ECSM 5th

5TH EUROPEAN CONFERENCE ON SLUDGE MANAGEMENT

6-7-8 October 2019
University of Liège, Belgium

BOOK OF ABSTRACTS

LIÈGE université

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PEPs CHEMICAL ENGINEERING

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BOOK OF ABSTRACTS

Sludge management … at the heart of wastewater treatment

Eleven years after its creation and first edition, the European Conference on Sludge Management, ECSM'2019, is back in Liège, Belgium, for its 5th edition.

From 6 to 8 of October 2019, it is organized by University of Liège, with the support of the Phos4You project (Interreg North West Europe), several sponsors and partners.

The previous dedicated meetings were:

- ECSM'2008, Liège, Belgium, organized by Prof. Michel Crine, Dr Jean-Christophe Baudez and Dr Angélique Léonard
- ECSM'2010, Budapest, Hungary, organized by Prof. Endre Juhasz and Agnes Czibok
- ECMS'2012, Leon, Spain, organized by Prof. Antonio Moran
- ECSM'2014, Izmir, Turkey, organized by Prof. Azize Ayol and Prof. Angélique Léonard

The main scope of the Conference is to provide a scientific program of cutting-edge research in wastewater sludge management. It will bring together international experts of sludge management, scientists, researchers and engineers, R&D laboratories, water agencies, governmental delegates, and private companies to discuss the problems, solutions, and innovative technologies and systems for the sludge management of water and wastewater treatment field.

By keeping a unique session of presentation, the organizers want to promote fruitful exchanges and to disseminate state of the art in the field of sludge management. We hope that the splendid Academic room will contribute to make the conference beneficial, and professionally inspiring.

Prof. Angélique Léonard

CONFERENCE CHAIR

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PROGRAM

Sunday, October 6, 2019

19h00 **Welcome reception at "Hotel provincial" – Place Notger 2 – 4000 Liège**

Monday, October 7, 2019

8h00 – 9h00 **Participant registration**
Academic Room of University of Liège, Place du 20 Août 7, 4000 Liège

9h00 – 9h15 **Conference opening by Angélique Léonard**
Welcoming address by Pierre Wolper, Rector of ULiège

9h15 – 10h00 **Plenary lecture 1 – Chair: Ludovico Spinosa**
« A holistic approach to face challenges of wastewater operators for sewage sludge management in Europe » by Jean-Pierre Silan, EurEau

10h00 – 10h45 **Plenary lecture 2- Chair : Andrea Gianico**
« Developments in regulatory and downstream user perspectives in sewage sludge management in Europe: drivers, challenges, opportunities» by Chris Thornton, European Sustainable Phosphorus Platform

10h45 – 11h10 **Coffee break and poster session**

11h10 – 12h30 **Session 1: Strategic aspects of sludge management – Chair : F. Dilek Sanin**

- 11h10 – 11h30: Re-conceptualizing Sludge Management: Regulatory and Socio-economic aspects, Ludovico Spinosa, Puja Doshi
- 11h30 – 11h50: Use of biosolids in Europe: possibilities and constraints, Andrea Gianico, Giuseppe Mininni, Camilla Maria Braguglia, Giulia Sagnotti, Marco Porrega
- 11h50 – 12h10: Handling sewage sludge – technological opportunities and limitations, Veronika Kerberová
- 12h10 – 12h30: Sewage sludge as a source of energy, Ferenc Zsabokorszky, Ferenc Ligetvári

12h30 – 14h00 **Lunch and poster session**

14h00 – 15h00 **Session 2: Thermal treatment and characterization – Chair: Antonio Moran**

14h00 – 14h20: Influence of back mixing on the pilot-scale convective drying of sewage sludge: evolution of the volume and exchange surface, Jie Li, Cheng-Wei Wu, Laurent Fraikin, Thierry Salmon, Dominique Toye, Angélique Léonard

14h20 – 14h40: Energy efficiency in sludge drying, Jasper Aalders, Peter Quaak, Jeffrey IJdo, Angélique Léonard, Laurent Fraikin, Thierry Salmon, Menno Maingay

14h40 – 15h00: Towards 3D rheology for sludge? Mohamed Mouzaoui, Martial Sauceau, Jean-Christophe Baudez, Patricia Arlabosse

15h00 – 16h20 **Session 3: Sludge valorization – Chair: Pascal Ginisty**

15h00 – 15h20: Enzyme production by bacillus licheniformis from thermally hydrolysed sludge, Manuel García, Sergio Collado, Paula Oulego, Mario Díaz

15h20 – 15h40: Ultrafiltration for recovery of valuable components from hydrolysed sludge, Sergio Collado, Daniel Núñez, Paula Oulego, Mario Díaz

15h40 – 16h00: Secondary sludge treatment by microbial electrolysis cell: simultaneous nitrogen and carbon removal, M. Isabel San-Martín, Guillermo Pelaz, A. Sofia Portillo, Adrián Escapa, Antonio Morán

16h00 – 16h20: Disposal of sludge in agriculture: the effect of the electro-dewatering process on biological stability and pathogenic contamination, Simone Visigalli, Jannatul Rumky, Andrea Turolla, Roberto Canziani

16h20 – 16h45 **Coffee break – Free time until bus departure**

18h00 **Bus departure from conference site to Blegny-Mine, one of the 4 majors mining sites of Wallonia recognized Unesco World Heritage**

18h30 **Visit of Blegny-Mine followed by conference banquet at 20h00.**

Tuesday, October 8, 2019

8h30 – 9h15 **Plenary lecture 3 – Chair: Angélique Léonard**
«Micropollutants in Sludge: Challenges and the Need for New Approaches in Sludge Management» by Prof. Dilek Sanin

9h15 – 10h35 **Session 4: Sludge digestion – Chair: Pavel Jenicek**

9h15 – 9h35: Improving the Flexibilization of Digester Gas Production Through Predictive Choice of Co-Substrates, Christian Hubert, Bettina Steiniger, Christian Schaum

9h35 – 9h55: Enhanced anaerobic digestion of sewage sludge by hydrogen addition: Influence on microbial population, Elia Judith Martínez, Ana Sotres, Georgios Papacharalampos, Cristian Bernabe Arenas, Antonio Morán, Xiomar Gómez

9h55 – 10h15: Investigation of energy production potential and toxic effects of industrial sludges during anaerobic digestion, Hazal Aksu Bahçeci, Latif Selim Sanin, F. Dilek Sanin

10h15 – 10h35: Comparison of Methane Yields from Batch Tests and Continuous Digesters, Bettina Steiniger, Christian Hubert, Christian Schaum

10h35 – 11h00 **Coffee break**

11h00 – 12h40 **Session 5 : Sludge dewatering – Chair: Marie-Line Daumer**

11h00 – 11h20: Economic and environmental overview of sludge treatment in reed systems - 30 years of experience, Steen Nielsen

11h20 – 11h40: Sludge conditioning, thickening and dewatering optimization in a screw centrifuge decanter: which means for which result ? Pascal Ginisty, Romain Mailler, Vincent Rocher

11h40 – 12h00: Sludge dewatering with automatically optimised conditioning –initial technical experience with the new flocculation principle, Michael Sievers, Michael Niedermeiser, Jochen Gaßmann, Tim Hartmann, Sven Dilba

12h00 – 12h20: Polyelectrolyte consumption optimisation of dewatering centrifuges at the North-Budapest Wastewater Treatment Plant, Katalin Kiss, Zsófia Kassai

12h20 – 12h40: Impact of the anaerobic digestion process configuration on the sludge dewaterability, Pavel Jenicek, M Capuano, Ch. Marchi, Marie Vojtiskova

12h40 – 13h45 **Lunch**

13h45 – 14h30 **Plenary lecture 4 – Chair: Laurent Fraikin**
« The new EU fertilizing products regulation and its practical implications» by Dr Antoine Hoxha, Fertilizers Europe

14h30 – 15h30 **Session 6: Phosphorus recovery – Labscale – Chair: Joe Harrington**

14h30 – 14h50: Understanding Phosphorus dissolution in sewage sludge by bioacidification, Mohamed Amine Saoudi, Karel As, Marie-Line Daumer

14h50 – 15h10: Potential for increasing phosphorus recovery from sewage sludge by bio-Acidification, Marie-Line Daumer, Younes Bareha, Mohamed Saoudi

15h10 – 15h30: Phosphorus recovery from dried sludge with reactive extraction to remove impurities, Zaheer Ahmed Shariff, Laurent Fraikin, Angélique Léonard, Andreas Pfennig

15h30 – 16h00 **Coffee break**

16h00 – 17h20 **Session 7: Phosphorus recovery – Pilot scale - Chair: Andreas Pfennig**

16h00 – 16h20: First results of the EUPHORE pilot plant, Daniel Klein, Karl-Georg Schmelz, Levent Pamuk, Marie-Edith Ploteau, Frank Zepke, Siegfried Klose

16h20 – 16h40: Results of Pilot Scale Tests for P-Recovery from Emschergenossenschaft-Lippeverband Sewage Sludge Ashes with REMONDIS TetraPhos® Process, Dennis Blöhse, Patrick Herr

16h40 – 17h00: P-recovery as struvite from digested sludge – experience from the full scale, Bart Saerens, Sam Geerts, Marjoleine Weemaes

17h00 – 17h20: Recovered Phosphorous fertiliser and effects on residual soil P indices in relation to commercial P fertiliser, Ciaran O'Donnell, Niamh Power, D. Barnett, Joe Harrington

17h20 – 18h00 **Conference conclusions and closing cocktail**

Posters

1. Anaerobic sludge as inoculum for innovative biolectrochemical systems, Raúl Mateos, Raúl M. Alonso, Daniela Carrillo, Ana Sotres, Adrián Escapa, Antonio Moran

2. Assessment of electrooxidation as pretreatment to enhance anaerobic digestion of waste activated sludge, Elia Judith Martínez, Cristian Barnabe Arenas, Georgios Papacharalampos, I. San Martín and Xiomar Gómez

3. Circular economy with sludge - a novel solution, Verma Prem, Hilmar Sune

4. Emerging pollutants in walloon sewage sludge: towards an integrated methodology to evaluate health and environmental impacts of farmland spreading, Cécile Kech, Stéphanie Bémelmans, Eric Moïs, Caroline Nadin, Christophe Frippiat

5. Implementation of the Struvia phosphorous recovery pilot plant at an Irish waste water treatment plant, Ciaran O'Donnell, Niamh Power, Denise Barnett, Joe Harrington

6. LC/MS and GC/MS determination of emerging pollutants in walloon sewage sludge, Stéphanie Bémelmans, Cécile Kech, Eric Moïs, Caroline Nadin, Christophe Frippiat

