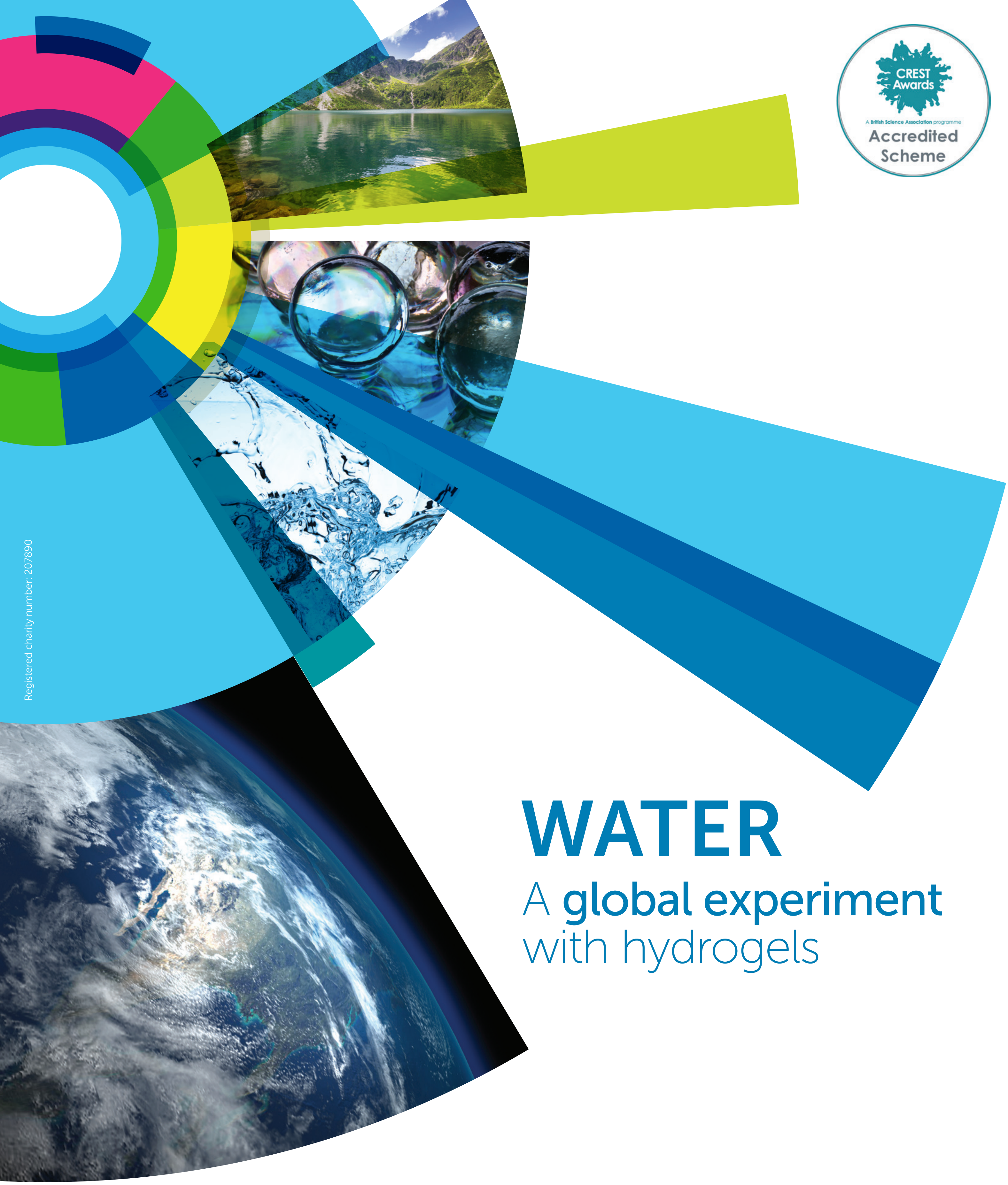


CREST Awards
A British Science Association programme
Accredited Scheme

WATER

A global experiment with hydrogels

http://rsc.li/ge-water

ROYAL SOCIETY OF CHEMISTRY

Contents

The water cycle

It is thought there is the same amount of water on earth today as there was when the earth was first made.

This is because all water on earth is constantly being 'recycled' in the process called the water cycle.

As humanity has built civilisations and societies, we have tried to develop ways of controlling water to meet our needs. One of the most recent developments has been the discovery of hydrogels – a man-made material able to absorb massive amounts of water.

