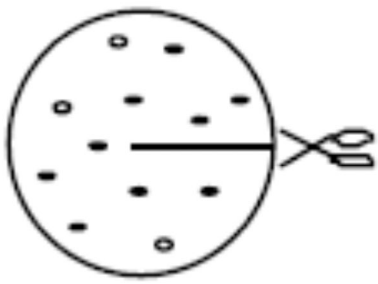


DISCUSSION QUESTIONS

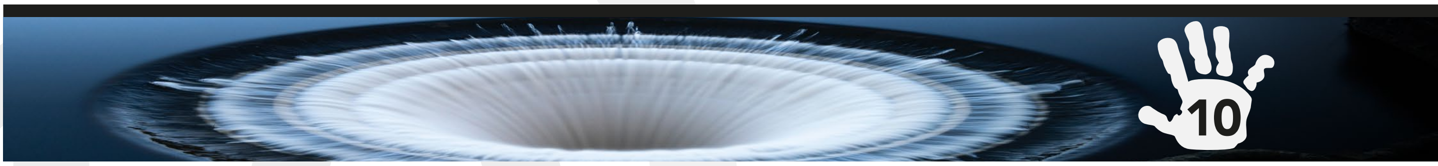
- Is the time taken or the clarity ('clearness') of the water most important? Why?
- Were any of the materials very good/bad filters? How?
- Is the water fit to drink after filtering? Why?
- Do any of the filters get blocked quickly?
- What might engineers do when the filters get blocked?
- How big do you think industrial filters will be?

EXTENSION ACTIVITY

Children test combinations of filters, e.g. a colander to remove coarse solids, followed by tights to remove fine solids. Children can also make their own filters by cutting holes of different sizes into card, using a hole punch, scissors (not the points) or a pin and making into a conical shape. Other 'mixtures' could be sorted using these filters, e.g. flour, rice, raisins, sesame seeds, etc.

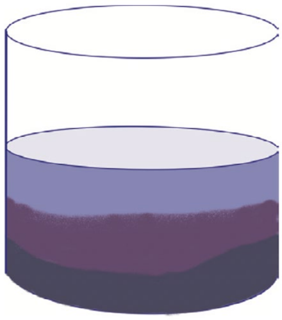


Activity Sheet 10: Filter fun!

