Determine Whether Salt Can Be Cleared from the Water of the Sea

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Abstract

Seawater contains dissolved salts that make it unsuitable for direct human consumption. This paper presents a safe school-level investigation of whether distillation can separate water from dissolved salt. The experiment uses evaporation and condensation to collect distilled water while leaving most nonvolatile salts in the boiling container. Salinity is evaluated through electrical conductivity or total dissolved solids measurements rather than taste. The paper explains the scientific basis of desalination, defines the research question, hypothesis, variables, apparatus, safety controls, procedure, data table, and methods of analysis. It also compares classroom distillation with industrial thermal desalination and reverse osmosis. The expected result is that the condensate will have substantially lower conductivity and dissolved-solids concentration than the original saltwater, although contamination, splashing, and equipment limitations may prevent perfect separation. The experiment demonstrates the principle of desalination but does not certify the collected liquid as safe drinking water.

Introduction

Water is essential for human health, agriculture, sanitation, industry, and ecosystems. Although oceans contain most of Earth's water, seawater cannot be consumed safely because of its high concentration of dissolved salts. The U.S. Geological Survey reports that ocean water contains approximately 35,000 parts per million of dissolved salts, whereas freshwater contains less than approximately 1,000 parts per million under its broad salinity classification (U.S. Geological Survey [USGS], 2019).

Desalination removes salts and other minerals from saline water. Two major approaches are thermal separation, in which water evaporates and condenses, and membrane separation, particularly reverse osmosis. A classroom experiment can demonstrate thermal desalination through simple distillation. However, it must be conducted with suitable laboratory equipment, adult supervision, and no tasting of samples.

The original experiment contained unsafe and unclear instructions that repeatedly suggested tasting water. Laboratory liquids should never be tasted. Distillation can reduce salt concentration, but it does not automatically remove every volatile contaminant, microorganism, or chemical hazard. The collected liquid is an experimental sample, not certified drinking water.

Research Question

Can simple distillation substantially reduce the dissolved salt concentration of simulated seawater?

This question can be tested by comparing salinity-related measurements before and after distillation. Electrical conductivity is suitable because dissolved ions allow water to conduct electricity. A total dissolved solids meter may estimate concentration from conductivity. If neither instrument is available, evaporation of equal measured sample volumes can provide a less precise comparison of remaining solid residue.

Hypothesis

If simulated seawater is heated and the resulting vapor is cooled and collected without transferring liquid droplets from the boiling flask, then the collected distillate will have much lower conductivity and total dissolved solids than the original saltwater. This is expected because sodium and chloride ions are nonvolatile under the conditions of the experiment and remain primarily in the boiling container while water molecules enter the vapor phase.

Scientific Background

Salt dissolves in water because polar water molecules surround sodium and chloride ions. The ions do not disappear; they become dispersed throughout the liquid. Filtration through ordinary paper cannot remove dissolved ions because they are much smaller than the filter pores and travel with the water.

Distillation uses differences in volatility. When saltwater is heated, water molecules escape as vapor. Dissolved sodium chloride remains in the container because it does not vaporize with the water at the experiment's temperature. The vapor is then cooled in a condenser, where it returns to liquid form.

Boiling alone does not desalinate water if the vapor is allowed to escape. In fact, boiling an open container makes the remaining liquid saltier because water is removed while salt remains. Desalination requires capture and condensation of the vapor.

Simple distillation is not perfect. Vigorous boiling can carry tiny saltwater droplets into the condenser, a process called entrainment. Dirty glassware or contaminated collection containers can also raise conductivity. Some volatile substances can distill with water. These limitations are why industrial drinking-water production uses multiple barriers, monitoring, treatment, and risk management (World Health Organization [WHO], 2011).

