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Episode 35: With No Grain Of Salt: Water Desalination Explained

Desalination

VOICEOVER
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SHANE HUNTINGTON
Hello and welcome to Up Close, coming to you from Melbourne University, Australia. I?m Dr Shane Huntington and today?s topic is desalination. The supply of clean and abundant drinking water has been a primary concern throughout human history. Populations in arid regions have needed to plan carefully and work hard to secure their water supplies. And now, with the onset of climate change more regions are under similar pressure and have to think long term about water security. In countries like Australia, where drought remains a significant threat, securing the water supply is critical. High on the list of large scale and long-term solutions is using seawater, minus the salt. Today on Up Close, we examine desalination as a concept, a technology and a possible solution to one of humanities gravest threats. Our guest on Up Close today, is Associate Professor Sandra Kentish, from the Department of Chemical and Bio-Molecular Engineering at the University of Melbourne. Welcome Sandra.

SANDRA KENTISH
Hi.

SHANE HUNTINGTON
Sandra, first of all, salt water itself: why is it problematic, why can?t we just use the water from the oceans for our crops, for our drinking supply?

SANDRA KENTISH
Well, the most obvious thing is, it is full of salt. It has about 35 grams a liter, which is just way too high for most humans and animals or crops to survive. I mean, there are specific crops and animals that survive in a seawater environment, but we are not

made for it.

SHANE HUNTINGTON
Nature has a way of removing salt from water supplies, and I guess there is a lot of fresh water lakes around the world, but we?ve been doing it for a long time too, so what are some of the earliest versions of desalination?

SANDRA KENTISH
Well, the most obvious version is simply by boiling the water and collecting the vapour. That is, if you like, nature?s way of doing it ? is you evaporate the water from the oceans and it comes down as rain which is fresh water. We?ve been doing that, probably for thousands of years ourselves: boiling water and collecting the condensate or the vapour that comes off from that water. That is quite pure water ? not as pure as you can get with some of today?s membranes technologies, but certainly pure enough to drink and that is an approach that has been used for a long, long time. The biggest problem is that it is very energy intensive.

SHANE HUNTINGTON
What are the key areas around the world where the desalination of water is a key requirement and I guess has been for many years?

SANDRA KENTISH
Well, primarily the ones that are lacking in water and the Middle East is the most obvious area that I am aware of. But even in Australia, up on the northwest shelf, where we have a lot our industry bases, there has been a lot of desalination for quite a while because of the need to access fresh water for industrial purposes. It is anywhere where there is no fresh water supply.

SHANE HUNTINGTON
Now, boiling water is one thing, but you and your colleagues work on a process called ?reverse osmosis?. Talk us through that.

SANDRA KENTISH
Okay, reverse osmosis is the technology that is taking over from the thermal approaches and there are a large number of commercial reverse osmosis installations now around the world. Primarily it is being put in place because it uses less energy than thermal methods, but it does still consume quite a reasonable amount of energy. In this approach, you essentially use pressure energy rather than thermal energy. So a membrane is a semi-permeable piece of plastic, if you like, and that plastic is permeable to water, but hopefully excludes all salt. In fact, most of the membranes today will exclude 99% of the salt. So, you literally push the water through the membrane and leave the salt behind. You end up with a fresh water product.

SHANE HUNTINGTON
Why specifically is that called ?reverse osmosis?? I mean, maybe talk a little bit through the osmosis process that people may be aware of.

SANDRA KENTISH
Probably a fundamental law of nature that a salty water solution doesn?t like to become more salty. If you place a container of salt water alongside a container of pure water and you place a barrier between them that is semi-permeable, the water wants to flow into the salt water to dilute it down. Ultimately the two solutions want to be at the same concentration. So, it is a natural process, if you like, for solutions to come to the same concentration. In reverse osmosis, we are trying to do the opposite. Trying to make salty water more salty by pulling water out of it. So, you?ve got to overcome some quite fundamental forces to do that. To pull water out of a salt solution requires some fundamental energy that no amount of engineering will ever overcome.

SHANE HUNTINGTON
So, because you are going the wrong way as it were, you have to put energy into the system in order to, I guess you?re really storing energy, aren?t you? In the sense of, the salt being put in one place and the clean water being put in another and they would recombine naturally to form a nice salty solution if allowed to, but you?re separating them.

SANDRA KENTISH
That?s correct. Trying to reverse the laws of nature.

