



**“The Future of Water/**

**Drinking the Sea”**

*April/May 2018*

<http://www.asc.org/chemmatters>

**Teacher’s Guide**



**Teacher's Guide for**

***“The Future of Water/  
Drinking the Sea”***

**April/May 2018**

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# Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Phase changes** | The distillation of seawater to provide freshwater is perhaps a novel way to discuss with students the transitions between the liquid and gaseous phases of water. |
| **Vapor pressure** | When looking at vapor pressure and boiling point, the process of multi-stage flash distillation (MSFD) can add to the discussion. |
| **Boiling** | Multi-stage flash (MSF) distillation of seawater can be used as an example of how boiling can be controlled by changing the pressure on a liquid. |
| **Boiling point** | Desalination techniques provide the opportunity to discuss the normal boiling point of a pure substance, conditions when boiling occurs at a different temperature, and what happens to the boiling point of solutions. |
| **Boiling point elevation** | The energy expense of simple seawater distillation provides an example of problems that can arise due to the boiling point elevation of solutions as distillate is removed. |
| **Separation techniques** | When studying separation techniques involving solutions, the examples of distillation and reverse osmosis to desalinate seawater can show students practical, large-scale, real-world applications. |
| **Distillation** | When introducing separation techniques, your students may think of distillation as one of the most familiar ways to separate liquids. However, they have not considered it a method that has long been used for desalination. |
| **Ions** | This article provides a relevant example of the importance of ions in everyday life, as they must be added back to water that has been desalinated by reverse osmosis, to replenish those lost in the purification process. |
| **Molecular motion** | Both diffusion and osmosis from the article can be used to show molecular motion occurring naturally; while reverse osmosis, a human-controlled process, can be used to show molecular motion that runs counter to that of nature. |
| **Diffusion** | The explanations and examples given in the article can be used to help students use molecular motion to distinguish between diffusion and osmosis. |
| **Chemical engineering (STEM)** | The process of developing ways to apply chemistry to the conversion of seawater into potable drinking water provides an example of the practice of chemical engineering. |

# Teaching Strategies and Tools

## Standards

* Links to **Common Core Standards for Reading**:
  + **ELA-Literacy.RST.9-10.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
  + **ELA-Literacy.RST.9-10.5**: Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
  + **ELA-Literacy.RST.11-12.1**:Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
  + **ELA-Literacy.RST.11-12.4:** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
* Links to **Common Core Standards for Writing**:
  + **ELA-Literacy.WHST.9-10.2F**: Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).
  + **ELA-Literacy.WHST.11-12.1E**: Provide a concluding statement or section that follows from or supports the argument presented.

## Vocabulary

**Vocabulary** and **concepts** that are reinforced in the April/May 2018 issue:

Food Chemistry

Structural Formulas

Chemical Reactions

Reaction Rates

Oxidation & Reduction

Distillation

Environmental chemistry

* Some of the articles in this issue provide information to help students consider their impact on the environment.
* Consider asking students to read “Open for Discussion: Weighing in on calories” to learn about calories in food prior to reading the article “The Protein Myth: Getting the Right Balance.”
* Students may find the infographic on page 19, “As a Matter of Fact: The Aroma of the Seaside” interesting after reading the article “Toxic Shorelines: The Science of Algal Blooms.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles.
* You might also ask them how information in the articles might affect their choices regarding food or water use. Also, ask them if they have questions about some of the issues discussed in the articles.

# Reading Supports for Students

The pages that follow include reading supports in the form of an Anticipation Guide, a Graphic Organizer, and Student Reading Comprehension Questions. These resources are provided to help students as they prepare to read and in locating and analyzing information from the article.

The borders on these pages distinguish them from the rest of the pages in this Teacher’s Guide—they have been formatted for ease of photocopying for student use.

* **Anticipation Guide (p. 8):** The Anticipation Guide helps to engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

***NEW!!!***

Instead of using the Anticipation Guide, consider these ideas to engage your students in reading.

**The Future of Water**

* Before reading, ask students to list at least 3 ideas they have for solving current water crises, including having enough clean water.
* As they read the two articles, ask students to add to the list they have already created.
* **Graphic Organizer (p. 9):** The Graphic Organizer is provided to help students locate and analyze information from the article. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher, if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the article. The use of bullets helps them do this.

If you use the aforementioned organizers to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

* **Student Reading Comprehension Questions (p. 10-11):** The Student Reading Comprehension Questions are designed to encourage students to read the article (and graphics) for comprehension and attention to detail, to provide the teacher with a mechanism for assessing how well students understand the article and/or whether they have read the assignment, and, possibly, to help direct follow-up, in-class discussion, or additional, deeper assignments.