So what will happen to the water in the water cycle that gets captured by the hydrogels? When the hydrogels are thrown away, where does all that water go? Does the absorbed water go back into the water cycle or is it wasted? Try our three global experiments with your students and give them the chance to come up with some answers.

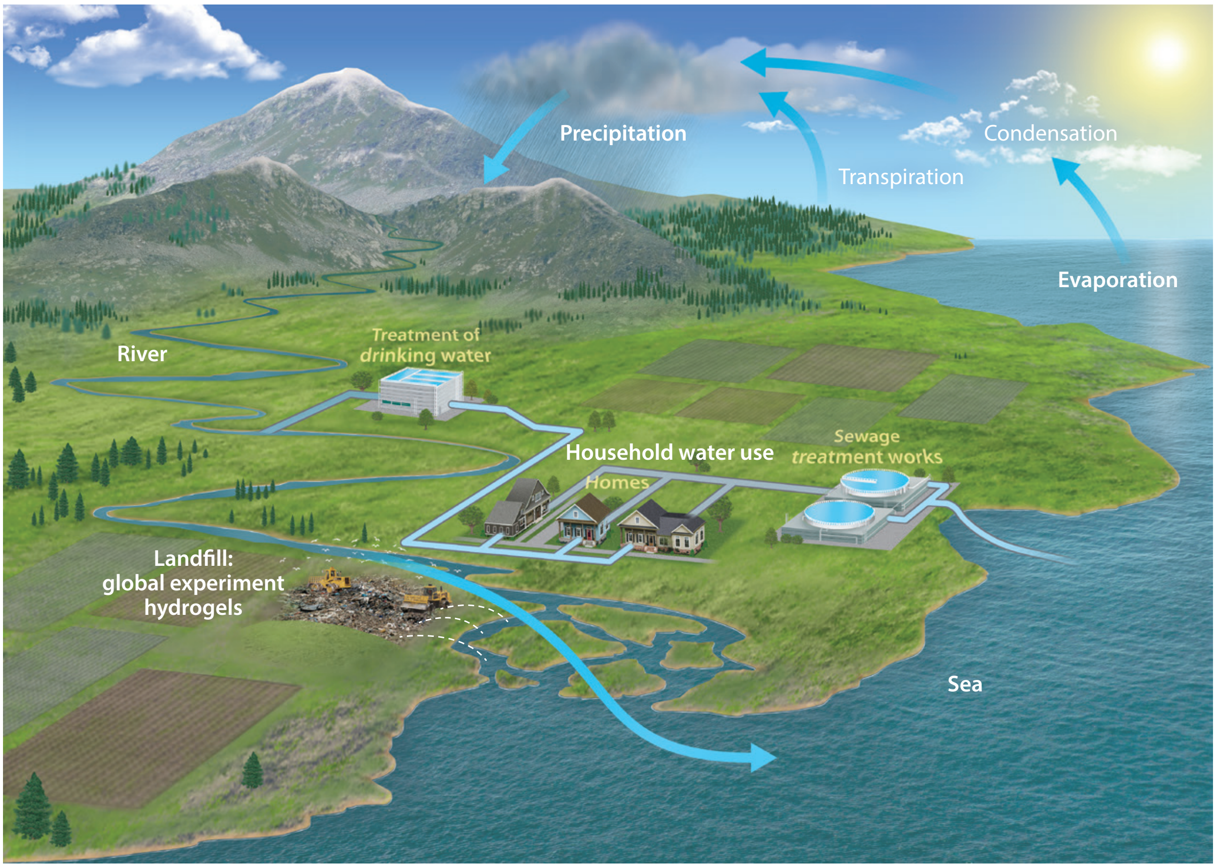


Figure 1 The water cycle, highlighting hydrogels in a landfill: are we wasting water?

The global experiment: an overview

These experiments are designed for mass participation using everyday items at home or in class, anywhere around the world. They aim to enhance science learning and encourage practical investigation. At the end, you can post your students' experiment data and photos to our website and they will be able to see the global picture.

The experiments in this resource, plus those in the extension activities, have been designed to challenge all ages and abilities.

In the main experiments your students will:

- investigate how water interacts with hydrogels;
- observe the interaction;
- record volumes and times;
- investigate how quickly hydrogels absorb water;
- measure the saturation point of their hydrogels;
- compare and analyse their own data and that from around the world; and
- make a conclusion on the environmental impact of hydrogels based on their findings.

