Supplementary information

An assessment of the drivers and barriers for the deployment of Urban Phosphorus Recovery technologies: A case study of The Netherlands

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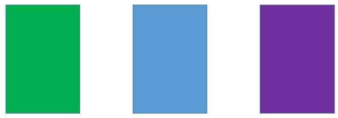
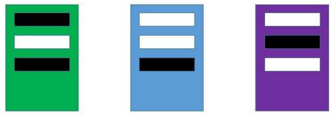
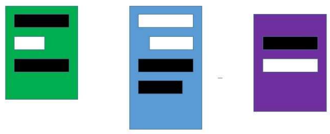
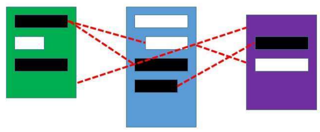
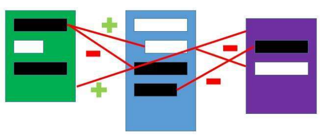
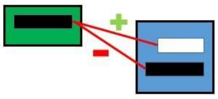
Contents

1. Interview data methodology

Scheme S1. The steps followed during the analysis of the interview data methodology of Gray (2013) in study one.

Step 1: Open coding: 'Naming and categorizing of phenomena through close examination of the data'		
Step 1a: Transcribe the data	Interviewees granted permission to record the interviews. Shortly after each interview, the recording was transcribed in word.	
Step 1b: Familiarization	After transcription was completed, the interview was subject to a read through where labels were attached roughly indicating the topic discussed in each particular section.	
Step 1c: Focused Reading	After the initial labelling was completed, the transcription was analyzed a second time by an independent person. In this step, statements were interpreted.	
Step 1d: Review / amend codes	In this step, the analysis so far was checked for mistakes. Inconsistencies between labels were removed. This involved merging and renaming labels.	
Step 1e: Generating theory	Labelling is now complete. An initial interpretation can occur and the development of framework can now begin.	
Step 2: Axial coding	This takes place by assessing whether categories have an effect on one another. Whether they provide context, whether it leads to certain interactions or if there is a causal relationship between categories.	

Step 3: Selective coding	In this stage, the core categories are identified. What are the most important system dynamics related to the research question? This takes place at a higher level of abstraction than the previous steps. Here, a story line surrounding the core category is developed and careful consideration what sub-categories are related to this.	

2. Extra information – Phosphorus taxes

Phosphorus taxes for usage in agriculture have already been experimented within several European countries; The Netherlands, Sweden, Denmark, Austria, Norway, and Finland. The aim of these taxes was largely to decrease phosphorus usage on farms for environmental reasons [1;2]. Taxes have shown to be effective to some extent [1;2]. Consequently, the phosphorus usage was halved due to taxation in combination with awareness programs. Since taxation has stopped, the phosphorus usage has declined further. In Austria, a similar scenario took place with a tax system on the total fertilizer usage. In The Netherlands, taxing surplus of phosphorus in the soils worked in some cases, but had high administrative costs. The effects were positive, especially for dairy farms, but failed for poultry and pig farms [1;2], because the tax system focuses on fertilizer usage and is based on nutrient concentrations in the soil. These farms have little land, import all the animal feed and produce large amounts of manure, resulting in P accumulation. The European Court stopped the tax system because it was not following the Nitrate Directive [1;2]. Currently there is a tax on the total usage of fertilizers. The crop prices were marginally higher in Austria and Sweden, but these are often subsidized by the national governments [1].

3. Interview summaries study two

The names of the interviewees has been changed for anonymity.

Interview 1: Water board 1

Position title: Senior wastewater engineer water board 1

Interview conducted: 18.05.2017

- The WWTP produces 430 tons of struvite on an annual basis
- The costs for magnesium oxide amount to 100,000 euros
- Their struvite product costs 63 euros per ton
- The struvite they produce uses a Phospaq reactor. The reason they chose to do so is because the reactor is was a more cost efficient choice than some of the others options. Additionally,

the reactor is particularly good at creating a more pure product with less heavy metal contamination. Jan compared this against the Airprex reactor in Amsterdam, which does result in a greater level of heavy metal contamination.

