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Water Purification and Ocean Salinity: The Colligative Properties and Engineering Naval Solutions

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Joni M. Lakin (Ph.D. , The University of Iowa) is Associate Professor of Educational Research at the University of Alabama. Her research interests include educational assessment, educational evaluation methods, and increasing diversity in STEM fields.

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Dr.Virginia A. Davis' research is primarily focused on using fluid phase processing to assemble cylindrical nanomaterials into larger functional materials. Targeted applications include optical coatings, 3D printed structures, light-weight composites, and antimicrobial surfaces. Her national awards include selection for the Fulbright Specialist Roster (2015), the American Institute of Chemical Engineers Nanoscale Science and Engineering Forum's Young Investigator Award (2012), the Presidential Early Career Award for Scientists and Engineers (2010), and a National Science Foundation CAREER Award (2009). Her Auburn University awards include the Excellence in Faculty Outreach (2015), an Auburn University Alumni Professorship (2014), the Auburn Engineering Alumni Council Awards for Senior (2013) and Junior (2009) Faculty Research, the Faculty Women of Distinction Award (2012), and the Mark A. Spencer Creative Mentorship Award (2011). Dr. Davis is the past chair of Auburn's Women in Science and Engineering Steering Committee (WISE) and the faculty liaison to the College of Engineering's 100 Women Strong Alumnae organization which is focused on recruiting, retaining and rewarding women in engineering. She was also the founding advisor for Auburn's SHPE chapter. Dr. Davis earned her Ph.D. from Rice University in 2006 under the guidance of Professor Matteo Pasquali and the late Nobel Laureate Richard E. Smalley. Prior to attending Rice, Dr. Davis worked for eleven years in Shell Chemicals' polymer businesses in the US and Europe. Her industrial assignments included manufacturing, technical service, research, and global marketing management; all of these assignments were focused on enabling new polymer formulations to become useful consumer products.

Dr. Edward W. Davis, Auburn University

Edward W. Davis received his PhD from the University of Akron in 1996. He worked in the commercial plastics industry for 11 years, including positions with Shell Chemicals in Louvain-la-Nueve Belgium and EVALCA in Houston TX. He joined the faculty at Auburn University in the fall of 2007. In 2014 he was promoted to Senior Lecturer. He has regularly taught courses in three different engineering departments. In 2015 he began his current position as an Assistant Professor in the Materials Engineering Program.

Chere' DeLayne Smith, Smiths Station High School

Water Purification and Ocean Salinity: The Colligative Properties and Engineering Naval Solutions (Resource Exchange)

The National Academy of Engineering's (NAE) *Grand Challenges of Engineering* (GCE) [1] are a list of 14 critical challenges that society faces and that can be addressed by engineers. The GCE highlight the ways engineering works to help others and emphasizes the collaborative, creative, and interdisciplinary work engineers do. Framing engineering as an altruistic career is believed to increase interest for more girls, underrepresented racial/ethnic minority, and first-generation college students [2] - [4]. In a grant funded by the Office of Naval Research (ONR), our interdisciplinary team has developed multiple hands-on lab and classroom activities for the high school classroom that use the Grand Challenges and Naval contexts as a motivation for the lab.

In this lab, students explore the relationship of boiling point and salinity in the context of purifying water. Prior to this lab, students should know about colligative properties and factors impacting boiling point. In this lab, students are tasked with helping the Navy adapt their water purification systems for different regions of the ocean where salinity varies. The lesson has both a scientific and engineering *briefs*. The scientific brief describes variation of ocean salinity.

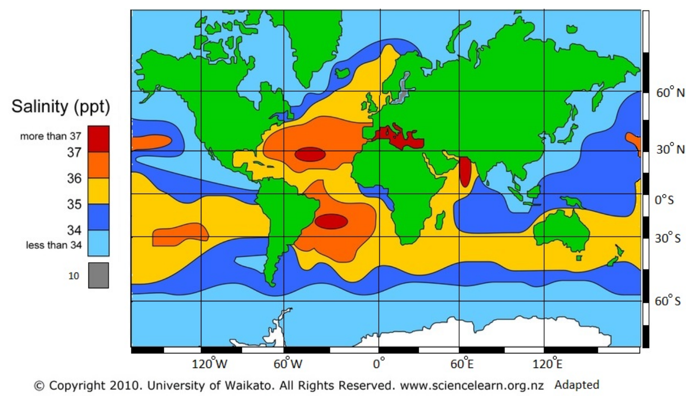


Fig 1. *Scientific brief:* Map showing how regions of the ocean vary in salinity.