Some of the articles in this issue provide opportunities, references, and suggestions for students to do further research on their own about topics that interest them.

To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles. The “Web Sites for Additional Information” section of the Teacher’s Guide provides sources for additional information that might help you answer these questions.

“The Future of Water/Drinking the Sea”, *ChemMatters*, April/May 2018

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

## Anticipation Guide

“A Close-up Look at the Quality of Indoor Air” (*ChemMatters*, April/May 2016 Issue)

**Directions** ***Before reading the article*,** in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. More than 2 billion people around the world live with insufficient clean water. |
|  |  | 1. About 10% of the water on Earth is available as freshwater. |
|  |  | 1. Most of Earth’s freshwater is trapped in glaciers and ice caps. |
|  |  | 1. Distillation of water was discovered in the 1800s. |
|  |  | 1. As salt water is distilled, salt becomes increasingly concentrated in the solution being boiled. |
|  |  | 1. Reverse osmosis requires high pressure to separate fresh water from saltwater. |
|  |  | 1. Desalination currently produces about 10% of the world’s drinking water. |
|  |  | 1. More than16 desalination plants have been approved in California. |
|  |  | 1. Solid water is more dense than liquid water. |
|  |  | 1. Middle Eastern countries have proposed towing icebergs to drought-stricken areas. |

## Graphic Organizer

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

“The Future of Water/Drinking the Sea”, *ChemMatters*, April/May 2018

**Directions**: ***As you read***, complete the graphic organizer below to compare different methods of desalination.

|  |  |  |
| --- | --- | --- |
|  | ***Distillation*** | ***Reverse Osmosis*** |
| What is it? |  |  |
| Where is it used? |  |  |
| What are some drawbacks? |  |  |
| How might it be used in the future? |  |  |

**Summary**: On the back of this paper, write a tweet (280 characters or less) about desalination, based on what you learned from reading the article.

## Student Reading Comprehension Questions

“The Future of Water/Drinking the Sea”, *ChemMatters*, April/May 2018

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Name

**Directions**: Use the article to answer the questions below.

**from “The Future of Water”**

* 1. (a) Where is groundwater located, and (b) what is one way to access groundwater?
  2. (a) What percentage of the water on earth is freshwater? (b) Calculate the percentage of this water that is not immediately available because it is either in the ground or frozen in glaciers and polar ice caps?

**from “Drinking the Sea”**

* 1. Describe, on the molecular level, the process of distillation.
  2. Why does distilling saltwater to provide freshwater for a community become very energy intensive?
  3. Explain the process that scientists and engineers use to reduce the amount of energy lost during distillation of seawater.
  4. Explain the process of osmosis.

**Student Reading Comprehension Questions, cont.**

“The Future of Water/Drinking the Sea”, *ChemMatters*, April/May 2018

* 1. How does reverse osmosis work to desalinate saltwater?
  2. In the desalination process, what is the purpose of (a) pre-treatment and (b) reverse osmosis?
  3. During the process of desalination, why is water poured over rock beds?
  4. (a) Which type of desalination process (distillation or reverse osmosis) uses the least amount of energy? (b) Why does its use still present a problem?
  5. According to environmentalists, what is a major concern about desalination plants?
  6. Give two reasons why the need for desalination will probably continue to increase.

## Answers to Student Reading Comprehension Questions

**from “The Future of Water”**

1. **(a) Where is groundwater located, and (b) what is one way to access it?**

*Groundwater is freshwater located below the surface of the ground.*

*One way that it can be accessed is by pumping it from wells.*

1. **(a) What percentage of the water on earth is freshwater? (b) Calculate the percentage of this water that is not immediately available because it is either in the ground or frozen in glaciers and polar ice caps?**
2. *2.8% of the water on earth is freshwater.*
3. *30% Groundwater OR 100% Total freshwater*

*+ 69% Frozen water – 1% Surface freshwater*

*99% Total freshwater not 99% Total freshwater not*

*readily available readily available*

**from “Drinking the Sea”**

1. **Describe, on the molecular level, the process of distillation.**

*As seawater is heated, the water molecules move faster and faster until they eventually reach their boiling point (100 oC), where they vaporize and can then be collected as distillate (pure water) leaving behind the higher boiling point salt.*

1. **Why does distilling saltwater to provide freshwater for a community become very energy intensive?**

