MICROSCALE GLOBAL WATER KIT INSTRUCTIONS

Global Experiment for the International Year of Chemistry

SuperPower Sun → Clean Water

(Designing and building a Solar Still)

Overview of the Water Treatment Activity

The title **"SuperPower Sun → Clean Water"** refers to the use of solar energy to purify water. Essentially this is a process of controlled evaporation and condensation, where water is allowed to evaporate in a closed container and the condensate is collected. Starting with natural surface waters obtained from the surroundings, or a salt solution, and using mostly commonly available materials or the Global Water Kit, students will design and build a Solar Still.

Background to the Solar Still Activity

Water covers about 70% of the Earth's surface, of which more than 97% is seawater – a concentrated saline (salt) solution that is unsuitable for most uses. Despite being an abundant resource, seawater requires desalination which is a process that promotes the separation of the water from the dissolved salts. The desalination produces purified water, the quality of which is adequate for various uses, namely for agricultural purposes and even for human consumption.

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 sampled:

Name of local water source:

Percentage yield obtained in Solar Still:

Nature of water: (fresh, sea, estuarine or salt solution)

Ambient Temperature: (average air temperature while Solar Still is in operation)

Number of students involved

School/class Registration number

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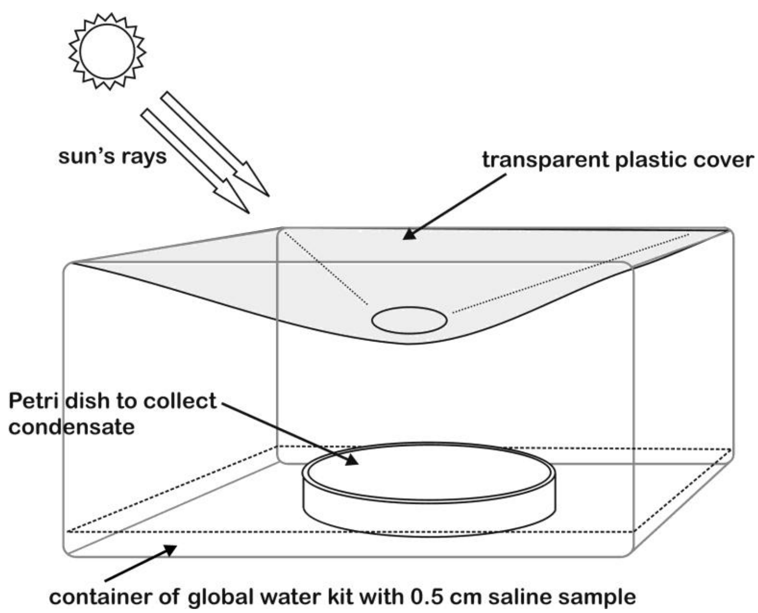
Instructions for the Activity (Teacher)

Experiment Outline

Water is the only substance found naturally in all three states: liquid, solid, and gas. The Earth is exposed to the Sun from which it gets the energy it uses for its needs. Solar heating promotes melting of ice to liquid water and evaporation of water into vapour, which may enter the atmosphere and form clouds. Evaporation followed by vapour collection and condensation is one of the recommended procedures to recover purified water. It efficiently separates water from non-volatile dissolved matter and plays a role in disinfection because microorganisms are also removed. This procedure can be done by distillation assisted by conventional heating, but environmentally friendly solutions, e.g. solar stills can be used with success. Solar stills can range from simple setups made from common materials, to more professional apparatus.

Students will use a saline solution for this activity, which may either be seawater obtained from the nearby sea or estuary, or a salt solution made up by dissolving table salt in fresh water, or some contaminated surface water. A simple solar still will be constructed using items in the Global Water Kit, which students will use to evaporate the water, condense its vapour and collect the resulting desalinated water.

The solar still should be made up according to the following schematic representation.



Other models and materials can be used to construct the solar still and the development of improved designs with more efficient performance is a challenge to students and teachers.

Older students may carry out an optional quantitative version of the activity where they can measure the volumes of the water samples before and after the desalination process. With this information they can calculate the yield of the process.

