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ENVIRONMENTAL SCIENCE

Rethinking Desalinated Water Quality and Agriculture

Damage to crops after irrigation with extremely pure water from the world's largest reverse-osmosis desalination plant reveals a need for revised treatment standards.

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With almost half of humanity suffering insufficient access to potable water (1) and water scarcity for agriculture considered to be a global crisis (2), seawater desalination has emerged as a feasible solution. Between 1994 and 2004, world desalination capacity increased from 17.3 to 35.6 million m^3/day (3). At present, seawater desalination provides 1% of the world's drinking water (4).

Desalinized water is increasingly considered a source of water for agriculture as well. With 69% of the global water supply going to irrigation (5), present freshwater resources may soon be insufficient to meet the growing demand for food. A recent report (6) concludes that, although the costs of desalination remain prohibitively expensive for full use by irrigated agriculture, for high-value cash crops like greenhouse vegetables and flowers, its use may be economically feasible.

In a few countries, desalinized brackish water (whose price is typically a third of desalinated seawater) is already widely used by farmers. For instance, ~22% of water desalinated in Spain goes to agricultural irrigation (6). An Australian survey found that 53% of the population envisioned desalinated water usage for irrigation of vegetables as highly likely (7). In Israel, the promise of new, profitable crop options has inspired farmers to request allocations of relatively higher priced desalinized waters.

In December 2005, a new seawater desalination plant was opened in Ashkelon, on Israel's southern Mediterranean coast. Its 100,000,000 m^3/year production makes it the largest reverse-osmosis (RO) desalination facility presently in operation worldwide (*8*). It is also the world's first desalination facility to produce potable water from seawater at a price below \$0.55/m^3 (*9*). Although the Ashkelon facility was designed to provide water for human consumption, because of relatively modest population densities in southern Israel, a substantial percentage of the desalinated seawater was delivered to farmers. Recent evaluation of the effect of the plant's desalinized water on agriculture, however, produced some surprising, negative results. Changing these outcomes will require modifying future water management orientation and revision of desalination standards.

WATER-QUALITY PARAMETERS AFTER DESALINATION

Parameter	Water from Ashkelon desalination plant	Recommendation for domestic and agricultural usage
EC (dS/m)	0.2–0.3	<0.3
[Cl^-] (mg/liter)	15–20	<20
[Na^+] (mg/liter)	9–10	<20
[Ca^{2+}] (mg/liter)	40–46	32–48*
[Mg^{2+}] (mg/liter)	0	12–18
[SO_4^{2-}-S] (mg/liter)	20–25	>30
[B] (mg/liter)	0.2–0.3	0.2–0.3
Alkalinity (mg/liter as $CaCO_3$)	48–52	>80*
CCPP (mg/liter as $CaCO_3$)	0.7–1.0	3–10*
pH	8.0–8.2	<8.5*

**Value based on the new Israeli recommendations for desalinated water.*

Effects of Desalinization

When farmers receive desalinized water, the lowered salinity is perceived as a bonus, because the salts (especially Na^+ and Cl^-) damage soils, stunt plant growth, and harm the environment. Salinity in water is measured by its electrical conductivity (EC). The EC of water produced at the Ashkelon desalination plant is 0.2 to 0.3 dS/m, replacing water from a national distribution system with an EC higher by a factor of three to five.

Boron (B) concentration in seawater averages 4.5 mg/liter and is slightly higher in the Mediterranean Sea. At these concentrations, B does not constitute a threat to human health (*10*) but is highly toxic to many crops (*11*). Boron in neutral and acidic environments readily passes through the RO membranes. Without additional treatment, B in Mediterranean seawater after RO will reach 2 mg/liter, which is toxic for all but the most tolerant crops (*11*). Toxicity symptoms in orchards were observed after irrigation with effluent originating from desalinated municipal water in Eilat with ~1.2 mg/liter B produced. Concentrations of 2 mg/liter B in irrigation water also caused reductions in yields in peanuts and tomatoes in the Negev region (*12*, *13*).

Desalination not only separates the undesirable salts from the water, but also removes ions that are essential to plant growth. Desalinized water typically replaces irrigation water that previously provided basic nutrients like calcium (Ca^{2+}), magnesium (Mg^{2+}), and sulfate (SO_4^{2-}) at levels sufficient to preclude additional fertilization of these elements.

Although water from Israel's national water carrier typically contains dissolved Mg^{2+} levels of 20 to 25 mg/liter, water from the Ashkelon plant has no Mg^{2+}. After farmers used this water, Mg^{2+} deficiency symptoms appeared in crops, including tomatoes, basil, and flowers, and had to be remedied by fertilization. Current Israeli drinking water standards set a minimum Ca^{2+} level of 20 mg/liter. The postdesalination treatment in the Ashkelon plant uses sulfuric acid to dissolve calcite (limestone), resulting in Ca^{2+} concentration of 40 to 46 mg/liter. This is still lower

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