European Sustainable Phosphorus Platform

SCOPE Newsletter Special Edition:

Three biosolids conferences

Summary of the

Berlin sludge conference 2019 (Berliner Klärschlammkonferenz)

4-5 November 2019

https://www.vivis.de/2019/11/berliner-klaerschlammkonferenz/8453/

The Berliner Klärschlammkonferenz (sewage sludge conference) is an annual meeting on sewage sludge processing and use, organised by the company VIVIS. The 2nd conference, 2019, at which ESPP participated, brought together some 350 stakeholders from industry and science.

German regulation guidance document

The first half day focused on the **guidance document to the 2017 German sewage sludge ordinance (AbfKlärV).**

This makes phosphorus recovery obligatory (by 2029 / 2032) for sewage works >50,000 p.e., as follows, under §3(1):

- from sewage sludge if the phosphorus content of the sludge has phosphorus levels > 20 mgP/kgDM (that is 2% P/DM). In this case, §3(a), P-recovery must ensure that either at least 50% of phosphorus in the sewage sludge is recovered, or that phosphorus levels in the sludge are reduced below 20 mgP/kgDM

or:

- from ash from mono- or co-incineration of such sewage sludge. In this case, §3(b), at least 80% of the phosphorus must be recovered.

This is a simplified summary, for details see ESPP SCOPE Newsletter n°129

Hans Peter Ewers (Federal Ministry of Environment, Nature Conservation and Nuclear Safety BMU), outlined the ordinance and its impacts.

Hans-Walter Schneichel (State Ministry for Environment, Energy, Nutrition and Forestry of Rheinland Pfalz), talked about the current status of the guidance document (underway) to this sewage sludge ordinance. **The guidance aims to provide clarification where the ordinance is somewhat vague.**

This first session was concluded by **Fabian Kraus (Kompetenzzentrum Wasser Berlin)** who discussed the practical consequences and implementation of the sewage sludge ordinance. He criticized that there is **no focus on recycled P mass flows** but on concentrations, which may be counterproductive in some cases.

Legal aspects of sludge management were discussed, including the how to achieve **End-of-Waste status for sludge ashes** – depending on many individual parameters that cannot be clearly defined, so leading to uncertainty.

Sludge disposal in Germany

Theresa Sichler (Federal Institute for Materials Research and Testing) presented the **decline by 25% of agricultural sludge use in Germany from 2016-2017**.

Ralf Hilmer (DWA Landesverband Nord = regional group north of German Association of Water, Wastewater and Waste) reported on critical bottlenecks for disposing sewage sludge in Northern Germany leading to **sludge disposal costs sometimes as high as 120-180 €/t of dewatered sludge**. His talk was followed by a podium discussion with **Johannes Grützner (Ministry of Energy, Agriculture, Environment, Nature and Digitalization Schleswig-Holstein), Ralf Hilmer, Thomas Obermeier (TOM M+C Management & Consulting), Ragnar Warnecke (GKS Schweinfurt)** and **Helge Wendenburg (former head of department, BMU),** discussing the bottleneck and future developments. Up to 15 new sludge incineration plant projects are now in the pipeline in Germany.

Six presentations by lawyers discussed inter-municipal cooperation and permitting aspects, with **Michaela Braun of the regional government of Münster**.

In a session of associations (Verbände), **Rolf Otte-Witte (Ingenieurbüro für Abwasser- und Klärschlamm-Behandlung und -Entsorgung)** reviewed the impact of the sewage sludge ordinance on small and medium wastewater treatment plants.

Cristina Pop (Straubinger Stadtentwässerung) discussed the pathway to plan and build a mono-incineration plant in Straubing with pro-active public relations, inclusion of citizens and the Straubing model of sustainability.

Helmut Löwe (Federal Ministry of Education and Research, Bonn), presented the German funding program "Regional Phosphorus Recycling" (RePhoR), for which some 30 M€ are available to finance 6-7 regional scale P-recovery implementation projects (18 regional projects have been submitted).

Incineration processes

Different incineration concepts were discussed by: **Sonja Wiesgickl (Slude2Energy), Jan Frederick Horstmeier (Standardkessel Baumgarte GmbH)** and **Rainer Busch (RWE Supply ad Trading GmbH).**

Innovative sludge drying processes were presented by:

- **Ulrich Jacobs (EcoSystemsInternational)** presented a review of different sludge drying systems;
- **Henrik Kruchen (Haarslev Industries)** sludge hydrolysis and drying;
- **Harald Plank (Huber SE)** quasi-wastewater free sludge drying solution;
- **Tanja Schaaf (Outotec)** energy efficient Closed Loop Steam Dryer for sludge drying.

A second technical session looked at decentralized sludge incineration processes with presentations of **adaptation to sewage sludge of combustion concepts which are well known and tested in other sectors**:

- **Bernhard Grimm (Michaelis GmbH)** furnace with rotating paddles;
- **Erich Eder (Carbotechnik)** sludge incineration after fine milling sludge particles by feeding to a dust burner with after burning chamber;
- **Steffen Ritterbusch (Thermo-System)** modified multiple hearth furnace for sludge incineration.

Limiting emissions from sludge incineration

Jörn Franck (Born-Ermel GmbH) talked about nitrous oxide during sludge incineration and their abatement.

Ole Petzold (WL Gore & Associates) presented Comprehensive Emission Controls for Mono Incineration Projects in North America.

Lutz Schröder (Born-Ermel) presented water recycling in a sewage sludge incineration plant.

Phosphorus recycling

Jana Krämer (DPP - German Phosphorus Platform) gave an overview of processes and P-recycling status in Germany.

Christian Kabbe (EasyMining Germany) reviewed the question of recovery of industrial commodity chemicals or of final products.

Tobias Ginsberg (RWE Power AG) presented an early stage concept of sludge gasification to elementary phosphorus by two different gasification processes.

Dieter Leimkötter (sePura) talked about the direct use to soil of so-called premium ash (from sludge incinerators in Bavaria with very low pollutant levels). He summarized a consortium planned **AshDec plant to enhance the fertilising efficiency of these premium ashes**.

Joachim Clemens (SF Soepenberg) reviewed experiences with handling and selling recovered struvites from different German recycling sites.