Students should work in small groups (4 – 6 students, or pairs if numbers permit) to construct a simple solar still and use it to desalinate a sample of water (i.e. a sample of seawater from a nearby seawater body, a salty solution or dirty water samples). One Global Water Kit should be used per group.

Prior to performing the Solar Still activity, use the thermometer in the Global Water Kit to measure the temperature of the water sample.

The Solar Still activity involves the following steps:

1. Collecting a seawater or surface water sample prior to the activity OR,

   Preparing a coloured, salty solution using the table salt and food colouring/copper sulfate provided in the Global Water Kit.

   HINT: The saline sample (without food colour or copper sulfate) can also be used for the Salty Waters activity, so keep a small amount on the side.

2. Construction of a solar still using the components in the Global Water Kit.

Thereafter, to get clean water,

3. Using the solar still to evaporate the water and collect the condensed vapour, by simple exposure to direct sunlight.

Lastly, to complete the activity,

4. Analyzing the data, discussing the success of the solar still and suggesting ways to improve the solar still.

5. Reporting results to the Global Experiment Database.

Students' Instructions

Materials needed for the Solar Still Activity

Collect the following:

- 1 x 250 mℓ sample of seawater or saline/dirty surface water OR a salty solution prepared as described in the Procedure below.
- a plastic cup or similar container (200 – 250 mℓ capacity)
- tap water
- a ruler
- a coin or stone
- adhesive tape (optional)

Components from the Global Water Kit:

- 1 x Petri dish
- 1 x microspatula
- a teaspoon
- a small piece of Prestik (adhesive putty)
- the lunch box of the Global Water Kit
- a piece of clean cling wrap
- 2 x elastic bands

Chemical from the Global Water Kit:

- table salt (i.e. sodium chloride)

From the School Resource Kit:

- copper sulfate crystals (or any powdered food colouring of your own)
- a thermometer

Safety Precautions

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

Procedure for Preparing the Salty Water Sample

1. If you have a seawater or surface water sample, then you do not have to prepare a salt solution. Simply use your collected water sample in the solar still. If the water sample is noticeably dirty, then use it without adding any food colouring. If the water sample is clear and looks like clean water, then add one level microspatula of the powdered food colouring or copper sulfate crystals to about 200 – 250 mℓ of the water sample and stir with the plastic teaspoon.

2. Try to use the water sample very soon after it is collected. Measure and record the temperature of the water at the time it is collected.

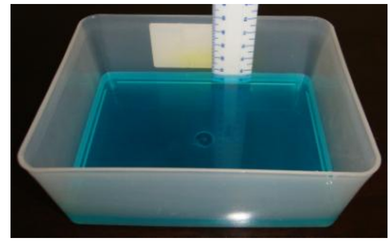
3. If you do not have a natural water sample, you will need to prepare a salt solution. First fill a plastic cup or similar container with about 200 to 250 mℓ of clean tap water. Measure and record the temperature of the water.

4. Add 1 level teaspoon of salt from the Global Water Kit (GWK) and stir until all of the salt has dissolved.

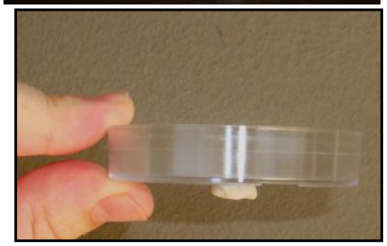
5. Using the spoon end of a clean microspatula, add one level spatula of food colouring/copper sulfate to the solution and stir until the colour is the same throughout the solution.

Procedure for Constructing the Solar Still

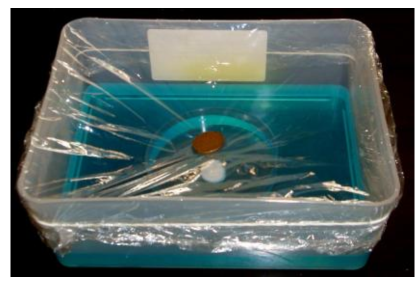
1. Take all the equipment out of the lunch box and put it in a safe place. Carefully pour about ½ cm of the coloured salt solution into the empty plastic lunch box (use a ruler to measure the depth of the solution in the lunch box).