- The company Aqua minerals in an intermediary between wastewater treatment plants and the market.
- EGF focuses more on promoting projects and engaging in knowledge dissemination
- EGF is focused on recovering energy (primarily
- The top five products recovered from waste plants in NL are:
    - Phosphate (more common)
    - Cellulose
    - Bioplastics (still costly)
    - Alginate
    - Biomass
- Another product they're currently focused on recovering at the plant is humic acid
- Humic acid is a biostimulant
- The humic acid improves root systems, currently a pilot for humic acid is being conducted in Tilburg, Venlo, and Amersfoort
- On an annual basis the WWTP is treating 25,000 tons of dry solids on an annual basis and 9 million cubic meters of biogas
- Their plant is energy neutral due to their production of biogas, they give part of their biogas to their industrial neighbor and the rest is sent back to the grid. However, prior to being used by other industries, the WWTP needs to inject more methane into the gas so that the methane content is around 80% rather than 69% which is what it is prior to injection
- They profit from this renewable energy generation because the dutch government promotes this via renewable fuel units
- They now gain 40 cents per cubic meter of biogas that they produce
- Alginate is produced mainly from the Nereda technology
- Alginate has dentistry applications, currently Europe gets most of their alginate from China
- Refer to the stowa reports on struvite for an in depth look at the quality of struvite
- Also refer to the report written by one of the ministry's departments (check which one) on the "potential of struvite for dutch agriculture"
- Struvite was only recently adopted as a product recognized for fertilizer in dutch legislation in 2015
- Struvite has other applications for agroforestry and golf courses (the agroforestry is not so much realized yet though)
- Since Holland has a surplus of phosphorus, there is no market for a domestic struvite demand. As such, Holland needs to open up trade alliances/ and a trade market with other nations who experience a phosphorus deficient such as Spain and France. These countries however can not purchase struvite unless struvite is registered as a legal product in their respective legislation. Without the consideration of struvite as a product, it still continues to be waste.
- Struvite, biochar, and ash are the three main concerns of the revised version of the EU fertilizer directive (2003/2003)
- The future revision of the fertilizer directive needs to acknowledge and support phosphate recovery materials as marketable products

- The only transnational trade relation The Netherlands had for struvite is with the Dominican Republic. In 2017 the ship Tres Hombres sailed from Holland to the DR to deliver struvite that will be utilized by cacao farmers in the DR.
- SNB produces 6,000 tons of recovered phosphorus
- Struvite is more common in plants that have a thermal hydrolysis reactor, which thereby produces a scaling problem of struvite that should be recovered in order to reduce maintenance costs. The plants that have this thermal hydrolysis are: Venlo, Hengelo, Apeldoorn, and Tilburg
- Not all Bio-P plants digest their sludge so not all of these plants have a P release
- Problems for innovation, infrastructure is a large commitment it must stand for around 20/30 years
- Their Phospaq reactor is built for 15 years

Interview 2: Water board 2

Position title: Policy Advisor for water board 2

Interview conducted: 31.05.2017

Interviewee 2 has been working for the water board for 17 years now. By training he is a chemist and physicist. Out of all WWTPs that the water board, only two have reactors in place. One utilizes the Ostara technology while the other has a NuReSys reactor. Another WWTP uses the Nereda technology which does promote phosphorus recovery however the recovered product is not struvite but rather alginate. Alginate has various industry applications, namely for dentistry however the interviewee remarked that he thinks in the future there will be more applications, specifically for agriculture use. Wageningen University is currently working on research that explores these potential applications.