7. Microplastic in sewage sludge - an extraction method as a pre-treatment step for the analysis of microplastic, Annett Mundani, Steffen Krause, Christian Schaum

8. Optimization and economic assessment of an environment-friendly in situ enzymatic biodiesel production method from urban sewage sludge, Cécile Kech, Damien. Garot, Caroline Nadin, Christophe Frippiat

9. Pulse process: recovery of phosphorus from sludge and its product quality assessment, Zaheer Ahmed Shariff, Aleksandra Bogdan, Laurent Fraikin, Evi Michels, Angélique Léonard, Erik Meers, Andreas Pfennig, B. Durand

10. Strategy and concept-approach for the recovery of phosphorus in one of the largest sewage sludge producers of Germany, Dennis Blöhse, Dirk Bogaczyk

11. Towards quality control of feedstocks for biodiesel production: the case of urban sewage sludge, Cécile Kech, Damien. Garot, Caroline Nadin, Christophe Frippiat

12. Utilisation of sewage sludge in combination with recultivation of degraded lands for in-situ production of a soil substitute, Balint Heil, Gábor, Kovács, Sándo, Horváth

13. Validation of a pilot scale belt filter for sludge dewatering, Laurent Fraikin, Pierre Wuidar, Thierry Salmon, Angélique Léonard

14. Demonstration of a continuous TORWASH® pilot plant for sewage sludge treatment, Nanou Pavlina, Jan Pels, Francesco Sebastiani, Christiaan van der Meijden, Hans Kuipers, Willie Driessen, Jaap Vogelaar

15. Wet oxidation of sewage sludge: a promising technology for sludge management, Carlos Ruiz de León, V. Ismael Agueda, Javier Cañas, Blanca Hermana, Juan García

16. Characterizing metal content and extraction potential in domestic sludge – the SUBLIMUS project, Natacha Brion, Xavier Nicolay, Gilles Bruylants, Philippe Claeys, Marc Elskens

17. Application of paddle dryers for pig manure drying: the Andritz experience, Elisia Prucole, Diogo Sebastião, Menno Maingay

18. Optimization of p recovery from sewage sludge by bio-acidification, Younes Bareha, Mohamed Amine saoudi, Marie-Line Daumer

ORAL PRESENTATIONS

RE-CONCEPTUALIZING SLUDGE MANAGEMENT: REGULATORY AND SOCIO-ECONOMIC ASPECTS

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Keywords: Circular economy; Regulation; Sludge management; Sustainability; Standardization

The global paradigm shift urges to re-think traditional approaches in wastewater management. This is well recognized by the Goal 6.2 of the Agenda 2030 for sustainable development, which aims at achieving universal access to adequate and equitable sanitation and hygiene, and by one of the major principles underlying the Lisbon Charter, which states to acquire sustainable and safe wastewater management.

Within this context, sludge plays only a minor role when planning water and wastewater management systems, because it is considered at the end of the water cycle train, i.e. the "*last wagon*" of the train. However, the selection of the most appropriate treatment chain for the wastewater treatment plant is strongly driven by the final sludge reuse/disposal option(s) available and consistent with the specific local situation, so sludge management should be considered as the "*locomotive*" of the water cycle train [1].

Therefore, a re-conceptualization of sludge management becomes increasingly necessary as a consequence of the rise of its production, complying with stricter environmental quality requirements, and growing problems in properly locating treatment and disposal works. Further, the objective of developing sustainable strategies requires a change in sludge management from solutions aimed at "*disposing of*" sludge to those oriented towards "*maximizing recycle or recovery benefits*" within the general frameworks of sustainability and circular economy concepts.

The re-conceptualization of sludge management includes both (i) technical aspects, such as reduction of production and improvement of quality, and (ii) socio-economic ones, such as regulatory approaches, pricing-mechanisms, challenges of implementation and institutional dynamics, which are often looked over and even ignored [2].

This paper discusses both above aspects, but draws a major attention to the regulatory and socio-economic ones that need to be considered for an effective sludge management systems re-conceptualization, thus providing with a holistic view.

REFERENCES

[1] Spinosa, L.; Doshi, P., 2018. Re-conceptualizing the sludge management within the sustainable development Goal 6.2. Proc. IWA Specialist Conf. on Sludge Management in Circular Economy (SMICE 2018), 34-36, Rome, May 23-25.

[2] Spinosa, L.; Ginisty, P.; Hendry, S., 2017. Sustainable sludge regulation: the start-point, not the finish-point, SludgeTech 2017, London, July 9-13.

USE OF BIOSOLIDS IN EUROPE: POSSIBILITIES AND CONSTRAINTS

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Keywords: heavy metals, organic micropollutants, pathogens, legislation, circular economy

The European Commission has released in December 2015 a Communication to the European Parliament and the Council called "closing the loop – An EU action plan for the circular economy" [1]. In this action plan, almost all economy sectors and related waste are included but not sewage sludge (SS). In fact, the revised legislative proposal on waste (the so called "Waste Package") does not include the revision of the old SS directive 86/278. In fact according to the Commission this directive dos not require any update. In the document ex post evaluation of certain waste stream directives [2] the SS directive was considered to be effective, efficient, relevant and coherent with other EU legislation. However, looking more in-depth this evaluation highlights that SS are used in agriculture in nearly 50% of the cases. Other uses like production of fertilising products, incineration and landfill are not considered at all. In the fertilizer regulation proposal [3] SS are excluded from the production of EU market organic fertiliser. SS is also not considered among waste flows for fuel application at EU level (Waste to Energy Communication – The role of waste to energy in the circular economy – EC 26/01/2017- COM 2017 34 final).

On the other hand, raising problems and issues related to the quality of SS used in agriculture raised since the publication of the SS directive. New organic pollutants are put on the market and released into the wastewaters, like micro plastics, perfluorinated compound, flame retardants, thus requiring attention. To fill the European legislative gap some Member States (MS) have provided national regulations fixing more stringent limits for SS use. This results in a fragmented legislative framework where SS is still qualified as waste and coherently managed. Nevertheless, few MS have recently started to release national End of Waste criteria, moving ahead from the typical restrictions of the SS directive.

In this paper, different MS regulations on SS management, with specific regard to agricultural use, are presented and compared. Limits on heavy metals in SS and soil, new limits on organic micropollutants, and additional requirements on pathogens and pathogens indicators will be discussed. Waste codes, included in the European List of Waste, suitable for agricultural use will be also presented. Other possibilities of non-agricultural uses currently allowed in some MS will be also discussed.

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[1] European Commission, 2015. Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions, Closing the loop - An EU action plan for the Circular Economy, 21 p.
[2] European Commission – DG Environment Ex-post evaluation of certain waste stream Directives Final report, 2014, 373 p.
[3] European Commission, 2016. Proposal for a Regulation Of The European Parliament And Of The Council laying down rules on the making available on the market of CE marked fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009, 43 p.

HANDLING SEWAGE SLUDGE – TECHNOLOGICAL OPPORTUNITIES AND LIMITATONS

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Keywords: WWTP, sewage sludge, energy, phosphorus, recovery

Sewage sludge (SS) from municipal wastewater treatment plant (WWTP) in the Czech Republic is mainly treated by anaerobic mesophilic digestion. Treated SS is then commonly used in agriculture by its direct field application or by application of composted SS (74 % in 2017) [1].

Legislative regulations are tightening lately due to the content of contaminants in SS and therefore the abovementioned ways of SS utilization gradually become impossible. In accordance with European legislation, valuable waste components have to be reused, where material and energy utilization is preferred over the disposal [2].

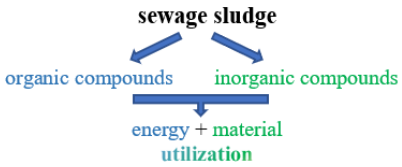

Figure 1 Utilisation of SS

In some European countries, the mono-incineration or the co-incineration became common ways of SS disposal. Moreover, some of those countries introduce an obligatory phosphorus (P) recovery from SS using transitional period to introduce relevant technologies [3]. In the light of mentioned legislative regulations, it is necessary to consider preferred technology option, because P recycling from SS co-incineration is rather impossible [4].

The world P stocks are decreasing (P is on the list of EU critical raw material) and thus requirements for P recovery from SS is very actual [5]. According to results of our project, P from SS can compensate for up to 30 % of Czech phosphate fertilizer consumption yearly. However, due to the SS contamination by toxic metals further SS treatment must be considered.

The Czech Republic does not have a system solution for SS thermal treatment. Therefore, it seems to be technologically and economically beneficial to design SS management as an integrated system, where heat from thermal treatment is used for SS drying, which is necessary prior to an incineration. Such integration may lead to technology self-sufficiency.

To design such technology, knowledge of SS fuel-energy parameters is crucial. In our study, samples of dewatered SS from several WWTPs were analysed for monitoring of SS variable properties depending on the WWTP technology and the WWTP size.

Acknowledgements
This work was supported by the specific research project No. FCH-S-18-5331 and project No. TJ0100074.

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[1] Czech Statistical Office, Water supply, sewerage and watercourses 2017.
[2] European Commission, Directive 2008/98/EC of the European Parliament of the Council of 19 November 2008 on waste and repealing certain Directives.
[3] H. Herzel, O. Krüger, L. Hermann, Ch. Adam, *Science of the Total Environment* 542 (2016) 1136-1143.
[4] L.Egle, H. Rechberger, J. Krampe, M. Zessner, *Science of the Total Environment,* 51 (2016) 522-542.
[5] European Commission, List of critical raw materials 2017 for the EU.

SEWAGE SLUDGE AS A SOURCE OF ENERGY

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Keywords: circular economy, sewage, waste water irrigation, soil recultivation

A circular economy seeks to rebuild capital, whether this is financial, manufactured, human, social or natural. This ensures enhanced flows of goods and services. This is in contrast to a linear economy which is take, make, dispose" industrial processes and the lifestyles that feed on them deplete finite reserves to create products that end up in landfills or in incinerators. [1]

In accordance with the principals and of the circular economy waste water should be considered as raw material instead of waste. In the light of the above, the process of conventional wastewater treatment should be reviewed.

In our paper we investigate what waste water or sludge treatments correspond mostly to the conditions of circular economy.

One of such solutions is the special irrigation with pretreated waste water. It' quite a significant circumstance that using wastewater irrigation we can keep away the polluting materials from the surface and subsurface waters, so that the nutrients with them can be utilized.

Another solution is the recultivation of degraded soils, surface mines, clay mines with sewage sludge. Previously excluded cultivated area once again be involved in production in order to grow energy plants.

