1. Research, Innovation and P recovery: Putting things in perspective

Wetsus includes projects on recovering P from waste streams like sewage and manure. But where does this fit in the grander scheme of closing the P cycle? How have the technologies in this area evolved over the years? Moreover, what does it take to be a researcher in this field and bring out innovations?

Let's hear all about this from two leading researchers and experienced campaigners on this topic: Professor Cees Buisman, who leads the chair of biological recovery technologies at Wageningen University, and Professor Mark van Loosdrecht, head of the department of environmental biotechnology at Delft University. Cees is also the scientific director of Wetsus.

***Mark van Loosdrecht**: "If you really want to be a researcher, you should be driven by curiosity. For me, the desire to know is more than the desire to find an application."*

***Cees Buisman**: "We need different approaches to innovation. We need different disciplines to come together, which results in new innovations to tackle the upcoming challenges. I call this the multidisciplinary magic."*

The research topics we will discuss here are resulting from a collaboration between universities and companies, facilitated by Wetsus. So, let us start by getting your view on that. How does the Wetsus framework help you to do research and innovate?

Cees: There are two main things that Wetsus does. One is to vastly improve the cooperation between industry and universities. The experience of the industry is way better connected with the knowledge potential of the professors. The second one is multidisciplinary cooperation. We bring the PhDs from different backgrounds together; they find time to cooperate and this in turn connects the professors. And so, we have access to all the knowledge and network these professors bring. I call this the multidisciplinary magic because this is where creativity happens. All the simple innovations are already done, and we need different disciplines to come together, which results in new innovations to tackle the upcoming challenges.

Mark: If you are serious about innovation, you cannot research without involving companies. By involving and discussing with them, you have experts around the table who know things in practice, who have a different line of thinking than the engineers from a university. That is part of stimulating creativity. But it does not work if the company is just there to provide money. It only works if there is someone from the company who is interested in the project. It is not about finances, it is about personal involvement from industries and waterboards, who like the project. And creating this right atmosphere of getting the companies involved is what results in successful innovations at Wetsus.

Human consumption for all sorts of industries is depleting the reserves of many natural resources. Like phosphate most other nutrients are finite as well. What is so special about phosphate then? Would you say there is a sense of urgency when it comes to P recovery from waste streams?

Mark: Phosphate is non-replaceable. Many other resources can be replaced. Oil for instance is replaceable by the wind. If you use oil for plastics that is replaceable by plants. If there is no phosphate, there is no food. The chemical that most closely competes with phosphorus is arsenic, which is highly poisonous. So, if there is no P, all life on the planet collapses.

Also, it is an urgent need because, amongst the elements needed in food, it is often estimated as one of the earliest to be depleted. Carbon, oxygen, nitrogen, hydrogen will always be there. From this point, P is the most limiting for life or food.

Cees: Phosphate has a double side – It is polluting and it is depleting as well. If you look purely from depletion, perhaps Zinc (Zn) is more problematic. The reserves of Zn are estimated at 19 years; P has reserves for 350 more years. Zn is also vital for human health and is often deficient in farmlands.

But if you look at wastewater, there is no wastewater without P and this gives a good scope to recover the P. Moreover, the fact that it can pollute the water via eutrophication makes it necessary to remove it.

A topic that is often brought up is the lack of P reserves in Europe. There is a small reserve in Finland, not much besides it. However, P is present in the food people consume. Does it mean if we recover all the P from sewage plants, we don’t need to rely on global imports? Or is there a waste even before the P reaches our plates?

Mark: If you look at the phosphate balance in Europe, only a very small portion, let us say less than 10 % ends up at the sewage plant. Most of the P loss is due to inefficient agriculture, and not everything is taken up by plants. If you want to improve the P management of the Netherlands, you do not look to the WWTP, you look to agriculture. Also, animal manure has way more P than human manure, so more recovery is possible from animal waste.

Hence, what we do in wastewater treatment plants (WWTP) in terms of P recovery is contributing to the solution, but not solving the problem. It is good to contribute, but the real problem is not solved by only focusing on WWTP. However, all these small contributions are necessary for taking the big step towards sustainable P use.

Cees: The Netherlands currently has a surplus of more than 50 million kilograms of P. The Dutch soil is filled so much with P that there is probably enough P for 100 years. So, the problem right now is not the lack of reserves but improper management.

If you look at the global distribution, there are hotspots like the Netherlands which have enormous concentrations of nutrients. The Netherlands is a very big food processing country, and the majority of the P is in animal feed and human food. Then there are places on earth where there is nutrient deficiency, and still, P from deficient regions is being transported to the hotspots. Hence, if we want sustainable solutions, we need to look at systems that redistribute the nutrients worldwide.

