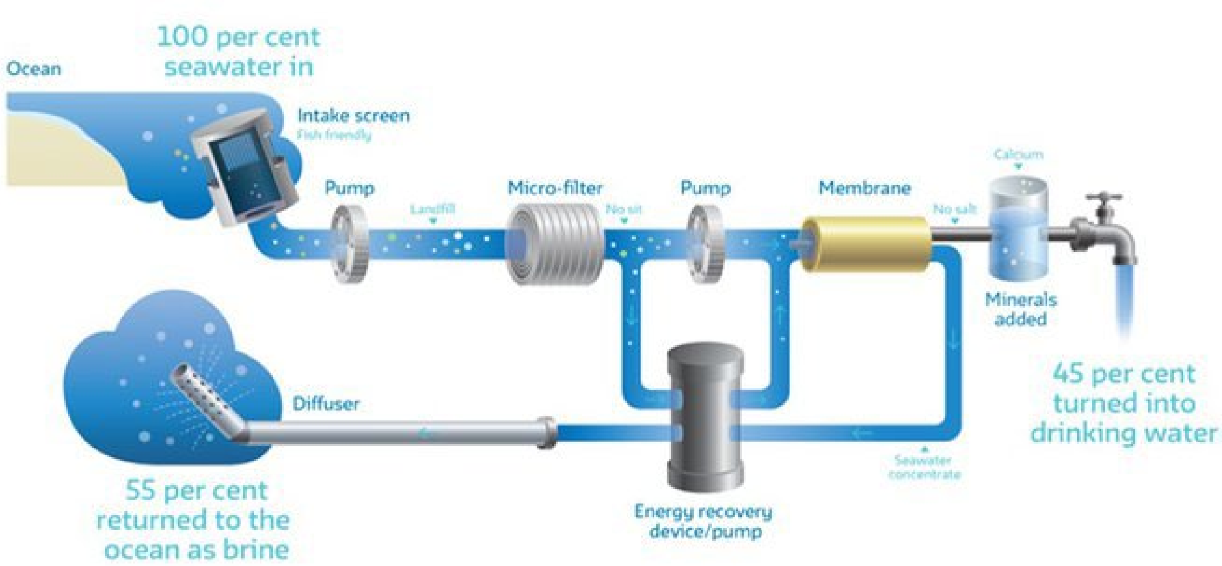
DESALINATION NOTES: Comments and Operational Description

How a Desalination Plant Works



Step one: get your seawater

First, you need a source of seawater, or brackish water (a mixture of sea and freshwater). Normally, seawater is piped in very slowly from an ocean depth of at least five meters.

“It’s very slow – only 0.1 of a meter per second – so the fish can swim against the current,” says Crisp. “You don’t want to suck in fish.”

The seawater is pumped into the desalination plant. At this point, it’s devoid of fish, but it contains plenty of small things you might find in the ocean – microbes, particles, and (of course) salt: mostly sodium chloride, or NaCl, but some other compounds as well.

“Seawater has got about 37,000 milligrams [of salt] per liter, which is the same as a teaspoon of salt in a glass of water,” says Crisp.

Step two: pretreatment

Prior to being desalinated, the water needs to be pre-treated – this treatment process is very similar to that done for fresh water.

“You put it through filters first to take out any particles, biological matter, and anything that makes it impure, because you want to be able to desalinate pure seawater,” says Crisp. The desalination process itself is very good at removing salt, and basically nothing else.

These pre-treatment filters can be sand-based, or materials called ultrafiltration membranes.

Next, the water is pumped through another filter called a cartridge filter, “just to make sure” it’s pure.

“The cartridge filter’s a bit like a canary’s cage in the mine, you just want to make sure the water gets through that last check.”

Step three: reverse osmosis

Next, the salt has to come out of the water. This is done via a process called *reverse osmosis* (RO). The water is pushed through a series of very thin membranes, with roughly atom-sized holes in them, at a very high pressure. Water molecules – H_2O – make it through these membranes, while salt stays on the other side.

You may have heard of osmosis in high school biology or chemistry: if there’s a membrane between two solutions of water, particles from the more highly concentrated solution will move across the membrane to the less concentrated liquid. Left to its own devices, this is what the water is going to do – so reverse osmosis, because it’s working against the chemical inclinations of the water, needs energy and pressure to achieve the opposite effect.

