

Why is the ocean salty while rain is not?

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Rain returns water from the atmosphere, but it does not return all the dissolved material carried into the sea by rivers. Ordinary evaporation transfers water into vapour while leaving most dissolved salts behind. Rocks, water and the seafloor supply ions; other processes remove them. The ocean's saltiness is the result of that selective circulation and chemical accounting, not simply a container that has accumulated salt without an exit since Earth began.

The phrase “rain is not salty” also needs qualification. Rain normally contains much less dissolved salt than seawater, but it is not chemically pure water. The contrast is one of concentration and transport pathways, not a distinction between water with chemicals and water without them.

1. Where the dissolved material comes from

Seawater contains electrically charged atoms and groups of atoms called ions. Sodium and chloride are especially abundant, but seawater is not merely table salt dissolved in water. Its chemistry also includes magnesium, sulfate, calcium and other constituents. NOAA gives a typical total salinity of about 35 grams of dissolved salts per kilogram of seawater. Local values differ. [1]

Rain and soil water interact with rock, dissolving and chemically altering minerals. Rivers deliver some of the resulting ions to the sea. [1] A river need not taste salty to transport a substantial mass: a modest concentration multiplied by a large volume of flowing water can produce a large flux. Concentration describes what is in a sample; flux describes how much crosses a boundary per unit time.

Seafloor circulation adds another pathway. Water entering hot crust changes composition through reactions with rock. Some constituents enter the fluid; others leave it. NOAA's hydrothermal-vent account explicitly describes removal of magnesium and sulfate alongside the addition of several metals. [2] Calling vents a source of “salt” without identifying the constituent would conceal this two-way chemistry.

2. Water and salt do not follow identical routes

At the sea surface, individual water molecules can leave the liquid and enter the air. Dissolved sodium and chloride do not ordinarily accompany them as an equivalent vapour of seawater. Consequently, evaporation can increase the concentration in the liquid that remains, while freshwater input can lower it. NOAA's account of surface salinity identifies both evaporation and rainfall as controls. [3]

This is different from throwing a droplet into the air. Sea spray transfers tiny pieces of liquid, potentially including their dissolved salts. Evaporation and mechanical production of spray must not be merged into one process. NOAA identifies sea salt among atmospheric aerosols and precipitation among their removal routes. [5] Dissolved gases also contribute material to rain. The title's contrast therefore does not imply that every rain sample has zero sodium, chloride or other solutes.

For example, carbon dioxide dissolves in rainwater and participates in its acidity, as the US Geological Survey explains in its account of the route from precipitation to rock

weathering. [4] Even before discussing sea spray, “pure water” would already be an inadequate chemical description of natural rain.

3. A concentration calculation

Consider a deliberately simplified container holding 1,000 kilograms of solution, including 35 kilograms of nonvolatile dissolved salts. Its salt mass fraction is $35/1,000 = 0.035$, or 35 grams per kilogram. Suppose 100 kilograms of water evaporate, with no salt lost and no new material entering.

The remaining solution has a mass of 900 kilograms and still contains 35 kilograms of salt. Its concentration is therefore $35/900$, about 0.0389, or 38.9 grams per kilogram. The salt inventory has not grown. Only the water inventory has fallen.

If 100 kilograms of salt-free water are then added, the original concentration returns. This toy calculation isolates dilution and concentration; it is not a reconstruction of an ocean basin. It neglects circulation, additional solutes, chemical reactions, precipitation of minerals and exchange with sediments. Nor does it equate grams per kilogram with grams per litre: mass and volume require a density conversion.

A second distinction follows. Water can move from a river into an ocean and subsequently leave by evaporation, while the dissolved material follows a different set of routes. A water cycle diagram that tracks only water is incomplete as a diagram of salt transport.

4. Why salt does not accumulate without limit

For a selected dissolved constituent, let M be its mass in the ocean, F_{in} its total input rate, and F_{out} its total removal rate. Conservation gives $dM/dt = F_{in} - F_{out}$. The equation says nothing by itself about the sizes of those fluxes; those require chemistry and measurements.

Water-rock reactions at the seafloor can remove magnesium and sulfate, and minerals can precipitate from hydrothermal fluids. [2] Biological uptake can transfer some constituents out of seawater. [1] That transfer alone does not establish permanent removal: subsequent decomposition or dissolution may return material. A chemical sink must be defined over a timescale and with a destination.

If inputs and outputs balance over a chosen interval, the inventory can remain approximately stable despite continuous throughput. Under that steady-state approximation, M/F_{out} defines a turnover timescale for the selected constituent. It is not the age of the ocean and does not establish the age of every ion in it. Different elements can have very different inventories and removal processes.

This matters historically. Dividing today's ocean salt content by today's river input would produce a time, but interpreting that time as the ocean's age would assume away outputs, changing inputs and initial conditions. A dimensionally valid quotient is not automatically a valid clock.

5. What observations establish, and what requires a model

Samples establish concentrations at particular places and depths. Repeated sampling can reveal changes. To estimate a river's delivery, concentration must be combined with discharge; to infer a basin-wide inventory, the sampled chemistry must be related to the volume and distribution of water. Those are separate observational tasks.

The conservation equation then connects the tasks. If an estimated inventory changes in a way the measured fluxes cannot explain, possible causes include incomplete sampling, an

omitted source or sink, and changes in the water inventory. The equation is a constraint on an explanation, not an independent measurement of an unobserved flux.

Local salinity can also change through exchange with neighbouring waters. An evaporating patch is not necessarily an isolated container. The simple numerical example explains a tendency; ocean circulation determines how that tendency is expressed in a particular region.

6. The answer with its limits intact

We know why ordinary evaporation separates water from most dissolved salts, and we can identify major routes that supply and remove dissolved constituents. Reconstructing the detailed chemical balance of an earlier ocean is harder: modern concentrations do not uniquely specify the history that produced them.

The ocean is salty because dissolved constituents enter it and follow removal pathways different from the atmospheric return of water. Rain is much less saline because evaporation does not carry the ocean's dissolved mixture into vapour in the same proportions. Neither statement requires chemically pure rain or a sea with no salt sinks.

Related reading

Article 020, “Why do rivers bend?”, follows the movement of sediment and channel boundaries. Its connection with this article is transport, not an assumption that dissolved ions and sediment grains behave alike.

References

- [1] NOAA National Ocean Service. Why is the ocean salty?
<https://oceanservice.noaa.gov/facts/whysalty.html>
- [2] NOAA Ocean Exploration. Factsheet: Hydrothermal Vents.
<https://oceanexplorer.noaa.gov/wp-content/uploads/2022/10/hydrothermal-vents-fact-sheet.pdf>
- [3] NOAA JetStream. Sea Water. <https://www.noaa.gov/jetstream/ocean/sea-water>
- [4] US Geological Survey. Why is the Ocean Salty?
<https://www.usgs.gov/water-science-school/science/why-ocean-salty>
- [5] NOAA. Aerosols, Weather and Climate. State of the Science Fact Sheet (August 2022).
<https://csl.noaa.gov/factsheets/aerosolsweatherclimatesos.pdf>