*As the water evaporates, the solution of salt and water left in the boiling container becomes increasingly concentrated, causing the boiling point of the solution to increase and requiring more energy to vaporize water from that more concentrated solution.*

1. **Explain the process that scientists and engineers use to reduce the amount of energy lost during distillation of seawater.**

*Scientist and engineers reduce the amount of energy lost during the distillation of seawater by using multi-stage flash distillation (MSFD). During MSFD seawater is heated in stages, using the heat from the hot water remaining in the container to initially heat the cool, starting seawater.*

1. **Explain the process of osmosis.**

*Osmosis occurs when a semipermeable membrane separates two salt solutions of different concentrations. Assuming this membrane allows only the passage of water molecules to reach equilibrium concentration, the water molecules will move from where the relative amount of salt is low to where the relative amount is high.*

1. **How does reverse osmosis work to desalinate saltwater?**

*In reverse osmosis, high pressure is applied to a salty solution in contact with a semipermeable membrane. To relieve the pressure, the water molecules move from the concentrated solution side through the semipermeable membrane, to be collected as fresh water on the other side of the membrane.*

1. **In the desalination process, what is the purpose of (a) pre-treatment and (b) reverse osmosis?**

*In the desalination process,*

1. *pre-treatment is used to remove large components, such as algae, from the seawater, and*
2. *reverse osmosis is used to remove the salt from seawater.*
3. **During the process of desalination, why is water poured over rock beds?**

*Water is poured over rock beds during the process of desalination to dissolve low concentrations of rock minerals into the water.*

1. **(a) Which type of desalination process (distillation or reverse osmosis) uses the least amount of energy? (b) Why does its use still present a problem?**
2. *The reverse osmosis process uses less energy than distillation, but*
3. *it still presents a problem because the start-up costs for new facilities are high.*
4. **According to environmentalists, what is a major concern about desalination plants?**

*A major environmental concern about desalination plants is that they steadily release the unnaturally salty water (left over after much of the freshwater has been removed) to the ocean, and this briny solution could harm marine ecosystems.*

1. **Give two reasons why the need for desalination will probably continue to increase.**

*The need for desalination will probably continue to increase*

1. *as populations grow and*
2. *climate change affects rainfall patterns.*

*Both of these changes increase the need for freshwater.*

# Possible Student Misconceptions

1. **“I am concerned because the energy for desalination comes from the burning of fossil fuel and this leads to global warming.”** *Fortunately, this is not always true. China’s desalination plants are powered by the wind; Saudi Arabia uses solar power; and Australia is using the energy from ocean waves as they pass over submerged buoys tethered to pumps on the ocean floor, as the motion of the waves drives the pumps.*
2. **“Desalination is so expensive that I don’t think the urgency for more water is a strong concern in the U.S.”** *Actually, there is considerable concern in the Western U.S. California has been pumping so much groundwater to meet their needs for human consumption and agriculture that the land is beginning to sink. In addition, the largest western U.S. water storage area, Lake Mead on the Colorado River, is now at only 39% of its capacity.*
3. **“I heard that water from reverse osmosis is bad for you because the process removes all essential minerals such as calcium and magnesium.”** *Although the reverse osmosis process does remove all ions from the water, essential mineral ions like calcium and magnesium are added to the desalinated water before it is sent to consumers.*

# Anticipating Student Questions

1. **“Why does distilled or demineralized water taste so ‘flat’”?** *Water without ions (minerals) lacks flavor, so water companies usually add minerals to water before it is sold to consumers. You probably use demineralized water in the chemistry lab to prevent interaction between the ions in your experiment and ions present in the water.*
2. **“What will happen if you drink seawater when you are desperately thirsty?”** *This is not a good idea.**You might get sudden severe diarrhea, urinate frequently, and become extremely thirsty—all because your kidneys need fresh water to dilute and expel the seawater, a very concentrated salt solution. If you continue to drink seawater, dehydration may lead to death. By osmosis, water molecules move through the cell membrane, leaving your body cells, where the* ***water*** *concentration is high, to dilute the seawater (low water concentration) that you drank.*
3. **“Sometimes we use distilled water in our chemistry labs; other times we use deionized (DI) water. What is the difference?”** *Both remove ionic impurities, so they work well for most pre-college experiments. However, their preparation methods differ, so their use in technical labs may differ. Volatile organics and metals like mercury will volatilize along with water during distillation, so the purity of distilled water depends upon the source water. Ions and other charged particles are removed from water as it passes through the electrically-charged resin to form DI water, but this process will not remove uncharged particles like sugar molecules, bacteria, and viruses.*
4. **“What about the people in poor countries with little water and no money to build desalination facilities?”** *In 2015, researchers at Alexandria University developed a cheap, quick method to desalinate saltwater. Membranes to filter out salt and large impurities are made from local materials plus a cellulose acetate powder that binds salt. Once filtered, the individual user at home needs to just heat, vaporize and condense the potable water filtrate.*
5. **“I read that reverse osmosis makes the water acidic. How does this happen?”**

