International Year of
CHEMISTRY
2011

Global Experiment for the International Year of Chemistry

Water: a Chemical Solution

Water is beautiful, useful and precious. The Global Experiment unites students around the globe to participate in activities that highlight the role that chemistry plays in issues of water quality and purification. The recognition that clean, fresh water is a limited resource is leading to increased interest in education about water.

The international nature of the experiment will be celebrated by participants contributing data and information to the Experiment's Global Database and displayed through web-based global maps. Students will be able to access data from the database for their school, local area, region and country as well the global map.

The Activities

Acidity - *pH of the Planet*: Students measure the pH of a local water source and explore the acidity of the water sample.

Salinity - *Salty Waters*: The salinity of a salty water sample is measured by evaporation.

Water Treatment – *Water: No Dirt, No Germs* - A dirty water sample is first clarified with a homemade filter and then disinfected.

Distillation – *Solar Still Challenge* - Students construct and test a solar still, exploring how it works, and then construct a still to their own design.

Schools are invited to register for the Global Experiment so that their classes can submit the results for the four activities to the Global Experiment Database.

Teachers should include the activities as they choose. They are invited to build them into their existing teaching topics during 2011, or use some, or all, of the activities to supplement their curriculum and give their students a chance to participate in the Global Experiment.

Materials for the activities can be downloaded from the IYC 2011 website: http://www.chemistry2011.org/.

Kits will be available providing the equipment and materials required for the experiment.

Global Experiment for the International Year of Chemistry

pH of the Planet

This document contains a description for the **pH of the Planet Activity** that is part of the Global Experiment being conducted during the International Year of Chemistry, 2011.

In this activity students will collect a water sample from a local natural source. They will measure the pH of the sample using coloured indicator solutions. An average value from the class results will be reported to the Global Experiment Database together with information about the sample and the school.

Contents

Submitting Results to the Global Database

The following information should be submitted to the database. If the details of the school and location have already been submitted in association with one of the other activities, these results should be linked to previous submission.

Date sampled: ___________________________

Local water source: ___________________________ (e.g. Nile River)

pH of local water source _______________________

Nature of water: ___________________________ (fresh, salt, estuarine, marine, etc.)

Temperature: ___________________________ (temperature while measuring the pH)

Number of students involved ______________

School/class registration number ______________

Instructions for the Activity (Teacher)

Experiment Outline

Students should work in small groups (usually pairs) to measure the pH of a local natural source of water. The activity involves three sections:

- Measure the pH of the sample from the local water source (and other samples if appropriate).
- Analyse the data and report results to the Global Experiment Database.

Materials

- 6 (six) sample **containers** (*white or transparent containers to hold 1 cm depth of liquid*).
- a **dropper** or pipette
- a bottle of **rinsing water**
- bromothymol blue **indicator** (*from kit, made up using the instructions*)
- *m*-cresol purple **indicator** (*from kit, made up using the instructions*)
- **colour charts** for indicators
- **local water sample** from local natural water body

Optional

- other water samples
- universal indicator

Method

Part A - Testing the local water source

1. Label the sample containers 1 – 6 and mark 0.5 cm depth on each container.
2. Take a portion from the local water sample and fill three of the containers up to the mark.
3. Add three drops of **bromothymol blue** indicator to each container and swirl it to mix the solution thoroughly.
4. Use the colour chart to estimate the pH of each solution and record the result for each container to one decimal place.
5. If the pH of the sample is 7.6 or greater, repeat the test three times using ***m*-cresol purple** as the indicator and record the results to one decimal place.

Part B – Analysing and Submitting the Results

6. Decide which indicator gave the best measure of the pH of the sample.
7. Calculate the average result for your water sample using the results from the best indicator.
8. Add your result to the Class Table of Results.
9. When the class results are complete, calculate the class average result for the local water sample.
10. Work with your teacher to submit the class average for the local water sample to the Global Experiment Database.

(OPTIONAL Other water samples)

11. Repeat the method, Part A and B, for other water samples that are available.
12. Rinse the containers thoroughly between tests to avoid contamination.

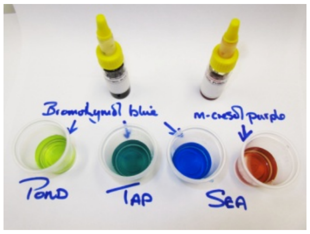
Class Results Sheet

Record students' average pH values for the local water source (and other water sources if available - see teacher notes). Record the ancillary data ready for submission to the Global Experiment Database.

	Water Samples					
Group	**Local water source**	A	B	C	D	E
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
Average						

- Local water source: ___________________________
- Nature of water: ___________________________
- Date sampled: ___________________________
- Temperature: ___________________________
- Number of students involved: ___________________________

Activity Worksheet (Student)



In this activity you will measure the pH (the acidity) of a local water sample. The pH is a number that allows you to compare different water samples. You will be able to compare your results with those from other schools around the world.

Part A - Testing the local water source

- Label the sample containers 1 – 6 and mark 0.5 cm depth on each container.
- Take a portion from the local water sample and fill three of the containers up to the mark.
- Add three drops of **bromothymol blue** indicator to each container and swirl it to mix the solution thoroughly.
- Use the colour chart to estimate the pH of each solution and record the result for each container to one decimal place.
- If the pH of the sample is 7.6 or greater, repeat the test three times using ***m*-cresol purple** as the indicator and record the results to one decimal place.

	Types of Water Sampled						
Test	Indicator	Local water source	A	B	C	D	E
1	bromothymol blue						
2							
3							
4	*m*-cresol purple						
5							
6							
Average							

Part B – Analysing and Submitting the Results

- Decide which indicator gave the best measure of the pH of the sample.
- Calculate the average result for your water sample using the results from the best indicator.
- Add your result to the Class Table of Results.
- When the class results are complete, calculate the class average result for the local water sample. This is the number that will be reported to the Global Experiment Database.

Teacher's Notes

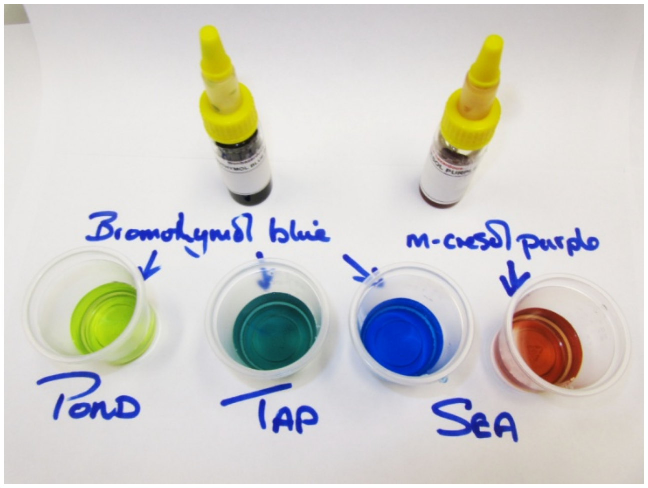
Chemistry is about us and everything about us. Exploring chemistry gives us deep insights into our world that are often surprising and useful. Acids are one of the first groups of substances that we recognize for their chemical properties, in the kitchen and the laundry as well as in the factory and the laboratory.

The activity will allow your class to explore the idea of acidity as it applies to our water supplies using the most common measure of acidity, pH. Students will learn a method of measuring pH and how to check its reliability. They will submit data to the Global Experiment database and be able to compare their results with others from around the world

Conducting the pH of the Planet Activity

The following notes are written to assist teachers use the pH of the Planet activity with their classes. The notes cover the following topics:

- Setting and Purpose for the Activity
- Learning outcomes
    - Primary classes
    - Junior high school classes
    - Senior high school classes
- Materials and Equipment required
- Safety
- Pre-activity preparation
- Background about pH and acidity
- Ancillary activities



Setting and Purpose

This activity has been written to be included as part of an existing water related unit of work. However teachers may wish to use it just to give their students an experience of contributing to an international scientific experiment.

Some elaborations for the activity and ancillary activities are provided so that teachers can choose options to suit the time their class has available and the depth of understanding about the topic of water acidity appropriate for their class.

Learning Outcomes

Scientific processes:

- Measuring acidity and assessing the quality of the data.
- Interpreting data in terms of the environment and nature of the water involved.
- Asking scientific questions.
- Carrying out scientific investigations.

Chemistry background.

- Acids and bases.
- Chemical reactions that involve acids and bases.
- pH as a measure of acidity.

Primary Classes - In the primary schools the activity provides an excellent opportunity for students to collect data using simple equipment and developing a useful skill of colour matching.

Students should have some understanding of decimals and the process of averaging to understand the analytical part of the activity.

The topic of acidity is one of the important chemical ideas that is firmly embedded in students' experiences of food and household chemicals.

It provides a good example when distinguishing between physical and chemical processes and is one of the early experiences students have with chemical reactivity.

The pH scale is best treated as a measure of acidity without reference to its chemical basis. However, the counter intuitive nature of the scale – lower pH implies more acidic – is unavoidable.

Emphasis can be usefully placed on exploring the scale, relating the terms *neutral* to a pH of 7 and *acidic* to the region of the scale below pH 7 and *basic* to the region above 7.

Students can usefully learn that substances with pH values well above or below 7 are both dangerous and the danger increases with the distance from neutrality.

Junior High School – The explanations include hydrogen ions (H^+) or (H_3O^+) and simple chemical equations where appropriate.

