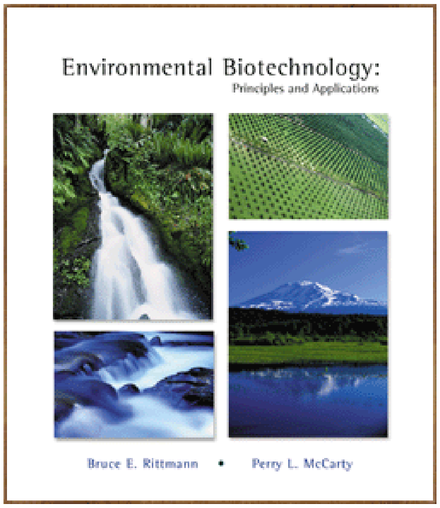
AN AFTERNOON WITH PROFESSOR HERMANOWICZ: EXPLORING SUSTAINABILITY AND WATER FILTRATION

By: Harshika Chowdhary, Luis Castro, Phillipa McGuinness, Juwon Kim, Saavan Patel, Kevin Nuckolls, and Manraj Gill.

BSJ had the distinct pleasure and honor of interviewing Dr. Slav Hermanowicz. Dr. Slav Hermanowicz is an Environmental Engineering professor at the University of California Berkeley. His research focuses on the process of water quality treatment so that wastewater can be reused. Another aspect of Dr. Hermanowicz's research is centered on improving the quality of stored water. In this interview, Dr. Hermanowicz talks about the process of wastewater filtration and how filtration techniques have changed over time. He also discusses the implications of environmental engineering and what constitutes sustainability. BSJ thanks Dr. Hermanowicz for his time.

Berkeley Scientific Journal: How did you get involved in your field of research?

Professor Hermanowicz: To give you a background, I was born and brought up in Poland. I also went to college there. The focus of environmental engineering was a little bit different than what it is today. At that time, environmental engineering was focused on public health, on providing safe water, sanitation, and cleaning the aquatic environment. The focus was on people, but the focus has evolved today to encompass the broader picture. I wanted to be an engineer because engineers are "doers". Environmental engineering is unique such that it cuts through many different sciences. Unlike civil engineers, I had to take microbiology, structure, and chemistry classes. Today, we encourage our students to study sociology or psychology because they will interact with communities and people. I like to compare civil engineering and environmental engineering with the following example. You are using an iPhone to record me. If this iPhone does not work properly, it is not such a big deal; you can buy a new phone. On the other hand, if we build a treatment facility or a bridge, the scale is larger and affects more people. There is perhaps a different perspective when considering the field of environmental engineering. The consequences of environmental engineering are not necessarily bigger, but they are consequences that last longer. These consequences are felt by very broad groups of society. What really drew me into the field of environmental engineering was that it is useful to large groups of people and allows the engineer to regard problems in many different scales. This turns out to be true. In my research, students are looking at the nanoscale of catalysts with modified properties to the scale of a whole building and then perhaps even larger scales, like the Colorado River. There is a huge range of topics and opportunities in this field.



BSJ: How exactly do you measure and define sustainability in the water reuse cycle?