Figure 2 The equipment needed to take part in the experiments.

It is possible to deliver the first two experiments independently or together. Experiment 2 reinforces the learning of Experiment 1 and gives you the opportunity to challenge your older or more able pupils.

Whether you have a background in science or not, you can use this resource with students of all abilities. Thought has also gone into making sure the equipment involved is widely available, with alternative suggestions for schools less able to source materials.

The extension activities (follow-on suggestions) and Experiment 3 are 'open-ended' investigations using hydrogels. Any of these activities can be photographed and posted to our website. You can also tell us about your experiments at learn-chemistry@rsc.org

How to use the experiment pages

You can choose to deliver the experiments as a demonstration or to conduct the experiments as hands-on activities in small groups.

For this reason, the experiment activities have been written in two parts:

- this information booklet for teachers; and
- a separate worksheet for students.

For ease of reference the experiments have been colour coded into:

Vocabulary	Identifies some of the key words that can be used during this activity.
Key concepts	Provides a checklist of the scientific concepts that students should understand and be capable of by the end of the experiment.
Resources	A list of the equipment needed to take part in the experiment.
Teacher notes	Ideas to help extend learning.
Method	Explains how to complete the experiment.
Data	Reporting results: what the students discover during the experiment. Please post these results to our website: http://rsc.li/ge-water
Conclusions	Questions: thinking about the results and discussing any discoveries.
Follow-on suggestions	Specifically related to each experiment. (Please note there are more extension activities in a separate document on our website.)
Further information	An easy-to-understand scientific explanation of the experiment.

The three experiments

Experiment 1: How much water can my hydrogel hold?

Most diapers (nappies) contain hydrogels because they are designed to hold lots of water. However, different countries use different types of diapers (nappies) which may use different hydrogels, different quantities of hydrogels or no hydrogels at all. Students can find out how these differences change the volume of water that can be held by comparing their samples to others around the world.

Experiment 2: How quickly can hydrogels absorb water? Does this ever change?

Hydrogels are used in many different ways throughout the world for many different reasons.

Building on knowledge from Experiment 1, students can investigate the rate at which hydrogels can absorb water and the effect this can have on possible uses.

Post the results to our website and discover other uses for hydrogels and the chemistry behind them.

Experiment 3 – an open investigation: Can we retrieve water from hydrogels?

In order to answer the question 'are we wasting water by using hydrogels?', try some open investigations with your students to discover if we can recover water from hydrogels.

Health and safety

The experiments in this document have been safety-checked by CLEAPSS: http://www.cleapss.org.uk/

Hydrogels are low hazard. The chemical name for hydrogels is sodium polyacrylate. There is a small risk of irritation if any fine dust is inhaled or comes in contact with eyes.

Participants in the experiment should be aware of potential slip hazards related to water spillages and wet hydrogels. We advise that you consider trays to collect and capture slippery materials. In addition, mops and cloths for wiping floor spillages should be readily available.

To avoid blockages, please don't dispose of your hydrogels down the drain. Instead, think about how you can use the saturated hydrogels (some suggestions are given in Experiment 3 and the extension activities). For disposal to landfill please dispose by your normal route for solid, non-hazardous waste.

Earn a CREST Award

When completing Experiment 3 with your students, why not use it as the basis for a Bronze CREST Award?

CREST is Britain's largest award scheme for project work in science, technology, engineering and maths (STEM), and is suitable for anyone aged 11–19. The awards are widely recognised and can be used to enhance applications to colleges, universities and employers.

You or your student needs to contact your CREST Local Coordinator at the start of your project by going to www.britishscienceassociation.org/crestcontacts. Your coordinator will also help you through the simple registration process.

Once registration is complete, your student will be provided with a profile form and guide. Students will need to fill this out as they complete the project work – the guide will help them through all the steps needed for the project to qualify for the Award.

Experiments 1 and 2 will act as research hours but the creativity and freedom of Experiment 3 is what counts for CREST Awards.

Learn more about CREST on the British Science Association website:
www.britishscienceassociation.org/crest-awards

Absorb, permeable, impermeable, cm^3 = ml, comparative test, bar chart, prediction, estimation

Experiment 1: How much water can my hydrogel hold?