At one WWTP, they officially opened the Ostara reactor in 2016 and was constructed in 2015. On a daily basis they produce around 700 kg of struvite that is then shipped to England which is used for fertilizer. Also at the WWT plant they generate biogas which is used for their plant as well sending it back to the grid. The ostara reactor needs constant monitoring and maintenance due to the high potential for scaling of struvite and high potential for fluctuations/ changes that occur during the precipitation process. Magnesium chloride dosing is the primary method used for both the Amersfoort and Apeldoorn plants despite the different reactors that they use. At this WWTP they also utilize the lysotherm (a mesophilic system) to control the heating of the water as well as the oil at the plant.

This LysoTherm technology is owned by Eliquo and it is a thermal hydrolysis reactor that controls the pressure treatment of the waste activated sludge during the biological treatment of sludge. With this reactor, "Sludge's are fed into the LysoTherm® by means of a feed pump and pressured in between 5-10 bar followed by a heating process where sludge's are heated in between 140-175°C. The temperature-pressure reaction time is approx. 1 hour." More information about the LysoTherm process can be found Eliquo's website. When plants have a thermal hydrolysis reactor this increases their chance of scaling on the pipes and thus promotes the incentive to recover struvite from the pipe systems in order to reduce maintenance costs. This statement was also validated to me in interview 1.

The interviewer had inquired to the interviewee about the carousel technique since the researchers have come across it in their research and wondered if it offered any innovative mechanisms for nutrient recovery in the same way the Nereda, Ostara, and other phosphorus recovery technologies did. He remarked that the carousel technique is not new, rather it is an older technique that was developed in the 1960s. At the WWT plant they use the carousel technique in the primary treatment stage. The carousel technique is just one of many different types of biological treatment methods that various WWTPs utilize in The Netherlands. Erik claimed that many plants already engage in nitrogen removal, which is an autotrophic process. However, phosphorus removal is an additional step and it is a heterotrophic process that is fueled by the addition of sugars.

The interviewee gave the researchers access to all of the data they have on monitoring the various WWTPs that they own. From every plant, they obtain one measurement every six days. In total they own 16 plants. From this measurement, they measure a few standard parameters include the P concentrations, the COD, BOD, aggregated concentrations for all nitrogen compounds, the total volume of wastewater in cubic meters, the chlorine concentration, and the total suspended solids. He claimed that gathering data on the heavy metals and the micro pollutants would be harder as a lot of plants and water boards do not readily have data on this. In total, they obtain around 120 samples per year. Regardless of the ability to regularly monitor the heavy metals and the micro pollutants, most plants do maintain a steady data collection process due to legislation is the past years pushing the water boards to ensure a better more regulated quality of their wastewater.

Interview 3: Water board 3

Position title: Head of innovation

Interview conducted: 01.06.2017

One of the WWTPs is the second largest WWTP in The Netherlands in terms of population equivalent. The plant in Harnaschpolder neighboring The Hague is the largest in The Netherlands. However, in terms of volume of sludge processed, their WWTP is the largest since it also processes sludge from the neighboring regions. The plant is owned and operated by the water board. The water board is unique compared to other sewage/ water purification companies because it is a water cycle company. This means that they control the water purification as well as managing the quality of the surface water.

Prior to what I had heard before, this water board is entirely a public company that is run in part by the city and the water board. This water board, as well as other water boards in The Netherlands have a large amount of funding available because they are able to take out loans for projects from the central water board bank. Other countries such as Germany do not have this opportunity and as such, their ability to engage in phosphorus removal and subsequent recovery is much less.

The WWTP has a population equivalent reaching just over 1 million p.e. The infrastructure at the plant is composed of a large amount of primary sedimentation tanks, three large digesters, the three P recovery reactors. All of the sedimentation tanks are sealed due to stringent air quality regulations. Only in the conveyer thickeners can you see the dewatered sludge. The WWTP utilizes Enhanced Biological Production Removal. The specific type of method they utilize is the MUCT which stands Modified University of Cape Town. The reject water is utilized again in the plant and it contains a large amount of ammonium. Research is currently being conducted that is examining how to remove the ammonium and subsequent applications for its use.