Professor Hermanowicz: First of all, no one knows the answer to that question. Sustainability is a term that is defined differently by every person. When pressed, people fall back to the definition of the Bruntland Report, which is now 30 years old. People quote a passage about meeting the needs of the current generation and allowing future generation to have a range of choices. This is more a process or a path, rather than a destination. We're trying to implement and find solutions in a way that will not preclude future generations from finding their own solutions. I mean, imagine if we were to exhaust natural resources, like some of the rare Earth metals, given that they are now used in phones and such technologies. We can probably recycle these phones, but at a certain level, it becomes not only non-economical, but also physically very difficult. People in the mining industry and many others know that it is much easier to mine and process rich ore than a very dilute ore. So, we were actually looking at this from the cell phone perspective and the rare Earth metals, such as gold, for there are gold contacts within cell phones. Depending on how you calculate, you can treat the disposed phones as a kind of mineral deposit that is distributed over a city area. Unfortunately, it turns out that this deposit is orders of magnitude lower in concentration than even the poorest ores that are mined now. So if we were going to do this without limitation, then we would be precluding future generations from using gold for their applications. Thus, we are trying to minimize this obstruction of the future. However, this is a very difficult concept. Sustainability originated in Germany around the eighteenth century, when they were approaching forest management. They realized that one cannot simply cut down the forest without limitation. Cutting down forests presents a very short-term solution, so they tried to create a system using replanting and selective cutting that continues forever. I think this is a good analogy. How do you measure that your system is working properly? Well, there are no simple measurements or indicators. Currently, there exists a list of about 120 different metrics used by different groups. Everyone has their own way of measuring this. It also depends on what background you come from. Some people have looked at this problem from a social perspective, by considering factors of social sustainability. These factors make sure that society, as a whole, does not collapse in the future. Historically, there are examples of societies that have collapsed rather quickly. There are people who consider economic sustainability, looking at the abilities to finance related activities. There are also people who consider physical sustainability. My interests in this problem lie in this final piece, primarily, looking at the physical sustainability aspects in the context of engineering solutions for these projects. We try to consider certain factors, such as energy and entropy. There are, in fact, tools that have been developed that are used for such matters, such as a life cycle assessment. Their effectiveness is still in question. I think what is important is that we are moving in a positive direction. There are a lot of embedded values that one must consider. Many times, engineers and others working on this problem do not talk about values. For example, how would you value a potential detrimental environmental effect that could happen 100 years from now versus the effects of environmental damage that is happening now? Is there a discount to consider? If so, how does this discount vary with time? I think we're not talking enough about these issues. It would be very nice to just invest in an agenda concerned with protecting the future environment and future generations without having to make difficult decisions today. That would be lovely! Sadly, this is not possible. So, how do we make these difficult decisions? I believe that we would be much better at making these decisions if we invested more time in discussing values, which may sound strange coming from an engineer. The issue we are dealing with concerns the values and ethics behind an environmental engineering problem.

> *"For example, how would you value a potential detrimental environmental effect that could happen 100 years from now versus the effects of environmental damage that is happening now?"*

BSJ: How have the standards for the "purity" of water evolved over time with new methods being developed to detect impurities?

Professor Hermanowicz: Since the end of the 19th century and particularly since the discovery of germs and microbes, by Pasteur and later Koch, water quality was placed on more of a scientific basis. The first regulations were related exactly to pathogenic microbes or, to be precise, to indicators of potential pollution. In the US the first federal regulation by at that time, what was called the US Public Health Service, was in 1912. Interestingly, they regulated water quality on cross-country trains, which had water containers from which people could drink. They believed that the role of the government was limited and that the role of the federal government was in interstate trade and commerce. This idea was taken very seriously at that time and therefore the federal government did not feel it was possible for them to regulate local water quality. However, since trains crossed the state boundaries they could regulate those and by default the expectation was that the local water would follow that quality. Hence, microbial water quality was first and the response to that was the introduction of disinfection in drinking water, which was probably one of the largest public health victories in our history. Typhoid, cholera and dysentery are practically non-existent in the developed world, unlike other parts of the world, where these diseases continue to plague the public. The regulatory process was progressing relatively slowly; there were only a few other parameters added. However, from the 1970s, when there became a large awareness of the environmental problems credited to a book by Rachel Carson called The Silent Spring, there was a push to regulate more contaminants, particularly chemicals. Advances in analytical chemistry, regarding the detection and identification of compounds at even lower concentrations, matched this new environmental awareness. We used to talk about concentration in parts per million, milligrams per liter, but then it was possible to go three orders of magnitude lower to micrograms per liter. In current times we are talking about parts per trillion. There is a cycle of being able to detect ever-lower concentrations of more exotic contaminants, and then a corresponding push to regulate. This push is moderated by costs; ideally it would be moderated by the cost-benefit ratio. The Environmental Protection Agency is trying to do that in some way but it is a difficult process. The regulatory process is cumbersome, especially in the US. We had a huge explosion of regulatory mandates, starting with the Safe Drinking Water Act and the regulations that followed, early in the 1980s and throughout the 1990s. This is now a little tapered because we cannot expand this list forever. There are new emerging contaminants such as pharmaceuticals, endocrine disruptors, etc. I don't know where this will go, but it is an interesting area.