Senior High School – The explanations include strong and weak acids and chemical equilibrium where appropriate. Alternative methods of measuring pH such as pH meters can be used if available.

Materials and Equipment

Water samples: The water samples can be collected in plastic drink bottles (1.5 L will be plenty). If samples need to be kept they should be stored in a refrigerator, allowed to come to room temperature before use, and used promptly after opening.

The local natural water source sample to be reported to the Global Experiment Database might come from the sea, a river, lake or large pond. Try to find a source that is a recognisable landmark that will be identifiable by students from other schools for comparative purposes. Collect the water sample as close to the time the class will be carrying out the measurements as possible.

If your students will be testing a range of other local samples you can ask them to collect samples and bring them to school. You should make sure you have some universal indicator in case students bring in samples that have pH values outside the range for most natural waters.

Indicators: Bromothymol blue is widely available from aquarium stores for use testing fresh water aquariums. *m*-Cresol purple is used for testing marine samples.

Primary school teachers may want to collaborate with local high schools if they need to make up the indicators from the solid samples provided in test kits.

Bromothymol blue recipe:

Dissolve 0.1 g of bromothymol blue in 16 mL of 0.01 M NaOH.
When dissolved, slowly add 234 mL of water (distilled if possible).
Store at room temperature.

m-Cresol purple recipe:

Dissolve 0.1 g of *m*-Cresol purple in 26 mL of 0.01 M NaOH.
When dissolved, slowly add 224 mL of water (distilled if possible).
Store at room temperature.

Safety

The materials used in this activity are not hazardous in the form of the dilute solutions suggested in the procedures. However the solid indicators may cause irritation particularly if ingested. They should be handled with care when making up the indicators and hands should be washed afterwards.

Test Kit

The test kit includes:

- Samples of the two indicators, 0.1 g bromothymol blue and 0.1 g *m*-cresol purple in plastic sachets.
- Colour chart for each indicator.

Instructions:

- for the experiment
- for indicator preparation and use of the colour charts.

Background Information - Acidity and pH

The first group of substances that people learn about based on chemical reactivity are often acids. Many acids are household products such as vinegar, hydrochloric acid or citric acid. Others, such as sulfuric and phosphoric acid, are used industrially, and millions of tonnes are manufactured each year.

Acids react with bases, a slightly less well known but equally important group of substances that includes ammonia, sodium bicarbonate and caustic soda (sodium hydroxide). Thousands of acids and thousands of bases have been identified, many of them naturally occurring and important in the processes of life.

Most of the common acid-base reactions occur in water. One of the special but not unique properties of water is that it can react as both an acid and a base. Because of this property, and because water is such a common and important substance, it is usually convenient to use it as the substance that divides acids from bases. Thus water acts as a base with acids and as an acid with bases. Samples of pure water and solutions that have the same acidity as pure water are said to be neutral. Acid-base reactions are often called neutralisation reactions.

$$\text{acetic acid} + \text{sodium bicarbonate} \rightarrow \text{water} + \text{sodium acetate} + \text{carbon dioxide}$$

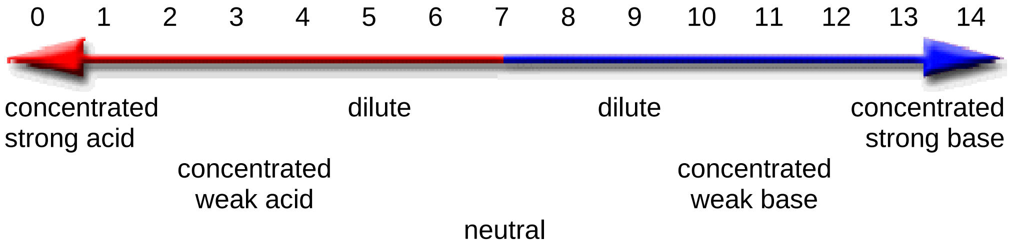
Variations in these acid-base reactions occur in cooking, in all the cells in our bodies and in many of the natural processes in the countryside.

Acid strength - The extent to which acids and bases react with water is a measure of how strong the acid or base is. Hydrochloric acid, a common strong acid, is found in the stomach and sold in hardware stores. It reacts almost completely with water. Other acids such as acetic acid, the acid found in vinegar, react only partially with water and are weak acids. Bases can be similarly classified as weak or strong.

The strength of an acidic solution, its acidity, is a useful property to know because it is an important indicator of how it might react chemically. For example concentrated hydrochloric acid is a useful substance for cleaning cement of brickwork, but concentrated acetic acid is much less effective. Diluting the acid reduces the acidity of an acidic solution and so adding water is usually a useful way of reducing the hazard of acid or base, spills.

pH scale - The pH scale is used to measure the acidity of solutions. The pH of most common solutions lie between 0 and 14. Lower values of pH imply greater acidity.

pH scale



Strong acids have the lowest pH and can have negative values for concentrated strong acids such as sulfuric acid. Strong bases have the highest values and can be greater than 14. Pure water on the other hand is neutral and has a pH of around 7 depending on the temperature.

The utility of the pH scale comes from what it is that is actually measured. The measure is the extent of the reaction of the acid with water. For example with hydrochloric acid:

$$HCl + H_2O \rightarrow H_3O^+ + Cl^-$$

Hydronium ions - The products are ions (they are charged particles) and the H_3O^+ ion (hydronium ion) is responsible for the acidic properties.

One of the reasons why acids form such a useful category of substances is because H_3O^+ ions are formed by all the common acids and hence acids have a range of common properties.

In the case of hydrochloric acid, the ionisation is essentially complete in water and HCl is called a strong acid. For acetic acid, much less H_3O^+ is formed and most of the acetic acid molecules are usually in the unionized form.

H_3O^+ or H^+

It is common to refer to acids in terms of the concentration of hydrogen ions, H^+, rather than H_3O^+ ions. This is based on convenience and tradition and while hydrogen ions do not exist in water solutions, the terms are used interchangeably.

Measuring pH involves determining the concentration of H_3O^+. The range of values is great so a logarithmic scale is used:

$$pH = -\log_{10}[H_3O^+]$$

This means that the concentration of H_3O^+ at pH 8.5 is one thousandth of the concentration at pH 5.5 (a common range for natural water samples).

Measuring pH - The two most common measurements of pH involve using indicators or pH meters.

Indicators are weak acids that are coloured and that change colour when they undergo an acid-base reaction and (formally) lose the H^+ ion. The reactions are usually reversible so that the indicator has two molecular forms: the acid and the base:

$$\text{bromothymol blue} \underset{+H^+}{\overset{-H^+}{\rightleftharpoons}} \text{bromothymol blue}^-$$

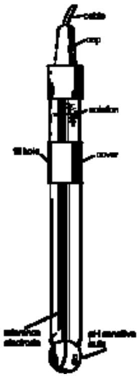
acid form base form

The colour change in indicators usually occurs across a 10-fold change in H_3O^+ concentration and so covers a change in pH of one.

Indicator solutions that cover more extensive pH ranges such as universal indicator are mixtures of a number of indicators.

pH meters - work by measuring the potential of a pH sensitive glass electrode. The glass membranes are sensitive to damage and need to be stored and handled carefully to achieve a lifetime of 2 years, or perhaps, more.

The electrodes change with age and so the pH meter needs to be calibrated regularly. This is done using buffers of known pH. Buffer solutions are usually mixtures of the acid and base forms of a weak acid. Buffer solutions are usually made up from recipes, or bought as a tablet or in liquid form.



Interpreting pH values

pH values obtained in the activity need to be interpreted cautiously because there is a natural variability due to differing light levels and temperatures and artifacts of the different measuring techniques. In the case of freshwater sources the natural variability is quite large, commonly between 6.5 and 8.0. Marine waters usually are buffered and have a smaller range in pH variation, between 8.1 and 8.4.

Temperature changes cause changes in the pH of sample solutions and of pH sensors. Although these changes remain small if the temperature remains close to 20-25°C, bigger variation is to be expected with more extreme temperatures.

For natural waters, the pH also changes during the day due to the living material in the water. Respiration of organisms produces carbon dioxide which lowers the pH of the sample. In daylight the pH increases because the photosynthesizing organisms reduce the levels of carbon dioxide.

The geology of the area can also affect the pH of the local water. The presence of limestone can raise the pH considerably. In the case of the oceans, the limestone and other sources of calcium carbonate contribute to the normal ocean pH of 8.3, but the additional carbon dioxide in the atmosphere due to climate change is partially dissolving in the ocean decreasing the pH (by very small amounts).

Additional activities

The following activities would provide students with opportunities to gain a deeper understanding of the concept of acidity and pH.

- Changing pH – experiments that establish the variable stability of pH in different setting e.g. blowing into water samples.
- pH in everyday life – measuring pH in everyday liquids from around the house and materials such as soils.
- Natural indicators – exploring homemade indicators such as red cabbage juice.
- Variation in pH – Measurement of natural variation in pH in water during regular events (24 hours) and after rain etc.
- Other activities etc.