To summarize: in our paper we wish to demonstrate that the above mentioned solutions for long-term utilization how they can meet the objectives of circular economy, what kind of advantages and disadvantages of all these.

REFERENCES

[1] https://www.ellenmacarthurfoundation.org/circular-economy/infographic

INFLUENCE OF BACK MIXING ON THE PILOT-SCALE CONVECTIVE DRYING OF SEWAGE SLUDGE: EVOLUTION OF THE VOLUME AND EXCHANGE SURFACE

Jie Li[1, 2, *], Cheng-Wei Wu[1], Laurent Fraikin[2], Thierry Salmon[2], Dominique Toye[2], Angélique Léonard[2]

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Keywords: Wastewater sludge; Drying kinetics; Fixed bed; X-ray tomography; Image analysis; Evolution.

For wastewater sludge, back mixing is mainly used to avoid the sticky phase that can produce damages in indirect dryers [1]. Léonard et al. [2] found that the back mixing had a positive effect on the drying kinetics of two residual sludges. Moreover, the expansion of the sludge extrudates bed due to increasing additions of dry product was also quantified by using X-ray tomography. However, the X-ray tomography was only used before and after drying in this research.

The influence of the back mixing operation (40%, 60%, and 70% on a dry basis) on the pilot-scale convective drying of sewage sludge was studied. X-ray macrotomography was used to research the evolution of the volume and exchange surface of sample bed during the drying process. Results first confirm the back mixing has a positive impact on the drying process from the mass fraction of 40%, with drying rates higher than that of the original sludge. The evolution of the volume and exchange surface, obtained from X-ray tomography experiments, was investigated. The relationship between the volume (exchange surface) and water content is nearly linearly for the original sludge and back mixing sludges. The 2D cross-sections of the single extrudate after drying of the original sludge and back mixing sludges, obtained from the X-ray microtomography experiments, show the shapes of the particles inside the extrudates of four sludges are similar, which are almost blocks.

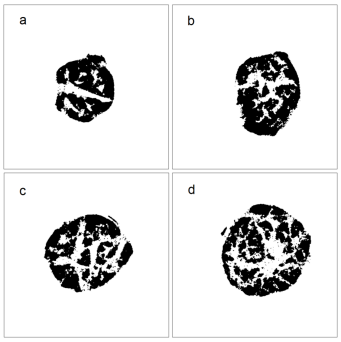

Fig. 2D cross-sections of the single extrudates after drying. a: Original sludge; b: Back mixing (40%); c: Back mixing (60%); d: Back mixing (70%).

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ENERGY EFFICIENCY IN SLUDGE DRYING

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Keywords: paddle dryer, belt dryer, OPEX reduction, thermal efficiency, cascading energy

Improvement of energy efficiency in sludge drying is still needed to face the challenges associated with sludge management. In this context, a research work is executed within the framework of the ISPT project "GRIP on drying", in cooperation with NWGD and Université de Liège. This study concerns the innovative combination of 2 types of ANDRITZ dryers, the paddle dryer and the belt dryer.
In the paddle dryer, the thermal energy input combined with the electrical energy input are used to dry the sludge resulting in both dried sludge and a hot vapour stream leaving the dryer. A possible route for improvement of energy economy is found in cascading energy. The drying process in the paddle dryer can be operated at elevated temperature and pressure, creating vapour which can be considered as low pressure saturated steam and can be used as thermal energy source for a second dryer: the belt dryer.
Some challenges need to be overcome. Dust load or impurities in the vapour stream leaving the first dryer asks for fouling management in the heat exchanger. With treating sludge at elevated temperature and pressure, a new territory is entered. The first results obtained at labscale under these unusual conditions will be presented.

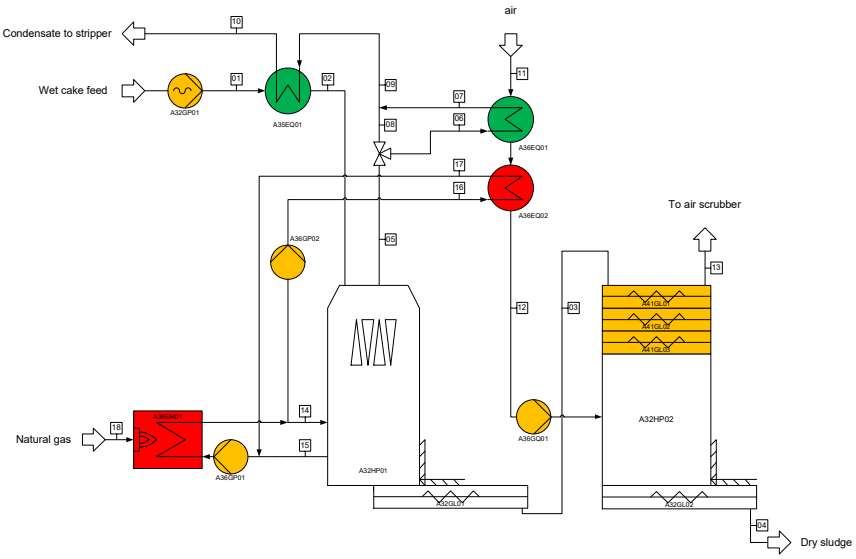

Figure 1. Scheme of the proposed combination between paddle and belt dryers

TOWARDS 3D RHEOLOGY FOR SLUDGE?

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Keywords: rotational rheometer, **FT4, normal stress, plastic state, granular material**

Sludge consistency is one of the top issues of common concern, whatever the technology combinations and the disposal strategies. Along the entire sludge treatment process, physical consistency may vary from liquid to solid state, through paste-like state. Handling, pumping and conveying issues often arise when the sludge reaches this paste-like state and become critical when TS content reaches 60 wt. % [1]. Indeed, as the total solids content (TS) increases, dominating interactions move from a lubricated regime to a frictional regime. Fluid rheology is used to describe the consistency. Recently, a new experimental procedure has been proposed to overcome issues related to cracks formation, which are almost systematically encountered with highly concentrated sludge in conventional rotational rheometers [2]. This protocol was successfully applied up to 43 wt. % [3], which corresponds to the Atterberg plastic limit. Above this threshold, a granular state appears and conventional rotational rheometers are no longer appropriate and other tools are thus required. Shear testers are extremely useful 3D rheology tools to characterize powders and bulk materials under consolidation at the onset of flow (ie. at the transition from static to dynamic behavior). The overall principle is to consolidate the material by applying a normal stress on the sample and then to exert a tangential stress until the medium yields [4]. In this work, powder rheometer (FT4, Freeman Technology, UK) was used to determine the yield locus curve, which links the consolidation to the rupture stress, for TS contents ranging between 20 and 48 wt. %. A stress-controlled rotational fluid rheometer (Haake RheoStress 600, Thermo Electron S.A., FR), equipped with a normal force sensor, was used to determine yield-like stresses at various TS contents under stress sweep measurements. The yield-like stress was defined as the critical shear stress at which the viscous modulus and the normal stress start decreasing. Provided that the same normal stress is used for the consolidation, both tools give the same yield-TS curve, which can be fitted by means of Eilers law. Coupling these tools and approaches led us to propose a rheophysical scheme that relates the rheological behavior to the sludge texture.

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ENZYME PRODUCTION BY *Bacillus licheniformis* FROM THERMICALLY HYDROLYSED SLUDGE

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Keywords: wet oxidation, thermal hydrolysis, culture media, enzymes, protease

The treatment and disposal of sewage sludge is an environmental problem of prime concern due to its high organic load and low dewaterability and imply great operational costs. Although different technologies have been applied for its management, it is not possible to implement them globally due to their drawbacks [1]. In the light of the above, the need for developing new sludge management strategies becomes clear. Currently, new perspectives are being opened, especially those focused on the recovery of valuable compounds from sludge.

One of these perspectives is the application of hydrothermal treatments, such as wet oxidation and thermal hydrolysis [2]. In these techniques, the sludge is treated at high temperatures and pressures (above 150 °C and 40 bar) in presence of oxidants like oxygen in wet oxidation or without them in the case of thermal hydrolysis. In this way, sludge can be hydrolysed in order to obtain proteins, fatty acids and carbohydrates, which are potential substrates in various bioprocesses. After a severe hydrothermal treatment, the solubilized proteins are further broken into amino acids, the carbohydrates into fermentable sugars and the lipids into fatty acids and glycerol [3]. These molecules, which are easily bioassimilated by many microorganisms, can be used as carbon and nitrogen sources in many fermentation processes [4,5].

In this work, a new bioprocess based on the use of the hydrolysate obtained after a designed hydrothermal treatment of the sludge as a medium for the growth of *Bacillus licheniformis* is proposed. This bacterium is known to produce various enzymes of industrial importance, such as extracellular proteases and lipases, as well as intracellular laccases which are widely used in detergents, leather, dairy and pharmaceutical industries.

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ULTRAFILTRATION FOR RECOVERY OF VALUABLE COMPONENTS FROM HYDROLYSED SLUDGE

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Keywords: fouling; hydrothermal treatment; recovery; sludge; ultrafiltration

Taking into account that sewage sludge mainly consists of proteins (61%), carbohydrates (11%) and phosphorous (3%), one of the most promising ways for its management is to use it as a potential source of bioproducts [1]. However, this option requires, before any further consideration, a controlled breaking of the biological structures to medium and/or small molecules. For this purpose, a variety of technologies can be used, with hydrothermal processing being one of the most attractive techniques [2]. This involves reactions carried out in aqueous media at intermediate temperatures and pressures, including thermal hydrolysis (in absence of oxidant) and wet oxidation (in presence of oxygen or air). It should be noted that these techniques do not generate harmful gas emissions (dioxins, furans and NO_x) or particulate matter, and moreover they can be autothermic processes. Although hydrothermal treatments have been commonly considered as a pretreatment step before the anaerobic digestion processes among others, such processes can also be utilized for: i) solubilizing biomolecules, i.e., polysaccharides, lipids, fragments of them, and phosphorus or ii) obtaining carboxylic acids and many other products [3].

Obviously, this implies the design of strategies to separate and purify these valuable products as well. Among these technologies, ultrafiltration (UF) is frequently used in the separation and purification of different bioproducts, because of its high efficiency and lower energy consumption, which reduces operating costs. Nevertheless, it has not been yet implemented until now for the hydrolysed sludge downstream [4, 5].

Based on these considerations, the use of ultrafiltration as a means of separating valuable products from hydrolysed sludge by hydrothermal treatments is here assessed, paying special attention to the effects of the hydrothermal conditions on recoveries and on membrane fouling mechanisms.