SHANE HUNTINGTON
This is a very hot topic in terms of research around the world at the moment, what key problems exist with the reverse of the osmosis process?

SANDRA KENTISH
There are a number of challenges. Probably the most critical is, again, trying to reduce that energy consumption because everybody around the world is concerned that this is not a very cheap process to run from an energy perspective. And there are a number of ways we can do that. While there is this fundamental energy barrier, we are nowhere near that energy level at the moment, we are considerably above it. So there is a lot of ongoing work to try and improve the actual membranes so that they permeate water more readily, but still retain salt. Part of that is related to the fact that the membranes eventually foul. They get covered in slime. And again, if you can create a membrane that doesn?t get fouled, then you can reduce the energy demand, because getting the water to pass through the slime is harder. And, it requires more energy. In many other processes you would use chlorine for that process. You?d dose it in some swimming pool chemicals, to stop the slime growth. But, the membranes of today aren?t very tolerant of those chlorine-based chemicals. So, another area of active research around the world is to make ones that are chlorine tolerant. The third area would be, probably also looking at the impurities in parts of the world, for instance there is concern about arsenic levels in water, and boron levels, some of these more minor constituents. The World Health Organization is continuing to drop the levels that is acceptable for those in drinking water. And so, having a membrane process, it also effectively excludes those sorts of contaminants is an area that is becoming important.

SHANE HUNTINGTON
You?re listening to Melbourne University Up Close. I?m Dr.Shane Huntington and today we?re speaking with Sandra Kentish about desalination. Sandra, internationally, I guess there is quite a bit of controversy associated with desalination plants. It sounds like a very good technology, it sounds like a logical thing to do, where does the controversy come from?

SANDRA KENTISH
There are probably two areas. Firstly, it does require a lot of energy. And specifically, see what a ?desal? requires is up to ten times the energy of recycling wastewater. So, you get into this argument of, ?why should we use sea-water when there is plenty of dirty water sitting around that we could use instead?? Most people though don?t like the concept of re-using some of those types of wastewater. So, that is probably one of the major concerns. The other major concern is that, while we produce pure water, on the salty side of the membrane we have a very strong salt solution remaining, that is, water that is now considerably above the salt content of the original sea water, and there is some dispute over what you do with that concentrated brine. Certainly, there are people who are opposed to returning that brine to the ocean because of likely impacts on the ocean flora and fauna.

SHANE HUNTINGTON
You?d be looking at way to return it in such a way that it distributes over the large volume of water that the ocean potentially gives you, without affecting local environmental conditions.

SANDRA KENTISH
Yes, that is certainly one option. The other option is not return it. Is to essentially to evaporate it to dryness in a salt pan or something like that, and essentially store pure salt as a by-product of the process. Certainly, if you are operating one of these plants at a location that is not coastal and if you are using this just for waste water treatment or something then you have no other option except accumulate a pile of salt.

SHANE HUNTINGTON
You mentioned these membranes are essentially plastic, so, talk us through that. What does that mean? I have this image of something akin to a fish-tank filter where the water is pumped through and the salt is left behind and they?re made of plastic.

SANDRA KENTISH
Yes, essentially that is the way they work. When you look at them, though, they don?t ? they appear almost like a piece of paper in a flat sheet. If you imagine a piece of paper, 98% of that paper would actually have quite large holes in it. Still not visible to the naked eye, but holes that don?t really offer much resistance to either water or salt flow, and then there is coated on the top, a very thin layer. It is about .1 micron, and that is the actual plastic that is selective that allows the passage of water and stops the passage of salt. So, it looks like a coated piece of paper, if you like, and it is only the coating that is actually doing the separation. But again, in the sorts

of plants that we?re talking about, you want thousands and thousands of square meters of this material, and so the standard approach is to roll the flat sheet of paper up into what is called a spiral arrangement. So, you end up with a roll of paper, if you like, that might be a meter or so in length and you put that roll of paper inside a container and you add some plumbing so that the water flows in at one end, pure water flows out the other end and you take the salt water out through another pipe. At a large membrane plant, there?d be hundreds, if not thousands of those modules stacked into a building.

SHANE HUNTINGTON
Now Sandra, you caught my interest in particular a moment ago, when you said that these films on the paper like material, or on these plastics are about .1 microns thick. I guess contextually, our hair is about 50 microns thick, how do you accurately produce that type of film?