*Following reverse osmosis, the pure water contains essentially no ions, so it is neutral; but, as soon as it’s exposed to atmospheric carbon dioxide, it becomes acidic:*

*H2O (*l*) + CO2 (g) 🡨🡪 H2CO3 (aq) 🡨🡪 2 H+ (aq) + HCO3– (aq)*

*(carbonic acid)*

*The hydrogen ions produced could corrode water pipes, so remineralization is used following reverse osmosis, via filters containing calcium and magnesium compounds, to neutralize the water and also to return essential minerals that were lost during the reverse osmosis process:*

*Ca2+ (aq) + 2 HCO3– (aq) 🡪 CaCO3 (s) + H2O (*l*) + CO2 (g)*

*Mg(OH)2 (s) + 2 H+ (aq) 🡪 Mg2+ (aq) + 2 H2O (*l*)*

*See this link for a further description of f****our solutions that are widely used to remineralize desalinated water. (***[*https://www.lenntech.com/processes/desalination/post-treatment/post-treatments/remineralization.htm*](https://www.lenntech.com/processes/desalination/post-treatment/post-treatments/remineralization.htm)*)*

# Activities

**Labs and demos**

“**Desalination of Sea Water”, laboratory activity:** This clearly written laboratory activity involves distillation, electrolysis, calculations and discussion questions. A diagram of an electrochemical cell and all the relevant redox equations are included. (<https://scilearn.sydney.edu.au/fychemistry/LabManual/E07.pdf>)

**“Water Distribution Demonstration”:** This demonstration—using water, a medicine dropper, and a graduated cylinder—provides a quick, easy way to draw attention to the minuscule amount of Earth’s water that is available freshwater. Complete instructions and suggested student questions are provided. (<http://cmase.pbworks.com/w/file/fetch/65195601/Water%20Distribution%20Demonstration.pdf>)

**Simulation**

**“Water Desalination by Electrodialysis”, a simulation challenge for students:** A simulator asks students to design a desalination process to purify brackish water with 7ppm salinity for the least cost per unit. Students will decide cell dimensions and cell stack, flow pressure level and amount of voltage needed; guidance for use of the simulator and additional challenges are provided. (<http://desalination.stanford.edu/simulation.html>)

**Media**

**“Boiling Point Elevation and Freezing Point Depression”, video (13:59):** This KhanAcademy video uses diagrams to represent molecules as it explains the elevation of boiling point at the particulate level. It explains the increasing energy requirements as the salt concentration of the remaining solution increases during distillation. (<https://www.khanacademy.org/science/chemistry/states-of-matter-and-intermolecular-forces/mixtures-and-solutions/v/boiling-point-elevation-and-freezing-point-supression>)

**“Making Desalination more Sustainable”, video (4:17):** Both animation and photos from industrial plants are used to describe various techniques to desalinate water; the energy required for each process is included. A new hybrid process developed by universities in Saudi Arabia and Singapore reduces the energy requirements of the other technologies by combining multi-effect desalination with adsorption desalination (MEDAD). (<https://www.youtube.com/watch?v=-ZenuOGTohk>)

**Lessons and lesson plans**

**“Process and Impact of Desalination on the Environment” (3+ days):** In this comprehensive NGSS-based lesson plan (grades 6–12), students study various ways to desalinate water, researching both the economic and environmental costs of these processes, while constructing a small-scale solar cell to desalinate water. This complete lesson plan from *Water Education Today* includes instructions, questions, teacher’s guide, and evaluation rubrics. (<http://watereducationtoday.com/pdf/WET_Lesson_Plan_11_Process_and_Impact_of_Desalination_on_the-Environment.pdf>)

**“Ocean Water Desalination”, NGSS lesson with the focus on engineering (60 min.):** Desalination processes are described as systems; students study nature’s water purification system, followed by engineering designs to desalinate water, which include multi-stage flash distillation, reverse osmosis, and electrodialysis. Students are asked to sketch desalination systems that they design.