Markus Heene (ICL Fertilizers, Germany) presented operating experience of adding sewage sludge incineration ash from Karlsruhe to phosphate rock in the ICL fertiliser plant in Ludwigshafen. This has generated a number of operational challenges, caused by material becoming sticky, not falling down from the conveyor belt and scaling/sticking in pipes.

Summary of the 5th European Conference on Sludge Management (ECSM)

Liège University, Belgium

https://events.uliege.be/ecsm2019/

The first ECSM took place in 2008 in Liège and this was the **fifth ECSM (European Conference on Sludge Management)**, **7-8 October 2019, Liège** with over one hundred participants from 17 countries, 30 presentations and 18 posters.

The conference opened with strategic **updates on sludge management and resource recovery** (Eureau, ESPP) and viewpoints from Italy, Czech Republic and Hungary. Sessions then addressed research into different aspects of sludge management in particular dewatering, digestion and drying. On session discussed **phosphorus in sewage sludge management**, looking at solubilisation of iron and aluminium phosphates in sewage sludge, several phosphorus recovery processes (including results from several processes at pilot or full scale), and field trials of recovered struvite.

ECSM was followed by the **ESPP workshop on phosphorus removal in sewage works**. This looked at directions for water protection policies and at operator experience and feasibility of phosphorus removal down to increasingly strict discharge limits. This industry / stakeholder workshop brought together sixty EU and national regulators with water companies and utilities from across Europe. Summary of this workshop and slides are here: http://phosphorusplatform.eu/Premovalworkshop

ECSM included the Interreg Phos4You dissemination event *https://www.nweurope.eu/projects/project-search/phos4you-phosphorus-recovery-from-waste-water-for-your-life/#tab-7*

Papers from the 4th ECSM, addressing sludge drying, are published here *https://www.tandfonline.com/toc/ldrt20/33/11?nav=tocList*

Below: ECSM mine visit

Strategic aspects of sludge management

Jean-Pierre Silan, Eureau, outlined the **water services vision**.

Eureau represents both public and private drinking water and waste water service providers. Eureau members manage nearly 19 000 waste water treatment works (wwtps) in 29 European countries.

Europe produces nearly 10 million t/y dry solids sewage sludge, **and around 50% is recycled to agriculture, as a fertiliser and soil improver,** usually after stabilisation (liming, anaerobic digestion, composting, …).

Agricultural reuse enables recycling of nutrients, return of carbon to soil and also brings benefits of alkalinity to many soils.

However, over 40% of experts consulted by Eureau (survey of waste water sector operators, year 2016) expect the amount of sewage sludge going to agriculture to decrease in the future. 65% consider that hazardous contaminants in sewage sludge could become an important pressure. 60-80% foresee an increase in phosphorus recovery due to possible evolutions of regulation on sludge management.

Water services call to have a **medium and long term strategic view** on sewage sludge management in order to develop **sustainable, practical and cost-effective solutions. RDI** should help to progress along this line and help defining the best and most effective policies and technologies, in the framework of the circular economy.

Legal context

Sewage sludge has a specific legal context, being **considered as waste only if NOT recycled to agriculture** (EU Waste Framework Directive and EU Sewage Sludge Directive). Under the 2018 revision of the Waste Framework Directive, sewage sludge is excluded from recycling targets applicable to "municipal wastes".

Art. 14 of the **EU Urban Waste Water Treatment Directive** (1991/271) specifies that "***Sludge arising from waste water treatment shall be re-used whenever appropriate***. *Disposal routes shall minimise the adverse effects on the environment.*" This Directive is currently under evaluation.

The **EU Sewage Sludge Directive** (86/278) is still in force, but is largely irrelevant as regards contaminant limits in that most Member States have more stringent requirements in place. However, this 1986 Directive is important for other aspects: it requires treatment of sludge before agriculture use (art. 6), specifies crops on which sludge may not be used (art. 7), specifies public information about where sludge is used (art. 10, updated by EU 2018/1010) and requires Member States to have a regulatory framework (art. 16).

Future directions

Eureau considers that control of pollutants at source is key to maintain and improve sewage sludge quality, and so enable reuse. On the other hand, possible increasing requirements on pharmaceuticals and microplastics will challenge agricultural recycling. A **mix of different sludge processing and valorisation routes** is therefore essential and must take into account energy and investment costs.

Needs for action include:

- Control of pollutants at **source**
- Scientific **risk assessment of contaminants** in the food chain
- New technologies for **contaminant removal**
- Improvement of **biogas** production
- Development of **nutrient recycling and materials recovery**

Water pricing and cost recovery

Questions and discussion noted the problems of the price of water and of **"cost recovery", required by art. 9 of the Water Framework Directive (2000/60).** Water pricing in Europe is generally today too low to cover supply, treatment and maintenance of infrastructure. Water must be affordable for those on lower incomes, but in fact water is a minor expenditure for most people in Europe, so that there is room to increase prices if a mechanism of minimum supply at a social price is in place. Also, 'Extended Producer Responsibility' should be explored to cover costs related to contaminants.

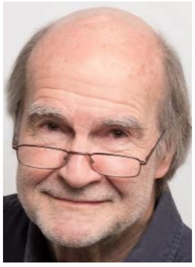
Opportunities for nutrient recycling

Antoine Hoxha, Fertilizers Europe, underlined the European fertiliser industry's engagement towards nutrient recycling. Fertilizers Europe represents companies employing 80 000 people with **120 production sites across Europe**.

The fertilisers industry aims to process recovered materials to high quality, safe, plant available fertiliser products. This requires updating of the legal framework which is engaged with the new EU Fertilising Products Regulation (2009/1009) and the proposed STRUBIAS materials.

All the major EU fertiliser companies are today working to take recovered materials into their processes, for example ICL, Yara, Borealis, Fertiberia ... The industry however faces **challenges of costs for plant modifications**.

Secondary raw materials need to be available in **high volumes, with reliable supply and consistent quality**. There is a need to address transport and logistics for secondary materials which are produced at many distributed, decentralised sites (wwtps and sludge incinerators).