BSJ: Once you determine cleanliness, how do you determine what level of cleanliness you need for the different functions in terms of, for example, which chemical you need to eliminate?

Professor Hermanowicz: Scientifically, we should do that based upon a risk assessment, and there is a push in that direction in the regulatory framework. You consider the exposure of people, aquatic animals, flora, and fauna to a particular chemical and you will assess what damage is being done. Then you can tie this exposure to concentrations and limit it at that stage. One thing that we do not perhaps talk about much is the whole issue of 'underlying' science and that science is not yet fixed. You are talking about one extra cancer over the lifespans of a million people, which statistically is a very, very small effect because people get cancer from many different causes and identifying that marginal additional contribution is difficult; thus, the science is difficult. This is true even for toxicity. For example, we have a lot of data on toxicity of cyanide, but only at the lethal doses. We do not have data for lower doses because it has not been done and maybe cannot be done. However, one issue is that at some point in that process we need to define what an acceptable risk is and that is a very difficult subject. 1 in 1,000,000 is a very abstract number, but if you talk about it in a public meeting - this is where I think my plea for students to learn more about psychology comes from - and say this facility will only have a 1 in 1,000,000 additional risk of cancer, then somebody will stand up and say "So you want my child to be that one case?" How do you answer that? I mean it's a legitimate concern! You cannot just say that somebody is ignorant! How do you handle that? There is a risk-assessment process because these actions cost money and there will always be a limit. In practice, I think the system is a little imperfect because, at least in the United States, there seems to be a general policy that industry and the judicial court control an actual process. Enough groups are involved in the process that things spin away from what the scientists would think is the ideal pathway. However, I think generally we are moving in that direction.

> *"One thing that we do not perhaps talk about much is the whole issue of 'underlying' science and that science is not yet fixed."*

BSJ: You have mentioned this timeline from detection to regulation. How long does this regulatory pathway take?

Professor Hermanowicz: That is a very good question. I think it varies a lot historically. It started with the idea that you have pathogenic microbes in water, and there the response was actually before the regulations came on board. In the late 19th century, around 1885, was when Robert Koch discovered chlorine could kill germs. Twenty years later, chlorination was a mainstream technique for treating water, even before regulation, so the time here is negative. Another example is the discovery of disinfection byproducts. The mid-1970s was when chemists discovered chloroform and bromoform at federal concentrations (tens of micrograms per liter) in drinking water and the scientists were positive that they were byproducts of the reaction of chlorine with natural organic materials. Therefore, by mixing chlorine in the water to prevent typhoid and cholera, which are very big issues, you are introducing this extra, much smaller risk. From 1975, I think it took around eight to ten years for the regulatory process to kick in and have the first regulation on these processes. However, that is not the end because we are still going through the process of making and discovering new compounds and putting them on the list. Originally it was only chloroform because it was easily identified and now we're talking about other compounds all coming from the same source. This is a process that takes certainly years and maybe longer. This also ties in with the fact that new facilities will be built or existing ones upgraded and this will take around the same amount of time.

BSJ: For our next question, we were hoping that you could explain how the definition of clean water has evolved over time with the improvement of detection methods. How would you measure how clean the water really is?

