MICROSCALE GLOBAL WATER KIT INSTRUCTIONS

Global Experiment for the International Year of Chemistry

No Dirt, No Germs!

(How Water Treatment helps us)

Overview of the Water Treatment Activity

The title **"No Dirt, No Germs!"** refers to one or both of the main steps of drinking water treatment, namely **water clarification** and **water disinfection**. Starting with natural surface waters obtained from the surroundings, and using mostly commonly available materials or the Global Water Kit, students will replicate these two steps in water treatment. Younger students will clarify natural surface water and readily observe the effects of clearing water of solid debris. For younger students, disinfection can be done by the teacher. Older students will both clarify and disinfect natural water.

Background to the Water Treatment Activity

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. Although waterborne diseases, such as typhoid fever and cholera, were still killing millions of people throughout the world, a new era of better public health was beginning. As we celebrate the International Year of Chemistry 100 years after Madame Curie received her award, waterborne diseases 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, namely clean drinking water.

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 the previous submission.

Date the water was sampled:

Name of local water source:

Minimum number of drops of disinfectant needed to reach a stable "free available chlorine level":

Nature of water: (fresh or estuarine)

Water temperature: (water temperature when collected)

Number of students involved

School/class Registration number

MICROSCALE GLOBAL WATER KIT INSTRUCTIONS

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Instructions for the Activity (Teacher)

Experiment Outline

Drinking water chlorination represents a smart use of chemistry in our everyday lives. Small amounts of chlorine 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.

Interesting Fact: According to historians, Alexander the Great, ruler of most of the known world 1,000 years ago, was among the millions of victims of waterborne diseases.

Students should work in small groups (4 – 6 students, or pairs if numbers permit) to treat dirty water from a natural local source. The experiment carries out one or both of the main steps of water treatment: clarification and disinfection.

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 dissolved in the water to escape and adds oxygen to the water, which will help to kill germs.

2. **Coagulation** is the process by which dirt and other floating solid particles chemically "stick together" into flocs (clumps of dissolved 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.

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).

Thereafter, to get clean drinking water,

- **Disinfect** the water sample using a chlorine-based disinfectant.

Lastly, to complete the activity,

- **Analyze** the data and report results online to the Global Experiment Database.

Students' Instructions

Materials needed for Water Clarification

Collect the following:

- 200 – 500 mℓ of "dirty" natural water. The water can be collected from a stream, pond, river or swamp (or you can add 2 – 3 teaspoons of dirt or mud to a cup of water and stir it well). Don't try to collect "clean" water – the water should be murky.
- 1-2 teaspoons washed and dried fine sand (± 1mm grain size).
- 1-2 teaspoons washed and dried coarse sand (maximum 5mm grain size).
- A clock with a second hand or a stopwatch, if possible.

Components from the Global Water Kit:

- 2 large sample vials with lids
- 2 x 2,5 mℓ disposable plastic syringes
- Comboplate
- Microstand with cross-arm
- A small piece of cotton wool
- 1 microspatula
- 2 propettes
- 1 plastic teaspoon

Chemical from the Global Water Kit:

- Crystals of alum in plastic bag (potassium aluminium sulfate).

Safety Precautions

The water in this activity is not safe to drink and direct contact with water, alum and disinfectant should be avoided. Wash your hands with soap and water after doing the activity.

Procedure for Water Clarification

1. Shake/stir your dirty water sample. Pour enough of your dirty water into one of the large sample vials to fill it ¾ full. Describe the appearance and smell of the water, using the Students' Observation Sheet for Water Clarification.

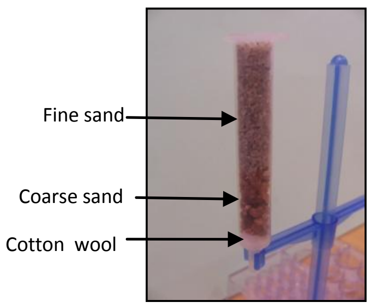
2. Place the lid on the sample vial and vigorously shake the vial for 30 seconds. Continue the aeration process by pouring the water into the second sample vial, then pouring the water back and forth between them about 10 times. Once aerated, any bubbles should be gone.