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SECONDARY SLUDGE TREATMENT BY MICROBIAL ELECTROLYSIS CELL: SIMULTANEOUS NITROGEN AND CARBON REMOVAL.

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Keywords: Secondary sludge, Microbial Electrolysis Cell, Sludge Treatment, COD removal, Nitrogen removal.

Secondary Sludge (SS) is widely produced in wastewater treatment plants. Therefore, it must undergo costly treatment and its disposal is usually seen as a problem [1]. However, in this work we used the potential of the SS to be used as feed in a Microbial Electrolysis Cell (MEC) for nitrogen and carbon removal.

The study was made with 3 identical MECs. Each MEC consisted of a methacrylate cell with a total volume of 50 mL equally divided between the anode and cathode chambers. Graphite felt and stainless steel were used for the anode and cathode, respectively. Chambers were separated by a cation exchange membrane (Nafion 117). The anodes were inoculated with sludge from a near wastewater treatment plant and was supplemented with 400 mg/L of acetate. +0.2 V vs. (Ag|AgCl|3 M KCl) of voltage was applied during the inoculation and the tests. After the start-up period, anode was fed with SS pretreated by microwaves. The catholyte was composed of a phosphate buffer solution at pH 6.

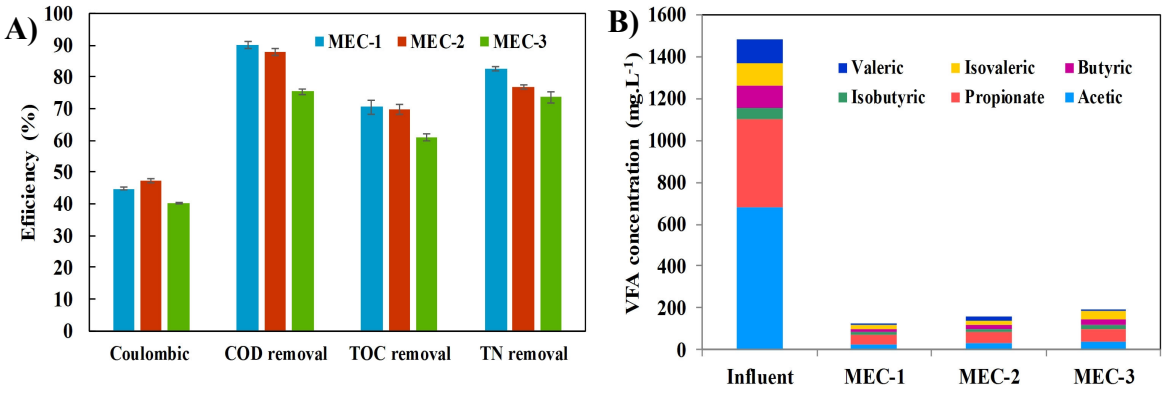

Figure 2. **A)** Coulombic, Chemical Oxygen Demand (COD) removal, Total Organic Carbon (TOC) removal and Total Nitrogen (TN) removal for MEC-1 (blue), MEC-2 (red) and MEC-3 (green). **B)** Volatile Fatty Acid (VFA) concentration in the influent and effluent of MEC-1, MEC-2 and MEC-3.

Figure 1A showed that >75% of the COD and TN were effectively removed. Moreover, results suggest that SS is a suitable feedstock for MEC as it contains large amounts of volatile fatty acids readily availables for electroactive microorganisms (Figure 1B).

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DISPOSAL OF SLUDGE IN AGRICULTURE: THE EFFECT OF THE ELECTRO-DEWATERING PROCESS

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Keywords: sludge; electro-dewatering; disposal; agriculture; OUR

The treatment of wastewater produces huge quantities of sludge, which contains a high portion of water. A dewatering step is usually carried out in order to reduce sludge volume and consequently reduce handling and disposal costs. Conventional methods include the use of mechanical processes such as plate or belt filter presses and centrifuges, which hardly can get a dry solid (DS) content of 30%. The implementation of an electric field during the mechanical dewatering (electro-dewatering, EDW) could improve the dewatering efficiency, getting a final DS content of up to 45-50% [1]. Sewage sludge disposal is crucial and a sustainable option for a long-term management of the sludge must be feasible, environmentally friendly and economically viable.

In this work, a lab-scale device [2] was used to study the dewatering kinetics of the EDW process and its water removal efficiency on two different sludge samples, one aerobically stabilized and one anaerobically digested. The experiments were conducted at constant pressure (300 kPa) and voltage (5, 15 and 25 V), and the results evidenced the feasibility of the process in achieving a DS content higher than 40%, with both the sludge samples.

Moreover, to assess the effect of the EDW process on the biological activity of sludge, oxygen uptake rate (OUR) tests have been carried out. The sludge samples have been diluted and homogenized with the Winogradsky salt solution at a concentration of 8 g_{DS}/l. Then, the solutions have been aerated for 30 min and, when aeration was stopped, the concentration of dissolved oxygen (DO) was recorded. When the DO reached values down to 4-5 mg/l, 10 ml of sodium acetate was added. The slope of the DO profiles recorded before and after the sodium acetate addition consisted in the endogenous and exogenous rate, respectively. The specific oxygen uptake rate (SOUR), was computed as the mass of oxygen consumed by microorganisms per gram of volatile solids per hour ($mgO_2\ mg^{-1}VSS\ h^{-1}$).

The exogenous SOUR of both sludge samples has decreased by increasing the voltage and the duration of the EDW tests. On the other hand, the endogenous SOUR has increased by increasing the voltage. The count of *Escherichia coli* in the sludge cakes showed a slight reduction in the presence of viable bacteria after EDW tests at 15 V and 25 V. These results can be explained considering that the temperature rise due to ohmic heating at these voltages has probably reduced the viable biological population, but, on the other hand, may have increased the lysis of organic substances, hence increasing the concentration of biodegradable substrate, which fuels the endogenous SOUR.

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IMPROVING THE FLEXIBILIZATION OF DIGESTER GAS PRODUCTION THROUGH PREDICTIVE CHOICE OF CO-SUBSTRATES

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Keywords: co-digestion, co-substrate, flexibilization

Depending on their physical and chemical properties, co-substrates differ in their suitability for use in digester of waste water treatment plants (wwtps) and can cause severe deterioration of the affected processes. The positive effect of increased gas yield must be contrasted with disadvantages such as a possible N and P back-loading, declined dewaterability, the introduction of contaminants and odour problems. In principle, especially co-substrates are recommended, which have similar properties in terms of their composition as sewage sludge. Choosing the right composition of co-substrates, negative impacts can be diminished. As part of an interregional project “The wastewater treatment plant in interaction with the waste and energy sector: A German-Austrian dialogue” funded by the EU, substrates from the dairy industry as well as biowaste from tourism are examined. Furthermore, studies are being made on the flexible operation of digesters using co-substrates.

Semi-technical investigations were carried out in four identical digesters (37°C) with a capacity of 30 liters. The feed consisted of municipal sewage sludge (mixture of primary and surplus sludge) und flotate sludge from the dairy industry. All digesters were operated with a hydraulic retention time (HRT) of 20 d, whereby the organic load was varied from 80.5 g COD/d in Digester 1 (D1) to 150 g COD/d in Digester 4 (D4) by increasing the amount of co-substrate. The ratio between the COD from flotate sludge (COD_{fs}) and the COD from sewage sludge (COD_{ss}) was between 0.4 (D2) and 1.9 in D4. To achieve a steady state, the digesters were fed over a period of 7 months constantly. The effects of co-substrates on N and P back-loading and the influence on dewaterability were investigated during the time of observation.

In addition to an increase in biogas production due to the higher energy in the co-substrate, an increased methane content could be assumed due to the more favorable COD/TOC ratio. This was also confirmed during operation. The similar properties with respect to the nitrogen and phosphorus contents, between the co-substrate and the sewage sludge used, had a positive effect on the back-load of these substances. Despite higher loads of dissolved ammonium in the output, the balance showed that there was neither a linear relationship between the degree of degradation and the back-load with N nor with the nitrogen mass flow and the back load. Phosphorus concentration was at a similar low level for all digester despite increasing the mass flow in D1 (1.7 g/d) to D4 (2.7 g/d).

The investigations have shown that a flexible operation of the reactor is possible if attention is paid to the physical and chemical composition of the co-substrates. The next step is to investigate to what extent mixtures of selected substrates can further reduce the negative effect on dewaterability

ENHANCED ANAEROBIC DIGESTION OF SEWAGE SLUDGE BY HYDROGEN ADDITION: INFLUENCE ON MICROBIAL POPULATION

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Keywords: hydrogen, microbial analysis, anaerobic digestion, sludge

Environmental concerns and stringent regulations regarding sludge management and disposal make it necessary to seek for alternatives and feasible solutions for the treatment of such wastes. Anaerobic digestion (AD) is a well-known technology that is widely used for the valorization of sludge. There have been several investigations related to the use of H_2 for improving methane production in anaerobic reactors[1]. Although, H_2 is a difficult substrate to be assimilated by microorganisms due to its low solubility in the liquid phase, several studies have shown that the application of H_2 pulses increases methane production (~30%) by the action of hydrogenotrophic methanogens. The aim of this work was to evaluate the improvement in anaerobic digestion of sludge by H_2 addition, analysing its influence on microbial population.

Sewage sludge (SS - was mixture of PS and WAS at 30:70 v/v) was used as feed. Semi-continuous digestion was carried out in completely stirred reactors. The reactors were evaluated with SS at a hydraulic retention time (HRT) of 21 days for a 106-day period (After an adaptation period of 28 days with a HRT of 25 d). One of the reactors was used as control (**RC**) and the other was used for evaluating the effect of the injection of H_2 pulses on biogas production (**RH**). H_2 was supplied to the reactor a rate of 0.5 to 2 L H_2 L Reactor^{-1} d^{-1}.

The specific methane production obtained for the control reactor (**RC**) and for the reactor with H_2 addition (**RH**). The average SMP was higher for the reactor with H_2 addition for the periods III to IV compared with the control reactor, indicating the benefits of H_2 addition in the anaerobic digestion of sewage sludge.

The benefits of introducing a H_2 stream in AD of sewage sludge resulted in a significant increase in biogas production, but it did not involve a significant improvement in methane concentration (% CH_4:62-67%) in RH, which was initially expected. Estimated values of methane content expected to be ~70% CH_4, associated with the consumption of H_2 by hydrogenotrophic methanogens as *Methanosarcinaceae* as found in works of Luo et. al.[2]. This result may be attributed to the predominance of acetoclastic methanogens (*Methanosaetaceae*) which follow the acetoclastic route [3]. In the present study, the proliferation of homoacetogenic bacteria was observed. These bacteria use the H_2 transferred from the gas phase and CO_2 to produce acetate, which is further consumed by acetoclastic methanogens to produce biogas. These latter organisms were found in higher proportion in the RH reactor compared with RC.

