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Saltwater intrusion threatens water supplies from tidal rivers worldwide

Worldwide, water obtained from tidal rivers for human use is threatened by saltwater intrusion. This is the result of a recent study by an international research team led by the University of Maryland in the US, which has now been published in the journal Environmental Science & Technology Letters and in which the Leibniz Institute for Baltic Sea Research Warnemünde (IOW) also participated. The main causes are the effects of climate change, such as prolonged periods of drought and sea level rise. In addition, local human activities affecting tidal rivers directly contribute to an increase in salinity in these vital freshwater resources.

Two-thirds of the world's drinking water supply comes from surface water, not groundwater. Rivers flowing into the sea and subject to tidal influences near the coast play a particularly important role in this regard. Their water is used in agriculture, for industrial production, as cooling water in industrial plants, and for other such purposes. Until now, the threat to the water supply for these uses posed by salt contamination through tidal rivers has received little attention from science and the public, even though increased salt levels in drinking water and agricultural irrigation are extremely harmful to health and the environment, and corrosion accelerated by salt is a major problem in industry.

“Salt contamination of water supplies in tidal rivers is a global problem but has received little attention beyond site-specific studies,” says Ming Li, an expert in coastal and estuarine dynamics modelling at the University of Maryland and lead author of the recently published study. The research team therefore goes beyond describing individual cases in which drinking water withdrawals from large rivers such as the Mississippi in the US, the Chao Phraya in Thailand, or the Rhine in Germany are threatened by salt contamination. They also – for the first time – compiled results from 170 studies from around the world on various aspects of saltwater intrusion into tidal rivers. The researchers looked at oceanographic and hydrological processes that promote this intrusion, as well as processes in watersheds that lead to increased erosion and weathering and thus to increased salt transport into rivers.

The key findings of the study are:

- Climate change is the main driver of saltwater intrusions. Accelerated sea level rise, increasingly prolonged periods of drought and the resulting very low discharge rates in rivers, but also extreme weather eventssuch as heavy rainfall, which lead to very high salt loads from catchment areas, are causing a significant increase of the salt contamination problem.
- Human activities, such as deepening shipping channels in estuaries, excessive use of road salt, and human-accelerated weathering processes on land, also contribute to increased riverine salt levels and further exacerbate the problem.
- Tidal rivers on all continents and in all climate zones are affected, from semi-arid to rainy temperate zones, both in terms of drinking water issues and damage to the environment and infrastructure.
- The salinization of freshwater can also lead to harmful secondary effects, such as the exacerbation of oxygen deficits and the additional mobilization of pollutants and nutrients in the affected rivers, including heavy metal and radioactive contamination.

Hans Burchard, IOW expert on oceanographic processes in estuaries and coastal seas, also contributed to the study. Together with Ming Li, he heads an international working group of the Scientific Committee on Oceanic Research (SCOR) on saltwater intrusion in tidal rivers. “Even in Germany, which is not one of the world’s typical arid regions, there have been periods of drought in recent years, during which freshwater discharge in some rivers has fallen to extremely low levels,” says the IOW researcher. For example, in the summer of 2022, the Rhine recorded its lowest ever measured discharge of 673 m^3 / s. Due to tidal influences, salt water intruded more than 10 km

further into the river in the Netherlands than the long-term average. In recent years, the Weser and Elbe rivers have also shown their lowest discharges since the 1950s, with similar consequences.

“These current salt intrusions were always caused by prolonged periods of drought in the river basins. Moreover, the deepening of estuaries over the past 100 years to accommodate ships with increasingly greater drafts contributes to the long-term trend of increasing river salinization,” says Burchard. Due to climate change and increasingly dry summers, this phenomenon is expected to increase in Germany in the future. “This will lead to problems with water extraction for agriculture and drinking water, as well as constraints on biodiversity along the estuaries, as many freshwater species cannot tolerate frequent saltwater incursions, concludes Hans Burchard.

In addition to the University of Maryland and the IOW, the team of authors behind the study also includes researchers from Pennsylvania State University, Rutgers University, the Woods Hole Oceanographic Institution, the University of Pennsylvania, and of Salisbury University. In view of the worsening global saltwater intrusion crisis, all see an urgent need for action, particularly the need to bring together science, engineering, water resource management, and legislation to protect endangered freshwater resources and the vital infrastructure that provides the water.

Specifically, they call for:

- Enhanced monitoring and measurement of major salt ions are crucial to better understand their sources, transport, and fate in watersheds and tidal rivers, aiding in the protection of infrastructure.
- The development of hydrological-hydrodynamic models that can simulate the transport of individual salt ions is essential for accurate prediction and for assessing risks to infrastructure.
- The development of decision support tools for predicting and managing salt contamination should involve stakeholders through a human-centered design approach, ensuring that infrastructure resilience is a key consideration.

Original publication: Ming Li, Raymond G. Najjar, Sujay Kaushal, Alfonso Mejia, Robert J. Chant, David K. Ralston, Hans Burchard, Antonia Hadjimichael, Allison Lassiter, Xiaohong Wang: *The Emerging Global Threat of Salt Contamination of Water Supplies in Tidal Rivers.* Environ. Sci. Technol. Lett. 2025, https://pubs.acs.org/doi/10.1021/acs.estlett.5c00505

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