Your students will learn:

- to observe, measure and record how much liquid water a hydrogel can absorb;
- to calculate the average amount of liquid water a hydrogel can hold;
- to compare and analyse the data in class and with other schools worldwide via our website.

Resources you need:

- Hydrogel samples: one 10cm x 10cm square of disposable diaper (nappy) per experiment – plus one for the teacher sample (For the best results, diapers (nappies) for larger baby weights work best. If students are measuring and cutting their own samples, they will also need scissors and a ruler.)
- Cloth samples: one 10cm x 10cm square of permeable cloth (eg towelling or flannel) per experiment
- Access to a water source
- Measuring jugs or beakers/cylinders (to measure 50ml and 1000ml)
- Plastic trays or storage boxes for the samples to rest on
- A large 1000ml bowl for the control sample
- Sieve (or tea strainer)

Teacher notes

Class organisation suggestion: split the class into smaller groups. This allows all the students to take part in some way and emphasises comparative test. The results table included reflects this suggestion (by the numbers in the 'Group' column) but this can be amended if it's decided to only do one experiment.

Take care when cutting and handling the 10cm x 10cm square of disposable diaper (nappy). The hydrogel grains can be easily lost, affecting the result of the experiment. You might want to have spare samples if students want to investigate before the experiment.

If the students accidentally pour too much water on the sample, just pour this excess water back into the measuring jug.

Method

1. Set up a teacher sample. Put the hydrogel sample in a large bowl and add water (1000ml). Wait for at least 30 minutes to completely saturate the sample. Pour the remaining liquid through a sieve (or filter through your fingers) and measure it. The difference between the initial and final amounts will be the total volume of water the hydrogel can hold. Record this in the results table. This only needs to be done once per session.
2. Place the cloth sample into the plastic tray.
3. Gradually pour 50ml of water at a time onto the centre of the sample until the sample is saturated. Record each 50ml addition as you go along. You can see when the sample can't hold any more water, as the excess liquid will be seen around the edge of the sample.

4. If you think the sample is saturated, wait for 60 seconds and see if you can add more water. If the sample is saturated and you have added too much water, this can be poured out, measured and removed from your result tally.
5. Note how much water (ml) the sample can hold and record this on your results table.
6. Using the information gained from this, predict how much water you think the hydrogel sample will hold. Note this on your results table.
7. Repeat steps 3–5 of the experiment – this time using the hydrogel sample.

If you choose to conduct this experiment as a hands-on activity in small groups, a separate student worksheet has been supplied that details all the steps of the experiment, explains how to record their results and suggests further questions for them to consider.

Results

Once your findings are posted to our website, you can compare your data to schools from other countries.

Estimates for the amount of water a hydrogel sample can hold (ml) ______________________

Group	**Cloth sample** (total amount absorbed – ml)	**Hydrogel sample** (total amount absorbed – ml)
1		
2		
3		
4		
5		
6		
Average		

Teacher sample Amount absorbed (ml) ______________________

Conclusions

Why was it important to make each of the samples the same size?

Is the amount of water that the hydrogel sample held more or less than you predicted?

How much water can a whole diaper (nappy) hold?

Compare your data to the website data (http://rsc.li/ge-water). If there is a difference, why?

If you have any questions you can't answer, email them to us and we will help.
learn-chemistry@rsc.org

Follow-on suggestions

1. Complete **Experiment 2: How quickly can hydrogels absorb water? Does this ever change?**
2. Try Experiment 1 with different diapers (nappies), eg different baby weights, ages, genders or brands. Ask your students to predict if there will be any differences in the amounts absorbed. What is the outcome?
3. The results can lead on to a debate about which is the best sample to use: cloth or hydrogel. Absorbency is one factor but discussion could be opened surrounding environmental concerns of both types of diaper (nappy), the cost of each and any other factors students can think of.
4. Using different materials, the groups could then make their own 'diaper'. Give each group a permeable, impermeable and absorbent selection of materials (plus other samples) and challenge them to design and make a diaper that is capable of absorbing water whilst being comfortable for a baby to use. If you plan to allow the students to use hydrogels we recommend that you read and comply with all relevant health and safety guidelines. A question to consider: how has the manufacturer made sure the hydrogels are evenly dispersed throughout the diaper?
5. Link this activity with the water cycle. Where will the water in the hydrogel eventually go? (see water cycle diagram on p2).
6. Look at the global experiment website (**http://rsc.li/ge-water**) for more experiment ideas using hydrogels.
7. In our experiment, the absorbent part of the diaper (nappy) divided into three equal squares of 10cm x 10cm. We could therefore work out the amount of water held by one whole diaper (nappy) by adding the amounts. There are opportunities for working out averages etc by looking at the results of your class and the other results from around the world on our global experiment website.