Variables

Variable type	Variable	How it is controlled or measured
Independent variable	Water treatment stage	Original saltwater compared with distilled condensate and a freshwater control
Dependent variable	Conductivity or estimated total dissolved solids	Measured with the same calibrated instrument and sample volume
Controlled variable	Starting salt concentration	Use one prepared batch of simulated seawater
Controlled variable	Apparatus and collection time	Use the same setup and a defined collected volume
Controlled variable	Sample temperature	Allow samples to reach similar room temperature before conductivity measurement
Controlled variable	Container cleanliness	Rinse glassware with distilled water and avoid touching inner surfaces

Materials

- Laboratory-grade distillation flask or heat-resistant round-bottom flask
- Condenser, tubing, clamps, and support stand
- Heating mantle or supervised hot plate appropriate for the flask
- Boiling chips, added before heating
- Clean receiving flask or beaker
- Thermometer adapter if included in the available apparatus
- Distilled water for rinsing and as a control
- Table salt and clean water for simulated seawater
- Balance and graduated cylinder
- Conductivity or total dissolved solids meter
- Heat-resistant gloves, splash goggles, and laboratory coat
- Labels and laboratory notebook

A sealed pressure system must never be created. The apparatus must remain open to atmospheric pressure through the receiving side. Students should use a standard setup approved by the teacher rather than improvising with unsuitable bottles, plastic tubing near heat, or tightly sealed containers.

Preparation of Simulated Seawater

To approximate ocean salinity, dissolve 35 grams of sodium chloride in enough clean water to make a final solution volume of 1 litre. For a smaller experiment, dissolve 17.5 grams in enough water to make 500 millilitres. The solution is only a model because natural seawater contains many salts and other substances.

Mix until the salt is dissolved. Label the solution clearly as “simulated seawater—do not drink.” Measure and record its conductivity or total dissolved solids. Measure the distilled-water control with the same instrument after rinsing the probe according to its instructions.

Safety and Ethical Controls

This experiment involves hot glass, steam, electrical equipment, and concentrated saltwater. It should be supervised by a qualified teacher or laboratory technician. Wear goggles and suitable protective clothing. Secure all glassware with clamps and inspect it for cracks before heating.

Never heat a closed system. Never add boiling chips to hot liquid because sudden boiling may occur. Do not touch glassware until it has cooled; hot glass can look identical to cold glass. Keep electrical leads and meters away from spills.

No sample should be tasted. Smelling directly from a container is also unnecessary. If observation of odor is part of a different experiment, laboratory wafting procedures require instructor approval, but this desalination investigation needs no odor test. Dispose of samples according to the instructor’s guidance.

Experimental Procedure

1. Clean and rinse the distillation apparatus. Assemble the flask, condenser, tubing, receiver, and clamps according to the instructor’s approved diagram.
2. Place a measured volume, such as 250 millilitres, of simulated seawater into the distillation flask. Do not fill the flask more than recommended for the apparatus.
3. Add boiling chips before heating.
4. Start cooling water through the condenser. Water should normally enter at the lower condenser port and leave from the upper port so the jacket fills effectively.
5. Apply heat gradually. Avoid violent boiling, which can transfer salty droplets into the condenser.
6. Collect a defined volume of condensate, such as 50 millilitres. Do not boil the flask dry.

7. Turn off the heat and allow the apparatus to cool before disassembly.
8. Label the condensate “distilled experimental sample—do not drink.”
9. Allow the original saltwater, condensate, and distilled-water control to reach a similar temperature.
10. Rinse and calibrate the meter as required. Measure each sample at least three times, rinsing the probe between samples.
11. Record the mean conductivity or total dissolved solids for each sample.
12. Observe the cooled boiling flask. Salt crystals or a more concentrated solution should remain, depending on how much water was removed.

Observation and Results Table

Sample	Trial 1	Trial 2	Trial 3	Mean	Appearance
Distilled-water control					
Simulated seawater before heating					
Collected distillate					
Concentrated liquid remaining in flask					

The units should match the instrument, commonly microsiemens per centimetre for conductivity or parts per million for an estimated total dissolved solids value. Record the instrument model, calibration standard, and sample temperature because conductivity changes with temperature.

Data Analysis

The percentage reduction in measured concentration can be estimated with the following relationship:

Percentage reduction = [(initial value − distillate value) ÷ initial value] × 100

For example, if the original solution measures 30,000 units and the condensate measures 150 units, the calculated reduction is 99.5%. This does not mean the sample is 99.5% “safe.” It indicates only the reduction in the selected measurement.