“We put it through really high-pressure pumps, which are what use most of the energy, and they pressurise the water,” says Crisp.

The RO process required a hydrostatic pressure of 700 metres – around 70 times higher than the water pressure required in a suburban house.

“You pressurize it to overcome osmotic pressure and you also pressurize it to push it through this very fine membrane,” says Crisp.

The RO membranes are usually a combination of polymers. The critical polymer is usually a substance called polyamide.

“The polyamide is microscopically thin – it’s only 0.2 of a micron thick,” says Crisp. This makes it similar in thickness to bacteria.

“It’s overlaying another polymer called polysulfide, which is 40 microns thick, that’s over a polyester fabric which is 120 microns. So if you add all that up together, you get an eighth of a millimetre.”

While thin, these membranes are highly effective at getting salt out of the water. This is good, because they’re also very expensive, and require a lot of attention to stop from fouling.

“Membranes, they’re a very expensive component – they probably cost 7–10% of the project,” says Crisp. “Modern desal plants probably cost $500 million, so at least 10% of that is $50 million.”

A membrane is supposed to last for around seven years before needing to be replaced.

“In some places we can get over 10 years, and that happens when the pre-treatment is very well done and you’re not stretching the membrane,” says Crisp.

Nevertheless, “every seven to 10 years, it costs you 10% of the capital cost of the plant to replace the membrane”.

The membranes also need to be tended to in order to prevent fouling, which Crisp says is “the single biggest headache of any desal plant around the world”.

“You can get algal blooms through climate change and just through hot weather, and this algae is almost impossible to get out of in the pre-treatment process,” he says. “So in some instances, we’ve had to run in our plants at half capacity because we can’t pre-treat it fast enough to get out all that algae. But we manage pretty well.”

Research is currently being done on better membranes that can resist fouling more effectively. One avenue is polymers that can resist chlorine: polyamide is degraded by it.

“That’s one of our problems because we like to have chlorine, to disinfect the water. And that’s why we’re so careful with our pre-treatment,” says Crisp.

Step four: the parting of the ways

The end result of reverse osmosis is not dry salt and pure water. It's pure water and very salty water.

"You're making 50% of sea water into pure, and the other 50% is returned back to the ocean at double the salinity of seawater," says Crisp.

"But that other 50% has still got all of this energy that you've put into it so we put it through a thing called an energy recovery device, and we get back half of our energy – that's a saving grace for modern desal plants."

This doubly salty water is pumped back into the ocean at a speed of four metres per second.

"That naturally mixes with seawater and within 50 metres of discharge, they can't measure the difference between seawater and what's come out [of the plant], which is very good," says Crisp.

Step five: de-purifying the pure stuff

Completely pure water, like the permeate made with reverse osmosis, is actually quite dangerous to drink. So the water needs some final treating before it leaves the plant.

"It's so pure that we put it through a promineralisation process," says Crisp.

"Essentially we inject carbon dioxide, and then we inject liquid lime, which adds hardness to the water in the form of calcium, so that it's drinkable."

These additions all happen on the order of between around one and 500 parts per million.

"Once we've done that and you have your drinking water, we just add fluoride for the kids' teeth, and we add chlorine to disinfect."

And then it leaves the plant, ready for drinking. (Reference 3)

Arizona thinks ocean desalination will bring it the water it needs. It won't.

All that ocean water just waiting to have the salt removed and be delivered to your tap. It can be done, but there are three hurdles:

- It’s costly.
- It’s energy intensive.
- And it creates a need to dispose of the leftover salt.

A proposal to desalinate water from Mexico’s Sea of Cortez. Construction cost estimates for this project range from $3 to $4 billion. That’s a lot of money – more than Arizona contributed to funding the Central Arizona Project. Yet, the estimates woefully understate the state’s ultimate liabilities.

We calculated in the report that building the binational project could cost more than $20 billion in capital costs and as much as $500 million in annual costs, which would be split in some unknown configuration among Arizona and other participating parties. Its operation could generate 300,000 tons of CO_2 per year. It likely wouldn’t be operational until the 2040s, assuming no permitting or other delays.