3. Use the thin end of the microspatula and add one large crystal (or two small crystals) of alum to the aerated water. Slowly stir the mixture for 5 minutes, using the back end of the plastic teaspoon. 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 vial (see photo on the right). Observe the water at 5 minute intervals for a total of 10 minutes. This (water + alum) sample is needed for the filtration stage.

5. 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.

6. Construct a sand filter in one of the disposable syringes (see illustration to the left):



a. Remove the plunger from one of the syringes and put it to one side.

b. Use the comboplate and the microstand to support the syringe.

c. Put a small piece of cotton wool in the bottom of the syringe. The cotton wool should be pulled apart so that you have a thin layer of cotton wool. If the layer is too thick, the filter won't work properly. Use a pen or pencil and lightly tap the cotton wool into position

d. Use the back end of the teaspoon to pour the coarse sand on top of the cotton wool, up to the 1,5 mℓ mark. It doesn't matter if there are spaces between the grains of sand.

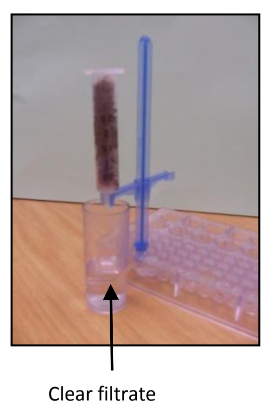
e. Pour the fine sand on top of the coarse sand, to fill the syringe, leaving a space of approximately 1mm at the top. You don't need to press in the sand tightly.

f. Clean the filter by slowly and carefully adding clean drinking water using a propette. Throw away the water that has passed through the filter.

7. Clean the second sample vial with clean drinking water. You are going to use it to collect the water which has been filtered.

8. After a large amount of sediment has settled on the bottom of the sample vial containing your (water + alum), use a clean propette to suck up some of the water/alum mixture from just below the liquid surface. Add the water/alum mixture to the filter in the syringe. Be careful not to disturb the sediment. Filter approximately ¾ of the water and alum mixture.

9. Collect the filtered water in the clean sample vial.



10. Compare the treated and untreated water. How has treatment changed the appearance and smell of the water?

11. Keep the filtered water for disinfection (for younger students, your teacher will do this step for you).

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 "free available chlorine" and it can be detected using chlorine test strips.

Materials needed for Water Disinfection

Your filtrate from the Water Clarification step

Components from the Global Water Kit:

- Chlorine test strips and colour chart
- One propette containing calcium hypochlorite solution
- 1x 2,5 mℓ disposable plastic syringe
- A clock with a second hand or a stopwatch

Warning:
Do not drink the water from this experiment.

Chemical:

- A solution of calcium hypochlorite (collect this from your teacher in the propette)

Procedure for Water Disinfection

(Based on U.S. Environmental Protection Agency activity at: http://www.epa.gov/ogwdw000/kids/grades_4-8_water_filtration.html)

1. Use the syringe and add 2mℓ of filtrate from the filtration activity to a large well in the comboplate.

2. Dip a chlorine test strip into the clear liquid and use the product colour-code chart to estimate the "free available chlorine" level of the liquid. Record the results on the Students' Result Sheet for Water Disinfection.

3. Add 2 drops of calcium hypochlorite solution to the filtered liquid, stir gently for 5 seconds with a microspatula, and repeat the test strip reading immediately. Use a new chlorine test strip for each chlorine measurement. Record your results. (If no free chlorine was detected now, proceed directly to Step 5).

4. Wait 10 minutes WITHOUT ADDING MORE CALCIUM HYPOCHLORITE and again record the "free available chlorine" level.

5. If less than 1ppm free chlorine level is measured after 10 minutes (Step 4), add 2 more drops of calcium hypochlorite and measure the free chlorine after stirring. Wait 10 minutes and measure “free available chlorine” again.