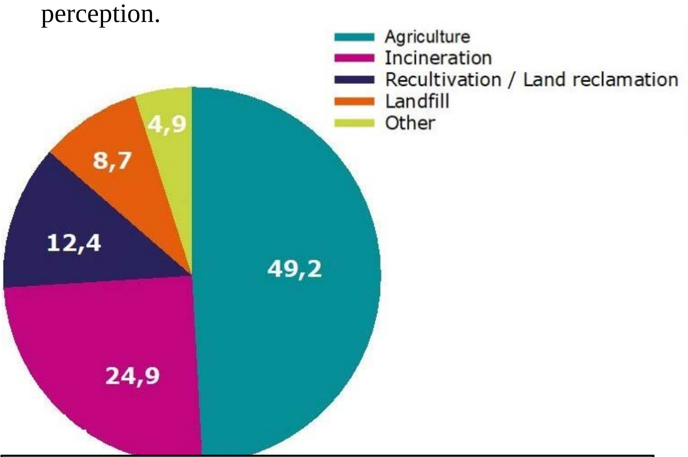


Ludwig Hermann and Chris Thornton, ESPP (European Sustainable Phosphorus Platform) outlined why phosphorus is a critical environmental challenge and relevance to United Nations Sustainable Development Goals (SDGs); European and national policies to address phosphorus sustainability; and relevance to waste water treatment and sewage sludge management.

These ESPP slides are online here:
https://www.slideshare.net/NutrientPlatform/ecsm2019-european-conference-on-sludge-management

ESPP summarised the range of different approaches to nutrient recycling which are already operating today at full-scale or industrial pilot scale:

- **Agricultural valorisation of treated sewage sludge.** Currently around half of EU sewage sludge goes to farmland, and is welcomed by farmers for economic and agronomic reasons. But this route is threatened by concerns about contaminants such as pharmaceuticals or microplastics, and consumer and food industry perception.



"Sewage sludge destination in Europe", Eureau, based on 2017 survey http://www.eureau.org/resources/past-events/water-events-docs/3430-sewage-sludge-destination-in-europe/file

- **Biochar and HTC technologies**, e.g.
  - **Hitachi-Zosen**, who operate full scale plants in Japan treating sewage sludge and are aiming to develop biochar from pig slurry in Europe www.hitachizosen.co.jp/english

- **Struvite precipitation,** producing a fertiliser product, proposed for acceptance under the EU Fertilising Products Regulation in the STRUBIAS final report (subject to quality criteria), e.g.:
  - **Ostara** www.ostara.com (Crystal Green)
  - **NuReSys** http://www.nuresys.be/
  - **Suez** www.suezwatertechnologies.com (Phosphogreen)
  - **Veolia** www.veoliawatertechnologies.com (Struvia)

- **Phosphorus recovery from ash,** producing quality phosphate products for industry markets (phosphoric acid, fertilisers, …), e.g.:
  - **EasyMining**, see SCOPE Newsletter n°132
  - **EcoPhos**, see SCOPE Newsletter n°127
  - Zurich Kanton **Phos4Life**, see SCOPE Newsletter n°119
  - Budenheim **Extraphos**, see SCOPE Newsletter n°103
  - Outotec **AshDec**, see SCOPE Newsletter n°132

Other P-recovery processes are **currently at various stages of research and development**, including WETSUS' ViviMag, see SCOPE Newsletter n°132 and Helsinki HSY's RAVITA process, both of which aim to recover phosphorus from iron phosphate in sewage sludge.

National viewpoints

Andrea Gianico, IRSA-CNR Italy, presented data showing that most EU Member States today have set significantly stricter contaminant limits for sewage sludge used in agriculture than those of the EU Sludge Directive 1986/278, updating tables from Mininni 2015 (see SCOPE Newsletter n°100 2014, published again in Hudcova 2019 with the addition of recently adopted Italy limits, e.g. for selenium and berillium). This is why the European Commission to date has indicated that there are no plans to revise the Sludge Directive (SCOPE Newsletter n°116). The presentation at ECSM suggests that **heavy metals and hydrocarbons remain a concern in sewage sludge in Italy**. Where this is the case, better efforts should be engaged to ensure source separation of industrial discharges.

Italy has also limits for certain organic contaminants in sewage sludge (PAH, PCB, PCDD/F and toluene). These four contaminants are **related to combustion or industrial emissions**, and are not found at significant levels if appropriate source control is implemented.

Veronika Kerberová, Brno University of Technology, summarised the current situation in the Czech Republic. Some 2 500 wwtps generate nearly 180 000 t/yDM sewage sludge.

Three quarters of Czech sewage sludge currently goes to agricultural valorisation. Landfilling of sewage sludge will be finally stopped in 2024. Much of the sewage sludge may not meet future Czech legislation for agricultural use (Decree 437/2016, applicable from 1/1/2020 but may be pushed back to 2023). 90 % of Czech wwtps use mesophilic anaerobic digestion of sludge whereas research of the Water Supply and Sewerage Association of the Czech Republic (SOVAK ČR), suggests that the Decree 437/2016 microbiologic criteria can be met only by thermophilic digestion. New solutions therefore need to be found.

Modelling based on laboratory tests of typical sewage sludge suggest that sewage sludge could cover 21% of current phosphorus fertiliser consumption. *ESPP comment: this appears to not take account of the fact that ¾ of sludge is already going to agriculture (and so replacing fertiliser).*

There are questions about the plant availability of phosphorus in sewage sludge, about the levels of heavy metals in Czech sludge and about the calorific value if sludge is incinerated (related to dry matter content after dewatering).

Nutrient recycling

Biomass systems for sludge treatment

Steen Nielsen, Orbicon, Denmark, summarised results of **more than thirty years of operation of full scale systems using reed beds to valorise sewage sludge**, at wwtps including Helsinge 42 000 p.e., Kolding 125 000 p.e. and Hanningfield Water 1.5 million p.e. Secondary sludge is applied to the reed beds by basin, leading to accumulation of around 1.5 m depth of (treated) soil after 10-15 years. Around 1 ha is needed per 30 000 p.e.

Results show operational reliability, flexibility, no odour, effective filtration and good quality of discharge water, and a final soil product with high dry solids content (low transport costs) which **can be valorised as a soil improver**. Monitoring shows 90% degradation of organic contaminants LAS and NPE (surfactants) after 150 days. The systems are economic after 4-5 years because of low operating costs compared to mechanical dewatering.

