TWV Podcast #071
Membrane Technology and the Revolutionary Aquaporin Membrane
with Claus Helix-Nielsen
Show Notes at http://thewatervalues.com/pod71

Intro: Welcome to The Water Values Podcast. This is the podcast dedicated to water utilities, resources, treatment, reuse, and all things water. Now here's your host, Dave McGimpsey.

Dave: Hello and welcome to another session of The Water Values Podcast! As my son Joey said, I'm Dave McGimpsey. Thanks for joining me.

Great and listener-requested guest coming up today, and before getting to that, thanks to Jody for awarding the podcast yet another 5-star rating and a fantastic review on iTunes – greatly appreciate Jody. I'd really appreciate it if you enjoy the show to give both a rating and a review on iTunes like Jody did. It's a great way to help the podcast reach others who might also be interested in water issues.

Today's guest is Claus Helix-Nielsen. He's Danish and well-versed in the science of water, particularly in the field of membranes. One of my several Danish listeners recommended that Claus come on the show and fill us in on the status of membrane technology. Turned out to be absolutely fascinating, and Claus was terrific. We had a great little talk beforehand about some of Copenhagen's improvements since I was last there in 1992. Claus mentioned the waterfront in Copenhagen has improved dramatically since then, much like many American cities.

With that said, let's get on with it. Open the valves, fasten your seatbelts and here we go.

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Dave: Well, Claus, thanks so much for coming on to The Water Values Podcast. Really appreciate your time, especially since we're a world apart or half a world apart, I should say. Could you tell us, Claus, a little about your background and how you got interested in water?

Claus: Sure. First of all, thanks for allowing me to talk here. Yes. So, my name is Claus Helix-Nielsen and I'm working in a company trying to commercialize these new types of membranes, biological membranes. I guess we'll get back to that later. But my background is really sort of not the typical membrane engineer. Actually, I'm trained as a bio-physicist. I did my master's and Ph.D. in computational neuroscience, very far from membranes, you can say. But still, at the end of the day, what we're talking about is really cells and how they communicate, especially neurons. And there's a lot of membrane stuff going on there. So membranes, although biological membranes have something that's been very close to my heart for a number of years. And also, especially the sort of intricacies of membrane transport, how water and ions have been transported, selectively across membranes.

So, then, just to cut a long story short, I got involved in this start-up, here in Denmark, Aquaporin A/S, which as the name also implies, is a company that actually detects one of these proteins that is responsible for only transporting water across cell membranes, the aquaporins approach that was discovered within the recent ten or twenty years, it's really been studied a lot and now we try to really lift it out of its sort of biological origin and put it into membranes and sort of the more classical membrane engineering polymeric membrane. And this, we're trying to make a happy marriage between the protein and this polymeric matrix. So, at the end of the day, why are we doing this? We're doing it because we really think that this holds very nice opportunities for giving new functionalities to membranes. You can get superior flux. You can get superior rejection of solutes. And we think that there's really some interesting applications and we also, I guess, get back to those later in this talk.

Dave: Sure. And that sounds absolutely fascinating. Now, let's start at the beginning of the membranes. Can you kind of walk us through the different kinds of membranes there are and the kind of membrane that your company and your research is focusing on?

Claus: Sure. We can start with a coffee filter, right. That's sort of very easy to picture. Ok, we have some stuff which is being retained and then we have our coffee going through the membrane. And that's basically a sieving effect. There are some microscopic pores in the membrane and in a way we can also refer to that as a microfiltration membrane. Then as you go down in the scale, we have an ultra-filtration membrane, a nano-filtration membrane, and as you can hear on the prefix, it really becomes the pores basically get smaller and smaller. Then it comes to the fact where you really want to sort of separate small monovalent anions and cations, sodium chloride, for an example, which you would do if you want to do desalination.

Then you have to move to a different type of membrane. We call it the reverse osmosis membrane basically also implying what technique we're using here. Because in a way, in order to, for example, remove ions from water, you need to overcome the osmotic pressure that it is in your solution you want to basically purify, extract the water from. In order to overcome that you have to apply some pressure. So that's basically what you do in a reverse osmosis membrane.