2. Attach a piece of Prestik to the underside of a clean Petri dish. Place the Petri dish into the centre of the solution in the lunch box, making sure that no solution splashes into the Petri dish. Use the Prestik to stick the Petri dish to the bottom of the lunch box.



3. Loosely cover the top of the lunch box with the piece of cling wrap. Secure the plastic around the sides of the lunch box in such a way that no air will be able to enter the lunch box. (You can use one or two elastic bands to help make the cling wrap airtight around the container.) The plastic must be loose on top– do not pull it tightly over the lunch box.



4. Rest a small coin or stone on the cling wrap over the centre of the Petri dish in the lunch box. If the coin/stone moves, you may tape it to the plastic in the correct position. The plastic should be slanting downwards/inwards over the centre of the Petri dish.

Procedure for Desalination

1. Carefully place the lunch box in a warm, sunny place for a few hours. Make sure that none of the coloured solution flows into the Petri dish whilst you are carrying the solar still. If you have time you can check on the lunch box every hour and write down what you observe.

NOTE: It is best to set up your solar still on a warm, sunny day. Record the weather conditions at the time that you carry out the desalination.

2. After a few hours, carefully remove the cling wrap cover from the lunch box.

3. Complete the Students' Observation Sheet provided with this activity.

Rinse and dry all of the equipment you used and place it safely back in the kit.

Wash your hands with soap and water.

Optional Quantitative Activity for Older Students

- Calculate the volume of the water sample used in the rectangular container of the solar still before desalination begins, by simple mathematical calculation (i.e. V = L X B x H).

- Measure the volume of the condensate collected after a certain time (or complete evaporation)

- Calculate the percentage yield of the desalination process by using the initial and final volumes of water sample and condensate respectively. (Senior secondary students can also take into consideration any volume of water remaining in the solar still where complete evaporation has not occurred, to calculate a more accurate yield.)

Students' Observation Sheet for the Solar Still Activity

1. Complete the following table:

Date of water sample collection	
Temperature of water when collected	………………….ºC
Type of water (sea, prepared salt water solution, swamp, etc.)	
Describe where you found the water	
Date the experiment was performed	
Conditions in which the water sample was preserved between collection and performing the activity	
Time when the desalination began	
Time when the desalination finished, or was stopped	
Weather conditions	Ambient air temperature………..ºC Wet ………………………Dry ………………. Wind…………………

1. What do you notice inside the Petri dish after desalination? (Take the Petri dish out of the lunch box if you need to see clearly what is in the dish.)

2. What do you notice inside the lunch box after desalination?

3. Has the desalination process changed the appearance of the water sample?

4. Does the Petri dish contain all of the clean water that evaporated and condensed in the still? (Are there other places in the still where the water may have collected and not fallen into the Petri dish?)

5. How can you improve your Solar Still so that more clean water is collected?

Optional Quantitative Activity for Older Students

Procedure for Quantitative Solar Still Activity

1. Follow instructions 1 to 4 above for the *Procedure for Preparing the Salt Water Sample*.

2. Follow instruction 1 above for the *Procedure for Constructing the Solar Still.*

3. Using your knowledge of 3D shapes (rectangular prisms), calculate the volume of coloured solution you have poured into the lunch box,
   i.e. Volume = Length x Breadth x Height/Depth

   This will be your initial volume, $\boldsymbol{V_i}$. Record this value on the Students' Result Sheet provided.

4. Follow instructions 2 to 4 above for the *Procedure for Constructing the Solar Still*, as well as all the instructions for the *Procedure for Desalination of the Salty Water Sample*. If possible, leave the solar still in the sun until all of the water has evaporated.

5. Use a clean, dry syringe to suck up the water from the Petri dish. Fill the syringe to the 2 mℓ mark each time and calculate the total volume removed from the Petri dish once all the water has been sucked up. This will be your final volume, $\boldsymbol{V_f}$. Record this volume on the Students' Results Sheet provided.