Ferenc Zsabokorszky, Enqual Ltd, Hungary, outlined ten years of use of municipal wastewater (after mechanical pre-treatment only) for **irrigation of tree plantations**: Zalakaros wwtp 1 000 m^3/day, 36 ha, and Nagykallo wwtp 500 m^3/day, 18 ha. Sewage nutrient recycling I willow tree plantations is estimated to generate 25 t/ha/y DM biomass. Monitoring shows no transfer of heavy metals to the cultivated plants.

See also: "Fate of pharmaceuticals in a spray-irrigation system: From wastewater to groundwater", Kibuye et al., doi: http://dx.doi.org/10.1016/j.scitotenv.2018

Struvite and residual soil P

Ciaran O'Donnell, Cork Institute of Technology, presented results of field trials of recovered struvite within the Interreg Phos4You project. Ostara Crystal Green struvite was tested on grass for silage at two sites, comparing to mineral fertiliser and to no fertiliser (control). Phosphorus was applied at 12.5 kgP/ha, identified as necessary for sustainable silage grass production, after liming to take soil to the recommended pH 6.3. Grass yield was measured in a typical three-crop silage system, with 3 cuts taken at 8 week intervals each following a fertiliser application.

Biomass production was around 5% lower (not significantly significant) lower with struvite compared to commercial fertiliser and significantly higher than control.

The most interesting result however was that the **soil residual P, after cropping, was very significantly increased by the application of struvite**: increase of +1.4 mgP/l (Morgan's extractable P) compared a non-significant change with commercial fertiliser and a small loss in the control (no fertiliser) plots.

This suggests that the struvite, which is considered to be plant available but not water soluble, increases the soil phosphorus pool without risk of run-off of dissolved phosphorus.

Struvite recovery

Bart Saerens, Aquafin, presented experience operating NuReSys struvite recovery full scale at Leuven wwtp 150 000 p.e.), Belgium from 2013 to 2018.

The struvite reactor treated all the plant's sludge after anaerobic digestion and before dewatering. Precipitated struvite was extracted using a hydrocyclone then a "sand washer".

Initial operating problems were resolved: a fibre cutter was added to prevent clogging problems and reactor tubing was changed to PVDF to avoid scaling. A remaining challenge was struvite abrasion of pumps.

The installation recovered only around 5% of total wwtp (25 t/y of struvite) influent phosphorus, because Leuven takes sludge from a number of wwtps not operating biological P-removal. **The struvite produced has End-of-Waste status in Flanders and can be sold as fertiliser**. Pot trials showed fertiliser performance similar to triple super phosphate for rye grass.

The struvite precipitation showed to significantly improve sludge dewatering (+2% DM), resulting in an overall net positive economic benefit. The struvite reactor has however now been stopped because the wwtp configuration has been modified, resulting in a SM content of >6% in the sludge before dewatering, that is too high for to operate struvite recovery.

P-release from iron and aluminium phosphates

Marie-Line Daumer, IRSTEA, Rennes, France, presented lab-scale tests of **biological phosphorus release from iron and aluminium phosphate compounds in sludge** (from wwtps operating chemical P-removal), as part of the Interreg Phos4You and the PhoSTEP (funded by French agency for biodiversity) projects. This work started with experience dissolving phosphorus in the solid fraction of pig manures (see SCOPE Newsletter n°91) and is summarised in SCOPE Newsletter n°131.

An organic substrate (currently a sugar-rich food industry waste is tested) enables existing bacteria in wwtp sewage sludge **converting up to 75% of total phosphorus to soluble phosphorus**, in sludge from wwtps operating biological and/or chemical P-removal, before anaerobic digestion. This is a higher P release than is achieved by mineral acids at pH1.

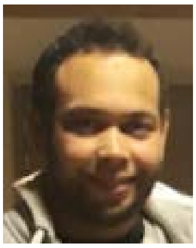
The **biological P-release mechanism** is thought to be triple:

- the organic substrate causes PAO (phosphate accumulating bacteria) to biologically release soluble phosphorus,
- bacteria generate lactic acid so decreasing pH, preventing precipitation of the released phosphorus
- the co-substrate could also induce iron reducing bacteria (DIRB) growth, so that **iron Fe^{3+} phosphate is reduced to Fe^{2+}(more soluble than Fe^{3+}).**

Methane production from the subsequent anaerobic digestion of the sludge is significantly increased, partly because of the addition of the organic substrate, but also additionally by the bio-acidification.

This bioacidification process has now been **tested at the laborabory scale with 20 different sewage sludges from 10 wwtps** using different combinations of biological P-removal, iron and aluminium dosing. Iron and aluminium concentrations in the sludges varied from 20 to 100 mg/gDM and phosphorus content from 1.3 to 4.3 $\%P_{total}$/DM.

The bioacidification released 10-75% of total phosphorus to ortho-P, with results depending on the P removal technology and where the sludge is taken out of the wwtp. **High P-release was observed even in sludges with high iron content (70-80% P-release)** and rather low release with high aluminium sludges. No clear link to pH nor to metal:P ratio could be seen.



Mohamed Amine Saoudi, IRSTEA, Rennes, France, presented further information on this **biological P-release** work and analysis of forms of iron phosphate in sewage sludges. He explained that dosing of iron salts in wwtps enables phosphorus removal by mainly two mechanisms: **adsorption onto iron oxides, chemical reaction to form iron phosphates** (either Fe^{2+} or Fe^{3+}). In both cases, P-removal is then achieved by separating these insoluble iron salts from the wwtp effluent by e.g. sedimentation, filtration …

A literature analysis suggests that neither there is no general rule linking the form of iron salt dosed (ferric iron II Fe^{3+} or ferrous iron III Fe^{2}) nor where the iron is dosed to wwtp discharge levels.

Five stage extraction, enabling to distinguish between iron II and iron III, showed that the **bioacidification modifies the form of iron, and that mainly iron II and iron hydroxide forms are solubilised** (not iron III).

Zaheer Ahmed Shariff, Université of Liège, presented the "**PULSE**" concept for a P-recovery process, aiming to use **very strong mineral acid** to extract phosphorus and iron from dewatered undigested sewage sludge from sewage works using chemical P-removal (within the Interreg Phos4You project). Some **initial beaker-scale test results** were shown.