International Year of CHEMISTRY 2011

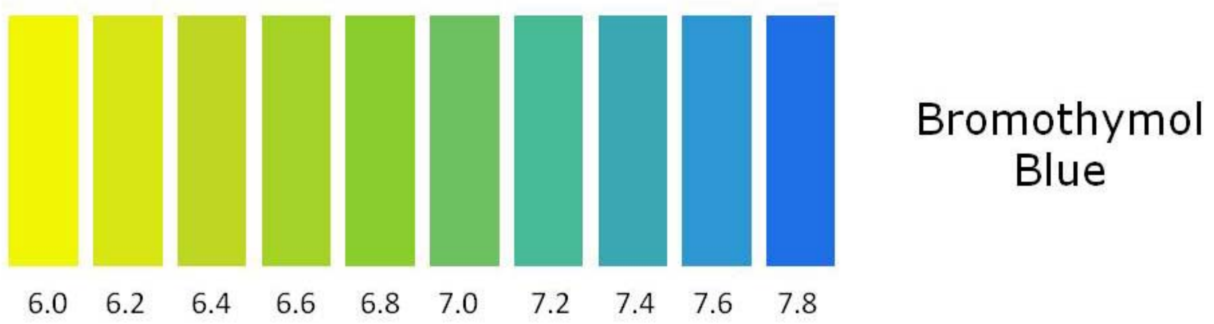
Class Results Sheet (Trial Data)

- Record students' average pH value for the local water source here and other water sources if available (see teacher notes).
- *(This data set was obtained using the above method by a class of 25 eleven-year-old students working in pairs.)*

	Types of Water Sampled					
Group	Local source Lake	A Tap	B Fish tank	C Sea	D	E
1	6.7	8.0	6.6	8.1		
2	6.9	7.9	6.5	8.0		
3	6.5	8.0	6.6	8.1		
4	6.7	8.0	6.7	8.2		
5	6.7	8.4	6.4	8.0		
6	6.9	8.1	6.3	8.0		
7	6.8	7.7	6.3	8.4		
8	6.8	8.0	6.5	8.1		
9	6.8	8.1	6.7	8.4		
10	6.7	8.1	6.7	8.3		
11	6.8	8.2	6.5	8.3		
12	6.6	7.8	6.6	8.1		
13	6.6	7.8	6.4	8.1		
14						
15						
Average	6.7	8.0	6.5	8.2		

- Local water source: Brisbane River opposite Oxley School
- Nature of water: Fresh
- Date sampled: 14/02/2011
- Temperature: 23.5 °C
- Number of students involved 25

Indicator Colour Chart



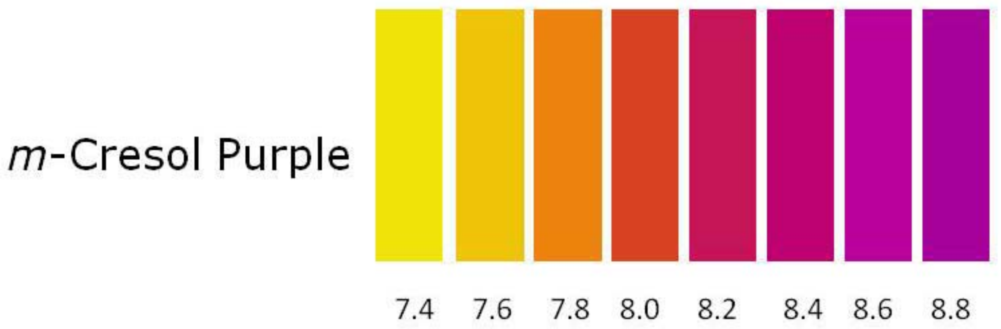


Table of RGB Indicator Colours

pH	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2	8.4	8.6	8.8
Bromothymol blue	241 231 19	216 231 19	189 215 35	165 210 38	137 206 44	108 192 95	70 185 149	57 166 180	44 150 210	30 110 230					
m-Cresol purple								240 227 7	239 195 7	237 130 13	215 66 35	198 20 88	189 1 113	186 2 154	166 2 154

International Year of
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2011

Global Experiment for the International Year of Chemistry

Water: No Dirt, No Germs

This document contains a description for the **Water: No Dirt, No Germs** activity that is part of the Global Experiment being conducted during the International Year of Chemistry, 2011.

At the time of Madame Marie Curie's acceptance of the 1911 Nobel Prize in Chemistry, water treatment to provide clean, safe drinking water was becoming common in many places in Europe and North America. As we celebrate the International Year of Chemistry, waterborne diseases, such as typhoid fever and cholera, have yet to be completely eliminated, although the chemical technology "tools" are available. This activity will raise awareness of the critical use of chemistry to provide one of the most basic human needs, clean drinking water.

Starting with local natural surface waters, students will replicate one or both of the main steps of drinking water treatment--**clarification** and **disinfection**. Younger students will clarify natural surface water and observe disinfection done by their teacher. Older students will both clarify and disinfect natural water.

Contents

Submitting Results to the Global Database

The following information should be submitted to the online database. If the details of the school and location have already been submitted in association with one of the other activities, the current results should be linked to previous submission.

Date sampled: ___________________________

Local water source: ___________________________ (e.g. Nile River)

Drops of bleach required to 500 ml water: ________________________ (average number of drops)

Nature of water: ___________________________ (fresh, salt, estuarine, marine, etc.)

Temperature: ___________________________ (temperature when water collected)

File names for water sample photos ____

Class name and number of students ____

School registration number ______________

Instructions for the Activity (Teacher)

Drinking water chlorination represents a smart use of chemistry in our everyday lives. Small amounts of chlorine are added to large volumes of drinking water help destroy germs, including bacteria and viruses that once killed thousands of people every year. Adding chlorine to drinking water has improved public health in many places in the world today.

Students should work in small groups (4 – 6, or pairs if numbers permit) to treat water from a natural local source. They will carry out one or both of the main steps of water treatment, clarification and disinfection, and then analyse and report results to the Global Experiment Database.

Clarification is the process used to remove solid debris from natural or waste water and involves four steps:

1. **Aeration,** the first step in the treatment process, adds air to water. It allows gases trapped in the water to escape and adds oxygen to the water.
2. **Coagulation** is the process by which dirt and other floating solid particles chemically "stick together" into flocs (clumps of alum and sediment) so they can easily be removed from water.
3. **Sedimentation** is the process that occurs when gravity pulls the particles of floc to the bottom of the container. At a treatment plant, there are settling beds that collect flocs that float to the bottom, allowing the clear water to be drained from the top of the bed and continue through the process.
4. **Filtration** through a sand and pebble filter removes most of the impurities remaining in water after coagulation and sedimentation have taken place.
5. **Disinfection** is the process used to destroy germs in the filtered water. In this activity, chlorine disinfectant will be used to destroy germs chemically (recommended for older students or as demonstration for younger students).

Materials for Water Clarification

- 2 liters of “dirty” natural water (or you can add 1 cup of dirt or mud to 2 liters of water)
- 1 two liter plastic soft drink bottle with its cap (or cork that fits tightly into the neck).
- 2 two liter plastic soft drink bottles, one with its bottom cut off to use as a funnel and one with the top cut off to use for sedimentation.
- 1 large beaker (with a volume of 500 ml, or 2 cups) or measuring bowl that will hold the inverted two liter bottle or you can use another two liter plastic soft drink bottle with its top cut off so the other bottle will fit inside of it.
- 2 tablespoons of alum
- 1½ cups fine sand
- 1½ cups coarse sand
- 1 cup small pebbles
- 1 coffee filter
- 1 rubber band
- 1 tablespoon for the alum
- 1 large spoon
- A clock with a second hand or a stopwatch

Safety

Safety glasses must be worn at all times during this activity.

The water is not safe to drink.

Direct contact with alum and disinfectant should be avoided.

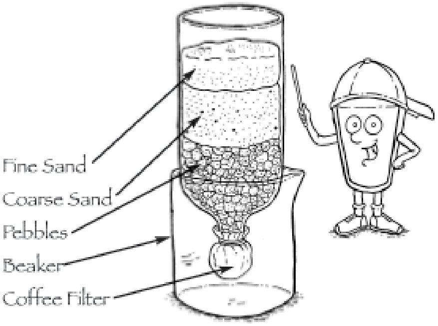
Procedure for Water Clarification

1. Pour dirty swamp/river/dam water (or the water sample you made by mixing dirt and water) into the two liter bottle with a cap. Describe the appearance and smell of the water, using the Students' Observation Sheet for Water Clarification.
2. Place the cap on the bottle and vigorously shake the bottle for 30 seconds. Continue the aeration process by pouring the water into another bottle or the beaker, then pouring the water back and forth between them about 10 times. Once aerated, gases have escaped (any bubbles should be gone). Pour your aerated water into your bottle with its top cut off.
3. Add two tablespoons of alum to the aerated water. Slowly stir the mixture for 5 minutes. Describe the appearance and smell of the water, using the Students' Observation Sheet for Water Clarification.
4. Allow the water to stand undisturbed in the container (see photo to the right). Observe the water at 5 minute intervals for a total of 20 minutes. Write down what you see - what is the appearance of the water now? Use the Students' Observation Sheet for Water Clarification to note your observations.

5. Construct a filter from the bottle with its bottom cut off as follows (see illustration left):

   - **a.** Attach the coffee filter to the outside neck of the bottle, using a rubber band. Turn the bottle upside down placing it in a beaker or cut-off bottom of a two liter bottle. (IF USING THE CUT-OFF BOTTOM OF A TWO LITER BOTTLE, PUNCH A SMALL HOLE IN THE SIDE OF THE BOTTLE TO PERMIT AIR TO ESCAPE.) Pour a layer of pebbles into the bottle - the filter will prevent the pebbles from falling out of the neck.
   - **b.** Pour the coarse sand on top of the pebbles.
   - **c.** Pour the fine sand on top of the coarse sand.
   - **d.** Clean the filter by slowly and carefully pouring through 3L (or more) of clean drinking water. Throw away the water that has passed through the filter.

