DESIGNING ADVANCED TREATMENT SYSTEMS TO PERFORM AT HIGH ELEVATIONS

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Has this ever happened to you?

- You sit down at a diner
- You ask if they serve **sweet** iced tea
- They reply, “No, but there is sugar on the table”

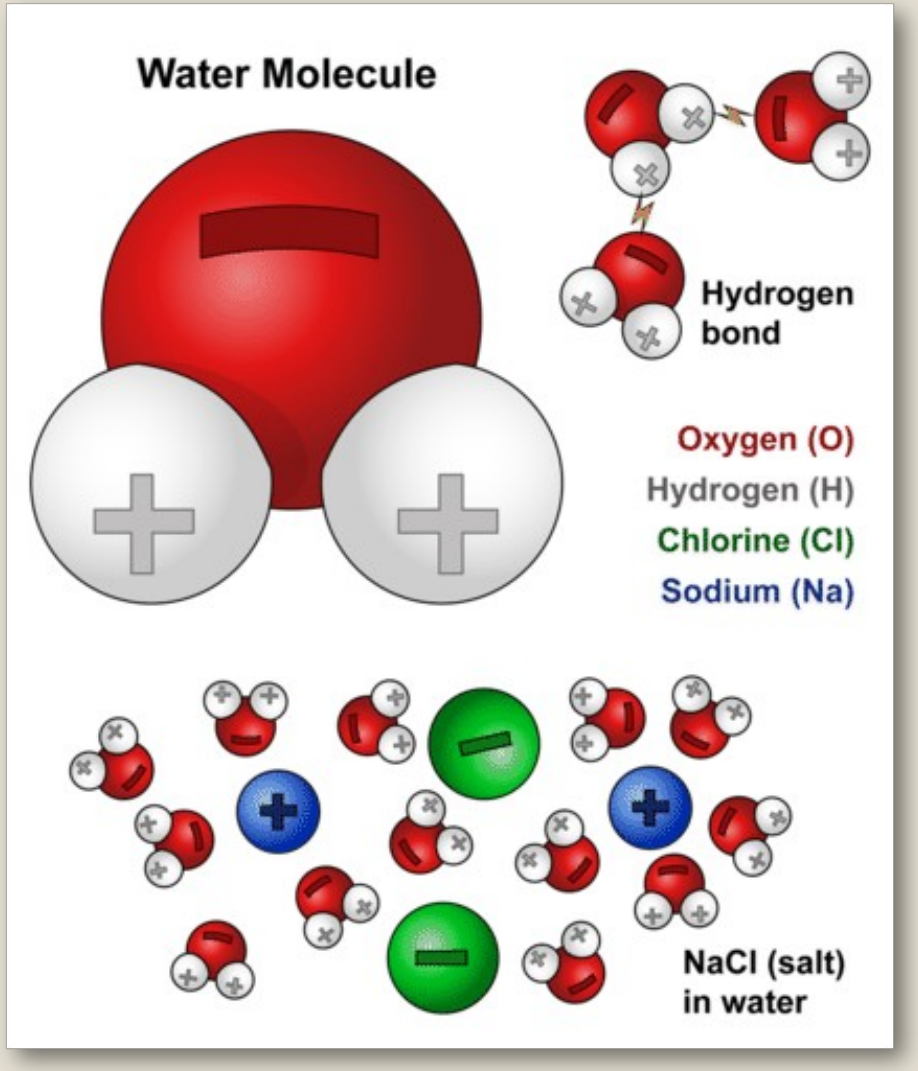
- Why won’t the sugar dissolve?