(<https://www.teachengineering.org/lessons/view/cub_desal_lesson01>)

**Projects and extension activities**

**“The Global Water Crisis”, suggestions for projects:** This Pulitzer Center program, introduced by videosfrom water-poor countries, provides data and suggests extension projects that include creative writing, debates, and research. The specific lessons focus on the water-poor countries of Ethiopia, Yemen, Kenya, and Nepal. (<http://pulitzercenter.org/education/lesson-plan-global-water-crisis>)

# References

**The references below can be found on the *ChemMatters* 30-year DVD, which includes all articles   
published from the magazine’s inception in October 1983 through April 2013; all available Teacher’s Guides, beginning February 1990; and 12 *ChemMatters* videos. The DVD is available from the American Chemical Society for $42 (or $135 for a site/school license) at this site:** [**http://ww.acs.org/chemmatters**](http://www.acs.org/chemmatters)**. Click on the “Teacher’s Guide” tab to the left, directly under the “*ChemMatters Online"* logo and, on the new page, click on “Get the past 30 Years of *ChemMatters* on DVD!” (the icon on the right of the screen)**

**Selected articles and the complete set of   
Teacher’s Guides for all issues from the past three   
years are available free online at the same Web site, above. Click on the “Issues” tab just below the logo, *“ChemMatters Online”*.**



***30* Years of *ChemMatters !***

Available Now!

Although this article is dated (2002), the diagram of the reverse osmosis (RO) system is well labeled and described. It includes a demonstration of the amount of potable water in the world and a lab where students test and compare tap water to filtered water. (Stewart, M. Tapping Salt Water for a Thirsty World. *ChemMatters,* 2002, *20* (3), pp 4–9)

This article uses a diagram and electrochemical equations to show an exciting new desalination technique using a bacteria-powered fuel cell to produce electricity as it removes salt from water. To date (as of 2010), this cutting-edge cell is still on the lab bench, not yet ready for a step-up to the industrial scale. (Anderson, L. Putting Bacteria to Work. *ChemMatters,* 2010, *28* (4) pp 14–17)

# Web Sites for Additional Information

**General summaries**

“Tapping the oceans” is an excellent article that describes the technological history of desalination and the worldwide need for water. It also discusses desalination’s high energy demands, scientific advances to reduce these, and the associated concerns of environmental pollution. (<http://www.economist.com/node/11484059>)

Hanson Cheah, Massachusetts Institute of Technology (MIT) graduate now working as a global entrepreneur based in Hong Kong, has prepared a series of excellent, clear and short descriptions using particle-based schematics of four types of seawater desalination processes, multi-stage flash distillation (MSFD), multi-effect distillation (MED), vapor compression (VC), and membrane processes such as reverse osmosis (RO). These links are all listed under the heading: “Seawater Distillation” on the left column of this Web site. (<http://www.separationprocesses.com/Distillation/MainSet1.htm>)

**History of desalination**

The equipment diagrams provided on this site, with their brief descriptions of processes that have been used over time to desalinate seawater, provide a good overview of the history and technological advances of desalination. Beginning with the evaporation of saltwater on steamships, the article moves through reverse osmosis and electrodialysis and concludes with multi-stage flash distillation (MSFD). (<http://www.brighthubengineering.com/structural-engineering/109915-multi-stage-flash-distillation-for-desalination/>)

This site describes and pictures the important events in desalination history from 1600 (on steamships) to April 7, 2010 (a solar-powered plant in Saudi Arabia). The reader can scroll across the timeline clicking on any entry for more information, or toggle to the “list”, which provides the details for and a photo of each item on the timeline. (<https://www.timetoast.com/timelines/important-events-in-desalination-history>)

**Sugar refining leads to new desalination processes**

In 1850, U.S. chemical engineer Norbert Rillieux tackled the problem of removing water from sugar cane juice. He developed a technique using multiple-effect vacuum evaporation, the same energy-saving technology used about 50 years later for the multiple-effect distillation (MED) process. (<https://www.acs.org/content/acs/en/education/whatischemistry/landmarks/norbertrillieux.html>)

**Worldwide water shortages**

“Why freshwater shortage will cause the next global crisis” predicts that fresh water shortages will be the next worldwide crisis; colored global maps show relationships between water stress and climate change. As the climate changes, projections show that both the quantity of freshwater and its purity will decrease. (<https://www.theguardian.com/environment/2015/mar/08/how-water-shortages-lead-food-crises-conflicts>)

“Is the world running out of fresh water?” is a paper from the British Broadcasting Corporation (BBC) that quotes a National Aeronautics and Space Administration-led (NASA) study (link included) on water resources, showing that the world is draining freshwater faster than it is being replenished. The article points to the high cost of desalination to meet global water needs and suggests ways to save water by improving agriculture efficiency and by recycling wastewater. (<http://www.bbc.com/future/story/20170412-is-the-world-running-out-of-fresh-water>)

**Major desalination processes**

IDE technology provides details of desalination by reverse osmosis and by thermal desalination (VC, MED, MSF—links can be found at this URL for further description). This site includes energy requirements, along with details of each process, and labeled photos of plants worldwide, including two in California.