The interviewer had asked the interviewee about the difference between some of the other terms related to EBPR such as BNR and Bio-P, which I thought were interrelated but it turns out they are all different and most plants have their own unique type of biological nutrient removal. Also, prior to what the interviewer had heard before, he claimed that most plants in The Netherlands still do chemical precipitation. As a result, this does not make struvite scaling a problem and then there is no incentive to utilize struvite recovery reactors such as the P recovery technology they have.

The reactor was assembled by Eliquo, a German engineering company. The technology utilized is Airprex. Prior to choosing Airprex, they had conducted a feasibility study for choosing between Airprex and NuReSys. Airprex turned out to be the more cost efficient technique with a ROI of only 6 years. 6 years is very quick as most other phosphorus recovery technologies such as the Phospaq one at another WWTP has a ROI time of 10 years. And the infrastructure only lasts around 15 years following the installation.

Due to the access of funding for innovation, the water board was able to invest in the Airprex reactors. They have three reactors in total. Two for the precipitation and formation of struvite as well as one additional settling tank. The reason they have three instead of one is due to the low spatial availability at the plant and the issue of getting the infrastructure over the adjacent railway. The idea for the project and the subsequent installation came very quickly as the idea was generated in 2011 and the plant was already installed in September 2013 and up and running by processing sludge in December 2013. This quick completion of projects does not typically happen so often at most water boards. That is why their project and case provided the short time line is impressive.

In total, these reactors help the WWTP to generate around 500 tons of struvite annually. Their future goal is around 800 tons of struvite annually which can be achieved by adjusting and modifying the process to make it more efficient. Generally they do not have much problems associated with the scaling and increased maintenance costs from the large amount of precipitation in the pipe systems.

The recent legislation shift in 2015 that allowed for the sale of struvite to commercial entities. As such, the WWTP was able to start selling their struvite to a fertilizer company. The plant also has a partnership for energy exchange with their neighbor AEB. AEB is the largest incineration plant of household waste in the world. These exchanges represent examples of industrial symbiosis put into practice.

The water board has a partnership with Aqua Minerals which is the company that helps them to sell their recovered products to other entities since the water board is not able to sell products themselves as a publically owned and funded company.

When the interviewer asked the interviewee about his suggestion for dutch plants to engage in local recovery versus engage in a partnership with SNB/ HVC and the ecophos partnership, he said you need a mix of both. For plants that already engage in chemical precipitation, it is better if they incinerate the sludge and get the phosphate products out of the ash. For those plants that already use EBPR, it makes more sense for them to engage in struvite recovery, as it is most likely already a problem in their pipes and causing maintenance problems.

Interview 4: Researcher in struvite precipitation technologies

Position Title: Researcher and expert in struvite precipitation technology

Interview conducted: 26.04.2017

Germany

The interviewer started out the interview by asking the interviewee about the landscape for the different processes that WWTP use in Germany as well as asking if there were any regional differences among the various Germany provinces. He responded that there is no difference between the federal states/ provinces. Instead, the focus is much more in the hands of the different German water boards/ associations. For most of the plants in Germany, chemical precipitation is used. In fact that figure is broken down into 94% chemical precipitation and only 6% for Bio-P. Chemical precipitation and the associated recovered P products are more appropriate is Germany due to the stricter regulations for the effluent in Germany.

In using chemical dosing, iron is much more commonly utilized over aluminum dosing. This is due to the lower cost associated with iron doing as well as the potential for greater toxic effects with aluminum. Although most plants use chemical precipitation, the chemical dosing is stronger in some regions than other depending on the regional regulations/ limits for the effluent. From this, the differences in dosing between provinces is due to the regulatory practices and guidelines decided by the regional German water boards. In Germany, there is one overarching and biggest wastewater authority and that is the DWA. In addition to chemical dosing, thermal treatment is the most commonly used subsequent method.