The idea is to **first dry the sewage sludge to 95% DM, then to attack it with mineral acid (hydrochloric or sulphuric) at pH 0 or even -1.** The drying is necessary to limit the quantities of acid needed and to improve filterability. The phosphorus-containing liquor is then treated by organic solvent extraction and alkali dosing to precipitate calcium phosphate salts and to separate heavy metals. The remaining sludge solids are then washed, to remove acid, leaving a solid waste, which could possibly be used as a soil improver.

Results so far show metal levels in the recovered phosphates lower than EU Fertilising Products Regulation limits, except for chromium (atypically high chromium levels in the sludge used).

Discussions questioned the **likely costs and LCA** of this PULSE process (energy for drying, acid consumption, alkali consumption, solvent extraction)

Phosphorus recovery from ash

Two **industrial pilot / full scale phosphorus recovery processes** were presented: EuPhoRe, Remondis Tetraphos, Others are operational today at this scale and are presented elsewhere (see Hermann & Thornton presentation above).

Daniel Klein, Emschergenossenschaft, Germany, presented the water board's pilot trials of the **EuPhoRe** process, underway at Dinslaken within the Interreg Phos4You project (see SCOPE Newsletter n°129). The 100 kg dewatered sludge per hour pilot was first operated for two days continuously in September 2019. The EuPhoRe thermal process, operating at 1000°C aims to generate an ash in which the phosphorus is plant available and with acceptably lowered heavy metal levels (magnesium chloride is dosed to volatilise heavy metals to the flue gases).

Results to date indicate that the EuPhoRe ash has fertiliser effectiveness close or apparently lower than commercial mineral phosphate fertilisers, and that heavy metal levels meet German (see SCOPE Newsletter n°129). Work underway aims to improve these results, and also to assess the possible corrosion resulting from the use of magnesium chloride.

A **partnership is in place with a local blender / fertiliser distributor** who will take 15-20 t batches of EuPhoRe ash and mix with other fertiliser products.

Dennis Blöhse, Emscher-genossenschaft, presented phosphorus recovery from sewage sludge incineration ash by the **Remondis Tetraphos** process (see SCOPE Newsletter n°129). The Tetraphos (pre) industrial demonstrator (50 kg /h ash), in Elverlingsen operated for several months, showing that **80% or higher of the phosphorus can be recovered as phosphoric acid** (75% H_3PO_4). The ashes came from Incinerators in Bottrop (Emschergenossenschaft) and Lünen (Innovatherm).

In comparison with German average of municipal sewage sludge incineration ashes, the P contents of the tested ashes are low (3-6%). However, even this low level is compatible with the REMONDIS P-recovery process.

Summary of the
24th European Biosolids Conference
Manchester, 19-20 November 2019

www.european-biosolids.com

This Aqua Enviro professional biosolids conference is **Europe's principal meeting place for the water industry and biosolids management companies**, with some 250 participants from water companies, sewage works operators, technology and know-how providers and regulators.

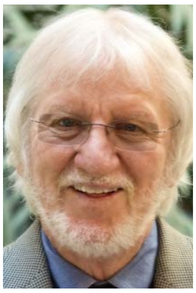
Themes addressed included developments in anaerobic digestion and biogas markets, dewatering, agricultural valorisation of sewage sludge and resource recovery.

The conference highlighted the **increasing complexity of sewage sludge / bioresource management** across Europe.

Maximising energy value means exporting only during peak value periods, putting pressure on gas and electricity infrastructure. At the same time, in-line sensing and real time control allow smaller numbers of professionals to manage a greater number of processes. With P recovery or removal targets requiring installation of additional processes, there are open questions around system resilience and the ability to maintain staff engagement.

Reliance on landbank (agricultural valorisation of sewage sludge) in the UK continues to present a risk, but there is as yet no open discussion of alternatives – or the implications of changing agronomic practises that improve nutrient use efficiency.

Challenges to agricultural valorisation biosolids



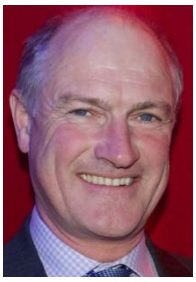
Ian Pepper, University of Arizona, presented developments in the USA. The recent Office of Inspector General (OIG) report on EPA biosolids policy (see ESPP eNews n°32), which was in reality an assessment of EPA procedures, is interpreted as suggesting that dangerous chemicals in biosolids are being ignored by EPA.

Concerns are raised by stakeholders about a range of contaminants in biosolids, including pathogens, pharmaceuticals, generation of antibiotic resistance in soils or consumer chemicals – in particular PFOS/PFOA.

Biosolids application has been shown to increase ABR (**antibiotic resistance**: presence of microbes with ABR traits) by only 0.1%, and these traits naturally disappear after a few weeks. There is no evidence that such environmental ABR poses any risk to health or ecology.

A key problem for biosolids use today is **perfluorinated chemicals**. PFOA is classified as a possible carcinogen. A number of US States have fixed limits for these chemicals in groundwater, which pose obstacles to biosolids use. Both PFOA and PFOS are being phased out, but industry is moving to other isomers.

UK dependency on the "landbank"



Alexander Maddan, Agrivert (biosolids processing and valorisation), opened the conference, summarising developments in biosolids management from a UK perspective. He identified nutrients (P and N), energy efficiency and contaminants as key challenges.

The UK continues to be completely dependent on agricultural valorisation of biosolids. Today, raw sewage sludge is no longer spread, but mainly processed biosolids, generally after anaerobic digestion. This results in a stable, odour-free product, which can be handled and transported. State of the art processing can reduce volumes by up to 70%. All UK water companies are certified under the BAS (Biosolids Assurance Scheme) criteria.

However, a number of questions are raised about the **future of the "landbank",** that is the agricultural valorisation of sewage biosolids, in the UK. Climate change can limit use (field flooding or changes in crops, for example to pulses which do not require nitrogen inputs). Questions are raised about traffic on fields (biosolids spreaders are heavier than fertiliser spreaders).