It's also very important to point out that the sign of the reverse osmosis membrane, or the RO membrane as we also refer to it, is really the fact that it is a non-porous membrane. It is a dense, polymeric matrix that sits on top of a support. You can maybe sort of picture it as a kind of carrot cake. You have an icing on top. And really, where all the fascinating stuff takes place, is really in the icing. That is the active layer where we get this effect that we want, that the water's passing through, and basically the ions are being left behind. Again, as I said, this is based on a very dense material that doesn't really have sort of physical pores that are going all the way through. It's a different mechanism than we have in the coffee filter for example.

Dave: Ok.

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Claus: So, basically, the RO system, what gives it its performance is really the fact that you have this very dense membrane but, that's also that gives it its drawbacks in the sense that ok, then the water process is now less because it is this dense material where they don't have really any physical force.

Dave: And so how long have these RO membranes been around?

Claus: They have been around for a good forty or fifty years. The technique was really pioneered in the late 50's, and early 60's that began to commercialize it. So, you can say in contrast to the science on biological membranes, the membrane engineering is a relatively new, from a technology point of view, a newcomer. So I would say the last fifty years has really sort of been the basic idea to have these membranes, now we're specifically talking about these membranes that are suited for reverse omosis. So you can say that of course there has been changes, modifications and improvements, but the basic design idea has basically persisted until this day.

Dave: Ok. and you also mentioned how these RO membranes work, is that you have to overcome the osmotic pressure. What all is involved in overcoming that osmotic pressure?

Claus: So, basically, let's say that you wanted to make, the economical example here would be desalination of sea water. And if we take sea water, you will see that the osmotic pressure is around twenty-five bars, twenty-five atmospheres if you want. That means that in order to squeeze water through a membrane, let's just for a second imagine that we have an ideally selective membrane that will only let water pass. Then we will have to apply a pressure that exceeds at least twenty-five bars or atmospheres of pressure before the first drop of water will ever appear on the other side of the membrane.

Now you can imagine that let's say we want to reduce the volume of our sea water to half of what we started with. Then, of course, the concentration of the ions will be doubled when we get to the end and when we have only our ion volume left, which also means the osmotic pressure will be doubled. In other words, that all translates into the fact that typically you would operate RO systems at pressures forty, fifty, sixty, even seventy bars and that is requiring a lot of energy in order to have electric pumps generate such pressures. But that's basically sort of a picture of a garden variety RO desalination plant.

Dave: Sure and so you're going to need real big pumps that's going to take a lot of energy, going to be very expensive to undertake that desal process. What about the maintenance of the membranes themselves? Cleaning, tearing, things like that. Are there any issues along those lines?

Claus: Oh, absolutely. Of course, any membrane process is only as good as the pretreatment of what you use to feed it with. So, in other words, if you have feed water of inferior quality, a lot of suspended solids and things like that, then of course pressure-driven process especially to something like RO would suffer a lot from this and actually the membranes would clog or foul, as we call it, very, very fast. Even within seconds in some cases. So, of course, pretreatment of what you want to do your RO process on, the reverse osmosis process is essential. And there of course you can maybe use some of the other membrane technologies like microfiltration, ultra-filtration. So basically, you can imagine that several steps where you may get the separation better and better and then at the end, you do your reverse osmosis.

But it is a problematic thing because also the way these membrane modules are designed, it's not enough to have just a sheet of membrane, you actually also have to have the membrane integrated. The geometry, for example, typically used in reverse osmosis membrane modules is really some kind of a spiral loom system where you have a system where the membranes are packed very, very tightly, which also means that of course you can have a lot membrane in a limited volume which is nice thing. But the drawback is that these are very, very difficult to clean. So, membrane operators, they really sort of tend to be a little bit anxious when you want to introduce membranes in something where you're not really sure about the quality of the feed water. That has to be controlled very accurately before you want to apply RO and really make RO efficient.

Dave: In terms of pre-treatment, my suspicion is that there's a number of ways that pre-treatment can be arrived at. In one of my earlier podcasts, we talked with Forbes Guthrie and his company works with a lot of produced water, a lot of frac water, industrial processed water and he was talking about the ceramic filters they use. Could you contrast the RO filter with the ceramic filter? Would the ceramic filter kind of be a good pre-treatment option for the RO membrane?