6. After a large amount of sediment has settled on the bottom of the bottle of swamp/river/dam water, carefully - without disturbing the sediment - pour the top two-thirds of the swamp/river/dam water through the filter. Collect the filtered water in the beaker/plastic bottle.
7. Compare the treated and untreated water. Has treatment changed the appearance and smell of the water?
8. Check with your teacher if you can also do the additional activity on measuring turbidity of the "dirty" water, the clarified water and your household drinking water.



9. **OPTIONAL** Place samples of the treated and untreated water side-by-side and take a photo for submission to the Global Database.

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[1] *Based on U.S. Environmental Protection Agency activity at: http://www.epa.gov/safewater/kids/flash/flash_filtration.html*

Procedure for Water Disinfection

Why is Disinfection Necessary?

Filtered water is clear of many visible particles but contains many invisible live germs that can make people sick. Chlorine is used in many water treatment facilities to destroy harmful germs and small particles of organic matter. In this part of the activity, we'll be measuring "free available" chlorine. "Free available" chlorine is the level of chlorine available in water to destroy germs and organic matter. Water treatment plants add enough chlorine to destroy germs plus a little bit more to fight any new germs that are encountered before the water reaches your home, for example. This small extra amount is known as the "chlorine residual" and it can be detected using chlorine test strips.

Safety

Safety glasses must be worn at all times during this activity.

The water is not safe to drink.

Direct contact with bleach should be avoided.

Senior high school students may be allowed to carry out this activity. Class demonstrations are recommended for junior

Materials needed for Water Disinfection

- Liquid laundry bleach (sodium hypochlorite)
- About 10 chlorine test strips
- One eye/medicine dropper or disposable pipette
- One large spoon
- A clock with a second hand or a stopwatch

Procedure for Water Disinfection

1. Dip a chlorine test strip into 500 ml (approximately 2 cups) of the clear liquid obtained from the filtration activity (the "filtrate") above and use the product color-code chart to estimate the "free available" chlorine level of the liquid. Record the level of chlorine in the filtrate in the table on the Students' Result Sheet for Water Disinfection.
2. Add 2 drops of bleach to the filtered liquid, stir gently for 5 seconds, and repeat the test strip reading immediately. Record your results in the table. Keep adding 2 drops at a time, and record the number of drops added, until a chlorine level registers on the test strip. As chlorine bleach is added to the filtered water, chlorine is being used up in destroying harmful germs, so it could take a few additions of bleach before a chlorine residual can be observed.
3. Once the chlorine residual is noted, wait 10 minutes WITHOUT ADDING MORE BLEACH and again record the free available chlorine level.
4. If the chlorine residual disappears over the course of 10 minutes, add two more drops and see if a free chlorine level reading of at least 1 – 3 parts per million can be measured 10 minutes after adding the chlorine. (If after 2 drops and 10 minutes, no chlorine residual is noted, increase the number of drops by 2, trying 4 drops. Wait 10 minutes and check for the chlorine residual. If no chlorine residual appears, increase the number of drops to 6, etc., until a chlorine residual can be noted after 10 minutes.) When this happens, you have added enough chlorine bleach to destroy many of the germs in the water, leaving a small excess of chlorine.
5. Calculate the total number of drops used for the disinfection and report it to help determine the class average.

Student Observation Sheet

Water Clarification

(Complete the following tables using the “dirty” water you have collected.)

Date of sample collection	
Temperature of water when collected	
Type of water: fresh (pond, river, stream or swamp) or estuarine	
Describe where you found the water	

Water Appearance

Appearance and smell before the start of treatment	
Appearance after aeration	
5 minutes after adding alum	
10 minutes after adding alum	
15 minutes after adding alum	
20 minutes after adding alum	
Appearance and smell after filtration	

Water Disinfection

(Use 500 mL of your **filtered water** for this activity.)

	Free Available Chlorine		
Bleach added	**Number of drops**	**Colour of chlorine test strip**	**Free available chlorine / parts per million**
No bleach	0		
Number of drops added until residual bleach present (**Step 2**)			
After 10 minutes (**Step 3**)	0		
Number of drops to give residual chlorine after 10 minutes. (**Step 4**)			
Total number of drops			

Conclusions

1. Compare the treated and untreated water. Has treatment changed the appearance and smell of the water?
2. Do you think your clarified water is safe to drink? Give a reason for your answer.
3. Do you think your filtered and disinfected water is safe to drink? Give a reason with your answer.

Class Results Sheet

NAME OF SCHOOL ____________________________

LOCATION OF SCHOOL ____________________________

Group number	**Type of water**	**Description of water source**	**Average number of drops of bleach added***
1			
2			
3			
4			
5			
Average			
Measurements of other water sources			
Water Sample Photographs (Clarification Step 9)			
Filenames			

Observation Sheet (*Trial results*)

Water Clarification

(Complete the following tables using the "dirty" water you have collected.)

Date of sample collection	*October 3, 2010*
Temperature of water when collected	*24 ^oC*
Type of water: fresh (pond, river, stream etc.) or estuarine	*Fresh, swamp*
Describe where you found the water	*In a wetland adjacent to Rock Creek in Rockville, Maryland, USA*

Water Appearance

Appearance and smell before the start of treatment	*Murky with individual small particles visible; smelled sulfurous.*
Appearance after aeration	*Less murky than when first collected; clumps of suspended sediment visible.*
5 minutes after adding alum	*Very much clearer than when first collected, with fewer clumps of suspended sediment visible, a few large pieces of twigs floating on the surface, and a few very small organisms swimming.*
10 minutes after adding alum	*Continues to become clearer; more sediment settling; a few pieces of twig still floating on the surface. Some of the smallest organisms have stopped swimming; others continue.*
15 minutes after adding alum	*No more noticeable change from at 10 minutes.*

20 minutes after adding alum	*No more noticeable change from at10 minutes*
Appearance and smell after filtration	*Clear light brown liquid; smell still present.*

Water Disinfection

(Use 500 mL of your **filtered water** for this activity.)

Bleach added	**Free Available Chlorine**		
	Number of drops	**Colour of chlorine test strip**	**Free available chlorine / parts per million**
No bleach	0		*0*
Number of drops added until residual bleach present (**Step 2**)	*4*		*1.0*
After 10 minutes (**Step 3**)	0		*0*
Number of drops to give residual chlorine after 10 minutes. (**Step 4**)	*18*		*1.0*
Total number of drops	*22*		*1.0*

Conclusions

1. Compare the treated and untreated water. Has treatment changed the appearance and smell of the water?

   After the treatment the water is clear and most of the smell has gone.

2. Do you think your clarified water is safe to drink? Give a reason for your answer. *I do not think the water is completely safe to drink now. I think there are still germs in the water that will multiply over time.*

3. Do you think your filtered and disinfected water is safe to drink? Give a reason with your answer.

   The water should be safer to drink now because enough bleach for some not to be used up. But I would not drink it because it was a school experiment done in a school lab not a food preparation area.

Class Results Sheet

NAME OF SCHOOL: Rocky Park Elementary School
LOCATION OF SCHOOL: Rockville, MD
USA

Group number	**Type of water**	**Description of water source**	**Average number of drops of bleach added***
1	*Swamp*	*Rock Creek wetland*	*22*
2	*Swamp*	*Rock Creek wetland*	*24*
3	*Swamp*	*Rock Creek wetland*	*22*
4	*Swamp*	*Rock Creek wetland*	*18*
5	*Swamp*	*Rock Creek wetland*	*18*
Average			***21***
Measurements of other water sources			
	River water	*Rock Creek near Parkvale Road, Rockville MD*	*7*
	Spring water	*Spring in the nearby hills*	*2*
	Pond water	*Pond outside the school, near the vegetable garden*	*10*
	Tap water	*From the teacher's home in Bethesda*	*0*
Water Sample Photographs			
Filenames		*RockyPark-unfiltered*	*RockyPark-filtered*

* Since this is an average figure, the result will not necessarily be an even number. Example for river water: Four groups in a school reported the minimum number of drops as 7, 6, 8 and 8 respectively. The numerical average is 7,25 but significant figures, as determined by the number of drops added, will require results to be reported as 7 drops.

Additional Information about the Experiments

Safety Precautions

Safety glasses should be worn at all times during these activities. It should be emphasized that neither the clarified water nor the disinfected water will be safe to taste or drink. The students should be made aware of this at the start of the activity. Contact with the solid substances (alum and calcium hypochlorite) should be avoided. The household bleach should be handled with care.