Thermal treatment in Germany is supported by the renewable energy act which helps support the development of mono-incinerators as opposed to co-incinerators. The interviewee believes that co-incineration will become more prominent as the 2018 mandate for phosphorus recovery from wwtp larger than 50,000 p.e. will become effective. He remarked however, that this decision is not set in stone. Rather, the decision of the mandate will be gradually incorporated into WWTP practices in Germany over the course of the next 12-15 years.

In The Netherlands, the landscape or trend for recovery will be centralized on increasing efficiencies via mono-incineration (since The Netherlands doesn’t engage in any direct land application of the sludge). The Netherlands has a future plan to deliver all their ashes to EcoPhos who is in the current process of constructing various ash valorization facilities. From the ash valorisation facilities, the ecophos plant strives to recover phosphoric acid.

The interviewer had asked the interviewee about the tension between public/ private sector in this field. For instance, as I understand from The Netherlands it sometimes is hard for Dutch water boards, as soon as they start to produce commercial products (struvite for instance) this poses issues since the water boards are funded by public tax money and are public entities. The interviewer had inquired to the interviewee whether there is room for the public and private sector to work in harmony together without these tensions. An example he provided was from Hamburg Wasser which has a partnership with Veolia and Tetraphos which assist with the ash valorization of thermally treated sludge. The point at which ash needs to be valorized is where the role of the private sector comes in. Before that, the management is primarily done via public entities.

There are some potential issues however with this public/ private balance. Water boards do not claim that this phosphorus removal is their responsibility. Their own primary obligation is to manage wastewater, not to invest and innovate. Additionally, the DWA of Germany who is responsible for managing wastewater is not particularly keen about phosphorus removal. Another issue is that professors who are heavily involved in the research and do policy briefing in this field do not have the greatest impact in terms of positive impact or driving change. This is because they are very ignorant and do not actually what is happening in the business field.

However, through the work of the P-Rex project, the interviewee was able to shift some of these negative attitudes more towards a positive direction for P recovery implementation. The interviewee indicates that he was able to utilize his dutch connections in order to put pressure on Germany to do more. Policy was still in a stage of reluctance until 2013 when the interviewee helped to organize a large agricultural workshop in Berlin. After this there was a switch in the mindset, after this they were more inclined to do technical P recovery instead of looking at just the direct land application.

Currently, the interviewee is shifting his focus away from projects like the p-rex project and focusing more on practical implementation. He strives to focus on making facts and implement real working value chains. He’s now working on a P recycling value chains in the organic farming sector where struvite production is the most appropriate recovered product to create a market for.

The Netherlands

The interviewee is a fan of the pathway for P recovery demonstrated by The Netherlands as opposed to Germany because it has taken on a much more evolutionary approach. By this he means that Dutch are not so much focused on maximizing recovery rates but rather to get plants up and running first. This is intelligent because then you can only maximize efficiency recovery rates after the plants themselves have been constructed. But something that greatly helps The Netherlands is the larger flexibility in legislation. Germany is more focused on the high recovery rates but because of this and instead of adopting an evolutionary focus, nothing from the technologies is being implemented.

General Remarks about Legislation in Europe

There is still a prominent lack of harmonization in legislation across EU Member States. Legislation surrounding phosphorus recovery is disaggregated in various directives (wastewater directive, IEA, fertilizer directive). The fertilizer directive is currently undergoing several revisions and is highly debated. There’s often tension in debating legislation due to the competition arising from different Member states. Every state will come to the table with their own specific agenda and care about their own industries. As such, tension arises.

Interview 5: Interviewee works at municipality in Austria,

Position Title: Researcher Water Quality Management

Interview conducted: 19.04.2017

The interviewee works for the city municipality as a researcher/ advisor for sustainable phosphorus management. His research has focused on material flow assessments of P flows throughout Austria as well as providing a comprehensive overview of the feasibility of different phosphorus technologies by evaluating them on a specific set of criteria. That criteria includes categories such as plant availability, pollution content, and costs and handling. This research project constituted most of his PhD research. Presently, he is working on implementing sewage sludge ash technologies within the municipality and is engaging in discussion with stakeholders from the fertilizer industry in order to gage their interest in P recovered products.