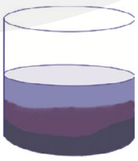


The Challenge

You must try to get the clearest water possible in the shortest time

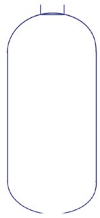


Water sample



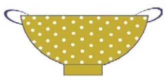
Stopclock or egg-timer

large plastic bottle or jug



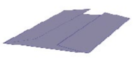
Funnel

Colander



Fishing net

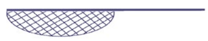
Paper towels



Paper tissues

Cotton-wool

Sieve



Tea strainer

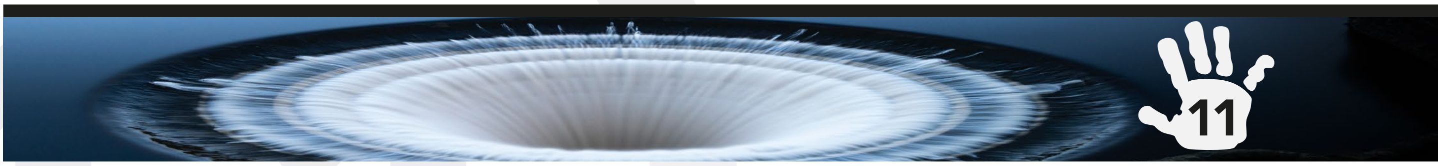
Filter paper

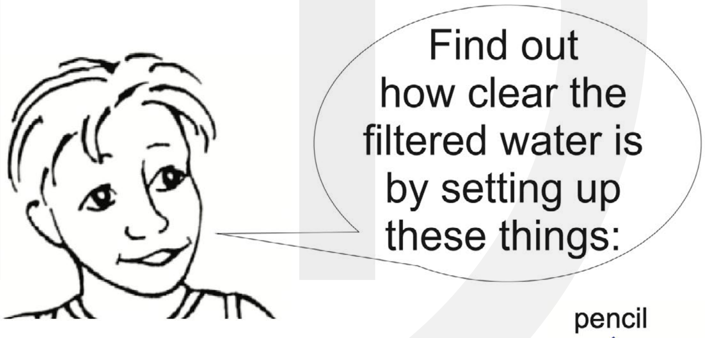
Cloth

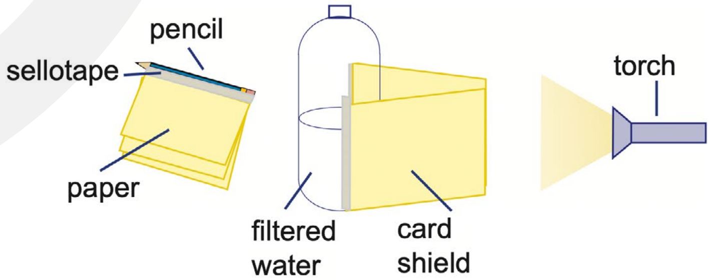
Nylon tights

Now plan your test!

Activity Sheet 11: Filter fun!







Write down how many pieces of paper it takes to block out the light.

Filters used	Time taken	Layers of paper	'Mud' depth

Leave you filtered water samples for 15 minutes, then measure the depth of mud that has settled in the bottle.

What have you found out to tell Scott Oil?

4. That's cool!

1 hour

Children model an industrial heat exchanger and investigate the temperature changes that can occur during this heat transfer.

OBJECTIVES

- To understand that heat will move across a boundary separating hot from cold water, without the two sources mixing.
- To take measurements, using a range of scientific equipment, with increasing accuracy and precision, taking repeat readings when appropriate

RESOURCES

(Per group of 4 children unless otherwise stated)

- 5m flexible PVC tubing[1]
- 2-litre plastic drinks bottle (preferably transparent)
- 2 thermometers[2] (alcohol-filled, not mercury)
- Funnel
- 2 measuring jugs (about 500 ml)
- Source of hot and cold water
- Food colouring (to colour the cold water)
- Plastic bowl or bucket
- Activity sheet 12 or sheets 13-14

Safety note

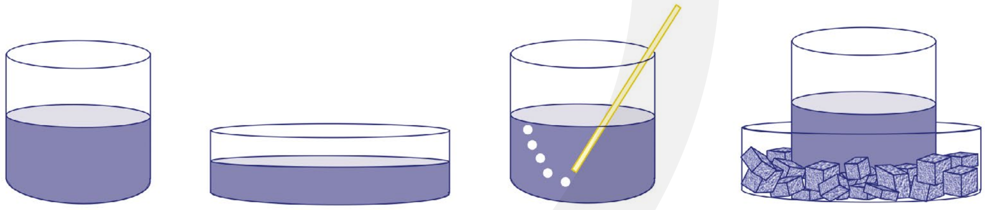
Children need close adult supervision when performing this experiment. They should be warned about the dangers of hot water and scalds.

1 PVC tubing is available from educational suppliers. It is sold in a variety of lengths and bore sizes. The bore chosen will depend on the size of the funnel used.
2 Data-logging equipment (i.e. temperature probes linked to a computer) can also be used as an alternative to thermometers, if available.

CARRYING OUT THE ACTIVITY

To introduce the children to simple ways of affecting the cooling rate of water, they measure the temperature of a-d below at regular intervals.

Each jug has 200 ml of water at 60°C



The control will show the rate of cooling due to classroom conditions, e.g. temperature. The water in b, c and d cools faster than the water in a. In b and c the water is exposed to a larger surface area of cool air (provided by air bubbles in c), and in d the water is exposed to a colder surface. Allow the children to offer explanations of their results whilst ensuring that the discussion covers the factors mentioned above.