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INVESTIGATION OF ENERGY PRODUCTION POTENTIAL AND TOXIC EFFECTS OF INDUSTRIAL SLUDGES DURING ANAEROBIC DIGESTION

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Keywords: Anaerobic digestion, energy production, industrial wastewater treatment sludge, organized industrial district, toxicity

Large amount of sludge is produced as a result of treatment processes. Undesirable characteristics, as well as the large quantities of sludge cause environmental problems if it is not managed properly. Anaerobic digestion has been established for domestic sludge as a sludge stabilization and biogas production method before ultimate disposal. Since it also reduces the sludge quantities, anaerobic digestion can create a sustainable solution for this challenging engineering problem. In contrast to municipal sludge, industrial sludge includes more toxic materials such as heavy metals and trace organic chemicals. Therefore, anaerobic digestion has limited success in industrial sludge applications. Most organized industrial districts (OID) that gather small to medium sized facilities accommodate mixed industrial sectors, which lead to the generation of sludge with varying contents. If it is possible to effectively generate biogas from these sludges is a significant question to answer. Unfortunately, there are limited number of studies that demonstrate anaerobic stabilization of these sludges. On the other hand, organized industrial district sludges that are difficult to manage, may serve as an alternative energy source before final disposal. This study aims to investigate biogas production from sludge generated during wastewater treatmet in industrial districts, alone or in mixtures with municipal sludge.

The selected OID for this study, hosts metal and machine manufacturing industries as the largest industrial sector. A biochemical methane potential (BMP) test was set for the evaluation of biodegradability and the biogas production potential of OID sludges. During BMP test, industrial sludge is mixed with municipal sludge sampled from Ankara Central wastewater treatment plant at different mass ratios (all had F:M=1.0). Five sets of triplicate BMP reactors that are: OID sludge only (A); 2:1 (w/w) OID sludge: municipal sludge (B); 1:2 (w/w) OID sludge: municipal sludge (C); municipal sludge only (D) and seed only (S) were prepared. Before reactor set-up, parameters including TS, VS, TSS, VSS, pH and COD were measured. Once the reactors were in operation, daily biogas production were monitored by using GC-TCD. After 29 days, gas production ceased; so, all reactors were terminated, and aforementioned parameters were measured again; COD and VS reductions were determined.

Results demonstrated that, average methane production followed a trend that is in inverse relationship with the amount of added OID sludge. The highest amount was in reactor D, which was followed by C, then B and A. As expected, lowest gas was produced in seed reactor. Results showed that, there is a clearly improved digestion potential when OID is in mixture with municipal sludge. These results have implications for the co-digestion of industrial sludges with municipal sludge and biogas production potential from industrial sludges.

COMPARISON OF METHANE YIELDS FROM BATCH TESTS AND CONTINUOUS DIGESTERS

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Keywords: methane yield, batch test, continuous digesters, full-scale digesters

Substrate-specific methane yields of full-scale digesters are reproduced in laboratory by running batch tests or continuous digesters. As the assessment of methane yields for continuous digesters from batch tests are doubted, the practical relevance of batch tests are questionable. Objective of the performed tests and data evaluation is to verify the transferability of methane yields for continuous digesters from batch tests.

For checking the comparability, batch and continuous tests were performed at 38 °C to determine substrate-specific methane yields. The automatic methane potential test system (AMPTS) from Bioprocess Control was used for the batch tests. The inoculum was fed once at the beginning of the test and the methane amount was quantified until the methane production stagnated. In contrast to this, 30 liters continuous digesters with an average hydraulic retention time of 20 days were fed once a day. As substrate a mixture of primary and secondary sludge and as inoculum sewage sludge from a municipal wastewater treatment plant with a capacity of 50,000 PE were utilized for both test procedures. Further, these tests were repeated with flotation sludges from dairies.

Results show for a ratio of 1:1 (primary to secondary sludge: 2.6 % TS, 70 % VS, 40,850 mg/l COD) that the specific methane yields from batch tests are 235 ml_N CH_4/g VS_{added} and 168 ml_N CH_4/g COD_{added} and for continuous digesters 224 ml_N CH_4/g VS_{added} and 143 ml_N CH_4/g COD_{added}. For the substrate-specific methane yield referred to VS_{added} this is a deviation of 15 % and referred to COD_{added} 5 %. All the methane yields are within the range of values from literature.

Higher methane yields from the batch tests traces back to the difference of experimental setup like the interval of feeding and the amount of added substrate, affecting the substrate to inoculum ratio and the degradation kinetic. The deviation between results from batch and continuous digesters further is caused by interval of mixing and type of quantification the methane amount. As in batch tests substrate is added only once, with proceeding test duration the nutrient supply declines until the substrate is completely degraded. After reaching a stagnating methane production, the batch test represent the maximum methane yield of the added substrate. Compared to the batch tests, the continuous digesters are fed once a day, so the bacteria have permanently a substantial offer of nutrients to metabolize. The retention time in average is 20 days, so the substrate is not fully degraded. Therefore, the transferability of methane yields from batch tests to continuous digesters is a first assessment influenced by the system itself and the test setup.

ECONOMIC AND ENVIRONMENTAL OVERVIEW OF SLUDGE TREATMENT IN REED BED SYSTEMS – 30 YEARS OF EXPERIENCE

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Keywords: Environmental benefits and impact, Low energy biosolid management, dewatering, Recycling, Economy,

Sludge Treatment Reed Bed Systems (STRB) have been used for dewatering and mineralisation of both sewage and water works sludge in Europe since 1988 [1]. Recently the method has been tested in Australia and New Zealand. STRB's provide substantial environmental, economic, and operational benefits compared to mechanical sludge dewatering solutions such as belt presses and centrifuges. They use less energy, no chemicals, reduce the sludge volumes and produce biosolids with dry solid content between 20 – 50 % depending on the climate and the sludge quality. Post treatment and further dewatering results in the stockpile area are also reported.

Experiences has shown that sludge treated in STRB's represent a high quality product, with very good pathogen removal and mineralisation of hazardous organic compounds, and is ideal for safely recycling on agricultural land as a fertiliser [2]. A study indicate that sludge from a STRB with more aerobic conditions in the sludge residue emitted less methane compared to the mechanical sludge dewatered sludge stored in a stock pile area [4].

STRB often have a higher upfront capital cost compared to mechanical dewatering devices [3]. The significantly lower operation expenses compared to conventional mechanical dewatering devices, deliver an economic break-even of about 3-5 years. This paper provides an overview of the operation and maintenance costs and environmental benefits based 30 years of operation with a large number of STRB's with yearly treatment capacities between 100 – 3,000 tonnes dry solid up to approximately 250,000 PE in Denmark and Europe.

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SLUDGE CONDITIONING, THICKENING AND DEWATERING OPTIMIZATION IN A SCREW CENTRIFUGE DECANTER : WHICH MEANS FOR WHICH RESULT ?

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Keywords: sludge, conditioning, thickening, dewatering, centrifugation

Sludge thickening and dewatering by screw centrifuge are classical operations in WWTP. They are usually assisted by chemical conditioning in order to enhance sludge concentration. Performances and optimal setting parameters are often difficult to predict owing to complex mechanisms occurring during separation, high shear stresses undergone by flocs and sludge variability (nature, composition, behavior). The success of the operation of a specific equipment relies on a number of factors like final dry solids content, separation efficiency and required amount of chemicals. Flocs resistant to high mechanical stresses are required. [1].

As the properties of the sludge can change with time, a repetition of the optimization trials is recommended at regular intervals to limit overdosing but is time consuming at full scale. The project is to develop a methodology at lab scale to optimize polymer and dosing selection in order to assess the best performances at full scale.

Several quick and easy tests are available to screen chemicals and their dosage at labscale in order to narrow the number of products to be tested during experiments with a screw centrifuge and to adapt flocculation conditions to the sludge variability. They include drainage test, CST tests, basket spin tests and require floc production in a repeatable way according to EN 14742 standard [2] with a specific device (Bootest). The dryness limit [3], parameter recently standardized in France (NF-T 97001-1, 2018) is a valuable parameter for assessing the maximum dryness obtained by mechanical dewatering. It was showed that the dryness of biological sludges, dewatered in a full scale screw centrifuge, represents in average around 70% of the dryness limit which depends on flocculation conditions. Laboratory assessment of centrifugability is affected by limitations mainly due to the difficulty to reproduce the conditions really occurring in the industrial screw centrifuges. A new type of device is lab screw centrifuge (flow rate < 30 L/h) which allows to reproduce more accurately the shearing action of the screw on the flocs during bowl rotation. Results of tests performed with different types of sludges with this equipment will be presented to point out the role of polymer nature, dosing and mixing with sludge.

The paper will present comparison of these lab characterization tests with performances of machines obtained at full scale for thickening and dewatering operations of different types of sludge (primary, activated, digested, physico-chemical) and to check how relevant they are to predict the performances and to assess the effect of operating parameters (conditioning, flow rate, centrifuge acceleration, screw speed, liquid ring height).

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ADVANCES IN SLUDGE CONDITIONING AND DEWATERING THROUGH OPTIMIZED FLOCCULATION DESIGN AND FEEDFORWARD AUTOMATION

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Keywords: automation, conditioning, dewatering, flocculation, sludge

The dewatering characteristics of digested sewage sludge depend on many factors, e.g. wastewater characteristics, operation of wastewater treatment, storage and handling of sludge. All these factors lead to hourly, daily, weekly and monthly changes in the sludge dewatering characteristics with changes in the polymer demand for conditioning, the total solids (TS) in dewatered sludge etc. This paper describes for the first time a new flocculation process and its automation. The automation is based on an in-line sensor system described in Sievers et al. 2002. It has been improved to an industrial system, which is able to predict the expected total solids of dewatered sludge by analysing the flocculated aggregates before they enter the dewatering machine. The sludge conditioning process of BMA AG is based on a two times step-by-step polymer dose and mixing.
The efficiencies of the automation and flocculation process were evaluated by a 6 month full-scale treatment and analysing program comparing two equally equipped sludge dewatering lines operated in parallel with same sludge volume rates of 8 m^3/h and flocculants type. One of the two lines was equipped with conventional on-step flocculation at the inlet of centrifugal decanter and the other with two dynamic mixers as well as with two in-line sensors for automation of polymer dose by prediction of expected TS in dewatered sludge.
It was found that the new conditioning concept leads to a reduction of polymer demand by 25 to 35 % (!) compared to the traditional flocculation at the inlet of centrifuge. These differences were found every time for all measurements within the whole 6 months. It should be noted, that the traditional dewatering line was also optimized compared to the data before test period started. Three different flocculants (polymers) from three different producers were tested within this period and each polymer test included an extensive analytical program with approx. 50 samples daily and 4-5 days weekly. Despite the significant less polymer demand, the total solids in the automated dewatering line was always slightly higher by 0.5 to 1 % dry matter (DM) compared to the other line.
The measured TS of all dewatered sludge samples of the automated dewatering line were found within a narrower range of 24% ± 0.5% of (DM) indicating that a constant TS was successfully predicted and controlled. The reducing of polymer demand as well as the control of constant TS was confirmed for all three flocculants, while the polymer dose was adjusted minutely between values of 8…12 kg/tDM, with slightly differences for different flocculants.