6. Calculate the yield of the desalination process: $\left(\frac{V_f}{V_i}\right)$ **x 100 %.**

   Record the yield on the Students' Results Sheet provided.

   Is there any of the original water sample remaining in the solar still?
   If so, what is a more accurate way of calculating the % yield, taking into account that evaporation has not gone to completion?

Students' Results Sheet for the
Optional Quantitative Solar Still Activity
For Older Students

Complete a separate Results Sheet for each solar still and each water sample tested.

1. Table of Initial and Final Volumes

Initial Volume (of water sample used in the solar still)	V_i = ________ **mℓ**
Final Volume (of condensate remaining in the Petri dish after desalination)	V_f = ________ **mℓ**
Total time allowed for desalination	____________**hours**
Yield	______________ **%**
Solar Still: description; photo or drawing	

2. Compare the treated and untreated water. Has treatment by desalination changed the characteristics of the water?

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

4. If the evaporation in your solar still did not go to completion, write down a better way of calculating the yield which will take into consideration any of the original water sample that remains in the solar still.

5. Suggest ways in which you could improve your solar still to improve the yield of clean water.

6. Suggest any disadvantages in using a solar still to desalinate salt water.

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 saline solutions and desalination appropriate for their class.

Learning outcomes range from constructing a simple solar still and observing the effects of evaporation and condensation for younger students, to evaluating and improving the still design for older students. Older students can also calculate the yield of their solar still and extend the activity by testing for dissolved salts and measuring conductivity of various solutions.

Teacher's Summary of School Results

Solar Still Observation Table
(summarizing results from a school)

NAME OF SCHOOL: ______________________________
____
____

LOCATION OF SCHOOL: ______________________________
____

NUMBER OF STUDENTS: ______________________________

Type of water	Description of water source	Time allowed for Desalination	Appearance of Water Sample before and after Desalination in the Solar Still
1.			
2.			
3.			
4.			

Teacher's Summary of School Results - Sample

Solar Still Observation Table
(summarizing results from a school)

NAME OF SCHOOL: *St. Benedict's College*

LOCATION OF SCHOOL: *Bedfordview, Johannesburg, South Africa*

NUMBER OF STUDENTS: *160*

Type of water	Description of water source	Time allowed for Desalination	Appearance of Water Sample before and after Desalination in the Solar Still
1. *Prepared saline solution*	*Tap water in school classroom*	*5½ hours*	*Before desalination the solution was red due to the addition of red food colouring, but after desalination the condensate in the Petri dish was clear and colourless.*
2. *River Water*	*Impenjati River, KwaZulu Natal, South Africa*	*4 hours*	*Before desalination, the sample was murky and there were bits of debris floating around. After desalination, the water collected was clear and colourless.*
3. *Sea water*	*Durban, KwaZulu Natal, South Africa*	*Complete evaporation (~48 hours)*	*Before desalination the sea water appeared clear and colourless. After complete evaporation, the condensate was also clear and colourless but there was a white residue (salt) on the bottom of the solar still.*

Sample of Students' Observation Sheet for the **Solar Still Activity**

1. Complete the following table:

Date of water sample collection	*3 October 2010*
Temperature of water when collected	*23°C*
Type of water (sea, prepared salty water solution, swamp, etc.)	*Prepared salty water solution*
Describe where you found the water	*Taken from a tap in the school classroom*
Date the experiment was performed	*3 October 2010*
Conditions in which the water sample was preserved between collection and performing the activity	*Water used immediately after collection*
Time when the desalination began	*10:00*
Time when the desalination finished, or was stopped	*15:30*
Weather conditions	Ambient air temperature *30* °C Wet ....Dry ......✓............ Wind....................

2. What do you notice inside the Petri dish after desalination? (Take the Petri dish out of the lunch box if you need to see clearly what is in the dish.)
There is a clear condensate in the Petri dish. It is also colourless.

3. What do you notice inside the lunch box after desalination?
Not all of the salty solution has evaporated. It is still coloured.

4. Has the desalination process changed the appearance of the water sample?
Yes, the sample/solution was coloured (red) and now it is colourless. It looks clean.