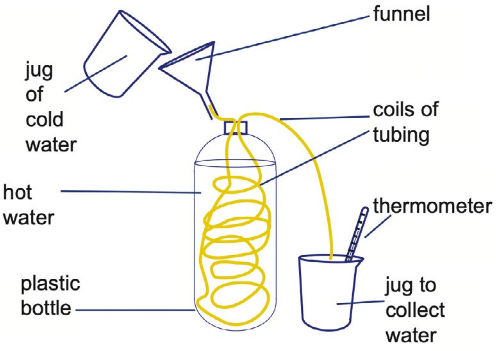
Activity sheet 12 provides an open-ended approach to heat exchange, challenging the children to find the quickest way to cool down a bottle of hot water. They are provided with the resources listed above and should be asked to think of a solution that does not involve removing the hot water. To do so would be unsafe, and would also provide an unrealistic method for industrial use, as the vessel shape and size are fixed and closed.

N.B. Whatever solution the children choose, they should be reminded to measure the temperature of the hot and cold water before and after cooling. They can be asked to measure the time taken for the water to reach a specific temperature, say 40°C.

Alternatively, the children carry out a more structured activity using Activity sheets 13- 14. This activity simulates the method used in industry to cool hot liquids. Using the equipment shown overleaf, a child holds one end of the tubing and pushes the rest of it into the plastic bottle, until about 30 cm of the tubing remains. The children fill a jug with tap water. The teacher fills the bottle with hot water, **which should be no hotter than 60°C.** With more able children, this procedure is repeated with a **control** bottle (see Appendix) to develop investigative techniques.

The empty jug is placed beneath the tubing outlet and a thermometer is placed in the jug. The children measure the temperatures of the hot and cold water and record these on Activity sheet 14. They complete the prediction boxes, giving reasons for their choices.

The cold water (coloured to show it does not mix) is poured slowly down the funnel and through the tubing coiled in the bottle. When the cold water has stopped flowing, the temperatures of the hot and cold water are taken again, and recorded on Activity sheet 14.



The temperature differences of the hot and cold water are compared. A space is provided on Activity sheet 14 for the children to record the differences. Typical results, with a starting temperature of 60°C, would show a rise of about 15°C for the cold water and a drop of about 5°C for the hot water.

If the bottle is to be used again immediately, the tubing should be removed and stretched out over a sink to release trapped water. If this is not done, water trapped in the tubing will mix with the next cooling water to pass through, and will increase the apparent temperature difference of the cooling water.

The illustration on Activity sheet 2 is not an exact representation of an industrial

site, but children can discuss which vessel is used for heat exchange. The best suggestions would be one of the two vessels the water passes through before flowing into the river.

DISCUSSION QUESTIONS

- What has happened to the temperature of the cooling water that has been poured through the tubing? Why?
- What has happened to the temperature of the water in the bottle? Why?
- In industry, cooling water often flows through many thin tubes in a container of hot liquid. What difference might this make?

BACKGROUND INFORMATION

The water passing through the tubing shows a marked temperature rise, as heat has transferred from the hot to the cold water. The percentage of cold water in contact with hot water is greater than the percentage of hot water in contact with cold water, as there is three times more hot than cold water. Therefore the cold water's temperature rise is greater than the hot water's temperature drop.

In industrial cooling systems, the surface area of contact between the two liquids

is maximised by putting hundreds of cooling tubes inside a vessel called a heat exchanger. The flow rate of water is controlled (either manually or automatically) to obtain the desired temperatures. For safety reasons, there must always be a flow through a heat exchanger, as a build-up of hot materials can result in high pressure and pipe rupture.

Water is not the only coolant used in industrial heat exchangers, air is also used. Cool air can be blown over exchanger tubes using large fans.