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POLYELECTROLYTE CONSUMPTION OPTIMISATION OF DEWATERING CENTRIFUGES AT THE NORTH-BUDAPEST WASTEWATER TREATMENT PLANT

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Keywords: dewatering centrifuges, polyelectrolyte, optimisation, sludge

In the 1.333.333 PE loaded North-Budapest Wastewater Treatment Plant (NB WWTP) the digested sludge is dewatered mainly by two, previously thickening, but then modified to dewatering centrifuges. Optimisation of their polyelectrolyte consumption was necessary (i) to reach lower quantity of the used coagulant, (ii) to decrease the WWTP internal load by improving centrate quality, and because (iii) higher polyelectrolyte content of the centrate can have an effect on the Microthrix parvicella filamentous microorganism growth at activated sludge treatment line ([1], [2]).

This paper introduces two methods to achieve the mentioned goals: polymer use decreasing (Fig. 1) and dry-matter content increasing of the dewatered sludge by SD-RTC (Sludge Dewatering-Real Time Controller) ([3]) at Centrifuge 2 and polymer dose decreasing by developing the polymer dissolution efficiency at Centrifuge 1 (Fig. 1). In the recent year, preliminary full-scale operation was carried out, and the results indicated forward experiment with extending the SD-RTC to the Centrifuge 1 and developing the polymer dissolution efficiency at Centrifuge 2.

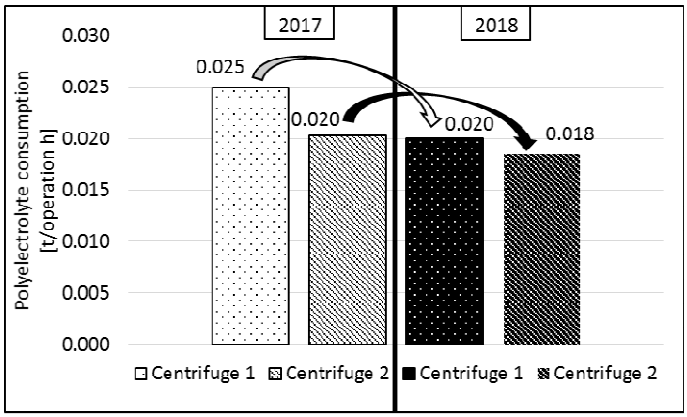

Figure 1: Decreased specific polyelectrolyte consumption (t/operation hour) at the centrifuges

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IMPACT OF THE ANAEROBIC DIGESTION PROCESS CONFIGURATION ON THE SLUDGE DEWATERABILITY

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Increasing amount of sludge being treated by thermal methods (drying, incineration, pyrolysis etc.) increases the importance of sludge dewaterability as a crucial parameter for energy balance of the process. The dewaterability is a complex parameter determined by many factors which were still not sufficiently evaluated. Main aim of presented contribution is to study how the anaerobic digestion (AD) process configuration can affect the sludge dewaterability.

Three technological alternatives of AD were tested: mesophilic (MAD), thermophilic (TAD) and temperature phased (TPAD) with operational temperature 37 ^{o}C, 55 ^{o}C and 55 ^{o}C in first stage and 37 ^{o}C in second stage respectively. All other technological parameters were identical. In addition also the effect of post-aeration (2 days hydraulic retention time) of digested sludge was tested. The dewaterability was assessed using two methods based on centrifugation and on filter pressing. Finally the sludge cake concentration of total suspended solids (TSS) was compared.

The results of the long term experiments showed the significant difference in sludge dewaterability for the tested anaerobic digestion process configuration:
The average sludge cake concentration was higher for TPAD sludge and MAD sludge (by 8-13 %) in comparison with TAD sludge.
On the other hand the average biogas production was higher for TPAD and TAD (by 12-18 %) in comparison with MAD.
Therefore TPAD seems to be the technology which is able to combine benefit of high digestion efficiency and improved sludge dewaterability.
Post-aeration of digested sludge brought the decrease of the final amount of dewatered sludge thanks to decrease of the VSS (volatile suspended solids) and TSS concentration (by 4-7 %) and thanks to increased sludge cake concentration (by 8-13 %).

UNDERSTANDING THE P DISSOLUTION IN SEWAGE SLUDGE BY BIO-ACIDIFICATION USING SEQUENCIAL EXTRACTION

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Keywords: Phosphorus recovery, sewage sludge, bio-acidification, sequential extraction

Phosphorus is a key element for plant growth and as such is a nutrient of limited availability in agriculture. To relieve these limitations modern agricultural practice has focused on the widespread application of phosphate fertilizers mined from phosphate rock. Harvest yields have skyrocketed since the introduction, feeding an ever growing world population with an ever growing demand for dairy and meat products. Coincidently the strain on phosphorus rock has increased immensely and it has been projected to be depleted in the next two centuries. To decrease the strain, phosphate recovery from sewage sludge has been proposed. To this end anaerobic acidification is regarded by IRSTEA as a promising method to release and reuse the phosphate stored in sludge. Anaerobic acidification involves the mixing of a Cosubstrate such as food waste with the sludge. Under anaerobic conditions the Cosubstrate is converted to volatile fatty acids (VFAs) by fermentative activity creating acidic (pH=4) conditions. Phosphorus stored in phosphorus accumulating organism (PAO) is released and the pH helps to dissolved minerals P compounds and prevent re-precipitation of phosphate. In this way release of phosphorus far exceeding 50% can be attained. The dissolved phosphorus will be used to precipitate mineral fertilizers such as Struvite.

Although P release works well for low iron sludge, it was observed to be severely limited when iron rich sludge is used (10% <recovery< 40%). The reason for this is enigmatic because the primary iron phosphate mineral in sewage sludge is generally regarded to be Vivianite which is only stable between pH 6-9 [2]. To investigate the phosphate mineral character in sewage sludge and the dissolved fractions; a sequential extraction based on the SEDEX method [2,3] was developed. Thus phosphorus was found in a wide range of forms: dissolved, as Vivianite, as refractory phosphorus but mainly as phosphorus adsorbed to iron hydroxides and humic acids.

The study has shown that the P fraction dissolved by the mean of bio-acidification was mainly the adsorbed fraction followed by the P-Fe^{2+} compounds (as Vivianite) then the minerals P (low pH extraction). While the Fe fraction dissolved was the mineral fraction followed by the adsorbed fraction. Moreover, we notice an increase in the labil (exchangeable) P and Fe fraction in all tests. This could mean that the dissolved P and Fe are re-immobilized by ions exchange. From this, an additional ions exchange process following the bio-acidfication could increase the P dissolution.

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POTENTIAL FOR INCREASING PHOSPHORUS RECOVERY FROM SEWAGE SLUDGE BY BIO-ACIDIFICATION

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Keywords: Phosphorus recovery, sewage sludge, struvite, bio-acidification

Phosphorus (P) recovery from sewage sludge is a way to avoid P rock depletion, surface water eutrophication and increase safety of food production in Europe. In some European countries, recovering P from wastewater should be mandatory achieved in a few years. To this end, bio-acidification is regarded by IRSTEA as a promising method to release and recover the P stored in sludge. P in sludge is mainly as intracellular P stored in the biomass especially when biological P removal (EBPR) is used or as mineral compounds with calcium, Iron or aluminum when chemical salts are added instead of, or to complete EBPR [1]. Bio- acidification involves the mixing of a cosubstrate such as food waste with the sludge. Under anaerobic conditions the cosubstrate is converted to volatile fatty acids by fermentative activity creating acidic (pH=4) conditions. P stored in phosphorus accumulating organism is released and the pH helps to prevent reprecipitation of phosphate with released calcium or iron. In this way release of phosphorus up to 75% can be attained. After separation of the liquid phase, the dissolved phosphorus will be used to precipitate mineral fertilizers such as struvite. The efficiency of the P dissolution, which determines the potential for P recovery, is depending on the forms of P in sludge and so, on the technology used for P removal in WWTP. A test has been developed previously to assess the potential of P dissolution by bio-acidification (BPDP) in different sludge [2]. In this study the test has been used to compare the BPDP of 12 sludge sampled in 8 WWTP from different size (from 10 000 to more than 300 000 p.e) and different technologies (EBPR, Iron salts, aluminum salts or a combination of the different technologies). This potential varied from less than 10% with sludge from a WWTP receiving wasted sludge from a drinkable water production plant containing high amount of iron and calcium salts, to 75% in 3 plants using mainly EBPR completed by Iron chloride addition as P removal technology. The ratio Fe/P or Al+Fe/P which depends on the amount of salts added in the WWTP seemed to be a crucial parameter for the P dissolution efficiency with a threshold at 1. In the four sludge with a Fe/P ratio above 1, the BPDP was less than 30%. When Fe/P ratio was less than 1 the BPDP varied from 40 to 75%. However this ratio cannot fully account for all the variations because a BPDP of 40% was measured in only one of the 5 sludge having the same Fe/P ratio (0.5).The BPDP of the others was 70-75%.

This work have shown that, depending on the technology used for P removal from wastewater, the P recovery rate from sewage sludge can be increased by a single step of bio-acidification without any chemical reactant. Further works are in going to better understand the link between P removal technology in WWTP and BPDP to manage P removal from wastewater in anticipation to P recycling.