6. Repeat Step 5, adding 2 additional drops of calcium hypochlorite at a time until a “free available chlorine” level reading of at least 1 – 3 parts per million can be measured 10 minutes after chlorine addition.

Students' Observation Sheet for Water Clarification

1. Complete the following table for the "dirty" water you have collected:

Date of water sample collection	
Temperature of water when collected	…………..°C
Type of water (pond, river, stream or swamp)	
Describe where you found the water	
Fresh or from a river mouth	
Appearance and smell of the "dirty" water before treatment	

Describe the appearance of the water:

Immediately after the alum was added.	
5 minutes after the alum was added	
10 minutes after the alum was added	

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

3. Do you think your treated water is now safe to drink? Give a reason for your answer.

Students' Results Sheet for Water Disinfection

Date of water sample collection	
Temperature of water when collected	…………..°C
Type of water (pond, river, stream or swamp)	
Describe where you found the water	
Fresh or water from a river mouth	

Free Available Chlorine Observation Table
(Complete a separate table for each water sample)

Filtered water/ Total number of drops of calcium hypochlorite solution added	**Free Available Chlorine**		
	YES/NO	**Colour of chlorine test strip**	**Free available chlorine/ parts per million**
No calcium hypochlorite solution added			
+2 drops calcium hypochlorite solution			
+2 drops calcium hypochlorite solution left for 10 minutes			
+4 drops calcium hypochlorite solution in total			
+4 drops calcium hypochlorite solution in total left for 10 minutes			
+6 drops calcium hypochlorite solution in total			
+ 6 drops calcium hypochlorite solution in total left for 10 minutes			

Do you think your treated water is now safe to drink? Give a reason for your answer.

Teacher's Notes

Using the activity with your students

This activity has been written so that it can 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 background information for the activity and suggestions for extension 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 treatment appropriate for their class.

Learning outcomes range from using simple equipment and making and recording observations for younger students to an introduction to and contrast between physical and chemical transformations for older students. The activity lends itself to discussions of the value of science to public health and the need to extend water treatment technologies to developing countries.

Teacher's Summary of School Results

Free Available Chlorine Observation Table
(Summarizing results from a school)

NAME OF SCHOOL: ______________________________
____
____

LOCATION OF SCHOOL: ______________________________
____

NUMBER OF STUDENTS: ______________________________

Type of water	Description of water source	Average minimum number of drops of disinfectant added to 2 ml of filtered water before free chlorine was detected after 10 minutes
1.		
2.		
3.		
4.		

Teacher's Summary of School Results - Sample

Free Available Chlorine Observation Table (Summarizing results from a school)

NAME OF SCHOOL: Izingolweni Primary School
LOCATION OF SCHOOL: Izingolweni Township, KwaZulu Natal SOUTH AFRICA

NUMBER OF STUDENTS: 200

Type of water	**Description of water source**	**Average minimum number of drops of disinfectant added* before free chlorine was detected after 10 minutes**
1.River water	Impenjati river, KwaZulu Natal, South Africa	7
2.Spring water	Spring in the nearby hills	2
3.Pond water	Pond outside the school, near the vegetable garden	10
4.Tap water	From the teacher's home in Margate Town	0

* 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.

Sample of Students' Observation Sheet for Water Clarification

1. Complete the following table for the "dirty" water you have collected:

Date of water sample collection	15 October 2010
Temperature of water when collected	20°C
Type of water (pond, river, stream or swamp)	Pond
Describe where you found the water	Len Rutter Park, Florida, South Africa
Fresh or water from a river mouth water	Fresh
Appearance and smell of the "dirty" water before treatment	No smell, but some fine sediment. A few pieces of floating plant material. No insects or moving organisms.