5. How can you improve your Solar Still so that more clean water is collected?
We can tap the plastic cover of the solar still periodically so that any water clinging to the plastic can drop into the Petri dish.

Teacher's Summary of School Results (2)

Quantitative Solar Still Results Table
(summarizing results from a school)

NOTE: This is an optional activity for older students

NAME OF SCHOOL: ____________________________
____
____

LOCATION OF SCHOOL: ____________________________
____

NUMBER OF STUDENTS: ____________________________

Type of water	**Description of water source**	**Time allowed for Desalination**	**Yield (%)**	**Appearance of Water Sample before and after Desalination in the Solar Still**
1.				
2.				
3.				
4.				

Teacher's Summary of School Results (2) - Sample

Quantitative Solar Still Results Table (summarizing results from a school)

NOTE: This is an optional activity for older students

NAME OF SCHOOL: *St. Benedict's College*

LOCATION OF SCHOOL: *Bedfordview, Johannesburg, South Africa*

NUMBER OF STUDENTS: *160*

Type of water	Description of water source	Time allowed for Desalination	Yield (%)	Appearance of Water Sample before and after Desalination in the Solar Still
1. Prepared salt solution	*Tap water in school classroom*	*5½ hours*	*2.08*	*Before desalination the solution was red due to the addition of red food colouring, but after desalination the condensate in the Petri dish was clear and colourless.*
2. River Water	*Impenjati River, KwaZulu Natal, South Africa*	*4 hours*	*15*	*Before desalination, the sample was murky and there were bits of debris floating around. After desalination, the water collected was clear and colourless.*

Optional Quantitative Solar Still Activity

(for Older Students) - Sample

Complete a separate Results Sheet for each solar still and each water sample tested.

1. Table of Initial and Final Volumes

Initial Volume (of water sample used in the solar still)	**V_i =** 96 **mℓ**
Final Volume (of condensate remaining in the Petri dish after desalination)	**V_f =** .....2 **mℓ**
Total time allowed for desalination	5½ **hours**
Yield	2.08 **%**
Solar Still: description; photo or drawing	Solar Still constructed from items in the small scale Global Water Kit

2. Compare the treated and untreated water. Has treatment by desalination changed the characteristics of the water?

   Yes, the treated water no longer contains red food colouring. The untreated water remaining in the solar still is still red.

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

   No. Although the treated water is clear, we cannot be sure whether it is free of microorganisms. We should chlorinate the water to further purify it.

4. If the evaporation in your solar still did not go to completion, write down a better way of calculating the yield which will take into consideration any of the original water sample that remains in the solar still.

5.

$$\text{Yield} = \frac{\text{Final Volume of Water Collected in Petri Dish}}{\text{Initial Volume of water used in solar still} - \text{Water remaining in solar still after evaporation}} \times 100\%$$

6. Suggest ways in which you could improve your solar still to improve the yield of clean water.

   We can tap the plastic cover of the solar still periodically so that any water clinging to the plastic can drop into the Petri dish.

Additional Information about the Activity

Safety Precautions

It should be emphasized that neither the water samples used before desalination nor the condensate collected after desalination will be safe to taste or drink. The students should be made aware of this at the start of the activity.
Contact with solid substances (such as copper sulfate crystals) should be avoided. Students should wash their hands with soap and water after doing the activity.

Materials and Equipment Listing

Materials needed for the Construction of a Solar Still and Desalination of a Saline Sample using the Solar Still

- 250 ml sample of seawater or saline/”dirty” surface water OR a salty solution prepared as described in the Procedure
- A plastic cup or similar container (200 – 250 ml capacity, for preparing the saline solution if a salt water sample has not been collected)
- Tap water (to dissolve the table salt)
- A ruler (to measure ½ cm of water poured into the lunch box of the Global Water Kit)
- A coin or stone (to ensure that the plastic cover of the solar still slants downwards and inwards over the Petri dish for collection of condensate)
- Adhesive tape (optional – only required if the coin or stone moves and students want to tape it in a fixed position)