Water is called the Universal Solvent*

- A variety of materials can dissolve in water
- The correct environmental conditions must exist
- It takes time for any material to fully dissolve

* USGS.gov June 9, 2018; accessed by author July 27, 2026

Water molecule chemistry details



Source: Mariana Ruiz Villarreal, CK-12 Foundation

Salts depress oxygen concentrations

- Sea water, with 36 parts per thousand (o/oo) salt dissolves into water
- Cocktail Party Analogy Sodium (Na^+) and Chloride (Cl^-) compete with Oxygen for water's attention
- As more salt ions occupy the water, fewer water molecules are available to "host" oxygen gas

Gasses also dissolve in water

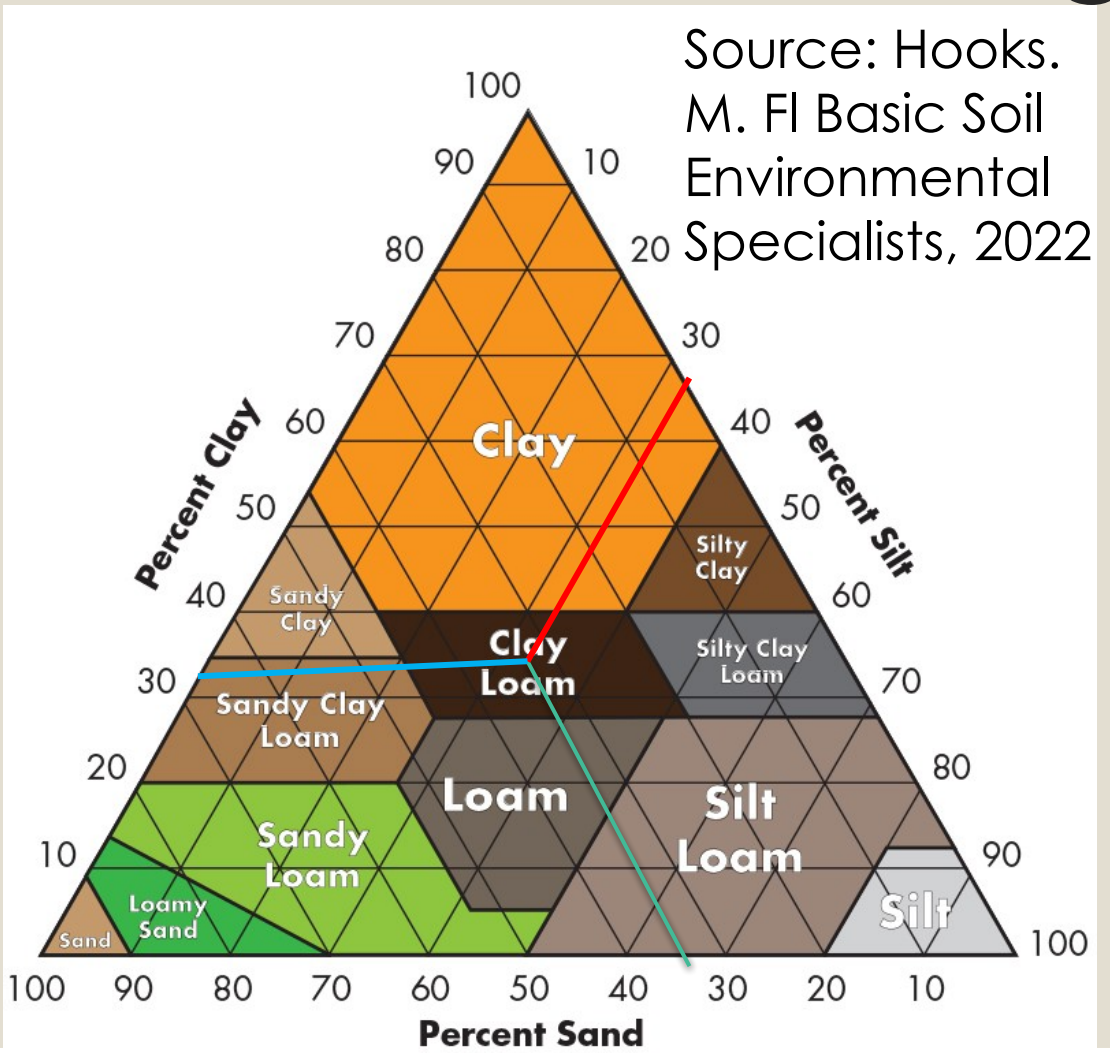
- in accordance with Henry's Law
- Equilibrium (saturated) gas concentration in water is a function of
  - the type of gas
  - partial pressure of the gas above the liquid