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PHOSPHORUS RECOVERY FROM DRIED SLUDGE WITH REACTIVE EXTRACTION TO REMOVE IMPURITIES

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Keywords: drying, leaching, reactive extraction, solid liquid speciation model, cascaded option trees

In the framework of the Phos4You (P4Y) project funded by Interreg North West (NW) Europe 6 different Phosphorous(P)-recovery technologies will be demonstrated. The University of Liège is developing one of the processes, called PULSE (Phosphorus ULiège Sludge Extraction) process, to recover P from fully or partially dried sewage sludge. The PULSE process is a modification of the PASCH process developed at RWTH Aachen to extract P from sewage sludge ashes [1]. In the PULSE process P is recovered from partially or fully dried sludge using acidic leaching. Purification of the leach liquor will be carried out by reactive extraction to separate P and other nutrients from co-leached metals. Finally, depending on the leaching and extraction approach used above, the final product of the PULSE process can either be obtained as phosphate salt or phosphoric acid. In order to better understand the different process steps, to reduce the numbers of experiments to be performed, and to support optimization of process parameters, a solid-liquid-liquid equilibrium tool has been developed in MATLAB, which also includes speciation in the aqueous phase. The different process options of each process step are evaluated applying the 'Cascaded Option Trees' method [2], which supports selecting the most feasible options.

Results from drying tests show that dried sludge is easy to handle, reduces the consumption of acid required for leaching, and also the solid-liquid separation after leaching is much easier. It was also found that the drying mechanism may also have an impact on the leached P, with tests indicating that slow drying leading to better P leaching efficiency. The type of acid used for leaching of undigested dried sewage sludge had no effect on the P leaching and the efficiency was dependent only on the pH.

In order to separate the metals and heavy metals that are co-leached, reactive extraction of the metals from the leach liquor was tested using different organic extractants based on the extraction mechanism. Among the extractants tested, only Alamine 336 was found to be efficient for extraction of most of the metals studied. Finally, P from the leach liquor was precipitated by adjusting the pH to 6-8. Results from the experiments and the SLLE with speciation tool are used to evaluate and identify the most suitable process options for PULSE process.

In the presentation, the concept of the PULSE process will be explained along with the results from the lab experiments and evaluation of process options. The concept of solid-liquid equilibrium speciation model and its application to optimize the PULSE process operation will also be presented.

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FIRST RESULTS OF THE EUPHORE-PILOT PLANT

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Keywords: incineration, sewage sludge, sewage sludge ash, redox, fertiliser

During the last years, the incineration of sewage sludge has become more and more important in Germany. Up to date, 2/3 of all sludges are incinerated. It is quite certain that this share will even increase; mainly due to strict limitations of land / agricultural use of sludge.
Since the German “sewage sludge ordinance" (AbfKlärV) includes the obligation to recover phosphorus from 2029 or 2032 (depending on the size of the wwtp), it is self-evident that the aspects “incineration” and “sewage sludge ashes” will play an important role with regard to P-recovery.
Unfortunately, phosphorus fixed in sewage sludge ashes (ssa) is poorly plant available. Moreover, pollutants such as heavy metals are concentrated in ssa; thus, the quality of the ssa strongly depends on the input material. Generally, ssa are considered as not suitable for a direct agricultural use (i.e., recycling). To be in accordance with the requirements of the AbfKlärV, phosphorus must then be recovered with high effort via leaching processes.

The EuPhoRe-process aims at creating ssa that might be directly used in agriculture, thus avoiding complex add-on technologies. The process consists of a rotary kiln where dewatered sewage sludge is successively dried, reduced and oxidised. Additives such as $MgCl_2$ are added to the sludge in order to remove heavy metals through the gas phase. Given this process, the ssa of the EuPhoRe-process is – compared to the aforementioned ashes of e.g. a fluidised bed incineration – plant available and has a notably lower heavy metal content.

Based on previous lab-scale results in which the feasibility of the EuPhoRe-process has been proven, the Emschergenossenschaft (as one of Germany’s largest water boards) constructed the first stand-alone EuPhoRe pilot plant within the framework of the Interreg VB NWE-project Phos4You. The pilot plant has a capacity of 100 kg dewatered sludge/h; corresponding to the sludge of 6.000 – 7.000 population equivalents.

At ECSM 2019, we’ll present the results of the first year of operation (starting Jan. 2019). Besides technical aspects of plant operation, we’ll focus on the optimisation of the pollutant removal and the relation between input- and output quality. First results of the actual use of the EuPhoRe-ssa as a fertiliser component are also expected.

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RESULTS OF PILOT SCALE TESTS FOR P-RECOVERY FROM EMSCHERGENOSSENSCHAFT-LIPPEVERBAND SEWAGE SLUDGE ASHES WITH REMONDIS TetraPhos® PROCESS

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Keywords: P-recovery, sewage sludge ashes, ash leaching, phosphoric acid, TetraPhos®

The Emschergenossenschaft (EG) and Lippeverband (LV) manage together as waterboards in combined administration approximately 60 wastewater treatment plants with a capacity of 7.2 million population equivalents and clean the wastewater of 3.6 million inhabitants. The majority of the resulting sewage sludge (90.000 Mg DM/a) is incinerated. For this purpose EG operates a mono-incinerator facility in Bottrop and further capacities are provided via the subsidiary BETREM by the INNOVATHERM incineration plant in Lünen.

On 3rd October 2017 a new Sewage Sludge Ordinance came into force in Germany, making phosphorus recovery mandatory for large waste water treatment plants after a transitional period of 12-15 years. The regulation states that from 2019/2022 on when incinerating sewage sludge with a phosphorus content exceeding 20 g P/ kg DM at least 80% of the contained phosphorus has to be recovered from the resulting ash.

Within the framework of the Project Phos4You (INTERREG V B North West Europe) LV is, among other activities, demonstrating the recycling of phosphorus from sewage sludge ashes of the EGLV area utilizing REMONDIS TetraPhos®-process at pilot-scale. The process treats the ash with phosphoric acid, then, after separation of acid insoluble residue, purifies the resulting leachate with sulphuric acid, ion-exchange and selective nano-filtration to generate an industrial quality phosphoric acid (brandname REPACID®), which is suitable for use in industrial applications.

The operation of the demonstrator plant should prove that the process -which is economical when processing ashes of medium to high phosphorus content- is suitable for utilization of material with low phosphorus content. For this purpose, preliminary lab scale tests were conducted using three types of EGLV ashes with different phosphorus content (3-6% P) to assess phosphorus extraction behaviour. The application of TetraPhos® standard conditions resulted in high phosphorus extraction rates (85-90%) significantly exceeding future legal requirements.

Following the lab scale tests the TetraPhos® -pilot plant in Werdohl-Elverlingsen (capacity 50-100 kg ash/h) was operated for several months processing one EGLV ash type. Operation of the demonstrator proved stability of the process and high and constant quality of the produced acid. Based on the results, EGLV developed a “Phos4You” business case for urban regions, which is also applicable in other metropolitan areas of Europe.

This presentation shows the results from the technical demonstration and a first basic concept for implementation scenarios of the TetraPhos®-process in the EGLV area.

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P-RECOVERY AS STRUVITE FROM DIGESTED SLUDGE – EXPERIENCE FROM THE FULL SCALE

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Keywords: struvite, phosphorus recovery, digested sludge, circular economy, full scale

At the WWTP of Leuven (Belgium, 120 000 PE), Aquafin operates a full scale plant to recover phosphorus as struvite ($MgNH_4PO_4 \cdot 6H_2O$) from digested sludge. There are about 50 full scale struvite plants in the world to recover P from wastewater [1]. Usually, struvite is recovered from digested sludge liquor (centrate). A handful of installations use the AirPrex® technology to recover directly from digested sludge, which has a positive impact on the dewatering of the sludge [2] and is therefore more cost-efficient [3]. The Aquafin struvite plant was one of the first plants to recover struvite from digested sludge and the first that does so using the NuReSys® technology. The plant started in 2013 as a pilot plant. After several years of operation and optimizations, the plant is now a fully functional full scale struvite plant.

Digested sludge goes through a fiber cutter to prevent clogging in the plant. The pH is raised in a stripper tank by blowing air into the sludge. In a reactor tank $MgCl_2$ is added and struvite is formed. A hydrocyclone separates struvite from the sludge. The struvite is alternately send to the reactor for further struvite growth or send to a sand washer to harvest. The sand washer removes remaining sludge and organics. About 1/3 of the removed phosphorus is recovered, resulting in an overall P-recovery of 5 % of the incoming phosphorus to the WWTP. About 500 kg of struvite is produced weekly.

The dry solids content of digested sludge was tested with a small filter press. The struvite process increases the dry solids content with 1.9 %.

The contents of heavy metals and organic pollutants are all below the legal limits. No harmful microbial pathogens were detected in the struvite. Storing dry for a long period, and washing and drying were found to be the most effective ways to reduce the presence of moulds and anaerobic spores.

Aquafin obtained a “raw materials declaration” for the struvite (i.e. end-of-waste status, yet only in Flanders). In March 2017, 10 tonnes of struvite were sold to a fertilizer company to be used as a resource for a compound NPK fertilizer.

Pot trials with rye-grass and coriander showed no statistical difference between the use of Aquafin struvite and the use of triple super phosphate as a P-fertilizer.

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RECOVERED PHOSPHOROUS FERTILISER AND THE EFFECTS ON RESIDUAL SOIL P INDICES COMPARED TO COMMERCIAL P FERTILISER

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Field trials were conducted, comparing recovered Struvite compound fertiliser with commercial triple super phosphate compound fertiliser and its effects on grass dry matter production and residual soil phosphorous indices. The trial followed the three-crop silage system, with three individual grass crops cut and measured through the growing season. Each trial plot was soil sampled before and after testing to establish the residual soil P content determining if the Struvite low water solubility prevents losses to ground water while still producing a sustainable grass crop.

The findings of this research provides information on the added benefits of recovered P fertilisers contributing to the potential to close the P-cycle. From the trial sites at both Cork and County Tipperary, Ireland, the soil P index had a statistically significant increase of 1.4mg/l when using Struvite in comparison to TSP. Among the conclusions are that the recovered Struvite produced a sustainable grass crop, while the observed reaction between the recovered Struvite and increased residual soil P indices is worthy of further study.

POSTER PRESENTATIONS

ANAEROBIC SLUDGE AS INOCULUM FOR INNOVATIVE BIOLECTROCHEMICAL SYSTEMS

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Keywords: Anaerobic digestion, Biocathode , Bioelectrochemical systems, Digested Sludge, Microbial Electrochemical Cell

Multiple environmental mixed inocula, including Anaerobic Sludge (AS), have been used to inoculate the bioanodes on Bioelectrochemical Systems (BES). However, methane formation is usually a problem when operating these systems, as methane acts as an electron sink, detracting from the amount of electrons that otherwise would be collected by the bioanode. In contrast, the methanogenic process represents an opportunity in CO_2-reducing biocathodes or when the BES are integrated with Anaerobic Digestion (AD) as it boosts the methane production rates.