(<http://www.ide-tech.com/desalination/>)

In addition to distillation and reverse osmosis, a third way to desalinate is particularly useful for recovering pure potable water from highly salted and/or contaminated water coming from fracking facilities and other wastewater sources. The interesting process of shock electrolysis, where electrically charged membranes are used to separate pure water from briny materials, is fully described in this MIT bulletin. (<http://news.mit.edu/2015/shockwave-process-desalination-water-1112>)

**Reduction in energy cost**

The history and high cost of desalination are followed by a focus on reducing the cost of RO membranes and applying nanotechnology techniques to design strong, chemical-resistant, highly-absorbent graphene membranes that require less pressure and energy. Additional suggestions include reducing energy by the RO-PRO (Pressure retarded osmosis) process, recapturing/recycling energy processes, and, finally, improving efficiency by replacing large industrial complexes with small community facilities. (<https://www.pri.org/stories/2015-05-15/desalination-expensive-energy-hog-improvements-are-way>)

Descriptions and diagrams of current technologies including electrodialysis, RO and solar distillation (SD); costs for various desalination processes are given, alternative energy sources are discussed and an excellent “At a Glance” table summarizes this information. The method chosen usually depends upon the resources of the country; the oil-rich can afford fuel energy-intensive technologies and arid equatorial coastal countries can use SD. (<https://www.sswm.info/content/desalination>)

**Post-treatment of desalinated water**

Although some Web sites declare the horror of desalinated water killing 100s of people, the World Health Organization (WHO) has produced safety guidelines to dispel the fear: “Safe Drinking-Water from Desalination”. Whatever method is used, post-treatment is essential to avoid blending the pure distillate with untreated, contaminated source-water, and to add minerals to supplement the primary dietary sources of these ions. (<http://apps.who.int/iris/bitstream/10665/70621/1/WHO_HSE_WSH_11.03_eng.pdf>)

The Israeli government is addressing four important steps described in the URL below to reduce public risk from contaminated water. Due to the lack of appropriate desalination post-treatment, citizens have experienced “red” water, when a high percentage of desalinated water lacking required buffering capacity was incorporated into their water supply; in addition, the lack of magnesium has led to decreased lung function in children and increased heart attacks in older people. (<https://www.haaretz.com/science-and-health/israel-dawdling-as-desalinated-water-kills-1.5462030>)

**Environmental impact of desalination**

This article focuses on both the economic and the environmental impacts of desalination; desalination produces very expensive water, and it contributes to climate change and global warming when the energy source is fossil fuel. The article also discusses issues of threats to ocean biodiversity, marine habitats, and coral reefs. (<http://www.theenergycollective.com/bobbipeterson/2396669/desalination-and-energy-consumption>)

“The Future of Seawater Desalination: Energy, Technology, and the Environment,” published in *Science,* includes suggestions for mitigating the impact of briny water discharge (twice the salinity of natural seawater) from desalination plants. Solutions include: placing desalination plants away from sensitive areas like coral reefs; considering a position near a power plant or waste-treatment plant that would mix and dilute the brine with treated fresh water; and developing foul-resistant membranes.

(<https://albertsk.files.wordpress.com/2012/08/science-2011-elimelech-712-71.pdf>)

# About the Guide

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Articles from past issues of *ChemMatters* and related Teacher’s Guides can be accessed from a DVD that is available from the American Chemical Society for $42. The DVD contains the entire 30-year publication of *ChemMatters* issues, from February 1983 to April 2013, along with all the related Teacher’s Guides since they were first created with the February 1990 issue of *ChemMatters*.

The DVD also includes “Article”, “Title”, and “Keyword” indexes that cover all issues from February 1983 to April 2013. A search function (similar to a Google search of keywords) is also available on the DVD.

The *ChemMatters* DVD can be purchased by calling 1-800-227-5558. Purchase information can also be found online at <http://tinyurl.com/o37s9x2>.