Oxygen solubility in water

- Three environmental parameters involved
  - temperature (as Temp. ↑ DO ↓)
  - salinity (as Salinity ↑ DO ↓)
  - barometric pressure (as ml Hg ↓ DO ↓)

- There aren't many three-parameter input relationships in this crossroad field
  - can you think of another?

USDA Soil Textural Triangle



Source: Hooks. M. Fl Basic Soil Environmental Specialists, 2022

Barometric Pressure is a function of elevation

Barometric Pressure	Elevation above sea level (ft)
760 mm of mercury	0' (at sea level)
734 mm of mercury	1,000'
682 mm of mercury	3,000'
630 mm of mercury	5,000'
578 mm of mercury	7,000'
526 mm of mercury	9,000'
500 mm of mercury	10,000'
474 mm of mercury	11,000'
448 mm of mercury	12,000'
370 mm of mercury	15,000'

Source: Tchobanoglous, G & Burton, F.L. Wastewater Engineering,3rd Edition, McGraw-Hill 1991.

Health Effects of Prolonged Exposure to high elevation

- Human physiology is affected beginning at 7,000 feet above sea level
- Warning signs: difficulty breathing, acute mountain sickness symptoms
- Mountain sickness symptoms include headaches, nausea, fatigue, dizziness and disturbed sleep

Source, scienceinsights.org March 18, 2026 accessed August 2, 2026

North America's 20 highest elevation summits

- Denali, USA, AK 20,310 ft
- Mt. Logan, Yukon, CAN 19,541 ft
- Pico de Orizaba, Vera Cruz MEX 18,491 ft
- Mt. Saint Elias, USA. AK 18,009 ft
- Popocatĕpetl, Puebla MEX 17,749 ft
- Mt Foraker, USA, AK 17,400 ft
- Mt, Lucania, Yukon, CAN 17,257 ft
- Volcán Iztaccihuatl, Puebla MEX 17,108 ft
- King Peak, Yukon, CAN, 16,972 ft
- Mt. Bona, USA, AK 16,500 ft
- Mt. Steele. Yukon, CAN 16,470 ft
- Mt. Blackburn USA AK 16,390 ft
- Mt. Sanford, USA AK 16,237 ft
- Mt. Wood, Yukon, CAN 15.945 ft
- Mt. Vancouver, Yukon, CAN 15,787 ft
- Mt. Slaggard, Yukon, CAN 15,558 ft
- Nevado de Toluca, MEX 15,387 ft
- Mt. Fairweather British Columbia, CAN 15,325 ft
- Sierra Negra, Puebla, MEX 15,059 ft
- Mt. Hubbard, AK & Yukon, CAN 14,951 ft

WEB TOOLS | DATA ACCESS TOOLS

DOTABLES

November 7, 2022

Access the web tool

DOTABLES is an online program that generates tables of dissolved oxygen (DO) solubility values and (or) salinity correction factors over a range of user-specified values for water temperature, barometric pressure, and salinity or specific conductance. In addition to generating tables, DOTABLES can compute a single-value of oxygen solubility and percent saturation for a specific instance of temperature, pressure, and salinity.