Materials and Equipment Listing

Materials needed for Water Clarification

6. 2 Liters of “dirty” natural water. The water can be collected from a stream, pond, river or swamp (or you can add 1 cup of dirt or mud to 2 liters of water). Don’t try to collect “clean” water – the water should be murky.
7. 1 Two liter plastic soft drink bottle with its cap (or cork that fits tightly into the neck).
8. 2 Two liter plastic soft drink bottles, one with its bottom cut off to use as a funnel and one with the top cut off to use for sedimentation.
9. 1 large beaker (with a volume of 500 ml, or 2 cups) or measuring bowl that will hold the inverted two liter bottle or you can use another two liter plastic soft drink bottle with its top cut off so the other bottle will fit inside of it.
10. 1 tablespoon alum
11. 1½ cups fine sand (white play sand, beach sand or fine building sand)
12. 1½ cups coarse sand (multi-purpose sand)
13. 1 cup small pebbles (washed, natural color aquarium rocks work best)
14. 1 coffee filter
15. 1 rubber band
16. 1 tablespoon (for the alum)
17. 1 large spoon (for stirring)
18. A clock with a second hand or a stopwatch

Notes on Materials Procurement:

1. Water Samples: The water samples can be collected in plastic drink bottles or in any other suitable container. For comparison with the treated water, it will be more suitable if the container is made of a transparent material.
   The local natural water source sample to be reported to the Global Experiment Database might come from a river, lake, large pond or an estuary. The activity is not suitable for sea water. Do not try and collect the “best” water from the water source; it should be murky. It can be collected from just beneath the surface of the water source. Try to find a source that is a recognizable landmark that will be identifiable by students from other schools for

comparative purposes. Collect the water sample as close to the time the class will be carrying out the activity as possible.

2. Alum, or potassium aluminum sulfate, is readily available and is inexpensive. In some countries it can be found in supermarkets, in the spice aisle. In others, it can be bought in pharmacies. The low-cost kit will contain alum.
3. Although the procedure for water clarification specifies using 2 L cold drink bottles, smaller bottles will also be suitable.
4. Although white play sand or swimming pool sand will be ideal, it can easily be replaced with clean fine building sand used for plastering of walls.
5. The multipurpose sand should have a larger grain size and can be the building sand used in concrete mixtures.
6. Small aquarium rocks can be replaced with washed natural pebbles, approx.1 – 2 cm in diameter.
7. If the low cost kit is used, filtration will be done using a funnel and a filter paper. The teacher should link that filtration with filtration through a sand filter.

Materials needed for Water Disinfection

- Chlorine laundry bleach (approximately 6% sodium hypochlorite solution)
- About 10 chlorine test strips
- One eye/medicine dropper
- One large spoon (for stirring)
- A clock with a second hand or a stopwatch

Notes on Materials Procurement:

Chlorine Test Strips: Common pool test strips that measure free available chlorine (and typically pH as well) can be used for this exercise. Students will dip the test strip into the water to be monitored and then wait 15 seconds before matching the color of the appropriate square on the test strip to the free chlorine color guide. Approximately 10 test strips will be needed.

Web Resources

Water Science and Technology For Students and Educators (US Environmental Protection Agency)
Water Treatment Process (U.S. EPA)
A Public Health Giant Step: Chlorination of U.S. Drinking Water (Water Quality & Health Council)
Water Science for Schools (U.S. Geologic Survey)
Chlorine Chemistry: Essential to Health in the Developing World (American Chemistry Council)
The Secret Life of Bleach YouTube video (Google title) (American Chemistry Council)

Student Learning Outcomes

Science Process Skills

- Observing and comparing the appearance of untreated and treated water.
- Measuring free available chlorine in terms of quantitative data using colour matching methods.
- Recording of the scientific data and observations in an appropriate manner.
- Interpreting data in terms of environment and nature of the water involved.
- Asking scientific questions about water treatment and water in the environment.
- Carrying out scientific investigations by selecting and controlling variables.

Chemical Background

- Aeration as a tool in water treatment – the role of oxygen.
- Coagulation as a chemical tool to clarify water.
- Filtration as a physical tool to clarify water
- Chemical reactions that involve chlorination of water.
- The role of chlorine indicators.

Learning outcomes for Primary Classes

In primary schools the activity provides an excellent opportunity for students to use simple equipment and develop a useful skill of recording observations. No quantitative processing of data is required; should the disinfection be done as a demonstration, the teacher can assist with processing data.

The topic of water treatment is one of the important chemical ideas that is firmly embedded in students' experiences of drinking water and waterborne diseases.

It provides a good example when distinguishing between physical and chemical processes and is one of the early experiences students have with filtration.

Students can usefully learn that clear water (as in the filtrate obtained in the experiment) is not necessarily safe to drink.

Learning outcomes for Junior High School

In addition to the learning outcomes mentioned for primary schools, the role of aeration during clarification can be included. A more detailed discussion on coagulation as a chemical process and filtration as a physical process can be given.

Learning outcomes for Senior High School

The explanations can include properties of chlorine, the role of the sodium or calcium hypochlorite and the link between the experiments and industrial water treatment.

Extension Activities

Measuring turbidity (recommended for students of all ages)

Materials needed

- A flashlight.
- A flat-bottomed drinking glass.
- Samples of unfiltered water (the original untreated water), filtered water (the filtrate from the clarification) and home drinking water.

Procedure

1. Pour equal volumes of unfiltered, filtered and home drinking water into a flat-bottomed transparent drinking glass.

2. Move the glasses of water into a dark room and place them on a flat surface.

3. Place the flashlight against the side of each container and shine a beam of light through each of the samples. Look at the path of the flashlight beam.

4. How does the path of the flashlight beam through filtered water compare to that through unfiltered water? How does the filtered water compare to tap water?

5. Now pour half of the filtered water out and replace it with home drinking water. Examine the effect by shining the flashlight through the glass. How many times must you repeat this dilution before you can see no difference between the filtered water and the tap water?

Other suggestions (recommended for older students)

These activities provide students with opportunities to gain a deeper understanding of the concept of water treatment.

- Variation in free chlorine – Measurement of variation in free chlorine in swimming pool water during regular events – e.g., change in temperature, after rain etc.
- Variation in free chlorine – Monitoring of free chlorine in home drinking water over a period of time (very little variation should be measured in urban areas).
- The role of metal salts in coagulation – the role of the Al^{3+} ion.

Global Experiment for the International Year of Chemistry

Salty Waters

This document contains a description for the **Salty Waters Activity** that is part of the Global Experiment being conducted during the International Year of Chemistry, 2011.

Almost all of the water on Earth is in the form of a solution containing dissolved salts. In this activity students are invited to measure the salinity of a sample of salt water. While carrying out the analysis they will learn about the nature of solutions, including the composition of sea water. The results of their analysis will be reported to the Global Experiment Database to contribute to a global survey of salinity.

The activity can be completed as part of the set of four activities that make up the Global Experiment, or it can be completed as an individual activity to allow students to participate in the International Year of Chemistry.

Contents

Submitting Results to the Global Database

The following information should be submitted to the database. If the details of the school and location have already been submitted in association with one of the other activities, these results should be linked to previous submission.

Date sampled: ___________________________

Nature of the water: ___________________________ (sea, estuary, bore, lake etc.)

Salinity of the water: ___________________________ (g/kg)

Location sampled ___________________________ (describe the location)

Number of students involved ______________

School/class registration number ______________

Investigating Salty Waters

Water has a special place in all our lives! There is lots of it (it covers about 70% of the Earth) and more than half of your weight is water. The focus for this activity is a property of water that makes it vitally important, namely the ability to dissolve a wide range of substances. Many substances, such as sugar or salt apparently disappear when they dissolve in water, but appearances are deceptive and the sugar and salt can be recovered from solution by evaporating the water.

This activity makes use of this property to measure the amount of salt in some natural waters. Chemists measure the amounts of many of the substances that are present in water samples and we use the information to both understand how the world works and to keep us safe and healthy.

Method – Measuring Salinity by Mass

1. Collect a sample, (at least 100 mL) of seawater or other water with a significant salt content.
   (If appropriate, this can be the same sample as used for the pH of the Planet activity.)
2. Weigh the dish as accurately as possible and record the result on the Results Sheet, m_D.
3. Measure the volume of about 100 mL of water as precisely as possible and place it in the dish, V_W
4. Weight the dish and water together, m_{D+W}.

Equipment

- Shallow glass or plastic dish or Petri dish (preferably clear to make it easy to see the salt).
- Cover for the dish that allows air circulation.
- Graduated measuring cylinder or jug.
- Balance that can weigh to 0.1 g with the capacity to weigh the dish and water (see method).

Evaporate the water by one of two methods:

5. EITHER - **Solar evaporation**: place the dish in full sunlight and, if necessary to prevent dust, cover it with a transparent cover that allows the air to circulate. It may take a day or more to evaporate so monitor it periodically.
6. OR – **Hotplate evaporation**: Heat a hotplate to about 80°C and place the dish on it. Monitor the process periodically, making sure the water does not boil and splatter

Dryness check – carry out this check to ensure the sample is dry. This process is called drying to constant weight.

7. Weigh the dish with the salt and record the result on the Results Sheet.
8. Return the dish to the sunlight, or the hotplate, and leave it for 15-30 minutes.

9. Allow it to cool and reweigh it, recording the result.
10. If the second weight is less than the first, repeat the process once more and record the results.
11. Continue the process until the weight does not change.
12. The final weight is the mass of the dish and salt, m_{D+S}.

Calculating salinity

13. First calculate the amount of salt by taking the final mass of the dish with the salt and subtracting the initial mass of the dish using the formula:

$$\text{mass of salt} \qquad m_S = m_{D+S} + m_D \quad \text{(g)}$$

14. Now calculate the mass of saltwater in the experiment:

$$\text{mass of saltwater} \qquad m_{SW} = m_{D+SW} - m_D \quad \text{(g)}$$

15. Finally calculate the salinity using the formula for the salinity:

$$\text{absolute salinity} \qquad S = \frac{m_S}{m_{SW}} \times 1000 \quad \text{(g/kg)}$$

This is the value that you should give to your teacher to contribute to the class average which will be entered in the Global Database!