Claus: In some cases, you can definitely use ceramic filters. I think for things, it really also depends a lot on your, the value of the basically costs associated with the value and the cost associated with the water that you get back or extract. For example, sea water desalination, you can say that you cannot charge a whole lot per gallon or liter of water produced. Which also means that you have to think of the economics of the pre-treatment, and ceramic membranes are quite expensive compared to polymeric membranes that typically are RO membrane design as we use today.

Yeah, sure, you can do it, however it might kill you in terms of the economics of the system because you have something which is too expensive. Ceramic membranes are nice from the point of view that especially frac water, produced water, when sometimes you would really need to clean the membranes. You can do really nasty things to ceramic membranes and they're still happy. You can heat them up. You can really use very, very harsh chemicals on them, where on the polymeric membranes, it's a bit more delicate.

You have to be careful with membranes. Of course, you can treat membranes but there are issues with changes in pH and things like that. You have to think about how you actually, which type of polymeric membranes that you use. So, yeah, I think ceramics, in terms of membranes, they have the niche in these sort of heavy duty, industrial applications such as the one that you mentioned. But again, we have to contrast that with the cost of the membranes.

Dave: So, what other technologies or membranes are out there that can provide this kind of pre-treatment before the RO process?

Claus: In that case, there's a whole bunch of, you can say, traditional things that you can do. Of course, there's chemical pre-treatment. Imagine that you have wastewater with a high concentration of heavy metals or something like that. There are various ways that we can precipitate these metals complexes out of solution. But, I mean, something which also is close to what I'm doing also in terms of both signs and technology development, is this thing called forward osmosis. And forward osmosis has arisen as sort of almost being the presented as the magic bullet that can solve all your problems and that's not really the case.

I am really fond of forward osmosis, don't get me wrong on that, but it has really to be sort of seen what actually can it be, can it be used for? So just sort of backtrack a little bit, so forward osmosis is reverse reverse osmosis. So basically we do not apply any pressure. We let the osmosis do the job in the sense that you have two different solutions. Then in the forward osmosis process, you will extract water into something which has a higher osmotic pressure then the feed solution. Now, you can say ok, what problem does that solve? I'm moving water from one side of the membrane to the other, but I still have something else because that is basically what generates the osmotic pressure that you can do this with.

But, you can imagine if you can picture this, that you have an FO, the forward osmosis as a pre-treatment to RO. So, you have your reverse osmosis process running. You are concentrating your, let's say you have saline solutions generate a concentrated brine and that brine you then pass back into the forward osmosis system and use that to extract the water. You dilute the brine and it goes in a circle. So, the reverse osmosis membrane will never see anything but say sodium chloride or magnesium chloride or something. Something very well defined which is good for the RO process because then it will be well behaved and we don't have to clean the membranes as much and so on.

And then for the forward osmosis, it's really the screen where you can have your ultimate, the feed water will actually be quite impaired with a lot of stuff in it but because the FO part is not pressure driven, we are not applying pressure there. That's means the propensity for fouling and other things with everything else being equal, it would be lower. So that actually one thing where I think that you could argue it would be a happy marriage. It could be a happy marriage between FO and RO.

But it is important really here to also highlight, is the fact that FO had a lot of buzz around it for a number of years and also some, I would say, misleading claims have been actually put out there because it was really also introduced as a technology that doesn't use any energy. And that is not really true. I mean you are using an osmotic gradient which is there but that gradient has to come from somewhere. You still have to pay the price. You cannot cheat on thermodynamics, not even in the corporate world. So, you just have to stick to this, and but what I'm trying to argue is that I think that FO is a great thing in combination with RO, but there could also be other examples. I think that is really where this forward osmosis has a future for it.

Dave: So this sounds very interesting. So forward osmosis, it's not a pressure driven membrane, you just kind of let the osmotic process work. What is it removing that the RO membrane is not going to remove?