DOTABLES is executed by choosing the type of desired result (single-value computation, DO solubility table, or salinity correction factor table), providing the required inputs, and then clicking the "Submit" or "Make Table" button from the appropriate section. The equations used to make these computations are valid for the following ranges:

Water temperature	0-40 degrees Celsius or 32-104 degrees Fahrenheit
Barometric pressure	380-836 mm Hg, 14.97-32.91 in Hg, 507-1114 mbar, 51-112 kPa, or 0.5-1.1 atm
Salinity or SC	0-40 ‰ salinity, or 0-59118 µS/cm specific conductance



Saturated Dissolved Oxygen tables

- DO concentration (mg/L) as function of temp & elevation (salinity is 0 0/00)

Temp °F	Sea level	5,000'	9,000'	11,000'
32	14.62	12.11	10.19	9.09
50	11.29	9.33	7.77	6.99
68	9.09	7.50	6.23	5.59
86	7.56	6.21	5.13	4.59

- DO concentration (mg/L) as a function of temp &salinity (elevation is at sea level)

Temp °F	Fresh Water	10 0/00	20 0/00	Sea (35) water
32	14.62	13.69	12.71	11.37
50	11.29	10.59	9.93	8.97
68	9.09	8.57	8.09	7.35
86	7.56	7.15	6.77	6.20

Data source ; USGS DOTABLES

Does higher elevation impact other environmental parameters?

- Yes, lower temperatures are linked to higher elevations
- Water temperatures below 50^{o}F (10^{o}C) inhibit the bacteria responsible for converting ammonia (NH_3) to Nitrate (NO_3)
- The process is called nitrification

HOW DOES COLORADO USE THE ABOVE INFORMATION?

- 3. Field Performance Testing
- g. Testing may be performed in locations other than Colorado, if elevation and climate conditions are similar to those in Colorado.

  (1) Increased elevation results in lower atmospheric pressure and lower oxygen content. If components are changed or adjustments made to compensate for these conditions, those changes or adjustments must be specified.

  (2) Colorado has a semi-arid climate. If components are changed or adjustments made to compensate for these conditions, those changes or adjustments must be specified.

  (3) If nitrogen reduction is claimed, the provisions for nitrification at cold temperatures must be specified.

REGULATION NO. 43 - ON-SITE WASTEWATER TREATMENT SYSTEM REGULATION

(5 CCR 1002-43)

43.13 Technology Review and Acceptance

D. Proprietary Treatment Product Acceptance Requirements

References, Sources of Add'l Information

- Atlas Scientific https//atlas-scientifc.com. What is the relationship between dissolved oxygen and salinity? July 30, 2025. Accessed July 29, 2026.
- Baquero-Rodríguez, G. A., Martínez, S., Acuña, J., Nolasco, D., & Rosso, D. (2022). How elevation dictates technology selection in biological wastewater treatment. *Journal of Environmental Management*, *307*, 114588. Elsevier 10 pp.
- Davis, W.M. and C.F. Dykstra (2012). *Physical Chemistry a modern introduction.* Second edition. CRC Press, Boca Raton, FL. 501 pp.
- Hooks. M. (2022) Florida Basic Soil for Environmental Specialists, Florida Department of Health, 96 pp.
- Jantrania, A.R. and Gross, M.A. (2006). *Advanced Onsite Wastewater Systems Technologies*. CRC Press, Taylor & Francis. Boca Raton, FL. 261 pp.
- Krauskopf, K. B., & Bird, D. K. (1995). *Introduction to geochemistry* (Vol. 647). New York: McGraw-Hill.
- Metcalf, L., Eddy, H. P., Tchobanoglous, G.& F.L. Burton (1991). *Wastewater engineering: treatment, disposal, and reuse* (3rd Edition) Appendix B Table B-1 Physical Properties of Air. New York: McGraw-Hill, 1334 pp.
- Sherman, K.M. 2008. Keynote Speaker 10th Annual State Onsite Regulators Alliance and Captains of Industry conference "Sharpening the Tools" Point Clear, AL March, 2008.
- USGS.gov 2022. DOTABLES web tool November 7, 2022 accessed 8 2 2026.
- USGS.gov 2018. Water, the Universal Solvent June 19, 2018 accessed 7 26 2026.

thank you

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