In Austria and Germany, Bio-P is much less common than in The Netherlands. Since Germany and Austria are landlocked countries, the regulations for pollutant concentrations in the effluent are much stricter than in The Netherlands. This is due to the fact that The Netherlands has a greater ability to dispose of effluent in water bodies. However, in the landlocked countries this is not possible. Chemical treatment however is not so readily utilized in Germany and Austria due to the high cost intensity. Using acid such as hydrochloric acid for treatment is costly and furthermore when you engage in chemical treatment, you get various side streams that contain heavy metals and therefore present a problem in the quality of the sludge and subsequent recovered products.

The best, or most feasible route for recovery for Germany and Austria is therefore via thermal treatment particularly mono-incineration. This should be favored over co-incineration. With co-incineration, this leads to a higher import of heavy metals in the recovered product and the quality of the recovered P product is therefore compromised. Mono-incineration is already utilized but more so for industrial purposes via the incineration of meat and bone meal ash. The waste product from Meat and bone meal is already utilized in the cement industry but the P is lost in this process.

Therefore, thermal treatment of the ash prior to this industry application helps to recover P. Despite the current use of these mono-incineration techniques in Germany and Austria, it is still not widely utilized by plants due to the additional infrastructure costs. Since direct land application of sludge is still allowed in these countries, this is still preferred over investing in new techniques. However, the advantage of incineration is that is offers a high quality recovered product due to the eradication of organic pollutants during the incineration process. All organic pollutants are destroyed at temperatures higher than 850 degrees with a small contact time of only 3 seconds.

The interviewee remarked that centralized recovery facilities will be much more effective for Germany and Austria than decentralized methods. A leading example of this is from a recent project created by the municipality of Zurich to develop a central mono-incineration plant where the sludge is collected from all plants in Zurich as well as the surrounding area. Another example is from the lower region of Austria where a centralized drying station for sludge was organized and dewatered sludge was brought from many neighboring regions to a central station. Plants that were transporting sludge from further away were provided with a cost break and had to pay less for the associated logistic cost of transportation. That way everyone in the region had to pay equal amounts. This example provides an ideal method for sharing a central facility among many different WWTPs.

Despite the public support for P recovery technologies, once legislation was created surrounding this field, there was still a large amount of backlash from plants because they did not want to change their techniques. Recently, Austria released a policy requiring a mandatory P recovery from WWTPs. The interviewee remarked that once this came out, they received a lot of backlash claiming that the time span for the mandatory P recovery implementation was too short. However, the interviewees believes that the Austrian government will soon complement these mandates with extensive support for plants in the form of tools to overcome these economic barriers for implementation (ex. subsidies).

When interviewer asked the interviewee what set of criteria he believed to be the most important he remarked that it is not always about heavy metal concentration. Studies that have been conducted so far on monitoring the concentration of heavy metals in ash once they have been applied on land have yielded negligible results. However, despite this finding, it is not always certain that there will be non-toxic concentrations. As such, additional monitoring studies need to be conducted.

Yet, the aim of fertilizer producers is not to totally eradicate heavy metal concentrations but rather to ensure that they do not exceed the regulation limits. The focus of farmers and fertilizer producers for quality of the recovered product is much more on the associated costs and the plant availability in the final product.

Farmers will keep a constant eye on the quantity and quality of the fertilizer that they are using and will monitor whether their crops are effectively taking up the P in the fertilizer. If the product has low plant availability, it is therefore highly unmarketable. Additionally, if there are high costs incurred from the use of a P recovered product, the farmer or fertilizer producer will be less likely inclined to use it. Furthermore, it is important to mention that the "best" type of recovered product (ex. struvite) is highly depend on the context of what a farmer is growing. For instance, some farmers may want struvite for crops because it is a slow-release fertilizer but this is not appropriate for every crop.

4. Questionnaire script for study two

Questions sent to all the Dutch water boards by E-mail. The questions were in Dutch, translations can be found below.