Professor Hermanowicz: That question is very relevant to what we are doing. Historically, people had some kind of notion for what clean water was. Primarily, people would determine the quality of water by its appearance and taste, but this method is obviously inadequate. Until the end of the nineteenth century, society still had no scientific definition of what clean water was. Some water can appear to be very clean, but can also contain many pathogenic microorganisms. For example, cholera was endemic in London. London was a leading metropolitan area in the nineteenth century, yet they still suffered from frequent outbreaks of cholera. Since the end of the nineteenth century, particularly since the discovery of germs and microbes by Pasteur and Koch, the study of water quality has become more scientific. The first regulations of water quality were directly related to this research concerning pathogenic microbes. Specifically, they related to the indicators of potential pollution. In the United States there has been always an expressly stated philosophy that drinking water should be of the highest available quality. That is one reason why we have the Hetch Hetchy built here, or the Los Angeles aqueduct. There are also other reasons, like the availability of water. Obviously every time we use water we degrade the quality of it, although we are trying to bring this up through treatment processes. But I think the major point is that water is in some way an ultimately sustainable product that is not really destroyed; it just cycles through nature and through the engineered processes. What we are trying to do is essentially make the best use of it. In some way, we have technology with which we can purify even the most polluted water to the highest quality. The question is how much money we are willing to spend and how much energy this takes. Geographic locations in many cases is a reminiscence of history: people settled along rivers because that was convenient—it was a mode of transportation, and a mode of having a water supply, but at the same time people settled Los Angeles which has no water and the water has to be brought to them. In the United States there has been always an expressly stated philosophy that drinking water should be from a source of the highest available quality and that is one of the reasons why we had the Hetch Hetchy built here and the Los Angeles aqueduct.

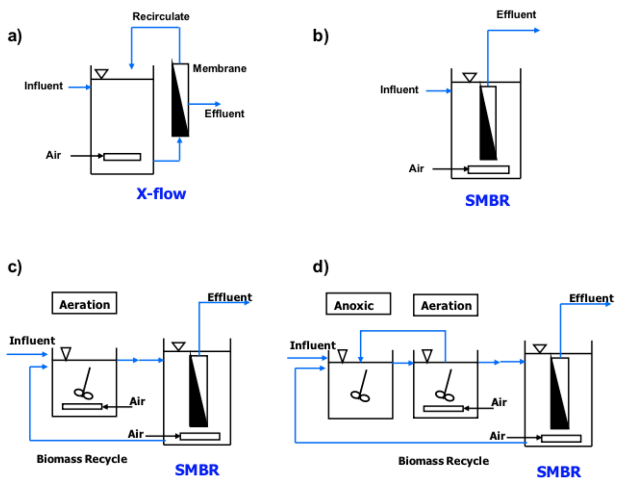


Figure 1. Various MBR configurations .

So considering geography is important because in some cases it allows for people to have cleaner water and in some cases it is more difficult, but we have solutions for both.

BSJ: You have talked a lot about cycling the water. A lot of your research focuses on new filtration technology for wastewater. Could you talk a little bit more about what a Membrane BioReactor is and what sort of issues led to its need?

Professor Hermanowicz: Essentially what happens is that we use water and this water becomes polluted. Although if you look at this from a scientific perspective even the highly polluted water is still 99.5% water, but we do not want to drink that 0.5% or it is harmful for the environment. Throughout history, civilization relied on a natural ability of nature to clean up water, which worked, as long as we do not abuse that natural ability and overload the system. I think that there were two issues that brought this problem to focus: one was the increasing population in urban centers, and therefore, concentrating this pollution in a much bigger fashion; the second was the introduction of xenobiotic compounds, primarily organics that were not present in nature, and were synthesized (pesticides, chemical solvents and so on) that nature has a much more limited ability to handle and sometimes cannot handle.