Results should be compared with the distilled-water control. If the condensate value is much higher than the control, possible causes include saltwater splashing into the condenser, contaminated glassware, probe carryover, poor calibration, or impurities in the source water.

Replicate trials improve reliability. The class can calculate means, ranges, and standard deviations and graph the average measurement for each sample. Error bars can show variation among repeated measurements.

Expected Results and Interpretation

The simulated seawater should have the highest conductivity because it contains many dissolved ions. The concentrated liquid remaining in the flask may measure even higher after some water has been removed. The distillate should have much lower conductivity and should approach the distilled-water control when the apparatus operates correctly.

These results would support the hypothesis that simple distillation removes most dissolved sodium chloride from water. Salt residue in the boiling flask provides visible supporting evidence. However, clarity is not evidence of purity; saltwater and distilled water may both look clear.

A failed result is still informative. If the distillate remains salty according to the meter, students should inspect the method rather than altering the data. Scientific investigation includes identifying sources of error and repeating procedures under better control.

Alternative Solar-Still Demonstration

A solar still demonstrates the same evaporation–condensation principle without an open flame. Saltwater is placed in a wide dark container, a clean empty cup is positioned in the center above the saltwater level, and transparent plastic film is sealed over the top. A small weight above the cup creates a low point. Sunlight warms the saltwater, vapor condenses on the film, and droplets run toward the low point and fall into the cup.

This method is slower and more affected by weather, sealing, and surface area. It is useful for demonstration but may produce too little water for precise measurement. The collected liquid must still not be treated as certified drinking water.

Industrial Desalination

Industrial thermal desalination includes multi-stage flash and multiple-effect distillation, which recover heat more efficiently than a simple laboratory apparatus. Reverse osmosis has become a dominant method in many regions. It applies pressure to saline water and forces water through membranes that reject much of the dissolved salt.

Desalination plants require pretreatment to reduce particles and biological fouling, energy for separation, post-treatment to stabilize and remineralize the water, disinfection, and continuous quality monitoring. Concentrated brine must be managed to reduce environmental harm. Energy demand and infrastructure cost remain major considerations (Elimelech & Phillip, 2011).

The WHO emphasizes a risk-management approach because desalinated water may require attention to source-water contamination, treatment performance, mineral balance, materials, storage, and distribution (WHO, 2011). The classroom experiment demonstrates one separation principle but not the complete production of safe municipal water.

Limitations and Improvements

Simulated seawater containing only sodium chloride does not represent the full chemistry of ocean water. Future experiments could use certified artificial seawater salts, compare different starting salinities, or measure recovery percentage. Students could investigate how heating rate affects entrainment or compare single and repeated distillation.

Conductivity meters estimate ionic content but do not identify individual substances. More advanced analysis could use ion chromatography or gravimetric residue measurement. Mass balance can also improve the experiment by comparing the mass of starting water, condensate, remaining liquid, and recovered salt.

Environmental analysis could extend the investigation beyond whether desalination works. Students could compare energy requirements, brine impacts, cost, renewable-energy integration, conservation, wastewater reuse, and alternative water supplies.

Conclusion

Simple distillation can substantially reduce salt concentration in simulated seawater. Water evaporates, moves through a condenser, and returns as liquid while most dissolved sodium chloride remains in the boiling flask. The result should be demonstrated through conductivity or total dissolved solids measurements, not taste.

The experiment supports an evidence-based conclusion when it includes a clear hypothesis, controlled variables, repeated measurements, safe apparatus, and honest analysis of error. It also teaches an important distinction: desalinated water is not automatically safe drinking water. Complete water treatment requires source assessment, multiple controls, monitoring, and appropriate post-treatment.

Desalination can expand freshwater supplies in water-scarce regions, but it involves cost, energy use, and environmental trade-offs. The classroom model is therefore both a chemistry experiment and an introduction to the larger challenge of managing water sustainably.

References

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