Questions

Vragen

1. Maakt uw rioolzuiveringsinstallatie al gebruik van fosfaat terugwinning? Zo ja, wat voor technologie gebruikt u en waarom?

2. Voorziet u belemmeringen om fosfaatherwinning toe te passen? Zo ja, kan u dit toelichten?

3. Ziet u ook potentiele voordelen van fosfaatherwinning voor uw installatie/bedrijf?

4. Welke WWTPs gebruik maken van chemische precipitatie (Fe, Al) en welke EBPR (en wellicht Bio-P)?

5. Overview of drivers and barriers of each water boards

Table S1: Drivers and barriers of each water board

Type of P Recovery Path	water board	Drivers	Barriers	Additional Remarks
SNB Partnership				
	Waterboard 1	Currently, they use a Phospaq reactor and advise to do so because it is more cost efficient than other options and additionally, the reactor is particularly good at creating a more pure product with less heavy metal contamination. Since Holland has a surplus of phosphorus, there is no market for a domestic struvite demand. As such, Holland needs to open up trade alliances/ and a trade market with other nations who experience a phosphorus deficit.	Not all Bio-P plants digest their sludge so not all of these plants have a P release. Problems for innovation: infrastructure is a large commitment it must stand for around 20/30 years. International trade of struvite is not possible unless struvite is registered as a legal product in a nation's respective legislation. Without the consideration of struvite as a product, it still continues to hold a waste status.	Currently are working on evaluating the feasibility of recovery of humic acid, which has potential for improving root systems in plants. Although this is not phosphorus recovery, it is an additional raw material recovery, which thereby yields added value.
	Water board 4	Largest advantage for utilizing localized P recovery technologies is the reduction in maintenance costs caused from avoided struvite scaling in the pipes.	P recovery is not fully supported by legislation in The Netherlands.	only water board that has a dual partnership with both SNB and HVC.

	Water board 5	WWTP is currently being renovated and will install an Anphos reactor for P recovery. This will be placed in the plant after the sludge digestion and dewatering phase. Advantages of engaging in P recovery include a better effluent quality and a more improved image. Overall, they do not foresee any obstacles in the future for engaging in P recovery processes.	No response.	
	Water board 6	There are several benefits of taking part in a mono-incineration partnership with SNB including the reduction of the cost of sludge handling and additionally, there is potential for the recovery of iron and other metals. Since they primarily use chemical precipitation they do not have a struvite-scaling problem at their plants.	As they are more focused on chemical P and subsequent thermal treatment, it is more difficult to propose an inclusion of more Bio-P WWTPs.	

	Water board 7	There is potential to get more value out of their wastewater as they state the phosphate in the influent amounts to 6-10 mg P / l, in the effluent <1-2 mg / l.	The use of a localized P recovery technology at their WWTPs is not on their agenda since they already are part of the recent EcoPhos partnership.	
	Water board 8	The benefit of P recovery is that it results in a greater process optimization by increasing the dewatering efficiency by 1.5-2%. The main benefit of recovering struvite is that it subsequently lowers maintenance costs from avoided struvite scaling.	More concerned with process optimization and energy efficiency rather than phosphorus recovery. It is not so relevant for them to recover P due to the low quantity of sludge they produce. It is primarily an administrative burden	
	Water board 9	onsite recovery of struvite yields a significant decrease in maintenance costs via avoided scaling in the pipe systems.	The investment time for P recovery technologies is a long process. WS have to make an investment in infrastructure and the payback time is typically between 10-15 years. Most ROIs for P technologies are uncertain.	