I am not going to use the term wastewater, as we now think about it as a resource. Treating wastewater as a resource is a big paradigm shift. We can recover water, nutrients, and energy. We found that one of the methods to treat the affluent is a biologically treatment process using microorganisms. This is the most efficient and efficacious way to deal with this problem. Because of this, we now have books such as Environmental Biotechnology, which is the text for a class dealing with this issue that I teach. We use biological processes; in some way we mimic, we intensify the processes that occur naturally in the environment. A prime example is when you put untreated waste in a river, bacteria that are already in the river utilizes the waste as food. Bacteria utilize the "food" and consume oxygen. However, this leads to the depletion of oxygen from the river causing the fish to swim belly up. What we do is we take these bacteria and concentrate them in a concrete box. We provide them oxygen at much higher rates. We take a process that would be detrimental to the environment and shift it into a controlled, intensified system. We also use natural systems such as wetlands and soil aquifer treatments, which work fine as long as they are not overloaded. In nature, however, if you want to have nice wetlands, you cannot engineer them to the extent that you can engineer the concrete box. So that is why they are biological processes and it is fun to work with bacteria. Membranes are an additional element that provide for separation of biomass and enhance the final effluent quality. You get a much better quality using membranes. Membranes are an additional element that provide for separation of the biomass and enhance the final quality so that you eventually have a higher quality using membranes. That's where that fits in.

BSJ: You talked about the problems that using bioreactors solves, could you go into some detail about its benefits?

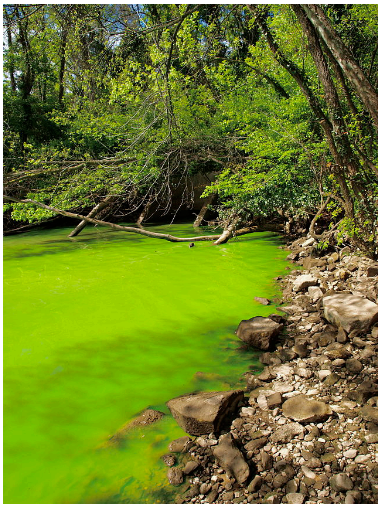
Professor Hermanowicz: It is a new tool in the toolbox of engineers to deal with water reuse. There are two advantages: One is that we process the same amount of dirty water in a much smaller box. We can intensify the process by an order of magnitude of 10 folds. It is much smaller and compact. There is some additional price to pay because bioreactors consume more energy. But if space is an issue, then bioreactors play an important part. Also, the facility has a capacity of tens of millions of gallons per day, which is better from an industrial aspect. Just to give you a perspective, I was looking up the total beer production in the United States annually and it is somewhere in the order of two million gallons. You have a plant in Chicago and they process three hundred million gallons per day. The scale of biotechnology operations in the environmental area is huge! So, reliability is an important part with the membranes. They provide an extra level of protection and make effluent of a higher quality; hence, they can be used much more easily and more widely.

BSJ: What were the unique benefits of the Fluidized Bed Reactors?

Professor Hermanowicz: Well, with the fluidized beds, there was a bit of excitement early in the 1990s. They have a bed of granular material, like sand, put in a column and the water flows upwards. If the water velocity is high enough, then the grains of sand become suspended in the flowing liquid. The major advantage was that it allowed a much higher concentration of microorganisms attached to the surface of the sand granules. So, when you have this pile of sand, the biomass fills the voids and the plugs of the filter. It is really very technical, but the engineers get excited about relatively small technical advances! This excitement is present in every research field! Like, in computer science, if your code is three lines smaller, you are a genius! So, these turned out to be useful, but were highly energy consuming.

BSJ: So, you're looking for means that also optimize energy consumption?

Professor Hermanowicz: Yes, absolutely! That has always been a dogma for engineers. Do things better and cheaper. Cheaper entails lower energy cost and material cost. Engineers have evolved to focus on sustainability, but they did not use this word until very recently. The word, "sustainability," has come about in their attempts to vocalize and sell the idea.



BSJ: So, you are constantly looking for sources with lower energy consumption?