Further information about the experiment

Hydrogels are known in chemistry as hydrophilic polymers. Hydrophilic means water-loving and a polymer is a long-chained chemical. Hydrogels are great at holding a huge amount of water because there are a vast number of places on the polymer for the water to loosely join.

Figure 3 The teacher sample and the hydrogel sample ready for testing.

Figure 4 The hydrogel sample during the experiment.

Absorb, permeable, impermeable, ml = cm^3, average, difference, compare, line graph, rate, time

Experiment 2: How quickly can hydrogels absorb water? Does this ever change?

Your students will learn:

- to investigate how quickly hydrogels absorb water and measure any changes;
- to use various units of measurement (eg ml, minutes etc); and
- to plot the results on a line graph.

Resources you need:

- One 2000ml plastic bottle with screw cap per experiment (The best 2000ml bottles are standard ones with smooth sides, eg lemonade/cola, rather than ones with ridged sides, eg certain bottled water brands, but you can experiment with this later if you choose.)
- 5g (or one level bottle capful) of hydrogel per experiment (The hydrogel can either be extracted from diapers (nappies) or purchased. See 'Teacher notes' for more information.)
- Timer (minutes:seconds, 00:00)
- Access to a water source
- Measuring jugs or beakers/cylinders (to measure 100ml and 1000ml)
- Sheet of paper for a temporary funnel

Teacher notes

There are lots of ways to extract hydrogels from a diaper (nappy).

1. You can put the sections of diaper (nappy) in a plastic bag and shake/rub from the outside. The granulated hydrogel crystals separate out and won't absorb any moisture from your hands.
2. You can break apart the diaper (nappy) with gloved hands (to avoid moisture from your hands) and collect in a bowl.

Both these methods work well and can be fun but are time consuming. If you are planning this experiment with a large class you may prefer to purchase granulated hydrogels which are widely available from garden centres, chemical supply companies or online retailers.

If you plan to buy hydrogels for this experiment, make sure you buy granulated hydrogels. They have a wide variety of names such as sodium polyacrylate, water crystals, gel crystals or Swellgel.

Decide as a class how to measure when the hydrogels look like they've absorbed all the water. It could be, for example, when the hydrogel has no liquid water showing on/around the sample. At the end of the experiment, this could lead to a discussion on one way that the experiment could be improved (see, 'Conclusions').

The hydrogels may take longer to absorb the water after each addition of 100ml. Due to this, it may be a good idea to set a maximum period of time to wait for the hydrogels to absorb the water (eg 20 minutes).

At first, the hydrogels will absorb water quickly but the absorption rate will slow down. Your students could start drawing up result tables/line graphs during any 'spare' time.

Method

1. Set up a teacher sample. Place one level capful of hydrogel into the bottle (using a paper funnel if necessary). Add water (1000ml) to the bottle and screw the cap on. Shake the contents five times and leave the sample for at least 50 minutes. This can be done at the start of the lesson and returned to later. Pour the liquid through a sieve (or filter by placing your thumb over the bottle opening and carefully pouring out the excess water) and measure the amount of water remaining. The difference between the initial and final amounts will be the total volume of water the hydrogel can hold. This provides a total absorption volume which can be noted at 50 minutes (even if it took longer) when graphing the results. Record this in the results table. This only needs to be done once per session.
2. Place one level capful of your hydrogel into the bottle (using a paper funnel if necessary).
3. Add water (100ml) to the bottle and screw the cap on.
4. Shake the contents five times.
5. Measure the time from the end of shaking to the point where you see no excess water on or around the hydrogel. Record the time taken in the results table.
6. Add another 100ml of water into the bottle; shake the contents and measure how long it takes for the hydrogel to absorb the water. Note this on your results table.
7. Repeat until it takes no less than 20 minutes (see 'Teacher notes') to absorb 100ml of water and record the time on your results table. You can also plot your 'rate of absorption' on the graph paper provided.

If you choose to conduct this experiment as a hands-on activity in small groups, a separate student worksheet has been supplied that details all the steps of the experiment, explains how to record their results, includes graph paper and suggests further questions for them to consider.