Each group needs the following which will be included in the Global Water Kit:

- 1 x Petri dish
- 1 x microspatula
- a teaspoon
- a small piece of Prestik
- the lunch box of the Global Water Kit
- a piece of clean cling wrap
- 2 x elastic bands
- a thermometer
- table salt (i.e. sodium chloride)

Collect from your teacher:

- powdered food colouring (any colour) or copper sulfate crystals

Notes on the Global Water Kit:

1. The IYC Global Water Kit (GWK) will be made available to schools in countries where resources for carrying out the Global Experiment are lacking. However, any school can use the kits for the Global Experiment. The apparatus in these learner kits is small scale and mostly plastic making it robust and safe to use in any environment. A laboratory is not needed and the kits can be safely taken into the field.
2. Students can work in groups of 4 to 6. If the school has received a School Pack, it should contain 10 GWKs which will cater for classes of 40 to 60 learners working in groups.
3. For the Solar Still activity, students will find most of the equipment in the GWK. The lunch box container of the kit will form the main body of the solar still. Some other items such as stones and rulers, should be easily found in the immediate environment. As with any kind of apparatus, students must take care of the kit components by ensuring that they always clean, rinse and dry the equipment after each activity. The equipment should always be placed back into the kit for the next group to use.
4. The School Resource Kit (SRK) has been specially designed as a supporting kit for the Global Water Kit. It is to be maintained and managed by the teacher, who must distribute the items as required per activity. For the Solar Still activity, the teacher must make the powdered food colouring or copper sulfate crystals available to students from the SRK.

Notes on Materials Procurement

1. If a salt water sample is not collected, the students will use the table salt (NaCℓ(s)) in the GWK to prepare a saline solution. There is only a small quantity of salt in each GWK, therefore two groups should be able to share one saline solution if a 250 mℓ sample has been prepared. If the salt in the kits is depleted, ordinary table salt should be available in local shops to replace it.
2. Teachers may need to replace some items after a few times of use e.g. the cling wrap for the solar still may become stretched or contain holes after several times of use. Cling wrap can be purchased in rolls from shops, but other types of thin, transparent plastic may be used (even recycled, uncoloured plastic bags that are transparent).
3. Water samples: The water samples can be collected in clean, plastic drink bottles (500 mℓ will be plenty), or in any other suitable container. For comparison with the desalinated water, it will be more suitable if the container is made of a transparent material.

4. The local natural water source sample to be reported to the Global Experiment Database might come from the sea, river, lake, large pond or an estuary. However, when using the GWK to conduct the Solar Still activity, the possible non-availability of natural salt water is taken into consideration. Table salt in the kit is dissolved in ordinary tap water to allow learners to prepare a saline solution. If the local tap water is not suitable for solution preparation, distilled water can be used. This is usually available from garage stations and pharmacies. Alternatively cooled, boiled tap water can be used.

5. If a natural body of salt water (such as the ocean or an inland sea) can be found nearby, students can collect water samples. The water source should be a familiar 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.

6. Since the Solar Still Activity uses a small volume of water, the salt water samples (or prepared salt solutions) can also be used for the Salty Waters activity. This will help to control consumption of the salt in the kits and avoid wastage should the saline solutions need to be discarded.

Student Learning Outcomes

Science Process Skills

- Taking samples that are representative of a system.
- Observing and comparing the appearance of untreated and treated water (i.e. treatment by desalination).
- Measuring volume using graduated apparatus.
- Preparation of a chemical solution.
- Using the environment (wind, sun) as a means of evaporation.
- 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 "purification" of water through desalination/distillation.
- Carrying out scientific investigations by selecting and controlling variables.
- Performing scientific calculations.

Chemistry background

- Solutions/Homogeneous mixtures
- Solutes, and qualitative and quantitative composition of aqueous solutions
- Physical and chemical properties of saline solutions
- Evaporation and condensation
- Evaporation and condensation as a method of separation (i.e. distillation)
- Desalination as a physical tool to purify water
- Chemical reactions that selectively involve chemical species in solution
- The role of energy in physical and chemical transformations.
- Calculation of Percentage Yield

Learning outcomes for Primary Classes

In primary schools the Solar Still activity affords students the opportunity to use simple, small scale equipment to conduct a scientific investigation and helps to develop the useful skill of recording observations. No quantitative processing of data is required.