Concerning contaminants, Mr Maddan notes that this a not a new problem. An archived sample of water **from 60 years ago showed the same levels of microplastics as today.**

David Tompkins, Aqua Enviro, discussed the UK water industry's **BAS (Biosolids Assurance Scheme).** This is recognised as an important quality tool for biosolids, but questions are raised about its credibility. All UK water companies and all biosolids processing sites today pass the certification. There is a lack of transparency in oversight of the scheme. Also, the emphasis on Critical Control Points (under HACCP) may mean that end product quality is not as consistent as expected.

Ruben Sakrabani, Cranfield University UK, presented development of a UK "**Phosphate Acceptance Map**", mapping potential for biosolids application to land. It is intended to be used as a tool to assess potential landbank available for biosolids application taking into consideration current soil P levels, crop type, biodiversity, land use, climate and stakeholder input.

See further information in: "Phosphate acceptance map: A novel approach to match phosphorus content of biosolids with land and crop requirements", R. Wadsworth et al., Agricultural Systems, 166 (October) 57-69, 2018 https://doi.org/10.1016/j.agsy.2018.07.015

Opening UK biosolids to competition

Richard Brindle, United Utilities UK, explained how the UK regulator **OFWAT plans to "open to competition" sewage sludge processing**. Water companies will be obliged to define in their five your plans (AMP) the quantities of sludge they will produce. OFWAT will then fix a processing-disposal price for each company. Private operators can than offer services to take on the sludge management. This is obliging water companies to develop much better data on sludge production by April 2020.

ESPP notes that this risks inhibiting innovation and progress on sewage treatment: optimisation of chemical dosing or mixing of sidestreams to improve methane production could be prevented if they modify "contracted" sludge quantities.

UK water companies face a number of other major challenges in sludge management, at the same time as **strictly tightening financial constraints** from OFWAT.

- The Environment Agency is currently redefining its **sludge strategy**, in particular as regards agricultural application, with conclusions expected in coming months.
- All **anaerobic digesters are now brought under the Industrial Emissions Directive (IED).** This implies significant investment costs, in particular construction of containments.
- **Renewable energy or greenhouse gas emission credits** are key factors in economics of sludge treatment, including methane production and heat valorisation (CPE, sewage heat recovery).

Water policy should push to resource recovery (Circular Economy) as well as to phosphorus removal.

National organic waste policy developments

Scotland

Mark Aitken, Scotland EPA (SEPA), outlined challenges to biosolids land application in Scotland. Scotland generates nearly 110 000 tDS/y of biosolids, of which currently around 40% goes to agriculture and 20% to land restoration.

A public petition to Government in 2015-2016 with 1300 signatures called to ban land application.

The Scottish Government's response "Review of the Storage and Spreading of Sewage Sludge on Land in Scotland" recommended that the requirements of the Safe Sludge Matrix, and the need for an operator's licence including a "fit and proper person" test should be incorporated into Scottish law, and there should be tighter monitoring of operator practice by SEPA. Other recommendations included that one integrated regulatory system should be introduced, covering all organic materials used on land (biosolids, composts, digestates, farm manures, whisky by-products etc).

For SEPA, well managed and regulated use of biosolids in agriculture can be the Best Practicable Environmental Option (BPEO) in many circumstances, and can contribute towards a more circular economy.

Quebec

Céline Vaneeckhaute, University of Laval, Canada, summarised policy and resulting developments. The new Pan-Canadian phosphorus discharge regulations are now tightened, with the strictest **discharge limits down to 0.1 mg P_{total}/l** applicable to many plants discharging into lakes (which is often the case in Canada).

Quebec has **banned incineration and landfilling of organic materials, including food waste and sewage sludge, by 2022**. Consequently, **multiple anaerobic digestion plants are under construction in the Quebec province**, and will take both food waste and sewage sludge. The resulting biosolids will be valorised in agriculture.

Université Laval applies a novel Quality by Design strategy and has developed a modelling tool **optim-O: www.optim-o.com** to enable operators to define investments and operating parameters to optimise methane production, nutrient recovery and biosolids product quality. For example, chloride can inhibit ammonia recovery, so struvite precipitation may preferably use magnesium oxide. The model also addresses challenges for biological nutrient removal (BNR) such as avoiding struvite deposits and optimising struvite recovery by mixing sidestreams or sludge hydrolysis.

Germany

Christian Kabbe, EasyMining Germany, outlined policy developments in Germany which are acutely **limiting nutrient loads allowed to arable land** (fertilising regulations DüV 2017, implementing the EU Nitrates Directive and limiting N and P applications) and which will **require phosphorus recovery for recycling** from all sewage works > 50 000 p.e. by 2032 or earlier (AbfKlärV 2017). For further details see SCOPE Newsletter n°129).

At the same time, food industry marketing initiatives are pushing against sludge use to land, for example products sold as "***without use of sewage sludge or manure***" (milk and potato products below)

In particular, the requirements of the AbfKlärV will most likely lead to **construction of around twenty new sewage sludge incinerators in Germany in coming years** (more than 30 projects are today announced, but not all will be realised). This will double Germany's current sewage sludge mono-incineration capacity from 0.67 to around 1.4 million tons dry solids / year, also compensating the declining fractions incinerated in coal power plants and agriculture. Today, there is a resulting bottleneck of incineration technology suppliers and installation contractors.

Today Germany incinerates around 38% of sewage sludge in sludge incinerators, with around 74% total incineration (including co-incineration with other waste or in cement factories), around 16% goes to agriculture, and 10% to landscaping or 'other'.

Ireland

Fionnuala Murphy, University College Dublin (UCD), outlined Ireland's national strategy for organic waste valorisation (**ABC Agri Bio Circular Economy**).

Around one third of Ireland's greenhouse gas emissions are from agriculture and food, and around one third of this is from manure management. This is expected to increase, with increasing dairy production for export.

Ireland today has very few anaerobic digesters (only around ten non industry/landfill biogas plants).

Case studies in the counties of Monaghan (large poultry production) and Tipperary (dairy dominated) are looking at development of anaerobic digestion, assessing GHG savings from avoided current fugitive emissions, replacement of mineral fertilisers. Objectives are not only biogas production, but also production of fibres, nitrogen recovery as ammonium sulphate and valorisation of concentrated digestate as fertiliser.