Results

Once your findings are posted to our website, you can compare your data to schools from other countries.

- **Don't forget** to stop once you reach 20 minutes to absorb 100ml

Amount of water added (ml)	Total amount of water in the bottle (ml)	Time taken for water to be absorbed in minutes and seconds (00:00)
100	100	
100	200	
100	300	
100	400	
100	500	
100	600	
100	700	

Teacher sample Total amount absorbed after 50 mins (ml) ____________________

Conclusions

Can you think of how to improve this experiment and/or the recording of the results?

Did you find that the hydrogels absorbed the water at the same rate throughout the experiment?

Why shake the bottle? And, if you don't shake the bottle, could it make a difference to the results?

What happened to the rate of absorption? Why?

If you have any questions you can't answer, feel free to email them to us at learn-chemistry@rsc.org

Follow-on suggestions

1. If you purchased hydrogels (sodium polyacrylate) for this experiment you might have come across both the bead and granulated form. Both are widely available, with the bead form often called water crystals in garden centres or online. Why not compare the differing crystal sizes and, therefore, the surface area of the hydrogels? Is the rate of absorption the same in each one? There are different types of hydrogel crystals with different structures. Could this affect absorption rate?
2. Experiment with the temperature of the water (perhaps three groups could use warm water and three groups use cold water). Does the water temperature make any difference to the rate of absorption?
3. Link this activity with the water cycle. Where will the water in the hydrogel finally go (see water cycle diagram on p2)?
4. Look at the global experiment website (http://rsc.li/ge-water) for more experiment ideas using hydrogels.

Further information about the experiment

Think of an empty room with a long line of empty chairs. The doors open and a large group of people come in, all wanting to sit down. The first group find a seat very easily and sit down straight away but, as the chairs get filled, the later people find it harder and harder to find an empty chair.

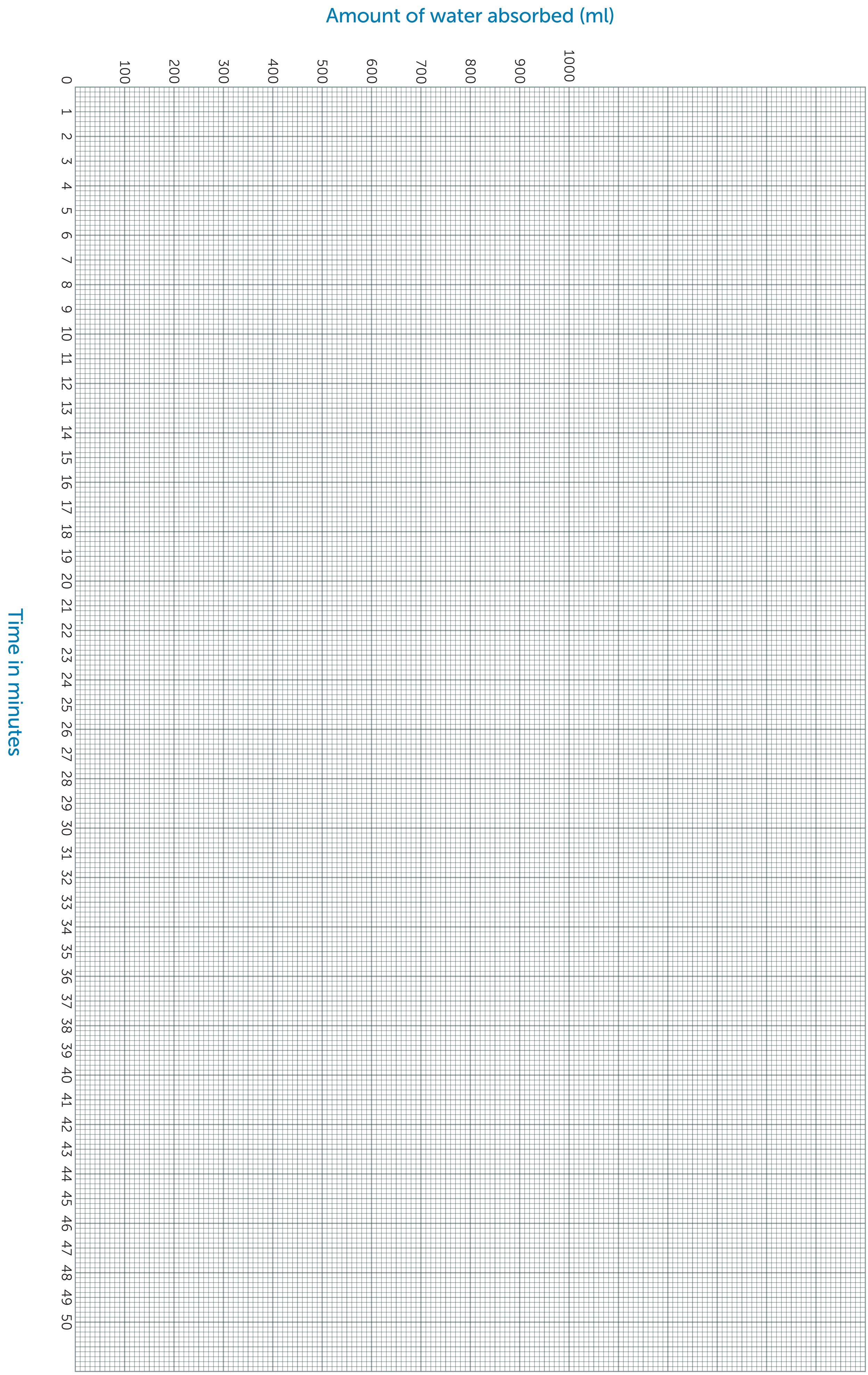
In this analogy, the hydrogel is the long line of empty chairs and the water is the group of people.