EXTENSION ACTIVITY

There are many factors which affect the rate of cooling which children can investigate, including the length of tubing coiled inside the bottle, coiling the tubing around the outside of the bottle and the diameter or thickness of the tubing. Only one variable should be varied during an investigation, to ensure fair test conditions are maintained.

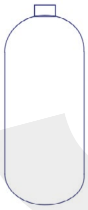
Activity Sheet 12: That's Cool!

Part of the letter from Scott Oil Refinery

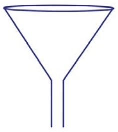
Finally, although this is not at present a problem, we would like you to advise us on the most efficient way to cool out hot liquids.

Plan your cooler here.

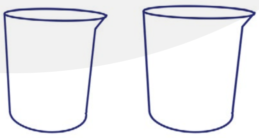
Activity Sheet 13: That's Cool!

2-litre plastic bottle 

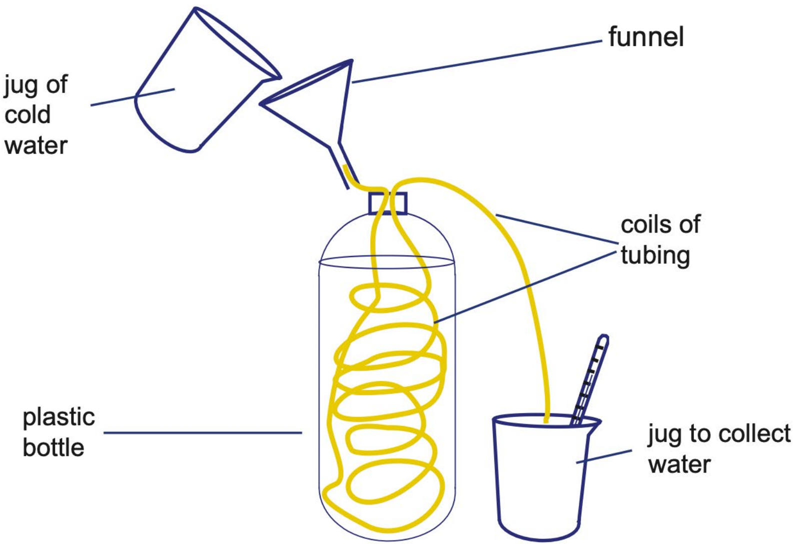
5 metres of plastic tubing 

Funnel 

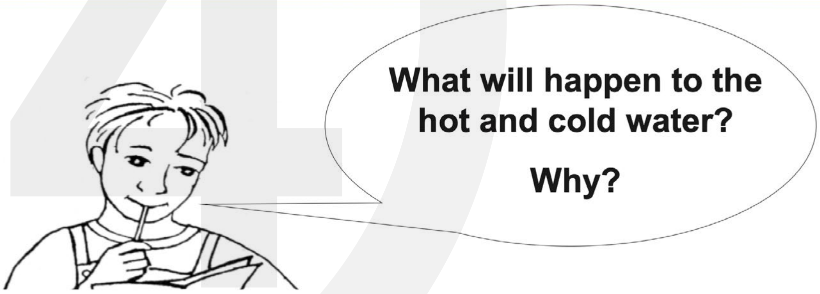
2 thermometers 

2 jugs (1 litre) 

Stopclock 



Activity Sheet 14: Cool It! temperatures



Hot water

Cold water

Which water?	Temperatures in °C		
	Start	Finish	Difference
Cold water			
Hot water			

Total cooling time____

What do these results tell you?____

How well do your predictions match the results?____________________________________

5. A neutral mixture

1 hour

Children investigate the classification of liquids using the pH scale, and try to neutralise a sample of alkaline water.

OBJECTIVES

- To classify liquids as acidic or alkaline and to understand that by mixing these liquids a neutral solution can be made.
- Taking measurements, using a range of scientific equipment, with increasing accuracy and precision, taking repeat readings when appropriate.