A key aspect is **dialogue with current users**. For example, approximately half of Monaghan poultry litter currently goes to mushroom production, so replacements need to be identified and assessed. Challenges include difficulty of **access to reliable data** and **identification and stakeholder acceptance of potential AD plant operators**.

Colombia

Juan-David Salazar Espita, SENAColombia and National University of Colombia summarised a literature assessment of biosolids regulations worldwide. This suggests that **over three quarters of biosolids worldwide are appropriately managed**, but also less than ten percent of the population has safe sanitation in low income countries.

He presented tests underway in Manizales, Colombia, **to use dried biosolids in brick production**. The biosolidsare dried at 105°C for 24h, then combined at 5 – 20%, mixed with clay and fireclay (ground recycled bricks).

Industry and public biosolids strategies

Biosolids and greenhouse emissions

Amanda Lake and **Sam Hughes, Jacobs**, outlined the real opportunities and challenges of reducing greenhouse gas emissions (GHG) related to sewage treatment, in today's climate emergency.

There is around ten times more **potential energy in sewage** (organic carbon, heat) than current electricity consumption in sewage treatment. This potential energy is enough to reduce total annual UK GHG emissions by some 0.75%. In addition, there are nutrients and other potentially recoverable products.

Taking meaningful climate action today is possible based on existing technologies and approaches - : green electricity purchase, combining flood mitigation with tree planting, heat recovery from sewage, addressing fugitive methane emissions, co-digestion of sludge with other wastes to optimise biogas production and nutrient valorisation (e.g. via agricultural sludge valorisation, or perhaps, in future, through protein production). To achieve these potentials, **market and planning tools must be mobilised**: pricing of discharges to sewers according to their real impact on treatment and on sludge valorisation, integrating water management, heat recovery and sewage biosolids management into city and regional planning.

Richard Brindle, United Utilities UK, reminded that **the UK water industry has committee to be carbon "net zero" by 2030**. To date, a key action has been moving to the purchase of green electricity. Purchase of emissions compensation (tree planting) will also be necessary.

United Utilities has developed an evaluation matrix covering all levels from strategy to action, to move this forward.

Biosolids management accounts for nearly half of all United Utilities greenhouse gas footprint. This entire footprint has only 31% from carbon dioxide with the remaining coming from **methane (40%) and nitrous oxide (29%)**.

Consolidating sludge treatment

Liz Cherry, Severn Trent Water UK, outlined key directions of the company's biosolids strategy for the future.

Monitoring of sludge quantities and qualities show that although total sludge treatment capacity appears adequate, in reality there are **bottlenecks because sludge production varies with weather** (higher sludge production after rain events which flush organics in sewers). Secondary Activated Sludge (SAS) from upgraded sewage works pose treatment difficulties in digesters.

The future tendency will be to **consolidate sludge treatment at high-performance sites** with high methane production (Advanced AD), generating high sludge quality. This may be accentuated by the application of the Industrial Emissions Directive to digesters, leading to capex costs, and by the opening to market competition of sludge treatment. At the same time, for logistics reasons, Severn Trent is actively looking for reliable advanced AD technologies for small sewage works.

Future challenges include contaminants, in particular **microplastics, which threaten the future of the landbank** (agricultural sludge valorisation).

Dave Auty, Projen Ltd., summarised the biosolids strategy assessment carried out for **Northern Ireland Water (NIW)**, including detailed cost assessment of different possible biosolids management options.

Northern Ireland currently has zero installed anaerobic digestion, but over forty sludge treatment sites, including many very small (several around 10 tDS/day). NIW's study mandate was to consider only proven technologies, with a base hypothesis being transport of all sludge to Belfast for centralised incineration.

The assessment conclusions however suggest that the optimal cost and environmental solution would be grouping of sludge to a number of **advanced anaerobic digestion sites**, then **agricultural valorisation of biosolids** except for incineration in the Belfast urban region.

One challenge identified is agricultural valorisation to grassland (most of Northern Ireland's agriculture is dairy pasture), for which liquid digestate is adapted but not dried pellets. Another challenge is the political decision to not co-digestate agricultural by-products or food wastes with sewage sludge.

The choice between incineration or agricultural valorisation is now pending political decision.

Innovative sludge processing

THP (thermal hydrolysis), Anammox and P-recovery

Kine Svensson, Cambi, outlined the advantages of **sludge thermal hydrolysis (THP)** for biosolids quality and for methane production, in different configurations.

The Cambi THP process (165°C) can be applied both upstream or downstream of anaerobic digestion (AD), according to what is most important for sludge processing: **smaller digesters or dryness in cake**. In both cases, **methane production can be increased and sludge cake sterilisation can be ensured**. Post-AD THP increases sludge cake dry matter by a factor of around 1,8x, Pre-AD THP can increase sludge cake dry matter by 7% points compared to conventional digestion.

Pascal Ochs, Thames Water UK and **Cranfield University,** explained that **anaerobic digester return liquors can contribute up to one third of wwtp inflow ammonia**. Adding THP to improve digester loading, and so methane production, can result a doubling of ammonia load and COD levels in digester return liquors. Thames Water has assessed five different technologies for ammonia removal from digester liquors, using biological nitrogen removal via partial nitritation and anaerobic ammonia oxidation (Anammox).

Lee Inkpin, contractor, summarised experience of sludge processing at **Basingstoke wwtp** (53 tDS/day sludge, of which around one quarter from onsite and three quarters intake from other sites). A combination of **Cambi THP** and **DEMON*** is installed, because SWECO offers a process guarantee of 95% ammonia removal and 88% total nitrogen removal (with caustic soda dosing but no organic carbon input). Challenges at start-up included heating outages (due to stoppages elsewhere onsite), foaming, dissolved oxygen content, cyclone and NOB population control. These have been successfully addressed, and the process shows to be reliable. The dosing caustic soda seems probably not necessary, in that it delivers only a limited increase in ammonia removal, with over 90% NH_4-N removal achieved without this.

** Demon = DEamMONnification: a continuous biological deammonification process*

Willie Driessen, Paques and **Charlotte Wendt, Severn Trent Water UK**, summarised innovative process design integration to achieve treatment performance and circular economy objectives.