HVC Partnership				
	Water board 10	Responsible for managing the largest WWTP in The Netherlands where they do struvite recovery using magnesium hydroxide dosage, but only for practical purposes not for a market value. Have plans to introduce a struvite reactor into another WWTP.	Separation of struvite on site at their WWTPs does not have a very strong business case.	
	Water board 11	Positive that the HVC and EcoPhos partnership can assist with better management practices for their sludge. The benefit of utilizing sewage sludge ash treatment for P recovery is that it destroys organic pollutants in the process.	Despite their new partnership with Ecophos, heavy metals concentrations in the ash are still a concern that they are working out with HVC. Their partnership with Ecophos is good for their sustainability reporting but it does not generate this local benefit to the Rijnland economy.	
	Water board 12	Are optimistic about the potential for phosphoric acid recovery with the new EcoPhos partnership with SNB.	Largest barriers for P recovery technologies include investment costs and ROI	

	Water board 13	No response.	No response	
	Water board 14	(see SNB section)	(see SNB section)	
Struvite recovery no partnership with SNB/ HVC				
	Water board 2	They have created their own market for selling struvite via a partnership with purchasers in England who use the product for fertilizer.	Their Ostara Pearl reactor requires a high level of monitoring and maintenance. This is due to the high potential for scaling of struvite and fluctuations that occur during the precipitation process.	In addition to P recovery, also focus on alginate recovery, which has industry applications is being applied at a WWTP via the Nereda technology.
	Water board 3	Their Airprex reactors at the WWTP help to generate around 500 tons of struvite annually. Their future goal is around 800 tons of struvite annually which can be achieved by adjusting and modifying the process to make it more efficient. The recent legislation shift in 2015 allowed for the sale of struvite to	In general, P recovery technologies have a very high investment cost and long ROI.	The installation of the Airprex reactor is one of the most impressive cases out of all water boards provided the short and quick installation of the reactor.

		commercial entities. As such, they were able to start selling their struvite to a fertilizer company. To date, 2016 the fertilizer company only uses 10-20% of the struvite for their products.		
	Water board 15	Currently engage in struvite production via source-separation of urine at their head office. The struvite is used locally for fertilizer on their dikes.	Despite acknowledging the scarcity of P in the future, at the present time the recovery of P in wastewater does not produce much value for them now. This is true for many other water boards in The Netherlands	Their future focus is much more on recovering alginate than struvite.
No struvite recovery or partnership with SNB/HVC				
	Water board 16	The partnership that will be the most important for P recovery in the future is with Ecophos and SNB/ HVC. The primary reason why plants will engage in local recovery of p onsite is due to the motivation for using these technologies as a measure for reducing	The problem with phosphorus recovery in The Netherlands is not due to economic barriers per se, but rather it is a legislative problem. Only half of the water boards have contracts for handling sludge. More innovation and commitment to	

		maintenance costs.	sustainability is needed.	
	Water board 17	The way forward for P recovery is best suited via mono incineration techniques.	P recovery methods have the disadvantage that the combustion energy from sludge is hardly used. At the present time they do not see any benefits yet to localized P recovery technologies.	
	Water board 18	Have plans for future P recovery at two WWTPs. They hope to utilize the Pearl reactor and generate the subsequent crystal green product. The benefit of utilizing local, onsite P recovery technologies is that it helps create a circular vision for their water board.	Largest barrier present is legislation, namely the end of waste status for struvite. They foresee no legislative change for this in the future. Additionally, EU fertilizer regulation does not support the recovery of phosphorus from sewage treatment.	They do not currently have a struvite-scaling problem at any of their sites.
	Water board 19	The greatest benefit of engaging in struvite recovery and additional production via the installation of a reactor	None of their plants practice struvite recovery due to the small size of the plants.	

		in the future would be the potential profit margins generated from producing fertilizer from struvite. P-recovery would result in better PR for their water board.		
	Water board 20	No response.	No response.	
	Water board 21	No response.	No response.	
	Water board 22	It is predicated that phosphate will primarily be recovered in the future via the production of sewage sludge ash and the utilization of incineration tactics. A key advantage of the P recovery is the reduction of maintenance costs caused by problematic struvite production/ clogging in the pipes. The recovery of P provides for a good mechanism promoting a better balance of P in The Netherlands.	No response.	

6. References

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