The topic of water quality and availability is one very important chemical idea that is firmly embedded in students' experiences of drinking water and waterborne diseases. Students can usefully learn that clear water is not necessarily safe to drink.

The concept of the Solar Still (evaporation and condensation as a means of separation) is one of the early experiences students will have with distillation, and provides a good opportunity to distinguish between simple boiling and distillation and the effect that each of these processes has on treating water.

Students can also discuss alternatives to distillation relevant to their particular environment.

Learning outcomes for Junior High School

In addition to the learning outcomes mentioned for primary schools, quantification of the yield of the process is included. Students should also be challenged to discuss ways of improving their yield through modification of the solar still used.

There is also an opportunity to discuss how knowledge of 3D shapes can be used to calculate the volume of a liquid or solution in a container, when no appropriate measuring apparatus is available for determining volume. In this particular activity the water poured into the lunch box is a 3D rectangle (i.e. a rectangular prism) and students should recognize that they can calculate the initial volume using the formula: length x breadth x height/depth.

The topic of units, namely SI units, for expressing volume can appropriately be discussed here.

The concepts of soluble and insoluble substances, solutions and solubility may be introduced.

A more detailed discussion on distillation can be given, involving the concepts and the assessment of heat, temperature and vapour pressure.

Learning outcomes for Senior High School

After ensuring that the learning outcomes described before have been covered, the definitions of solute concentration and solubility may be explored. The explanations can include the nature of the chemical species in solution, the effect of the solvent (water) on the dissociation or ionization of the dissolved substances (solutes) and the ability of the solution to conduct electrical current. The electrical conductivity of the solutions can be easily measured, giving evidence of the efficiency of the solar still in producing water with a lower concentration of salts.

Reference to local water regulations which link the quality of water with different uses, is suggested.

The link between the Solar Still activity and industrial desalination plants can be established.

At this level, students can be asked to properly calculate the percentage yield of water they have obtained. For junior high, the initial and final volumes alone can be used. However, senior high school students should be aware that any of the original water sample remaining in the still after desalination cannot be ignored. They will need to use the formula

$$\frac{\boldsymbol{V_f}}{\boldsymbol{V_i - V_r}} \times 100\ \%$$

where $\boldsymbol{V_r}$ is the water remaining in the solar still due to incomplete evaporation.

Chemical reactions to identify ionic species in solution, namely the chloride ion, $C\ell^-(aq)$, from dissociation of sodium chloride, $NaC\ell(s)$, should be learned and the test applied.

Solar Still - Extension Activities

The following activities can be carried out to help students gain a deeper understanding of saline solutions and desalination. In some cases, the Global Water Kit can be used but for other activities additional equipment may be required. None of the reagents are supplied however.

- Detecting the presence of the chloride ion in aqueous solution: using the equipment in the GWK together with 0.1 M silver nitrate solution ($AgNO_3(aq)$) and 2 M nitric acid ($HNO_3(aq)$),older students can carry out the test for chloride ions.

  Exemplar Procedure:

  1. Before desalination, use a clean propette to add 5 drops of the saline solution/sample to a small well of the comboplate.
  2. Add 2 drops of 2 M nitric acid and 3 drops of 0.1 M silver nitrate solution. Observe what happens.
  3. After desalination, repeat steps 1 and 2 using the condensate collected in the Petri dish.

Students should observe that a white silver chloride precipitate forms with the original saline solution, but that there is no precipitate with the condensate because the salt has been removed by desalination.

(see background information below on the Knudson-Mohr method of assessing salinity)

- Using conductivity to determine salt content of a sample: the equipment in the GWK can be used together with a suitable conductivity meter to allow older students to measure the conductivity of the original water sample before desalination. They can then measure the conductivity of the condensate in the Petri dish. The difference in results should indicate that salt has been removed from the water by desalination. Students can also measure and compare the conductivities of different water samples, e.g. river water vs. sea water.