At **Tilburg WRRF, The Netherlands**, centralised sludge treatment site, treating 25 000 tDS/yr sludge, **Anammox nitrogen removal, Phospaq struvite recovery and Cambi sludge hydrolysis are combined**. The sludge processing chain starts with THP, then anaerobic digestion, then dewatering and **struvite precipitation**, and finally Anammox (granular sludge process at 27-35°C, to reduce nitrogen return to the sewage works). A challenge is limitation of Anammox by alkalinity, nonetheless over 2.5 kgNH_4/m^3 ammonia removal is achieved.

At **Minworth WWTP, UK** (1.7Mln p.e) sidestream **THP then Anammox** are installed downstream of sludge anaerobic digestion and Klampress dewatering (89 000 tDS/yr sludge). Over 80% ammonia removal is achieved, and this has resulted in a 25% reduction in WWTP blower electricity consumption (reduced ammonia return load).

Severn Trent are now also installing **THP and Anammox** for sludge treatment at the **Stoke Bardolph WWTP** (0.7Mln p.e,) where Phospaq struvite recovery is already installed

System optimisation

Edwin Jonker, Kemira, showed the potential benefits for sludge management of **KemConnect** automation of sewage works parameters, today installed for over 400 wwtps. KemConnect includes monitoring of works operating parameters (sewage works, sludge processing and dewatering) and automatic adjustment (using **specific "fuzzy logic" algorithms**) of coagulant and polymer dosing parameters.

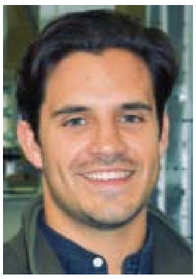
New developments include **continuous and automatic sensor cleaning** (CIP = cleaning in place) for total solids (TS) measurement in the centrate from the centrifuge, resulting in a stable measurement for over one year (to date) without having to retract and manually clean the sensor from the system

The **case study of a wwtp Denmark** (1.2 million p.e., 3000 tDS/year of sludge) was presented. After one year's operation, KemConnect has enabled an increase of dry solids content in sludge after centrifuge dewatering **from 21% to 25% DS**, then increased to 35% in a drier, before incineration. Overall sludge disposal costs have been reduced by 17% and additional advantages shown include faster sludge dewatering, lower phosphorus in filtrate (returned to wwtp) and lower coagulant consumption. See: https://www.kemira.com/kemconnect/

Maria Dittmann and **Neil Willoughby, Eliquo**, presented the combination of **LysoTherm THP, EloVac vacuum degassing of digestate with simultaneous struvite precipitation at Lingen wwtp,** Germany (EBPR, 195 000 p.e., 10 m^3/h digested sludge).

Vacuum degassing of digestate increases pH, whilst **reducing vestige methane losses**. Ammonia could potentially also be captured and stripped. If combined with magnesium dosing (EloVac-P), then **struvite is precipitated as small crystals into the digestate**. This improves sludge digestate dewatering (> +5% increase in sludge DS at Lingen), reduces phosphorus return to the wwtp (in the dewatering liquor), reduces dewatering polymer consumption and avoids nuisance struvite deposits in the plant. The struvite microcrystals remain in the sludge, as plant available phosphate if the biosolids are valorised to agriculture.

Ammonia and CO_2 recovery



Alex Hammond, CCm, presented the company's innovative process for resource recovery, including **carbon dioxide and ammonia capture from waste streams, by combination with organics, producing biogenic fertiliser pellets**.

An **industrial pilot** (*below*) has now been operating for 6 months at the Viridor (Walpole, Somerset, UK) food waste processing plant. The installation uses CO_2 and ammonia stripped from the digester, combined with recovered waste cellulose fibres to produce organo-mineral carbonate fertiliser. Waste heat from the CHP flue gas is used to dry and in pelletisation of the fertiliser product. Heat storage equipment is in operation to 'top-up' heat in food waste pasteurising lines.

A **second fully automated pilot, capacity 10 000 t/y product**, has now been tested in Swindon, UK (*photo above*), with several day runs using different digestates from food wastes, agri-food materials and sewage sludge. The automated operating system ensures **full traceability** of inputs through to end-product, necessary for End-of-Waste certification.

Field tests of the fertiliser product show compatibility of the pellets with existing farm fertiliser spreaders (up to 30m wide spreading radius), crop performance comparable to commercial mineral fertilisers and positive impacts on soil bioflora, water retention, soil carbon and reduced nutrient runoff.

See Lake, JA. et al. (2019) Sustainable soil improvement and water use in agriculture: CCU enabling technologies afford and innovative approach. Journal of CO2 Utilisation. https://doi.org/10.1016/j.jcou.2019.03.010

CCm estimates that this process generates around 0.3 tCO_2/tN compared to 3 – 8 tonnes for mineral fertiliser production.

See also: Viridor News Release 27 July 2017 "Innovative project harvests carbon dioxide from food waste to plough back into land" https://blog.viridor.co.uk/2017/07/21/innovative-project-harvest-carbon-dioxide-from-food-waste-to-plough-back-into-land/

Research

Ruggero Maria Cavallino, Rigenera Srl, Italy, presented testing of a mobile pilot/plant (sewage sludge 20% DS input 10-12 Tons/hour) where sewage sludge is treated with lime, sulphuric acid, and natural or synthetic **zeolites (i.e., clinoptilolite).** This results in a biosolids product with 65-70% DS, containing the phosphorus from the sewage sludge, in which **ammonia nitrogen from the sewage digestate is fixed into the zeolite**. The heavy metals are also still present, chelated in the zeolites and therefore completely immobilized.

Marc Heitmann, Imperial College, London, presented lab-scale testing of flash sewage sludge pyrolysis (>600°C, 10 kg/hour). **Treatment of the char with dilute mineral acids increased char surface area and removed >90% of its phosphorus content**. Neutralisation of the leach solution, enabled recovery of soluble P compounds as iron/aluminium/calcium phosphates, however sulphuric acid leached chars were limited to 72% recovery due to lower cation availability. Compared to ash, char leached less heavy metals, more P and more iron cations. Sulphuric leached char contains stable carbon and calcium sulphate and could be used as a soil amendment for clay soils. However this requires further research, and is subject questions concerning the residual heavy metals.