The engineering brief shows how a *still* can produce fresh water from a salt water source. Students determine how the local salinity of the ocean affects the efficiency of producing fresh water.

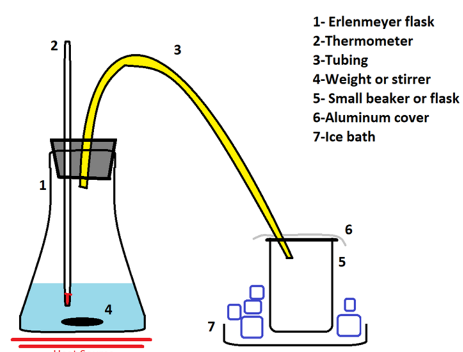


Fig 2. *Engineering brief:* Boiling Desalination Still

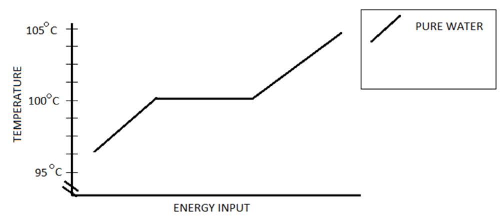
Grade level: Grade 8-12
Duration: One 90min or 2 50min class
Learning objectives: Students will be able to…

- calculate the expected change in boiling point based on a specified salinity, with the provided equation, and compare this result to observed data.
- connect this real-world example of intensive or colligative properties, including osmotic pressure and boiling point elevation.
- discuss how colligative properties have real world consequences for providing access to clean water through engineered solutions.
- identify strengths and weaknesses of their boiling water still and describe improvements to the design.

Materials/procedure: Students use a hot plate and a "still" comprising an Erlenmeyer flask with a rubber stopper that has a thermometer and hose inserted. "Ocean" water of different salinities are provided. Water vapor travels up the hose and is collected in a small beaker. Students monitor the boiling point and the amount of water produced over a specific time period. Students can also use test strips to ensure the water produced is less salty. Each group is provided with one salinity level and differences across groups provide additional comparison points.

Evaluation: Each has been evaluated through student surveys and through implementation by teacher. Students in a variety of classrooms have found the lab engaging.

Reflection questions:
1. Which properties from this exploration are <u>extensive</u> and which are <u>intensive</u>?
2. The diagram *to the right* shows the phase change of pure water from liquid to gas. Using your data, draw in the phase change of your salt water. Label the liquid, gas, and phase change portions of the diagram. Assume 1atm of pressure.



3. The following table shows the output of several common desalination processes. Complete the table with your data and analysis of the pros and cons of your system compared to other processes. How does your system compare to the others?

Process	mL/hr	L/day	Pros and cons
Solar still	53	0.6	No active maintenance required; must remain at surface and sunny.
Hand-operated reverse osmosis pump	946	22.7	Requires active work of pumping device; can run day and night
Boiling desalination still	?	?	?

Alignment to *Next Generation Science Standards*:
HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
Practices: Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. (HS-PS1-5)
Alignment to *Project Lead The Way*:
PLTW Unit 1 Design Process; PLTW Unit 6 Reverse Engineering.

References

[1] National Academy of Engineering, *NAE Grand Challenges for Engineering*. Washington, DC: National Academies Press, 2008.
[2] J.M. Lakin, V.A. Davis, and E.W. Davis. "Finding fit: Alignments between career values and future career as predictors of engineering commitment for women and underrepresented minority students." *International Journal of Engineering Education,* vol. 35, no. 1A, pp. 168–181, 2019.
[3] J.M. Allen, G.A., J.L. Smith, D.B. Thoman, and E.R. Brown. "To grab and to hold: Cultivating communal goals to overcome cultural and structural barriers in first-generation college students' science interest". *Translational Issues in Psychological Science*, vol. 1, no, 4, pp. 331-341, 2015.
[4] A. L. Belanger, A. B. Diekman, and M. Steinberg. "Leveraging communal experiences in the curriculum: Increasing interest in pursuing engineering by changing stereotypic expectations". *Journal of Applied Social Psychology*, vol. 47, no. 6, pp. 305-319, 2017.