Optional Activity – Measuring the salinity of other samples

If other samples of water are available for testing, repeat the salinity measurement procedure for one of the other samples.

Optional Activity – Measuring the salinity using a conductivity meter

If a conductivity meter is available it can be used to provide a complementary measurement of the salinity. Check with your teacher.

Results Worksheet

Record the results of your salinity analysis in the following table and then answer the questions below:

			Saltwater sample	Other sample (optional)
Mass of dish	m_D	(g)		
Volume of saltwater	V_{SW}	(mL)		
Mass of dish and water sample	m_{D+SW}	(g)		
Drying to constant weight				
Mass of dish and salts – 1st test		(g)		
Mass of dish and salts – 2nd test		(g)		
Mass of dish and salts – 3rd test		(g)		
Final mass of dish + salts	m_{D+S}	(g)		
Calculations				
Mass of salt	$m_S = m_{D+S} - m_D$	(g)		
Mass of saltwater	$m_{SW} = m_{D+SW} - m_D$	(g)		
Absolute salinity	$S = \frac{m_S}{m_{SW}} \times 1000$	(g/kg)		
Density	$\sigma = \frac{m_{SW}}{V_{SW}}$	(g/mL)		
Optional - Conductivity Test				
Salinity from conductivity		(psu)		

Question 1

Examine the dish containing the salt and see if you can see signs of crystals. Crystals glint in the light because they have flat faces that reflect light when they are big enough. You can often see the crystals better with a hand lens of simple microscope.

Describe the appearance of the salt in your dish.

Question 2

Compare the value of the salinity of your sample with the class average. Can you explain any factors that may have contributed to the difference in values?

Question 3

If you have been studying a seawater sample, compare your class average value to the common value for seawater of 3.5% salt by weight. Identify any possible reasons why the class value might differ from the average.

(If you have been investigating a different type of water, look up common values and comment of the relationship to your measurement.)

Question 4

When you swim in salt water how can you tell that it is more dense than pure water which is slightly less than 1 g/mL at 20^{o}C.

International Year of CHEMISTRY 2011

Class Results Sheet

Record students' average absolute salinity values for the saltwater sample being tested for the Global Experiment (and other water samples if appropriate - see teacher notes). Record the ancillary data ready for submission to the Global Experiment Database.

		(Optional) Other samples tested by class				
Group	**Saltwater sample**	A	B	C	D	E
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
Average						

- Location of water sampling: ___________________________
- Nature of water: ___________________________
- Date sampled: ___________________________
- Temperature: ___________________________
- Number of students involved: ___________________________

Teacher's Notes

Instructions for the Activity

The following notes have been written to assist teachers implement the Salty Waters activity with their classes. It is hoped that the activity will be used together with the other Global Experiment activities and in conjunction with local resources that help students understand water, its chemistry and its vital role in our lives and its importance on Earth. But the activity will be equally useful if carried out on it own to provide students with the experience of collaborating with their colleagues around the world.

In the activity students are invited to explore the nature of solutions and focus on dissolved substances, the solutes. In both this activity and the Solar Still Challenge, they use the process of evaporation to separate components of the solution. In this case, wherever possible, they will use marine or other naturally salty waters and will measure the amount of salt in the water, its salinity.

Learning Outcomes

During the activity students will:

- Explore the properties of water solutions containing salts.
- Use the process of evaporation to extract the salts from solution.
- Measure the concentration of salts in a water sample and use the a class average to estimate the quality of the measurement.
- (Optional) Explore other methods of measuring salinity and the process of crystalisation.

Planning the Activity

A strategy using students working in pairs is often a successful way of carrying out this type of activity as it halves the amount of equipment required while students support each other. The activity can be carried out in a single 1-2 hour period if the a source of heating such as a hotplate is used, or, if the water is allowed to evaporate in the sun, it is best completed on over two days.

When selecting the dishes for the evaporation, dishes with a large diameter will allow the water to evaporate quickest. 15 cm diameter Petri dishes work well as do plates with a comparable diameter. Check that the weight of a dish plus water can be measured successfully on the balance. The greater the mass of water used, the more precise the measurement will be, but also the longer the evaporation time.

Carrying out the Activity

The activity has been designed in three parts:

- Initially students set up the experiment, measuring the mass of the dish they are using, the volume of the salty water they are adding and the combined mass of the water and the dish. Students can increase the precision of their measurements if they measure each value several times and practice the transfer processes to minimise losses.

- The length of time required for the evaporation part of the activity depends critically on the local conditions. Pre-testing the length of time required for the equipment that students will use will ensure the experiment goes smoothly.

  One of the biggest sources of error in the measurement occurs if the sample is not completely dry, even when it appears dry. For this reason the standard analytical method of drying to constant weight is recommended. Carrying out this procedure is useful to students appreciate the care needed to get good results. However, younger students particularly may be confused by the procedure and it can be avoided if the time to get to get the sample completely dry is pre-tested.

- The third part involves carrying out the calculation. The method described has been written for upper primary and lower secondary school students and should be adapted for use by other groups. Normally repetition of measurements would be recommended to check the quality of the results, but in this case the length of time for the measurement would make this arduous and the repetition is achieved through the averaging of all the individual results in the class. At the same time this means that all students contribute to the result that is posted to the Global Experiment Database.

Water Samples

Seawater samples are particularly good for this activity because the amount of salt in seawater is readily measurable, usually around 3.5% which means that students using 100 mL water samples are measuring masses of salt between 3 and 4 g. Samples collected from the sea, or from estuaries will work well.

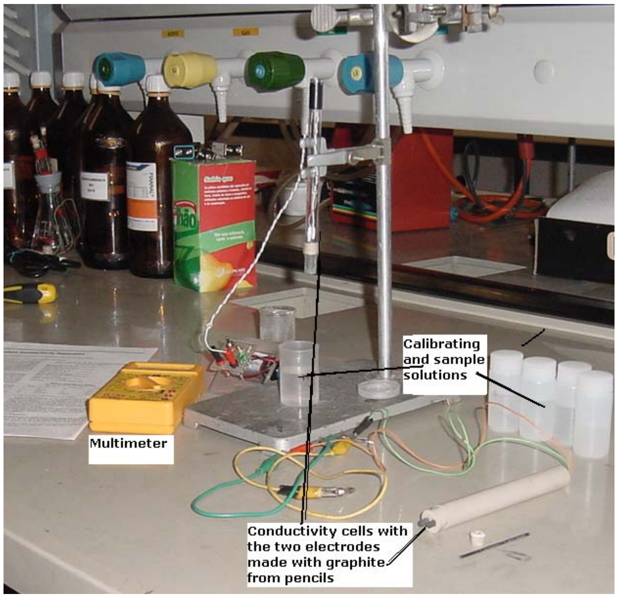
Samples from sources that are usually regarded as fresh water and likely to have much smaller salt contents. In these cases it may be appropriate to make up a “synthetic” seawater with 35 g of table salt (sodium chloride) per litre of water. Students can then test the method on the synthetic seawater before they attempt to measure their local water source.

Filtration: In the case of waters with visible suspended matter, filtration is recommended before evaporation

Optional Activities

Other Water Samples

Students can explore the salinity of other water samples to get an understanding of how much salinity changes in different common liquids such as the normal saline solutions used in medicine. Students can be invited to bring samples of everyday solutions to test in which case students can each test different samples so that the class gets the results for a range of solutions to discuss. (However care has to be taken to check whether the samples contain significant amounts of dissolves substances that are not salts.)



Measuring the Salinity using a Electrical Conductivity Meter

If your school has conductivity meters students can get a second source of salinity data to compare with the evaporation experiment.

Simple qualitative conductivity meters can be readily made from general laboratory equipment to demonstrate that salt solutions conduct electricity and that the current is proportional to the salt concentration.

Calibration has to be performed with seawater of known salinity or an equivalent potassium chloride solution. The assessed value is thus relative and salinity is expressed in dimensionless Practical Salinity Units, PSU.

Levels of Explanation

Primary School

In primary schools the activity provides an excellent opportunity for students to use simple equipment and develop useful skills of recording observations. The calculations need to be presented in an appropriate way to suit the class.

The topic of water quality and availability is one of the important chemical ideas that should be firmly embedded in students' experiences of drinking water and waterborne diseases.

The activity helps students learn that clear water may contain various substances, useful or harmful, in different concentrations, and that appropriate means can be used for their separation.

The activity also gives students the opportunity to learn about changes of states that occur in Nature and identify processes such as evaporation and crystallisation. The activity is also an opportunity to create awareness to the mineral resources that may be obtained from aquatic systems.

Junior High School

In addition to the learning outcomes mentioned for primary schools, students can utilize they developing knowledge of algebra in the calculations and explore the proportionality involving volume and mass in the determination of concentrations and densities..

The topic of the units, namely SI, for expressing the various quantities can appropriately be discussed here.

The concepts of soluble and insoluble substances, solutions and solubility should be examined. The process of crystal formation should be discusse. This can be extended to redisolution followed by recrystallization as an optional activity associated with crystal growing.

A more detailed discussion of changes of state can be held, involving particle theory and the concepts of heat, temperature and vapour pressure.

