

4.2 WHAT'S IN CLEAN WATER?

TRY THIS ACTIVITY: TESTING FOR HARD WATER

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Observations are recorded in **Table 1**.

Table 1 Thickness of Soapsuds in Test Tubes

Test tube	Thickness of soap suds at surface (cm)
hard water liquid soap	2.2
hard water sodium carbonate liquid soap	5.2

- (a) The soapsuds are thicker in the water that was treated with sodium carbonate and filtered, compared with the suds formed in the hard water.
- (b) Yes, sodium carbonate is effective in softening water. Sodium carbonate, $\text{Na}_2\text{CO}_{3(s)}$, softens water by removing calcium ions as an insoluble precipitate, solid calcium carbonate, $\text{CaCO}_{3(s)}$. Once filtered, the water had the characteristics of soft water.

TRY THIS ACTIVITY: DETERMINING THE CONCENTRATION OF DISSOLVED OXYGEN IN WATER

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The results from three tests on two freshwater samples are shown in **Table 2**.

Table 2 Dissolved Oxygen in Freshwater Samples

	DO results 1 (ppm)	DO results 2 (ppm)	DO results 3 (ppm)	Average
lakewater sample	5	5	5	5
rainwater sample	7	7	7	7

- (a) It is important to perform three tests and average the results because experimental error may cause a test measurement to be higher or lower than the actual value. Averaging three measurements of the same sample balances the high and low errors. Also, the concentration of oxygen may vary slightly from place to place in a body of water. Measuring the concentration of three samples and averaging the results produces one value that is representative of the body of water as a whole.
- (b) The results may indicate that rainwater is of higher quality than lakewater in terms of dissolved oxygen concentration.

SECTION 4.2 QUESTIONS

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Understanding Concepts

1. The two most common ions responsible for hard water are calcium ions and magnesium ions.
2. Compounds that contain sulfur dissolved in ground water might cause the water to have an unpleasant odour.

3. High concentrations of iron ions may cause water to have an unpleasant taste. Heavy metals, such as mercury, lead, cadmium, and arsenic, are unsafe in water since they are harmful to human health.
4. Hard water is a problem for areas that border the Great Lakes because of the high limestone content of the underlying soil and rock. As slightly acidic water flows through limestone, the water dissolves calcium and magnesium ions.
5. (a) Hard water reduces the effectiveness of soaps and detergents. The minerals in hard water may also cause a hard scale deposit to form on the inside of kettles and in water pipes.
(b) The minerals in hard water may clog water flow in pipes and decrease the efficiency of appliances used to heat water.
6. Boiling hard water that contains hydrogen carbonate ion, HCO_3^- , causes solid calcium carbonate, $\text{CaCO}_{3(s)}$, to form. The calcium carbonate forms a scale on the bottom of the kettle. The efficiency of heat transfer from the heating element to the water is reduced.
7. (a) $\text{CO}_3^{2-} + \text{Ca}^{2+} \rightarrow \text{CaCO}_{3(s)}$
 $\text{CO}_3^{2-} + \text{Mg}^{2+} \rightarrow \text{MgCO}_{3(s)}$
(b) By adding sodium carbonate to hard water, a reaction occurs to produce insoluble calcium carbonate or magnesium carbonate precipitates. The remaining sodium ions do not form a precipitate with soap or form a hard scale inside pipes.
8. After an extended period of use, the resin in a home water softener becomes saturated with calcium ions and magnesium ions, which have been exchanged for sodium ions. During regeneration, the resin is rinsed with a concentrated brine (sodium chloride, NaCl) solution from a salt tank. Sodium ions from the brine replace the calcium and magnesium ions on the resin. The hard water ions are washed down the drain, and the resin is ready to exchange ions with incoming hard water.
9. $3\text{CO}_3^{2-} + 2\text{Fe}^{3+} \rightarrow \text{Fe}_2(\text{CO}_3)_3$
10. (a) Some oxygen gas may dissolve directly into water from the air above the water's surface. Additional oxygen dissolves in water by aeration, which occurs when water flows over a dam or rocks, or breaks as waves on a beach. Aquatic plants also contribute dissolved oxygen to water as a by-product of photosynthesis.
(b) The concentration of dissolved oxygen in water decreases as the temperature of the water increases, since the solubility of gases in water is inversely proportional to temperature. An overabundance of oxygen-consuming bacteria can also decrease oxygen levels in water. The rapid growth of algae in nutrient-rich lakes also causes a decrease in oxygen levels in water.

Applying Inquiry Skills

11. Student answers may vary. The following Procedure is as an example of an activity to test the effectiveness of (a) sand filtration, (b) Calgon, and (c) sodium ion exchange resin.