RESOURCES

(Per group of 4 children unless otherwise stated)

- Lemon juice, stomach settlers, cola, tap water, distilled water (optional)
- 100 ml vinegar
- 12 teaspoon bicarbonate of soda dissolved in 200 ml water litmus paper, red and blue (1-2 rolls of each)
- Pipette or medicine dropper
- Yoghurt pots or 100 ml measuring jugs
- Teaspoon
- Activity sheet 15 or 16

BACKGROUND INFORMATION

Tap water and rain water are usually slightly acidic, as are most liquids that we drink. Sea water is usually slightly alkaline and river or pond water is often slightly acidic.

Some industrial site treat the water they use to make it alkaline. This is to protect the pipelines and vessels from rusting, etc. (see background information on page 10). Adding zine phosphate to the water, to protect the pipeline,, makes the water slightly alkaline.

When the water is returned to the river, its alkalinity must be returned to neutral. This is done by adding sulphuric acid to the water. The salt products in low concentrations do not present a problem to humans or river life. However, dissolved metals such as zinc (added to protect the pipeline against corrosion), whilst beneficial in small amounts, can have detrimental effects on both humans and river life. The regulatory bodies set strict discharge limits for such substances, which are designed to ensure that environmental quality standards are met.

CARRYING OUT THE ACTIVITY

To introduce the classification of liquids, it would be useful for the children to test the acidity or alkalinity of a variety of everyday liquids. These might include lemon juice, stomach settlers dissolved in water, fizzy drinks, distilled and tap water, etc. Red litmus paper will turn blue when dipped into an alkaline solution and remain red when dipped in an acidic solution. Blue litmus paper will turn red when dipped in an acidic solution and remain blue when dipped in an alkaline solution. The results of these tests are recorded in a table with two columns, one labelled 'acids' and one labelled 'alkalis'.

The children test the vinegar and bicarbonate of soda, using both red and blue litmus paper. The children allow the pieces of litmus paper to dry and stick them onto Activity sheet 15 or 16 (depending on the approach taken.

The teacher then reminds the children, using the relevant points from the letter on sheet Sa, that the water leaving the industrial site is slightly alkaline and must be returned to a neutral pH before being returned to the river. The teacher discusses with the children ways in which they think this might be achieved. If the children do not think of mixing an acid with the alkaline water, the teacher introduces the idea. The activity can be left open-ended for groups of children to devise a test to find out how much acid should be added to an alkaline liquid to neutralise it. They are given resource Activity sheet 15 as a stimulus.

A structured approach is provided on Activity sheet 16. To simulate the process of neutralisation, the children gradually add vinegar to the solution of bicarbonate of soda, to obtain a neutral mixture. The container holding the bicarbonate of soda should be about twice the volume of the solution, as a gas (carbon dioxide, and therefore not harmful) is released when the vinegar is added, which creates a frothy head.

The children initially add 5 full pipettes (not 5 drops) of vinegar to the solution of bicarbonate of soda and stir the mixture, before testing its acidity with both red and blue litmus paper. These pieces of litmus paper are stuck on Activity sheet 16 above the appropriate number of pipettes of vinegar added to the mixture. This procedure is repeated until the red litmus paper does not change colour, and the blue litmus paper is starting to go slightly pink. As the litmus paper begins to change colour and to ensure the mixture does not become too acidic, the teacher can suggest that the children add fewer full pipettes of vinegar each time.

N.B. *The litmus paper must be left for a few seconds before the children make a decision about the neutrality of the solution. A clearer colour can then be observed.*

DISCUSSION QUESTIONS

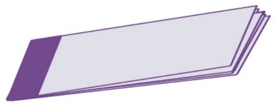
- Discussion questions
- How can you decide whether a liquid is acidic or alkaline?
- How can you make an alkaline solution neutral?
- Does the liquid look clean enough to be put into a river?
- Do you think vinegar will be used in industry to neutralise alkaline water?