Describe the appearance of the water:

Immediately after the alum was added.	Large suspended flocs form
5 minutes after the alum was added	The larger flocs have settled, some small flocs are still suspended
10 minutes after the alum was added	The top 1cm of the water is entirely clear

2. There is a big difference between the treated and untreated water. Visibly, the treated water is yellow-brown, but essentially transparent. The untreated water is darker brown and muddy. The treated water smells a better than the untreated water, less sulfurous.

3. I would not want to drink the treated water and I don't think it is safe to drink because of the things I can still see in the water, such as a few very small animals darting around. The water must also have some germs in it, which would probably make me sick.

Sample of Students' Observation Sheet for Water Disinfection

Date of water sample collection	15 October 2010
Temperature of water when collected	20°C
Type of water (pond, river, stream or swamp)	Pond
Describe where you found the water	Len Rutter Park, Florida, South Africa
Fresh or estuarine water	Fresh
Appearance and smell of the "dirty" water before treatment	No smell, but some fine sediment. A few pieces of floating plant material. No insects or moving organisms.

Free Available Chlorine Observation Table
(Complete a separate table for each water sample)

Filtered water/ Total number of drops of disinfectant added	**Free Available Chlorine**		
	YES/NO	**Colour of chlorine test strip**	**Free available chlorine/ parts per million**
No calcium hypochlorite solution added	no		0
+2 drops calcium hypochlorite solution*	yes		3.0
+2 drops calcium hypochlorite solution. Left for 10 minutes	no		0
+4 drops calcium hypochlorite solution.	yes		5.0
+4 drops calcium hypochlorite solution. Left for 10 minutes	yes		3.0

I do not think the water is completely safe to drink now. I think there are still germs in the water that can multiply over time.

Notes to teacher:

* If there is no free available chlorine immediately after disinfection addition, there is no purpose in waiting 10 minutes and measuring free available chlorine again.

** For this particular sample, a value of 4 drops will be reported to the Global Experiment Database.

To get more accurate results, the experiment can be repeated a number of times, depending on availability of filtrate and chlorine test-strips. If needed, drops of disinfectant can be added in increments of one drop at a time.

Additional Information about the Experiments

Safety Precautions

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. Students should wash their hands with soap and water after doing the activity.

Materials and Equipment Listing

Materials needed for Water Clarification

Collect the following:

- 200 – 500 mℓ of "dirty" natural water. The water can be collected from a stream, pond, river or swamp (or you can add 2 – 3 teaspoons of dirt or mud to a cup of water and stir it well). Don't try to collect "clean" water – the water should be murky.
- 1-2 teaspoons washed and dried fine sand (± 1mm in grain size).
- 1-2 teaspoons washed and dried coarse sand (maximum 5mm in grain size).
- A clock with a second hand or a stopwatch, if possible.

Components from the Global Water Kit:

- 2 large sample vials with lids.
- 2 x 2,5 mℓ disposable plastic syringes.
- Comboplate
- Microstand with cross-arm
- A small piece of cotton wool
- 1 microspatula
- 2 propettes
- 1 plastic teaspoon

Chemical from the Global Water Kit:

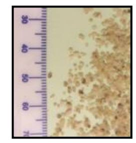
- Crystals of alum in plastic bag (potassium aluminium sulfate).

Notes on Materials Procurement:

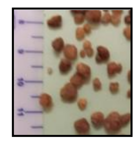
1. Water Samples: The water samples can be collected in plastic drink bottles or in any other suitable container. For comparison with the treated water, it will be more suitable if the container is made of a transparent material.
   The local natural water source sample to be reported to the Global Experiment 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 aluminium sulfate, is easily 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 Global Water Kit will contain sufficient alum for many clarification experiments.
3. Although the procedure for water clarification specifies using 200 – 500 mℓ cold drink bottles, smaller containers will also be suitable. A transparent container is best.
4. Although white play sand or swimming pool sand will be ideal fine sand, it can easily be replaced with clean fine building sand used for plastering of walls. The grain size for the Global Water Kit is shown in the photograph alongside.