SANDRA KENTISH
It is a very good question because it is an art. To be honest, it is an art that is restricted mainly to the membrane companies. It is something that we are learning to do in our laboratories. But it is a technique involving polymer science in order to create that very fine layer on top of the porous structure. There?s two basic sorts of membranes; there is ones where that thin layer is actually the same polymer composition as the surrounding bulk, and you tend to make that layer by taking a solution of polymer and then selectively precipitating the polymer from the solution. But the sorts of membranes that we are talking about tend to be asymmetric membranes, where the porous support is formed quite separately first and then the top thin layer is coated on top of that.

SHANE HUNTINGTON
And as you said, these things do foul and they do presumably get damaged just through use.

SANDRA KENTISH
They get damaged to an extent. Again, in seawater desalination you?re applying pressure of maybe 65 bar, 65 atmospheres onto this membrane. That is the pressure you need to force the water through. And so, you do get what we call compaction, which is the whole membrane compacting down, but that is not an issue really in today?s membranes. So, that side of things we can handle. The fouling is more of an issue.

SHANE HUNTINGTON
With the fouling, is it a replacement issue at the moment, do you pull the membranes out and throw them away, are they cleaned, how do you go about the continual maintenance of large amounts of this material?

SANDRA KENTISH
Yeah, they are cleaned on a monthly or twice monthly basis. But they do have an ultimate life. You?d hopefully get two or three years, hopefully, we can stretch that to

five years use out of a membrane material and then would have to be discarded and a new module put in place ? new role of paper put in place. Everything else stays.

SHANE HUNTINGTON
And the technology you are working on, you mentioned before that desalination is fairly energy intensive relative to something like the use of sewerage, filtered sewerage water, are these membrane technologies being used in both areas, or is it a completely different world?

SANDRA KENTISH
No, most definitely they are being used in both. And you can buy from a manufacturer today a membrane that is designed specifically more for your sewerage or brackish applications or for your seawater. I should add that in the sewerage recycling and water recycling area, you actually use a range of membranes. You actually start with a membrane that has much larger pores, what we call a micro filtration membrane, and you would use that to get rid of some of your larger impurities in the water, you might then step down hole-size, if you like, the size of holes to an ultrafiltration or a nanofiltration membrane. And the pore size gets selectively smaller as you move through those operations. And then your reverse osmosis, if you like, is your final polishing membrane, where you finish off the process and it has the smallest pore size and therefore the largest energy costs because you have to apply the most pressure to pass the water through.

SHANE HUNTINGTON
Right. A question I guess I love to ask of people doing this sort of work is, if I gave you a glass of water from reclaimed sewerage and a glass of water from a desal plant, in your lab, would you be able to tell them apart?

SANDRA KENTISH
I wouldn?t be able to tell which one was which if they had both passed through the same sort of reverse osmosis at the end. I could tell them apart from, say, rain water, because they would actually probably be purer than rainwater. And so again, to somebody tasting them, there might be a subtle difference in flavour, but that would probably be because the water from sewerage was cleaner.

SHANE HUNTINGTON
Recycled sewerage is being rejected and yet the rainwater that we drink out of our taps is actually dirtier than what is offered from these plants and certainly the idea that seawater is cleaner, well, fish go to the toilet too and a lot of our junk goes into the sea, it is a very interesting mindset.

SANDRA KENTISH
Yes it is. It is a really interesting philosophical position for a lot of us to be in as to which way we go.

SHANE HUNTINGTON
Professor Sandra Kentish, Department of Chemical and Biomolecular Engineering,

here at the University of Melbourne, thank you very much for being our guest on Up Close today.

SANDRA KENTISH
Thank you.

SHANE HUNTINGTON
Relevant links, a full transcript and more information on this episode can be found on our website, at upclose.unimelb.edu.au. We also invite you to leave your comments or feedback on this or any other episode on Up Close, simply click on the add new comments link at the bottom of the episode page. Melbourne University Up Close is brought to you by the Marketing and Communications Division in association with Asia Institute of the University of Melbourne, Australia. Our producers for this episode were Kelvin Param and Eric van Bemmel. Audio recording by Craig McArthur. Theme music performed by Sergio Ercole. Melbourne University Up Close is created by Eric van Bemmel and Kelvin Param. I?m Dr Shane Huntington, until next time, thank you for joining us. Goodbye.

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