Claus: Ok. So basically the forward osmosis could, in principle, remove the same things as a reverse osmosis membrane. Both membranes will have to be very, very water selective and have a high selectivity for the water and a high rejection of anything else but water, including small monovalent ions such as sodium or potassium chloride. And that is really, you can say the similarity. But, of course, the process itself is different because given the fact that the RO membrane is a pressure driven process, which means that backing up the membrane, the whole structure of the membrane has to be able to withstand these very high pressures.

That means that the way that these membranes are designed is really with that in mind. That they have to be able to work even at these very high applied pressures, which means, now it's getting a little bit technical but, the structure of these membranes is so that if I wanted to use those in FO and make a forward osmosis membrane process with an RO membrane, that would not work. So, basically, the big challenge in this forward osmosis is really to design the membrane in such a way that you could have this osmosis going.

And it sounds a bit paradoxical because you can say, "Osmosis, come on, we have known this for two hundred fifty years. How come we haven't figured out how to make membranes?" That is due to the fact that it has to be a very open structure that really would allow this osmotic process to take place and yet, it has to also have this very high selectivity and very high rejection of solute and basically everything else except water. And that just proves to be a technical, challenging thing to do. And I think this is where you can see there's a lot of progress. Several groups around the world are now developing these FO membranes with better and better, you can say performance data, but we're still, I would say, it's still a little bit early days. There are commercial products out there including the ones from our company but there's still room for improvement, and there's room for how really to show how it can be integrated in existing systems. And really prove its case there.

Dave: I definitely want to get in and learn some about what Aquaporin does, but before we get to that point, what are the industries where you see that forward osmosis could make a difference? I mean, we've talked about pre-treatment for desal and the general FO process. What would be the commercial application of FO?

Claus: I guess you can think of a variety of commercial applications. Food and beverage, just to take one segment, is clearly a segment where you would like, for example, to extract water. You may want to up-concentrate for wine production or juice or fruit juice or something. And in those concentration processes and also in the whole bio-refinery segment, you may want to do that but you may not, for economic reasons but also for technical reasons may not want to use excessive heat, for example.

You can evaporate water, right, but then maybe if you do that you will destroy whatever you have in your solution that you want to concentrate. It could be your fruit juice. It could be a bio-refinery product. So therefore, you would need to figure out a way to remove the water, extract the water in a, very unscientific term, gentle way of doing it without excessive perturbations. And there I think forward osmosis could have potential and indeed has been shown in many pilot scale applications of various things we want to extract water from, fruit juice and bio-refinery products. Actually, it has proven that it works. We're still, I guess, a little bit waiting to see the big break through commercially for FO as the thing to do. But I guess we will definitely see that in the years to come.

Because in these also, there's another technical issue here. In these applications where the concentrate, where the concentrate is your final product, let's just think about that. Then, of course, I'm extracting the water in one direction by my osmotic solutions that I have on the other side which is doing the job. It's of course a high concentration of something. It could be, let's say, sodium chloride but it could be in principle, anything.

Then if the membrane is not perfect, there'll also be a reverse salt flux. There will be a reverse flux of your osmolite or the osmotic agent on the other side going back into your food concentrate. And you're not interested in that. So, the membrane also has to, at least it has to have a high water permeability. Maybe not too high because you can live with that if you just wait long enough. But what really is important is the fact you don't have this reverse solute flux or reverse salt flux as we typically call it. And that's another hard thing to actually achieve.

Dave: What about, I've seen a lot of concern about pharmaceuticals and nano-pollutants and other pollutants in waterways, can any of the membranes we're talking about today, could they help filter out those types of pollutants?

Claus: Right. So basically you can say that, let's imagine that we have some water which is in pretty good condition, it's pretty clean and so on, but there's still some very hard to get rid of small solutes. I could be biotics, pharmaceuticals, it could be pesticides, metabolites, small molecular weight, molecules, many of these that don't carry a charge, which also means that it's just harder to separate them using membrane technology. They're small and no charge. That's really a bad guy for a membrane because it would really easily go through.