Professor Hermanowicz: Of course! There has always been a dogma for engineers: do things better and cheaper. Cheaper includes lower energy costs and lower material costs. In some ways, engineers have always been involved and focused on sustainability; they just never used the word until recently. They were never able to vocalize this idea and sell it, but this is exactly what we're doing.

BSJ: What are the alternative forms to fluidized bed reactors and MBRs? What are used in treatment facilities today? What do you see used in the future?

Professor Hermanowicz: MBRs are now a hot technology. They are growing by leaps and bounds. There are certain fashions in engineering, and this is very fashionable right now because they provide very high quality effluent with very high reliability. It has other problems, however, that people are trying to solve. Fluidized beds have been used for a while and they have a niche, particularly for industrial waste treatment. However, I do not work on them anymore, in some way they have not become obsolete, but they are a technology that has already found its niche. For example, car manufacturers use them to treat the waste from their painting operations. This is because there is a very high concentration of organics, and you can treat the water in a very small footprint. However, they don't reuse this water so they just have to meet the regulatory standards for wastewater. If you need a high quality, membrane technology is certainly the answer now.

BSJ: So you mentioned the idea of using lakes and natural sources to discharge water into. What are the benefits vs. the costs, for example eutrophication, associated with their usage?

Professor Hermanowicz: Eutrophication is certainly a problem. This is primarily due to non-point pollution. The two culprits are agriculture and atmospheric deposition. With atmospheric deposition you have high temperature processes, such as internal combustion, which release nitrogen oxides into the atmosphere. Nitrogen oxides return to the ground through as rain. With agriculture, it is essentially the use of fertilizers. In some ways, it is just economic. It is much easier for farmers to overdose in fertilizer, which is still very cheap, to increase yield. Agriculture, however, is moving in the right direction, in what is called precision farming. In this method, nutrients and fertilizer are deposited to plants in a much more precise and controlled fashion. The combines and applicators have GPS systems and measure and map local pH levels, becoming high tech and high science. At the same time, it is much simpler to just spread fertilizer, with plants absorbing some of it, and the rest goes into the water. That is the major problem with eutrophication. In this country, we have already solved the issue of point source pollution from pipes and wastewater. The big problem is, especially with things like the hypoxia in the Gulf of Mexico, is that it is coming from other sources. This is a difficult problem to solve because there is no end pipe to treat, so we have to rely on conservation techniques on the different farms. The change is happening though, in 1920s and 1930s, for example, there were very few people who knew about erosion control in farming; now, this is a common practice.

BSJ: Now, how would you see your research going in the future?

Professor Hermanowicz: That's a really good question! The part of doing research, and the fun of doing research is that it is a never-ending story. You think you solved the problem, but in reality you have opened up new areas and think of new questions. As you learn more, very rarely are you completely satisfied with what you have done. I am definitely very interested in a few areas in the future. One is the usage of biological processes, primarily in controlling microbial community structure. We are just learning how to do this with things like QPCR and fish techniques. The difference between biological technology in pharmaceuticals and us is that we have relatively little control over what we get into our systems, like the type of bacteria. We are trying to understand these problems in large scale, open systems. Certainly, the area of sustainability and trying to push some metrics into current regulations would be interesting. We are also going into the area of water reuse and water acclimation on the small scale. We have this project together with two of my colleagues from bioengineering and architecture for greywater reuse in the facades of buildings. Here, it will be interesting to combine different approaches for sustainability and to look at heat recovery. We will see! On a very practical level, it really depends on where the funding is. This is the reality these days, especially in the areas of science and engineering.

BSJ: Thank you for your time!

IMAGE SOURCES

http://www.ce.berkeley.edu/~hermanowicz/hermanowicz.jpg

http://ecx.images-amazon.com/images/I/51BUD6L02bL.jpg

http://upload.wikimedia.org/wikipedia/commons/thumb/3/36/Potomac_green_water.JPG/640px-Potomac_green_water.JPG

Layout by Jingting Wu