5. The coarse sand should have a larger grain size and can be the building sand used in concrete mixtures. The grain size for the Global Water Kit is shown in the photograph alongside.



6. Sand samples can be washed and dried before using them in the sand filter. This will provide a cleaner filtrate.

Materials needed for Water Disinfection (using the Global Water Kit)

The filtrate from the Water Clarification
Students should be able to collect at least 10 mℓ of filtrate from the sand filter.

Components from the Global Water Kit:
- Chlorine test strips
- One propette
- 1x 2,5 mℓ disposable plastic syringe
- A clock with a second hand or a stopwatch

Chemical:
- A solution of calcium hypochlorite (to be made up by the teacher)
  The solid hypochlorite is found only in the School Resource Kit.

Teachers' Instructions for making up the disinfectant (calcium hypochlorite) solution (a fresh solution should be made up every day):
1. Use the 100 mℓ plastic bottle supplied in the School Resource Kit.
2. Use the Digital Pocket Scale and weigh 0.03 g of calcium hypochlorite into the 100 mℓ bottle.
3. Use distilled or boiled water to fill the bottle, but don't fill the neck of the bottle. Shake well.

Notes on Materials Procurement:

Chlorine Test Strips: The strips are supplied with a colour-code linked to parts-per-million "free available chlorine". Students dip the test strip into the water to be monitored and then wait 15 seconds before matching the colour of the appropriate square on the test strip to the free chlorine color guide. Approximately 10 test strips will be needed for each disinfection experiment. These will be included in the Global Water Kit. Additional strips will be supplied in the School Resource Kit.

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 – the role of alum.
- 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 developing 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 of the 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.

In filtration, a filter medium prevents particles from passing into the filtrate. A sand filter traps particles of flocs in spaces between the grains of fine and coarse sand and only allows clear water to pass through. During the filtration process, the filter itself becomes dirty and after a period of time, it will no longer be useful, because too many dirt particles will have been trapped inside.

Filtration can also be done using funnels and filter paper. Because the spaces in filter paper are much smaller than those in the sand filter, filtration takes longer and the filter can block more easily.

Filtration is often used to remove solid particles from a liquid, but can also be used to remove solid particles from air. The protective masks worn in dusty areas and those worn by health workers are a good example of such types of filters.

Coagulation, on the other hand, requires addition of a chemical, in this case alum. When alum dissolves in water, it allows the dirt particles to move closer together until they stick together to form large flocs. The large flocs are easier to filter in either a sand filter or a conventional filter. This action of alum is due to the presence of the potassium ion, K^+, and the aluminium ion, $A\ell^{3+}$, in solution. In water treatment plants, the quantities of coagulants are controlled carefully so that there are no harmful amounts of these ions left in the water by the time we drink the water.

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.

Chlorine, $C\ell_2$, is a strong oxidizing agent and can be used as a disinfectant. It is however a gas at room temperature and the handling is difficult for everyday use. Swimming pool disinfectant is available in solid form and laundry bleach in liquid form. Swimming pool chlorine, calcium hypochlorite, $Ca(OC\ell)_2$, is a mixture of calcium hypochlorite and calcium chloride. It produces chlorine in water, according to the reaction represented by the following equation

$$Ca(OC\ell)_2(aq) + CaC\ell_2(aq) + 2H_2O(\ell) = C\ell_2(aq) + 2Ca(OH)_2(aq)$$

The chlorine is soluble in water and produces hypochlorous acid, $HOC\ell$, which is responsible for the disinfecting action of swimming pool chlorine. This takes place as follows:

$$C\ell_2(aq) + H_2O(\ell) = HC\ell(aq) + HOC\ell(aq)$$

Similar reactions take place for household bleach, sodium hypochlorite, $NaOC\ell$.

Extension activities

1. 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)

Activities that 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 $A\ell^{3+}$ ion.
- The use of activated carbon in water purification.
- Research how chlorine test strips work (internet based).