But, actually by virtue of being a non-pressure driven process, then FO actually seems to have better rejections just by the fact that it's a FO membrane than RO of such things. So, you could again, going back to the idea as using FO as a pre-treatment to something else, that pre-treatment could actually be superior in removing these small compounds based on membrane technology. There might be other ways you can remove them but of course, that chemical way, degradation, whatever. But if we are restricting our discussion to membranes, I think that that's actually a case where you could argue that FO membranes actually has a value proportion. Because they can actually achieve this, and we have seen this with our membranes and other people have seen all types of FO membranes. I think there is definitely a case there also to be fully explored, exploited commercially in the coming years.

Dave: Ok. so, I think, now is the time to ask you about Aquaporin. You mentioned it earlier. Can you kind of tell us, what's your role at Aquaporin and what does Aquaporin do?

Claus: Right, so ok, just to give you a brief story on Aquaporin. Aquaporin was a company that was founded in 2005. One of the co-founders actually did some computer simulations of aquaporin protein. A couple of years before, in 2003, Peter Agre was awarded the Nobel Prize for the discovery of aquaporins. Physiologists and so on have been talking for years and years there must be something like a water channel. But it was very hard for them to nail it down and really prove that's the one, this is the protein that's doing that job. And Peter Agre and his team were able to do that and they published a seminal paper in the early 90's and then he was awarded the Noble Prize about ten years later.

In the meantime, the first really sort atomic resolution structures of these proteins became available by structural biologists. Again, you can see how I like to talk about biology also because I really think this is fascinating, this whole idea of biomimetics that you can learn things from nature. But here, in this case, this atomic structure of aquaporins allows you then to make these computer simulations. You can really see how the water molecules are moving through and how other things are being rejected.

And you know, he was working on that and that sort of prompted him to say, "well, you know, if you look at this and do a back of the envelope calculations, imagine the greatest perfect membrane." Imagine that we can put 50% of that area is covered by these aquaporins. Then you can crank out a number for the water permeability, which is orders of magnitude higher than what you see with these commercially available RO membranes that we can buy today. So, say here's is something that actually could be of something to do.

And then he teamed up the other co-founder of the company, who is now the CEO, and actually created the company. So the first thing, of course, that they had to show was, can we actually take these proteins and build them into something and show that they are a select transporter of water? And that's where I came into the picture because at the time I was an associate professor in the Department of Physics at the University of Denmark. And my colleague, the co-founder who did those simulations, he was basically sitting a few offices down the hall. So we got together on coffee breaks and though it would be fun to look at this. And that's basically how we started. So, first we have to prove that actually we could build these proteins into membranes and also at the same time, submit the first patents to really protect the technology. And then basically, it sort of took off from there.

So, now, ten years later, so what did we spend all the venture money on? We spent it primarily on showing how can you actually upscale this? In comparison, there's a of lot of nice science in how to study these proteins and making small micron size membranes under a microscope and you can really nice things about that but that doesn't really make it in terms of technology. You have to be able to argue that you can actually make this in millions of square feet or square meters. Really that is a scalable technology and also the fact is that it has to be cost effective. Going back to desalination membranes, you will look at the price or the cost of desalination membranes over the last ten years or so, it's really exponentially going down. There's a driver there which is the price or the cost which is going down and down and down. Which means that in order to be competitive in that market segment, your membranes cannot be much more expensive as the one that they use today otherwise you don't have really an entry to that market.

And those were the things that we, from the very beginning, thought, "Ok, how can we do this in a cheap way that allowed us to really make this a scalable technology?" So that's really what we have now achieved, and I'm making, we have pilot scale production of these membranes and are basically like role to role membranes. They could be suitable for like spiral modules as you have an in RO. And we've also recently succeeded in making hollow fibers based on the same technology. So that's basically the very short story of Aquaporin.

Dave: Ok. So aquaporin's a protein that was discovered in the 90's by one of the co-founders of the company Aquaporin. Is the membrane made out of aquaporin protein? Or, how does the existence of the protein aquaporin, how does that assist in the membrane filtration process?

Claus: Ok. Just to clarify. So the co-founder did not participate in the discovery of aquaporin. I was referring to Peter Agre who got the Noble Prize for this. But in due course, there were some structures coming up and these structures could then be simulated in the computer. And then we could learn from this how it actually works. Some interesting bio-physics in that. So that just to clarify this.