Activity Sheet 15: A neutral mixture

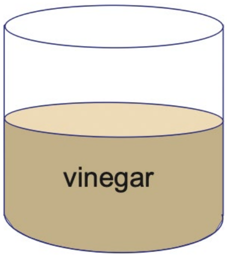
The water is made 'neutral' before it is returned to the river and we need to know how to achieve this.

Dropper

Litmus paper

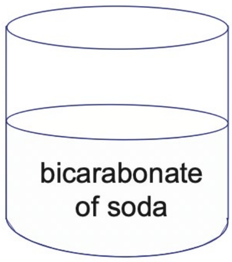


Vinegar



Bicarbonate of soda

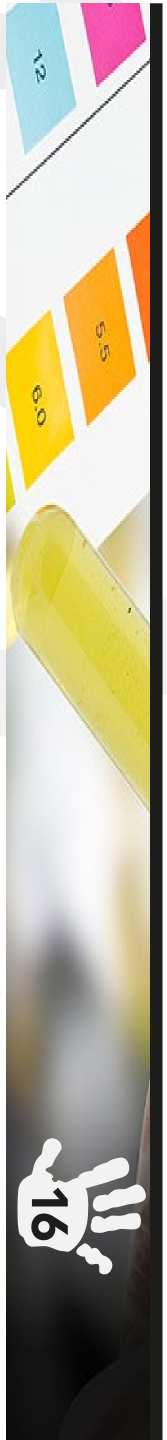
(1/2 teaspoon in 200 ml water)



Now plan how to make the water neutral.

Think about how you will record you results.

Activity Sheet 16: A neutral mixture



red = acid

blue = alkaline

Litmus paper when dipped in a liquid turns . . .

Vinegar is an

____

blue litmus paper

red litmus paper

Bicarbonate of soda in water is an

____

blue litmus paper

red litmus paper

A neutral liquid is not acid or alkaline

Mixing a neutral mixture

0	5	10	15							

Number of 'droppers' of vinegar added to the bicarbonate of soda in water

Appendix: Using a control during heat exchange

The extra resources required are:

- 5m flexible PBC tubing
- 20 litre transparent plastic drinks bottle
- 2 thermometers
- Source of hot water

A control can be used alongside the test bottle, to ensure fair test conditions. This control is set up in exactly the same way as the test bottle, so that as many factors as possible remain constant. *The control bottle will monitor any temperature changes that occur due to the surrounding conditions* (e.g. the room temperature). The difference between the two bottles is that cooling water is poured through the tubing in the test bottle, but not the control bottle.

N.B. *It is not possible to obtain the same 'pattern' of coils in each bottle. The effects of this on the surface area of contact between the two liquids can be discussed with ore able children.*

The variables to be controlled (i.e. kept the same) are: Size, shape, material of the bottle

Length, diameter, material of the tubing

Volume of hot water

Position of the thermometer in the water

Timing of the readings of the test and control water

The control of variables should be discussed with the children before carrying out a controlled experiment.

The children can predict what they think will happen to the temperature of the control water as well as the test water, using the space provided on Activity sheet 14.

Comparing the results for the test bottle with those for the control will show any change in the cooling rate of the hot water due to the presence of the cooling water passing through the coils. For example, a typical temperature drop for the control water is 1-2 °C and the hot water in the test bottle will drop about 5-6 °C over the same period of time.

If no control has been used, there would be no way of knowing how much heat was lost to the surroundings and how much to the cooling water. It could therefore be argued that none, or little, of the temperature difference was due to the cooling water.

RECORDING RESULTS

An empty row has been left in the table on Activity sheet 14 for children to add temperature readings for a control bottle, and make comparisons

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or contact:

Centre for Industry Education Collaboration
CIEC Department of Chemistry
University of York
York
YO10 5DD

01904 322523

ciec@york.ac.uk

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