Figure 5 A capful of granular hydrogel.

Figure 6 Waiting for the water to absorb.

Figure 7 Water fully absorbed.

A graph for the rate of absorption



Experiment 3 – an open investigation: Can we retrieve water from hydrogels?

In order to answer the question 'are we wasting water by using hydrogels?', we need to investigate if water can be retrieved once it is absorbed and what is involved in that process.

This experiment has been purposefully left open with little guidance to give your students the opportunity to fully investigate.

We recommend starting with their saturated hydrogels from either Experiment 1 or 2 and investigating what effect any of the following materials may have on the hydrogel. Suggested materials to try include: sugar, vinegar, salt, pepper and bicarbonate of soda. When using other materials always carry out a full health and safety assessment on your chosen material.

It will be up to your students how they conduct their experiments, collect their data and record their findings. But an example might be: does stirring make a difference?

Please share their discoveries by uploading images of their work to our website **http://rsc.li/ge-water** or emailing us at **learn-chemistry@rsc.org**

Notes

Sodium Chloride (salt) has a stronger attraction to the hydrogel and pushes the water out of the way. This resource describes the process in more detail if required:

www.rsc.org/learn-chemistry/resource/res00000690/experiments-with-hydrogels-plant-water-storage-crystals

Conclusion

Can you answer the question: are we wasting water by using hydrogels?

Glossary

Absorb	To soak up a liquid/take (water) in. A sponge absorbs water.
Permeable	Allows liquid through, often because it is porous (contains tiny holes). Chalk rock is permeable.
Impermeable	A material that does not allow liquid to pass through. Common alternate phrases are 'water-resistant', 'water-repellent', 'airtight' or 'sealed'.
Saturate	When a material cannot absorb any more water, it is said to be saturated.
Hydrophilic	A hydrophilic substance is one that is water-loving ('hydro' from the Greek for water, 'philic' meaning loving/having an affinity for).
Hydrophobic	A hydrophobic substance is one that is water-repellent ('hydro' from the Greek for water, 'phobic' meaning repellent or failing to mix).
Comparative test	A test completed by one group, which is then repeated by another group, and the results compared and/or averaged.
Prediction	A proposed outcome of an experiment based on previous knowledge.
Water cycle	The constant process where water changes state and, in various states, can move from land, rivers and the sea to air (clouds) and back to land.
Evaporation	When liquid water gets enough heat energy to change state from liquid water into water vapour (the gas state of water).
Condensation	When water vapour (the gas state of water) cools and turns into droplets of liquid water.
Precipitation	When water falls from clouds in the sky. It can either fall as the liquid form of water (eg rain) or the solid form of water (eg snow/hail).
Transpiration	When water moves out of plant leaves/stems through small pores/holes called stomata, it evaporates as water vapour. In this way, transpiration is also part of the water cycle.
Polymer	A polymer is a long-chained chemical made from repeating small units. Plastics are a common example of a polymer.
Biodegradable	A material which can be broken down naturally by the earth (or by bacteria) and thereby avoids pollution.