So basically what aquaporins can do, they have this enormous turnover of water. Basically the permeability of aquaporin is really, really high. It's a molecule, you could say. It really is a pore that is spanning biological membrane. So you have them on all living, on all cells that you can think of, there will be aquaporin sitting in the membrane. So what they do is the cells are the water transport. As an example of that, you're re-circulating a lot of water everyday but you're not excreting that much compared to this amount of water. And that is that re-circulation of water for a large part taken care of by these aquaporins that are sitting in the kidney and therefrom.

So, back to the membrane. The challenge that we had was we had to take these proteins out of their biological habitat, so to speak, and put them into a polymeric structure. And in that respect, again, it's a long story, but the bottom line is that we have, had at the time, a nice starter collaboration with Singapore Membrane Techology Center. Together we found a way to actually do this. So basically building the aquaporins into some very small nano-sized spheres that are then integrated into the membrane. So basically you can think of your carrot cake as I talked about before, with the icing and now we're just dumping a lot of raisins in that icing. And then the raisins are representing a bunch of aquaporins who are basically increasing permeability to water while preserving a high rejection of everything else. You can say that the fact that the aquaporin proteins are in the membrane is way of tweaking or tuning the waterfill activity of the membrane. I hope that kind of makes it clear. But it is really, the aquaporin is really the component in the membrane that endows it with this very high water permeability.

What we have now and the thing we are producing in the pilot scale is what we first in racing membrane. Of course, there's a lot of improvement that can be made but on the other hand, I think it's important that actually this technology comes out and get also tested as it is. Because, of course, one of the first questions you will get when you are trying to commercialize this is that, "Well, ok, you are using these proteins. Proteins are fragile structures. Are they going to fall apart? Can you clean the membranes?" I mean all these kinds of things is things that we also have to address. I can tell you that the membranes that we have today are from that point of view, not that much different from sort of the garden variety RO membrane you can buy today. So it's not really an issue in terms of stability. Once the protein is sitting, the aquaporins, are sitting in the membrane, it seems to be remarkably stable. But before, to get it in there is really sort of higher French cooking. A lot of things you have to be careful about in order to do it and get it right. But if you have that, then you know, it's fairly stable at least compared to, I would say what you have in reverse osmosis membranes today.

Dave: Terrific. Well, I think the visual you gave really helped me, at least, visualize what these membranes, or how the aquaporin fits into the membrane. Thank you for that. Claus, you've been absolutely fantastic walking us through all these membrane technologies, educating us about forward osmosis and reverse osmosis and telling us about aquaporins. Sounds like a very revolutionary idea you're working on there. Thank you again. For those folks who want to find out more about what we've talked about today and Aquaporin, where can they go to find that information?

Claus: Well, I mean as a good corporate person, I should point to the webpage of the company of course. Aquaporin.dk or Aquaporin.com. There's also actually some reference literature and stuff. If you basically Google aquaporin and membranes, you'll find us. Several academic groups around the world are working on this and describing it. We also have gotten together with our colleagues in Singapore, I wrote a recent review in the journal *Desalination* that came out this year. In that paper, we sort of present the real state of the art in the last ten years of development of these types of membranes since we started. So I think that paper kind of gives you the overview of where we are in terms of performance, scalability and so on. Not just from our work but we really try to sort through what is out there in terms of other groups and approaches.

Dave: Sure. And for those folks who want to find out more about you in particular, I shouldn't have asked this in conjunction with my earlier question, but for folks who want to find out about you and your work, where can they go to find that information?

Claus: You can also go the company website. There's a small profile of me. I used to be, you could say, the research director at Aquaporin. Now my official title is Vice President of Public-Private Partnerships, which is basically just sort of name in disguise for still doing research. because the way, we're still a research based company and the way we finance research in the company is really to engage in public-private partnerships. Specialties of course, would be universities and other knowledge institutions to really drive the research ahead. And that is good because when you go to the board room and have to explain why your burn rate is as it is, it's a good thing because in that case, we're gearing, typically, maybe you get 50% funding from public money to drive the research.