Procedure

1. Measure 250 mL hard water into each of four labelled beakers.
2. Determine the quantity of dissolved minerals in beaker 1 by conducting a soapsuds test or a single displacement reaction with sodium carbonate. This beaker is the control.
3. Pour the water in beaker 2 through a sand filtration device. Collect the water after the treatment.
4. Add some Calgon to beaker 3. Stir to dissolve.
5. Pass the water in beaker 4 through a sodium ion exchange resin. Collect the water after treatment.
6. Perform a hard water test, such as a soapsuds test or a reaction with sodium carbonate, to determine the quantity of minerals remaining in each water sample following treatment.
7. Compare the results of each treatment with the results from beaker 1. Determine which treatment was most effective in reducing the mineral content of the water.

Making Connections

12. An ion-exchange water softening system would not be appropriate for large-scale municipal water softening because of the time required to regenerate the resin. There is a constant demand for water from a large municipal water system, unlike a household softening system that can regenerate the resin during periods of low use, such as at night. An ion-exchange system cannot effectively soften large volumes of water consistently. A municipal ion-exchange system may be overwhelmed by the demand for softened water.
13. (a) Generally, a water-softener unit supplies all water taps, except for outdoor taps, with softened water in a house that draws water from a well. In some homes, however, the cold-water tap in the kitchen is supplied with water that has not been softened.
(b) Health concerns related to drinking water with high sodium content include hypertension, or high blood pressure, and heart disease.

- (c) Student answers may vary. The health effects of drinking softened water appear to be debated widely. Many people believe that drinking salt-softened water increases sodium levels in the body, which can lead to the development of heart disease. Generally, the amount of sodium added to the water is very low. Studies have shown, however, that drinking softened water can be harmful to people on a sodium restricted diet or to bottle-fed babies less than six months old.

There is also debate as to whether people who drink softened water experience mineral deficiencies. Generally, requirements for minerals are met by eating foods, not drinking water. Studies have shown that people who drink naturally soft water do not suffer from mineral deficiencies.

One study investigated the possibility that softened water increases the potential for leaching heavy metals from pipes and plumbing fixtures. High levels of heavy metals are associated with health problems. Increased levels of copper, lead, zinc, and cadmium have been found in soft water, particularly when it stands overnight in the plumbing system.

4.3 WHAT'S IN POLLUTED WATER?

CAREER CONNECTION: WATER TREATMENT PLANT OPERATOR

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- (i) The most important aspect of a water treatment plant operator's job is collecting water samples for analyses and recording the test results. A water treatment plant operator must be organized and able to carefully record the details of test results and actions performed to provide an accurate record for tracking purposes. Without such organization, a water system can quickly become contaminated.
- (ii) Programs are offered at various community colleges. For example, Fanshawe College offers Cooperative Education in Environmental Science. Duties involved in cooperative postings include performing chemical, physical, and microbiological analyses of water from water treatment plants, maintaining records of analytical results, and ensuring that lab equipment functions properly. Once students have completed the course, they are eligible to write the Water Quality Analyst (WQA) examination. Upon successful completion, students receive a licence and may perform analytical tests on drinking water within water treatment facilities. Students are also eligible to write the Operator-In-Training (OIT) certification examination. Upon successful completion, students may pursue a career as an operator of a water and wastewater treatment facility.

Courses for Environmental Technician (ETN) are also offered at Sir Sanford Fleming College. Students receive hands-on training with access to environmental training facilities and a biological water treatment system. Fleming also offers the use of the Alternative Wastewater Treatment Centre, a research facility for designing and testing small-scale wetland treatment systems.

- (iii) The average starting salary for an Environmental Technician is \$31,400.
- (iv) The demand for Environmental Technicians in water treatment operations is high. Fanshawe College reports that 88% of recent graduates from the Environmental Technician program are employed in related positions. Fleming reports that 92% of graduates work in the environmental field.

SECTION 4.3 QUESTIONS

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Understanding Concepts

1. (a) The three types of contaminants that contribute to water pollution are physical contaminants, which do not dissolve in water, biological contaminants, which include viruses and bacteria, and chemical contaminants.
- (b) Student answers may vary. **Table 1** lists some possible answers.

Table 1 Water Pollutants

Physical contaminant	Biological contaminant	Chemical contaminant
<ul style="list-style-type: none">• silt• clay• debris• garbage	<ul style="list-style-type: none">• <i>E. coli</i>• coliform bacteria• <i>Cryptosporidium</i>• <i>Giardia</i>• <i>Campylobacter</i>	<ul style="list-style-type: none">• metals• fertilizers• petroleum products• pesticides• toxins