  (see background information below on Conductivity Measurements)

A Microconductivity Unit is available to measure conductivity of solutions in the comboplate of the GWK

- Researching the use of Reverse Osmosis to desalinate large volumes of sea water in the Middle Eastern Gulf States.
- Comparing different types of bottled water with respect to dissolved salt content.

Background Information on Extension Activities for Senior Students

The ocean is naturally saline at approximately 3.5% (35‰) salt. Salinity is a measure of dissolved salts in sea water, i.e. the mass of salts (in grams) dissolved in 1000 grams (1 kilogram) of sea water. We call this absolute salinity, S ‰. Observations of the chemical composition of sea water have made it apparent that its salinity can change. It can become either more saline or less saline due to input of fresh waters or by evaporation, but the proportion of its various solutes remains fairly constant (NaCℓ being the major component).

The first method recommended for assessing salinity is a chemical one known as the **Knudsen-Mohr** method. It is based on the volumetric analysis of the halide ions i.e. chloride, $C\ell^-(aq)$, bromide, $Br^-(aq)$ and iodide, $I^-(aq)$. By addition of a standard solution of silver nitrate, $AgNO_3(aq)$, these ions react with the silver ions, $Ag^+(aq)$, and form a white precipitate of silver chloride, AgCℓ(s), silver bromide, AgBr(s), and silver iodide, AgI(s).

$Ag^+(aq) + C\ell^-(aq) \rightarrow AgC\ell(s)$

$Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$

$Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$

Due to the large majority of the chloride ions, the mass of the precipitate is considered to be approximately all made of silver chloride, thus allowing the definition of chlorinity, Cℓ ‰, as the mass (in grams) of the element chlorine (Cℓ) present in each kilogram of sea water.

In 1969, UNESCO proposed a relation that helps one use chlorinity to calculate salinity, namely: S = 1,80655 (Cℓ). A salinity of 35 ‰ corresponds to a chlorinity of 19,374 ‰.

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

In 1978, oceanographers redefined salinity in Practical Salinity Units (psu): the conductivity ratio of a sea water sample to a standard KCℓ solution. Ratios have no units, therefore 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 plays in the context of current environmental problems associated mainly with Global Change.

Knudsen-Mohr Method

Take 10 ml seawater; dilute with distilled water up to 100mℓ. Measure a 25 mℓ aliquot and add two or three drops of potassium chromate, $K_2CrO_4(aq)$, indicator solution. Titrate with 0.1 mol dm^{-3} $AgNO_3(aq)$. A white precipitate will be formed. Measure the volume of added titrant until the end point is detected by the formation of a yellow precipitate of silver chromate, $Ag_2CrO_4(s)$ (the product of the reaction of Ag^+ with the chromate ion, CrO_4^{2-}) .

$$2Ag^+(aq) + CrO_4^{2-}(aq) \rightarrow Ag_2CrO_4(s)$$

Conductivity Measurement

Electrical conductivity is a very sensitive property of aqueous solutions. Many chemical laboratories have commercial conductivity meters. When available they can be used according to instructions.

Good conducting media have low electrical resistance; higher resistance, *R*/ohm corresponds to lower conductance, *G*/siemens, and vice-versa. Conductance, *S*, and resistance, *R*, are inverse concepts, $G=1/R$. Measuring conductivity, σ ($S.m^{-1}$), is basically measuring resistivity, ρ (Ω.m) ; $\sigma = 1/\rho$.

Simple measuring setups have been developed with materials often available from electrical kits. Measurement results may be of limited quality for quantitative assessment, but an interesting exercise and an experiment worth doing is the comparison of seawater, river water, drinking water and laboratory water (Seawater:5 $S.m^{-1}$; drinking water: 0.05 - 0,0005 $S.m^{-1}$; distilled water: < 0,0001 $S.m^{-1}$).

High ionic strength gives rise to high electrical conductivity, but high electrical conductivity may also be the result of acidic or basic substances in the water associated with industrial pollution sources.