So we are doing, you can say, maybe a little bit atypical because we're really going out and we have done that consistently over the last ten years to talk to a lot of people and really do this co-development of the membrane. That, of course, also entails that we need to be sure that we protect the IP that basically is the core value of the company. Now we begin to have products, now it is a different situation but in the first many years, it was really the IP that was the core value of the company. So we've also been, you can say, quite, aggressive.

In that sense, we have an aggressive IP strategy. We're doing filing several patents, having many patent families that are covering our technology. And then we have done and prioritized this because that will then allow us to go out and engage in all of these collaborations. So, the amount of public money that we have gotten to do research over the last ten years, I don't have the figure on the top of my head, but it's substantial, absolutely. And that also means that we can argue to our investors, "Well, your money is actually going to what you would like it to go to, to bring a product to market and not doing all kinds of strange nerdy science that they may not appreciate."

On the other hand, we think, in the company, that it is very, very important to have a broad research base in order to really fully exploit it. Because this is really a platform technology. And especially in the early stages of development we had so many unanswered questions that it was impossible for one or two types of persons, you know chemists, engineers, to be the one to come up with all the solutions. We had to go out to talk to everybody from molecular biologist to plumbers basically. We were spanning a huge amount different disciplines and research areas and technology development areas. And that has really, I think, also been a hallmark of our approach and I would say, still is.

So my role is really sort of to try and foster the R&D work that we do and I'm also part-time associate professor at the Denmark University. I, in the meantime, transferred from physics to environmental engineering to get closer to the water. I also am heading a laboratory in University of Maribor in Slovenia, also because they thought it was cool to really work on these membrane developments in that setting. So I'm really living this Dr. Jekyll-Mr. Hyde life where I'm in the company part of the time and in university. I really like this kind of split. Sometimes it can be a slight schizophrenic experience because the mindsets are really different, but I think really the advantages clearly outweigh the disadvantages.

Dave: Well, Claus, thank you so much. This has been clearly fantastic learning experience for me. I just want to thank you again for your time. It's been greatly appreciated.

Claus: You're really welcome and thank you for inviting me on your show.

Dave: You bet. We'll talk to you soon, Claus. Thanks.

That was my interview with Claus Helix-Nielsen. As you can tell he's a very smart and yet very personable man. Rare combination to find both of those qualities in the same person.

As a native English speaker, I was impressed with Claus' excellent command of the English language, especially when he dropped the word perturbations – I went back and listened to that one twice.

My big takeaway from the interview is the state of membrane technology and from what I can gather, it appears that we're on the cusp of a lot of innovation in membranes. Aquaporin was one example, but even with Claus warning us that forward osmosis membranes are not a miracle membrane, they still hold a lot of promise for the future. I really look forward to seeing how these membranes progress commercially as we enter this era of both water quantity and water quality scarcity. My position is that the membranes Claus discusses could dramatically help improve the water quality side of that problem.

I'm curious about your thoughts on the membrane technology Claus discussed. Please let me know by commenting on the Show Notes for this session, which can be found at http://thewatervalues.com/pod71. You could also email me at david@thewatervalues.com, and you can tweet at me @DTM1993. Please tweet about the podcast using #WaterValues. And as I stated at the top of the show, please do me a favor and rate and review the podcast on iTunes, Stitcher, TuneIn and other podcast directories. You can also sign up for The Water Values Newsletter and take the listener survey to let me know about topics you'd like to hear about at http://thewatervalues.com.

In closing, please remember to keep the core message of The Water Values Podcast in mind as you go about your daily business. Water is our most valuable resource. So please join me by going out into the world and acting like it.

Outro: You've been listening to The Water Values Podcast. Thank you for spending some of your day with my dad and me.

Dave: Thank you for tuning in to the disclaimer. I'm a lawyer licensed in Colorado and Indiana. And nothing in this podcast should be taken as providing legal advice or as establishing an attorney-client relationship with you or with anyone else. Additionally, nothing in this podcast should be considered a solicitation for professional employment. I'm just a lawyer that finds water issues interesting and that believes greater public education is needed about water issues. And that includes enhancing my own education about water issues because no one knows everything about water.