Senior High School

The quantitative approach brings the opportunity for students to explore the significant figures associated with the values of the measured and calculated quantities.

The activity can be expanded to the chemical identification of some of the species in solution, namely sodium chloride, by writing simple chemical reactions.

It is appropriate to introduce the concepts of amount of substance, concentration and stoichiometric coefficients and to practice writing chemical formulae and chemical equations.

The use of electrical conductivity meters is particularly recommended to illustrate different possible approaches to acquiring quantitative data.

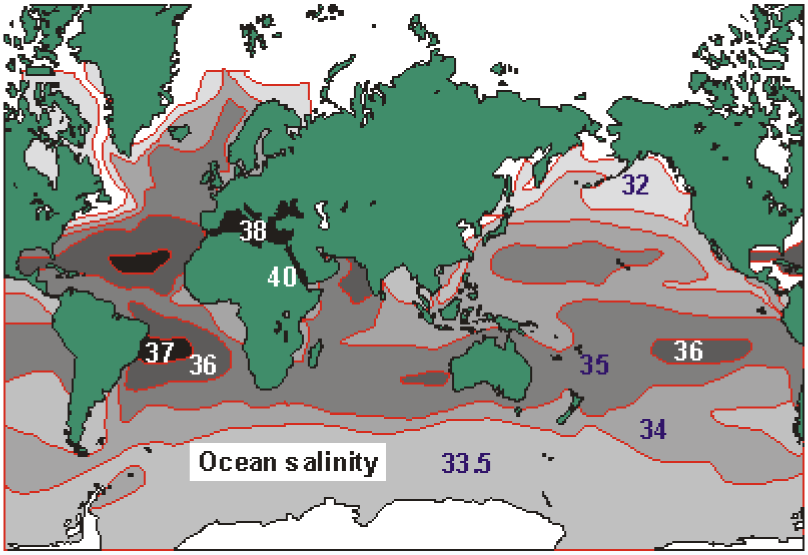
Background Information

The ocean is naturally saline at approximately 3.5% salt. **Salinity** is a measure of the dissolved salts in water, i.e. the amount of salts (in grams) dissolved in 1000 grams (1 kilogram). This is the **absolute salinity, S** (g/kg) of seawater. The symbol ‰ is also used meaning parts per thousand.

The composition of seawater is quite complex and a range of salts exist in significant amounts. All salts are made up of ions such as the sodium and chloride ions in sodium chloride. In water all the ions separate and so the ions exist independently in seawater (Table One).

Table 1 Typical Concentrations of Ions in Seawater

Ion	g/kg
Chloride Cl^{-1}	19.345
Sodium Na^{+1}	10.752
Sulfate SO_4^{-2}	2.701
Magnesium Mg^{+2}	1.295
Calcium Ca^{+2}	0.416
Potassium K^{+1}	0.390
Bicarbonate HCO_3^{-1}	0.145
Bromide Br^{-1}	0.066
Borate BO_3^{-3}	0.027
Strontium Sr^{+2}	0.013
Fluoride F^{-1}	0.001



Methods for measuring salinity

The first method recommended for measuring salinity was the chemical, Knudsen-Mohr, method based on the volumetric analysis of chloride, Cl^- , bromide, Br^- and iodide, I^-. The method involves the precipitation of the ions with silver nitrate, $AgNO_3$ (aq). The mass of the precipitate can then be measured and the concentration of chloride ion calculated.

The first empirical equation converting this measure of chlorinity (Cl ‰) to absolute salinity, S ‰, dates from 1902: S= 0,03 + 1,805 (Cl). For zero chlorinity, the salinity would not be zero, which goes against the Principle of Constant Proportions. To overcome this contradiction, in 1969 UNESCO proposed a new relation: S = 1,80655 (Cl). A salinity of 35 ‰ corresponds to a chlorinity of 19,374 ‰.

The electrical conductivity of water can also be taken as a measure of its ionic composition and, hence of its salinity. The instrumental method is based on the comparison of the conductivities of the water sample and conductivity standards, assuming proportionality between conductivity and salinity. Potassium chloride solutions, KCl (aq), are used as conductivity standards.

In 1978, oceanographers redefined salinity in **Practical Salinity Units** (**psu**) in which the conductivity ratio of a sea water sample to a standard KCl solution is measured. Ratios have no units, so 35, is equivalent to 35 ‰. Standard saline waters of known conductivity have been developed to work as standards in the calibration of salinometers which are specially designed conductivity meters used to assess the salinity of seawater.

Assessment of high quality salinity values has become of particular relevance and is of worldwide concern, due to the main role that salinity takes, in the context of current environmental problems associated with global climate change.

Sample Results - Results Worksheet

Record the results of your salinity analysis in the following table and then answer the questions below:

			Saltwater sample	*Normal saline*
Mass of dish	m_{D}	(g)	*73.2*	*74.5*
Volume of saltwater	V_{SW}	(mL)	*102*	*97*
Mass of dish and water sample	$m_{\text{D+SW}}$	(g)	*178.5*	*172.1*
Drying to constant weight				
Mass of dish and salts – 1st test		(g)	*78.5*	*75.7*
Mass of dish and salts – 2nd test		(g)	*77.0*	*75.7*
Mass of dish and salts – 3rd test		(g)	*77.0*	
Final mass of dish + salts	$m_{\text{D+S}}$	(g)	*77.0*	*75.7*
Calculations				
Mass of salt	$m_{\text{S}} = m_{\text{D+S}} - m_{\text{D}}$	(g)	*3.8*	*1.2*
Mass of saltwater	$m_{\text{SW}} = m_{\text{D+SW}} - m_{\text{D}}$	(g)	*105.3*	*97.6*
Absolute salinity	$S = \frac{m_S}{m_{SW}} \times 1000$	(g/kg)	*36*	*12*
Density	$\sigma = \frac{m_{SW}}{V_{SW}}$	(g/mL)	*1.03*	*1.01*
Optional - Conductivity Test				
Salinity from conductivity		(psu)		

Question 1

Examine the dish containing the salt and see if you can see signs of crystals. Crystals glint in the light because they have flat faces that reflect light when they are big enough. You can often see the crystals better with a hand lens of simple microscope.

Describe the appearance of the salt in your dish.

Most of the material in the dish was powdery and slightly brown coloured. Some of the material in the middle of the dish had bigger bits that glittered when we shone a torch at them.

Question 2

Compare the value of the salinity of your sample with the class average. Can you explain any factors that may have contributed to the difference in values?

The class average for the saltwater sample 36.7 g/kg which was slightly higher than our value. But a lot of other groups got numbers that were not as close.

Question 3

If you have been studying a seawater sample, compare your class average value to the common value for seawater of 3.5% salt by weight. Identify any possible reasons why the class value might differ from the average.

(If you have been investigating a different type of water, look up common values and comment of the relationship to your measurement.)

Our class value showed that the salinity was very close to the normal value seawater. The slightly high value might be because the sample was taken in a shallow area where the water was very warm so more water may have evaporated.

Question 4

When you swim in salt water can you tell that it is more dense than pure water. (which is slightly less than 1 g/mL at 20°C).

Yes because it is easier to float in the sea than in fresh water.

Global Experiment for the International Year of Chemistry

Solar Still Challenge

This document contains a description for the **Solar Stills Challenge Activity** that is part of the Global Experiment being conducted during the International Year of Chemistry, 2011.

In this activity students will make a solar still and measure its efficiency. They will develop their understanding of water in liquid and gaseous states and how distillation can be used to purify water. They will be challenged to design and make a more efficient still. A diagram and photograph of the most efficient solar still made in their class will be reported to the Global Experiment Database together with the efficiency data.

The activity can be completed as part of the set of four activities that make up the Global Experiment, or it can be completed as an individual activity to allow students to participate in the International Year of Chemistry.

Contents

Submitting Results to the Global Database

The following information should be submitted to the database. If the details of the school and location have already been submitted in association with one of the other activities, these results should be linked to previous submission.

Date sampled: ___________________________

Nature of water: ___________________________ (tap, river sea, etc.)

File Name of diagram: ___________________________

File Name of Photograph: ___________________________

Efficiency of the still: ___________________________

Number of students involved ______________

School/class registration number ______________

Solar Still Challenge

The Challenge

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

Water covers most of the Earth (about 70%), but almost all of it is in the oceans and is salty. Much of the water on land or in the ground is also salty or otherwise unsuitable for human use. The challenge of finding ways to purify water is increasing with human population.

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

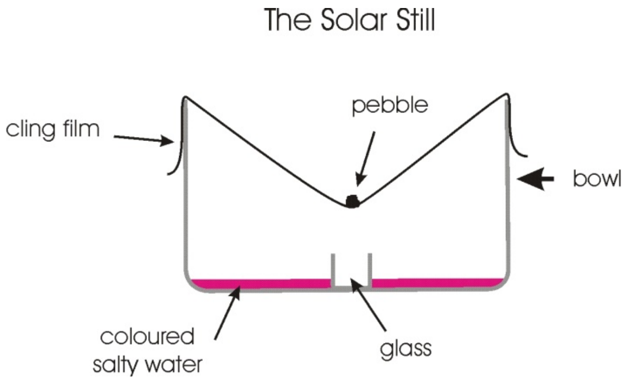
(*An alternative method for Part A for classes with access to laboratory equipment is included at the end of the document*.)