Once the plant began running, the challenging task of disposing of the salty brine would begin. The northern Sea of Cortez contains habitats protected under Mexican law and endangered species, the most iconic being the severely endangered vaquita porpoise.

It is by no means certain that Mexican regulators would grant the numerous permits the project would require. More certain is the likelihood of U.S.- and Mexico-based environmental groups challenging and extending the permitting process.

Readers may be wondering what’s in this for Mexico? We wondered the same thing and concluded: not much.

The project would simply offset the Colorado River water Mexico already receives. It *could* be expanded to net the nation additional water, but that would exacerbate costs and environmental challenges. Mexican workers would be paid to build the project and then to operate it.

Is that enough? We have significant doubts that Mexico will sign on to the proposal.

This would be a pay-first, benefit-later infrastructure project. Are Arizonans prepared to foot the bill for a multibillion-dollar project that may never deliver a drop of water? (Reference 1)

Legislators consider desalination as solution to Arizona water shortage

One of the options would build two desalination plants along the coastline of the Sea of Cortez in Mexico.

The treated water could stay in Mexico in exchange for allowing the U.S. to keep a portion of that country's Colorado River allotment.

"The technology is there. The question is related to the costs and the environmental impact," said Sharon Megdal, who heads up the University of Arizona's Water Resources Research Center.

Megdal has been working on water policy and management in Arizona for 30 years. While not involved with the study, she has studied desalination plants around the world and said they come with significant challenges.

Cost being one of the biggest.

The study estimated $4.5 billion to $4.9 billion to bring the plants online.

The costs to operate the plants could range from $148 million to $197 million annually.

The amounts are well above what users currently pay.

For context, in 2023, water that comes from the Colorado River through CAP canal will cost users an average of $270 per acre-foot.

Estimated costs of water from desalination plants in the study could reach $2,200 per acre-foot.

But Megdal said only a fraction of seawater that goes through the process is useable.

"It's more like a 50% throughout," she told ABC15. "So for every gallon, if we just talk about gallons you put into the process, you'll get a half gallon of good quality water, and then a half gallon of brine to dispose."

And the question of what to do with all that brine, or heavily salted water, has complicated answers.

Desalination supporters point to the country of Israel as a model.

"Israel is often looked at, as it should be, as a success story for dealing with water scarcity," Megdal said. One of her visits to Israeli plants is highlighted in the documentary Beyond the Mirage.

But she pointed out that there are real differences between a sovereign Israel and the state of Arizona.

One of them is that Israel has a readily available source of water since it borders the Mediterranean Sea.

She said another difference is their centralized approach to the governance of water.

"They have a master plan for water for the whole nation, the whole region, and they follow it," Megdal said.

That includes what to do about brine, which largely ends up back in the Mediterranean Sea.

"There are concerns about the impacts of marine life," Megdal said. "If there are plants being operated for many years, what is the cumulative impact of the brine disposal?"

Still, she says desalination should not be counted out. But it can't be counted on as the only solution.

"You kind of build a portfolio, and you build something that's resilient, and going to carry you through. And that means you don't bet on just one option, but you look at multiple options," she said. (Reference 2)

References:

1) *Opinion - **Robert Glennon** is a Regents Professor Emeritus at the University of Arizona College of Law, and author of 'Unquenchable: America's Water Crisis and What To Do About It.' **Brent M. Haddad**, Ph.D., is Professor of Environmental Studies at U.C. Santa Cruz and author of 'Rivers of Gold: Designing Markets to Allocate Water in California'.*

2) *Interiew ABC 15- Phoenix - **Sharon B. Megdal**, Ph.D. is Director of The University of Arizona Water Resources Research Center (WRRC), a Cooperative Extension center and a research unit in the College of Agriculture and Life Sciences. Other primary titles are Professor and Specialist in the Department of Environmental Science, C.W. & Modene Neely Endowed Professor, and Distinguished Outreach Professor.*

3) ***Ellen Phiddian** is a science journalist at Cosmos. She has a BSc (Honours) in chemistry and science communication, and an MSc in science communication, both from the Australian National University.*