What is the current industry standard for recovering P from waste streams and how much P is recovered in such a case? Has this changed during the timeframe of your careers?

Mark: When I was a PhD researcher it was struvite and it still is struvite. The recovery is usually not more than 10 to 30 % of the P from the influent of the WWTP. If you want to fully recover the P, one option could be to use the sludge directly as fertilizer on the land. But then P present might not be in a readily accessible form, plus there might be harmful contaminants in the sludge. You can otherwise use incinerators to burn the sludge and recover the P from the ash, and incinerators can even be energy positive. But as a downside, currently, not all sludge is burned in an incinerator and there is still a negative impression about incinerators amongst the public. So, having an alternative recovery method from the sewage sludge is still useful.

Cees: If you look at municipal wastewater, only a little bit of P is recovered and mostly it's struvite. The focus has been more and more struvite during my time because that's the easiest, just add magnesium and you are ready. P recovery from incineration is still not allowed in most places because it contains too many heavy metals, so the ash would need further cleaning to recover from it. Thus, most of the P from the sewage sludge is wasted and hence there is a need to develop alternate recovery technologies.

As experienced researchers, I have a question for you regarding competing technologies. It can well happen with your research projects that you come up with different solutions, for instance, P recovery as iron phosphate or vivianite as compared to recovery in the form of calcium phosphate. How do you deal with this as a researcher/professor?

Cees: From my point of view, you need different approaches to innovation. Because you never know, and it is impossible to predict which one will win for which situation.

For instance, from an agricultural point of view, the iron phosphate or vivianite method is not handy because it is not readily available to the plants. But it proves that from the magnetic separation point of view, it is very practical and handy, the recovery is very easy from sludge. For iron-free situations, like manure or blackwater, the biological calcium phosphate seems more practical and I think it is easier to bring P back into the phosphate cycle. For the electrochemical P recovery method, we use the wastewater from the cheese factory. This wastewater is very salty, is also iron-free, bacteria cannot live in there, and this recovery method seems to be more practical for that situation.

So that is what happens in many cases, that technologies find their own niches. Nowadays everybody does struvite because there is nothing else. But maybe later we can choose from vivianite, calcium phosphate recovered biologically, calcium phosphate recovered electrochemically. So, there are all these different opportunities. And that is my idea, to create as many technologies as possible, even if they are competing. All technologies will have their own application.

Mark: If the project is competing, it does not matter as long as it is interesting. I am not worried whether one research will be chosen for application over another one. Research should be driven by curiosity. For instance, with the vivianite project, I was intrigued by the question of what is happening with the iron balance at the WWTP. Then it was about getting a PhD to start at Wetsus, then the company Kemira got involved because they are also interested in iron (Fe) based products. My interest in Fe coincides with their interest in Fe, and I thought let's go. And that will be the same with let us say another team that works with a calcium-based P recovery technology. I do not see that as competition.

This question is a request from a good friend. What is it that drives you to work every single day when you wake up? You surely must have a drive and a vision. Can you share that with us?

Mark: Just curiosity. Wanting to understand how things work, to understand what is going on. For me, the desire to know is more than the desire to find an application. It is of course nice to have research like Nerada or Anammox that are applied in the real world, and I believe in it, but in the end, I am interested in the why. For instance, why are there strange Fe balances in the WWTP? I am happy that I can contribute with a P recovery method that can be put to practice, but my main motivation is to understand how iron is turned over in the WWTP. Iron conversions in WWTP are hardly researched, very limited and this got me curious to start the research.

Cees: I think I am a multi driven person. At my current age, inspiring young people has become very important. When I started Wetsus and I just became a professor, it was also about creating new things, showing the world how much more new technologies can be developed. And with Wetsus, this cooperation between industries and academia, which results in so many innovations, is motivating. Also, my teams, teams that I am responsible for, teams that I want to stimulate, grow, and make something of their lives, that is very inspiring.

Thanks for your insights. Before I move on with the PhDs to learn more about the specific projects, I would like to know if you have any advice that can serve as an inspiration for upcoming researchers in the field of wastewater treatment?

Mark: If you really want to be a researcher, you should be driven by curiosity. If you are not driven by curiosity but want to focus on improving systems, then try to move into the industry. From the industry, you can very well work together with universities and still be able to drive the research.

Cees: Researchers in environmental technology are special people. They are engaged people. If you want to become rich easily, then this is not the right business. I think we are here because we are engaged with the world. Also, as a researcher do not be discouraged if whatever you do is not successful at the beginning or never. Do not get discouraged so soon for possible applications, because we do not know all applications, but we can look for applications. The percent of environmental engineers is negligible, and we save the world, so be proud to be part of that community.