Method - Part A – Building a Solar Still

Equipment

- Large metal or plastic bowl
- Small, shallow glass or cup (clean)
- Measuring jug or cylinder
- Cling film (wider than the bowl)
- Small stone (pebble)
- Hot water
- Food dye and salt

1. Add a measured volume of hot water (about 1 cm) to the bowl.
2. Add some food colouring and about a teaspoonful of salt to the water in the bowl.
3. Take all the equipment out to a sunny, level place.
4. Place the glass or cup in the middle of the bowl making sure no water splashes into it.
5. Cover the bowl loosely with cling film, sealing the film to the rim of the bowl. (Use tape or string if necessary.)
6. Place the stone in the middle of the film above the cup.
7. Leave the still for at least an hour (the longer the better) and then check that there is some water in the cup.
8. Take the still back indoors, remove the cling film and take out the cup without splashing any water into or out of the cup.
9. Measure the amount of water in the cup.
10. Observe the colour of the water in the cup and test it for salt.



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

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

12. Look at your results and see if you can explain what happened to the water. Why is it called “purified water”? Write your suggestions on the Results Sheet under Question One.

Part B – The Design Challenge

Your challenge is to modify or make a more efficient solar still than the one that you made in Part A.

13. Write down some ideas about how you might improve the still. For example you might try using different coloured containers to find out which absorbs the sunlight most efficiently.
14. Discuss your ideas with your teacher and get his/her permission to carry out the experiment.
15. Carry out the experiment recording the volume of water you start with and the volume you purify.
16. Calculate the % water purified and record it on the Results Table.
17. If you have time, you can develop your design further. Make sure you get permission from your teacher for each experiment you carry out.
18. Draw a diagram of your most efficient still showing why it is more efficient than your first still. Take a photo of your still if you can.
19. Complete the other questions on the Results Sheet.
20. Hand in your results to your teacher so that the most efficient still can be selected and uploaded to the Global Experiment Database.

Student Results Sheet

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

Trial	Volume of water added (mL)	Volume collected (mL)	% water purified
Part A – First still			
Part B –			

Part A

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

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

Part B

3. Explain the design for a still that will work more efficiently than the still you made in Part A and then discuss your ideas with your teacher.

4. (After you have finished testing your new still.)
Draw a diagram to show how your new still works.

5. Paste a photograph of your new still here:

Teacher's Notes

Instructions for the Activity

Two different approaches to the activity are presented in this document. The first is appropriate for all students, uses household items for making the still and is simple to make and use. The second is appropriate for more advanced students who have access to laboratory glassware and resources.

Solar Still Challenge

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

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

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

Safety

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

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

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

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

- At the completion of the activity collect the work from all the groups that have completed the challenge and select the winning entry for the challenge. If appropriate this can be made into a culminating event for the **Global Experiment** and the class can be involved in the selection.

The diagram (and an accompanying photograph) of the still producing the highest yield in the class should be submitted to the Global Experiment Database.

Learning Outcomes

During the activity students will:

- Learn about the liquid and gaseous state of matter (water) and their inter-conversion (evaporation and condensation).
- Learn about the use of the process of distillation to purify water.
- Develop an appropriate level of scientific explanation for the distillation process.
- Use their knowledge about distillation to carry out a technology process improving the efficiency of a solar still.

Hints for making the solar still work well Part A:

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

Arranging the design challenge Part B:

This is an opportunity for students to use their ingenuity to improve the efficiency of the solar still. At the same time students learn about the relationship of technology to science. The technological process usually requires criteria on which the technological product can be judged.

In this case, the criterion for the design challenge should be clearly explained. The simple criterion of % water purified is a good start for primary school students but should be made more sophisticated for older students. For example the criteria might specify the time length of water collection.

An attractive range of factors can be explored by students including:

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

How the Still Works

Summary

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

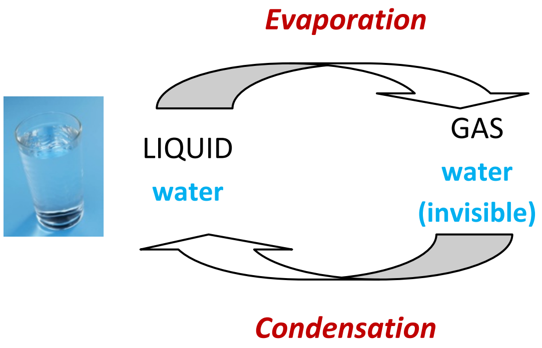
The purification works because both the salt and the food dyes do not evaporate.

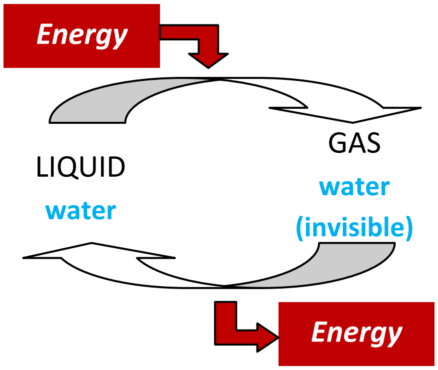
A deeper level of explanation is available if the students have been introduced to the particle nature of matter and the concept of energy:

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

Background

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





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

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

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

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

At the molecular level, salts are made up of ions and very large amounts of energy are needed to separate ions, making evaporation almost impossible. In the case of food dyes, the molecules are large and ionic and so are similarly involatile.

Water is less volatile than alcohol (ethanol), which appears surprising because water molecules are less massive than alcohol molecules. However water molecules stick together particularly strongly. Chemists call this interaction hydrogen bonding and it is responsible for many of the important properties of water. In the case of evaporation, because of the many hydrogen bonding interactions between water molecules more energy is requ

Addressing the Challenge

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

Sample Results - Student Results Sheet

(*Grade 7 student sample*)

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

Trial	Volume of water added (mL)	Volume collected (mL)	% water purified
Part A – First still	*100*	*12*	*12*
Part B – *Second trial 1st still*	*50*	*16*	*32*
Third trial 1st still	*50*	*22*	*44*
Second still	*50*	*27*	*54*

Part A

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

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

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

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

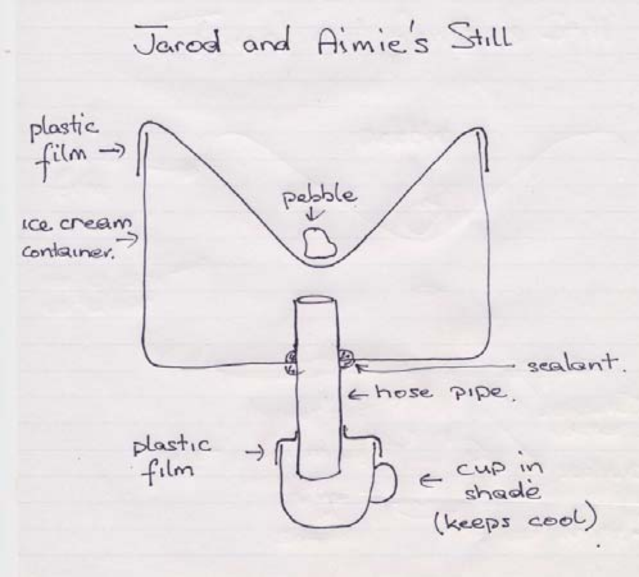
Part B

3. Explain the design for a still that will work more efficiently than the still you made in Part A and then discuss your ideas with your teacher.

First we tried to make the still more efficient by using less water so it heated up quicker and then we made sure that the water was warm before we started. Both changes made the still work more efficiently.

Then we cut a hole in the bottom of the container (an ice cream carton) and put a piece of hosepipe through the hole. We stopped it leaking with sealant, and then collected the water in a cup that was kept cool in the shade of the container. Then we were able to collect more than half of the water we started with.

4. (After you have finished testing your new still.)
Draw a diagram to show how your new still works.



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

5. Paste a photograph of your new still here:

(See below for an example of a still constructed using laboratory glassware.)

An Alternative Design for the Solar Still Using Laboratory Equipment

If access to laboratory equipment is available, there is scope for students to make a greater range of designs. For example, the following method describes a design that utilises a large funnel and a Petrie dish.

(The design allows the students to complete the salinity measurement **Activity Three – Salty Waters**. See below.)

Equipment

- A large surface dish, e.g. Petri dish, Ø= 15 cm.
- A glass funnel, Ø= 15 cm.
- A rubber stopper to fit the funnel's outlet.
- A plastic tube, Ø= 2 cm, 50 cm long.
- A sheet of black plastic.
- Adhesive tape.
- A measuring cylinder for measuring the water volumes.

Method

- Take the glass funnel and close its outlet with the rubber stopper.
- Take the plastic tube and cut it along its 50 cm length.
- Fit the plastic tube around the funnel's edge.
- Add a measured volume of water to the Petrie dish (about 100 mL is suitable).
- Cover the Petri dish with the inverted funnel and seal with adhesive tape.
- Place the Petri dish on the black sheet.
- Place in sunlight until the level of water in the Petrie dish has changed significantly.
- Carefully remove the funnel and take out the tube where the evaporated water has condensed.
- Pour this desalinated water into a beaker or the graduated cylinder and measure the volume.
- Calculate the percentage of the water that was collected.

Notes

1. This method replaces **Part A - Building a Solar Still** described earlier.
2. This still can also be used for the investigation of salinity outlined in the **Salty Waters Activity**. The activities can either be carried out sequentially, or combined, in which case the **Salty Waters** method should be employed.