The objective of this study is to evaluate the suitability of using AS as an inoculum source for two specific bioelectrochemical-based processes with industrial interest: biocathodic carbon dioxide reduction, and improved anaerobic digestion through AD-BES hybrid reactors.

(i) CO_2-reducing biocathodes. Two strategies for developing carbon dioxide reductive biocathodes were tested. First a straightforward cathode was inoculated with digested sludge, eventually leading to a very productive acetogenic reactor which was interestingly enriched in hydrogen producing bacteria during operation. Acetic acid was the main final product, although microbiological analysis suggested that the process was hydrogen mediated. Second, an anode was grown to force potential inversion after the anode was stable in operation. This led to a final very diverse biocathode which was less favourable in productivity, and having acetic acid, hydrogen and methane as joint coproducts.

(ii) AD-BES hybrid reactors. To study the effect of different mixed inocula on the performance of AD-MEC systems, three digesters inoculated from AS, fluvial sediment and a pre-enriched consortium were put into operation. The reactor in which AS was used showed a more robust behaviour and achieved a long-term improvement in biogas production, although it took a longer time to reach the same substrate degradation and electrical performance as in the other two.

The conclusions of this study indicate that the combination of microbiological specialization and the moderate diversity of AS lead to the development of robust exoelectrogenic communities that facilitate the industrial exploitation of this emerging technologies based on BES.

ASSESSMENT OF ELECTROOXIDATION AS PRETREATMENT TO ENHANCE ANAEROBIC DIGESTION OF WASTE ACTIVATED SLUDGE

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Keywords: waste activated sludge, hydrolysis, electrooxidation, anaerobic digestion, improvement

Anaerobic digestion is a well-known and effective process for sludge treatment and stabilization. Nevertheless, waste activated sludge (WAS) is known to be more difficult to digest due the complexity of structure which limits the biological process [1].Several pre-treatments, such as chemical, thermochemical, shear stress, sonication and oxidation have been proposed to disrupt cell walls and increase digestibility of EPS [2].Electrochemical oxidation or electrooxidation, is an attractive pretreatment technology due to its ability to treat (under moderate conditions, ambient temperature and pressure) toxic and/or complex organic pollutants present in the sludge accelerating the hydrolysis step and increasing biogas production [3].The objective of this study was to evaluate the effects of electrooxidation as pretreatment to improve the anaerobic digestion of WAS. The efficiency of the process was assessed in terms of the quantity and quality of the biogas and organic matter removal.

Electrooxidation experiments (EO) were conducted in batch mode, using a 150 mL chamber. BBD electrodes were used as anodes and stainless steel was used as cathode. Experiments were carried out at an applied current density of 6.6 mA cm-2 and room temperature (25±1 °C). The tests were labelled according with the conditions used at the experiments: Control-WAS without pretreatment, T1-WAS electrooxidation (EO), T2-WAS EO with 3 g L^{-1} Na2SO4, T3-WAS EO with 6 g L^{-1} Na2SO4, T4- WAS EO at pH 4 (adjusted with H2SO4), T5-WAS EO at pH 10 (adjusted with alkaline solution). Batch digestion experiments were performed to evaluate the evolution on methane production of WAS after electrooxidation pretreatment. Results shows the enhancement on the solubilisation of the organic matter compared with control sample. This is reflected by the rise in TOC and COD values which were measured after the application of the pretreatment to the WAS. The increase in TOC and COD values obtained with the maximum value of initial conductivity measured (linked to the effectiveness of the electrooxidation process), may be explained by the lysis of cells and release of the intracellular organic materials.

Methane yield curves obtained for all experiments indicated an increase in methane yield with the application of EO pretreatment T5, T1 and T4 and a decrease with the application of EO T2 and T3 (addition of Na2SO4). The adjustment of pH to 7 increase the conductivity by the addition of alkaline solution (T5) improved the methane yield about 18%.

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CIRCULAR ECONOMY WITH SLUDGE - A NOVEL SOLUTION

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Keywords: Sludge, Phosphor, Energy, Ash, Circular Economy

Sludge is produced as rest product from treatment of waste water from industry and cities sewer system. Different kinds of sludges have different contaminants like bacteria, heavy metals [4], antibiotics and residual medicines passing through human body along with important nutrients like phosphorous and humus. Effective treatment of sludges is an important issue [1,2,3].

This paper presents a novel solution for effective treatment of sludges and truly create a circular economy. Contaminants from food chain are effectively removed and nutrients recycled back to agro industry for growing food and animal feed.

Methodology involves following steps:

1. Mechanical dewatering of sludge using filter press or decanter.
2. Thermal dewatering (drying) of sludge using Super-Heated Steam Dryer technology [5, 6].
3. Combustion of dried sludge and production of heat and power.
4. Recovery of phosphorous from ash [7]
5. Disposal of ash after phosphorous recovery to break food cycle

Above 5 steps achieve closed cycle and provide circular economy for sludge treatment. The methodology can be applied to both industrial and municipal sludge.

Key technology in this novel solution is Exergy Super-Heated Steam Dryer Technology (SHSD). SHSD is most energy efficient technology consuming 150 kWh/ton evaporated water, oxygen and emission free, explosion and fire free. Sludge gets sterilised and smell free. All volatiles from SHSD process is collected and effectively destroyed in the combustion process. This makes the process emission free. SHSD has been mentioned over 100 years ago [5, 6]. The technology has been developed and commercialised by Swedish Company Swedish Exergy AB since 1979.

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EMERGING POLLUTANTS IN WALLOON SEWAGE SLUDGE: TOWARDS AN INTEGRATED METHODOLOGY TO EVALUATE HEALTH AND ENVIRONMENTAL IMPACTS OF FARMLAND SPREADING

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Keywords: sewage sludge, land spreading, emerging pollutants, endocrine disruptors, pharmaceuticals compounds

Nowadays, with the growing numbers of wastewater treatment plants (WWTPs), the annual production of urban sewage sludge is steadily increasing. In Wallonia, farmland spreading represents the main management solution for this sludge. Concentration limits prior to application are set by the European Directive 86/278/CEE for heavy metals and PAH. These contaminants have been widely studied and are well documented in Europe.

Nevertheless, there is a current concern on emerging substances. An improved assessment of the risks associated to the application of sludge on cultivated soils to humans and the environment requires an improvement of the quantification of these substances in sewage sludge and of the knowledge on their transfer to plants and groundwater. In Belgium, emerging substances in sewage sludge have been poorly explored until now. In this context, the project CARIBOUH (ISSeP, Belgium) started in July 2017 with the aim of developing a methodology for the establishment of a diagnosis of the impact on human health and environment of sewage sludge farmland spreading. Specific endocrine disruptors and pharmaceuticals compounds are more particularly focused on.

The classical *"Source-Transfer-Target"* approach is applied in order to evaluate human and environmental risks. First, the *"source"* term is characterized by means of (i) a prioritization methodology and the setting of an initial working list of substances, (ii) the characterization of Walloon sewage sludge through complementary tools: chromatographic analysis (chemical identification and quantification) and ecotoxicological tests (evaluation of the global toxicity of the sludge). Secondly, the *"transfer"* term is characterized using experimental approaches. Persistence of the pollutants in soils, leaching toward groundwater and transfer into the vegetables are determined under real conditions by means of representative crops. The results obtained from this part of the project will provide a global view of the distribution of emerging substances in cultivated soils. Finally, experimental data on fate and transport in cultivated soils, supplemented by literature data, allow evaluating health risks related to farmland spreading. This is done quantitatively for dietary and dermal exposure using standard Walloon risk assessment methodologies established in the framework of soil management legislations. At the end of the study, limit values of the studied substances will be determined for urban sewage sludge.

In addition to the general methodology, this communication presents (i) prioritization methodology, (ii) methodology of sludge samples selection, (iii) first results of the sludge characterization, (iv) first results of experimental determination of pollutants fate in cultivated soils.

Implementation of the Struvia phosphorous recovery pilot plant at an Irish waste water treatment plant

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Keywords: Phosphorus, phosphorus recovery, wastewater treatment plant, effluent

The EU INTERREG Phos4You project is investigating the recovery of phosphorus (P) from municipal wastewater streams with P return to land. The EU recognises that phosphorus is a finite element, which is vital to sustain life. Mineral P is derived from P- rich rock and is used as an artificial fertilizer which is central to sustaining modern farming practice. However, the modern P cycle is slowly transforming finite P-rock from accessible land based resources to inaccessible dissolved river and ocean based reserves. This nutrient flux is partly a consequence of modern municipal waste water treatment processes.

This research aims to review the installation and operation of a Struvia phosphorous recovery pilot plant which has been developed by Veolia Environmental. The pilot plant was sited and commissioned at a municipal waste water treatment plant (WWTP) in Ireland. During the operation of the plant a number of process iterations were conducted to optimise the process to the requirements of the site. From this the recovery process, recovered material and final effluent quality was assessed with a view to establishing an effective and efficient P-recovery process to satisfy the requirements of a typical Irish WWTP potentially closing the P-cycle reducing P losses and also reducing the potential eutrophication effects of wastewater effluents on receiving waters and potentially providing Ireland with an indigenous source of P fertiliser.

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LC/MS AND GC/MS DETERMINATION OF EMERGING POLLUTANTS IN WALLOON SEWAGE SLUDGE

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Keywords: sewage sludge, emerging pollutants, endocrine disruptors, ULC/MS, GC/MS

Nowadays, with the growing numbers of wastewater treatment plants (WWTPs), the annual production of urban sewage sludge is steadily increasing. In Wallonia, farmland spreading represents the main management solution for this sludge. Concentration limits prior to application are set by the European Directive 86/278/CEE for heavy metals and PAH. These contaminants have been widely studied and are well documented in Europe.

Nevertheless, there is a current concern on emerging substances. An assessment of the risks associated to the application of sludge on cultivated soils to humans and the environment requires an improvement of the quantification of these substances in sewage sludge. In Belgium, emerging substances in sewage sludge have been poorly explored until now. In this context, the project CARIBOUH (ISSeP, Belgium) started in July 2017 with the aim of developing a methodology for the establishment of a diagnosis of the impact on human health and environment of sewage sludge farmland spreading. Specific endocrine disruptors and pharmaceuticals compounds are more particularly focused on. A classical *"Source-Transfer-Target"* approach is applied in order to evaluate risks.

A first screening of Walloon sewage sludge samples by means of mass spectrometry has confirmed the presence of relevant emerging substances belonging to the families of alkylphenols, phtalates, perfluorinated, pharmaceuticals and personal care compounds (triclosan, tonalide/galaxolide, UV filters, tertiary butylphenols, and parabens). For the characterization of the *"source"* and the *"transfer"* terms of the project, quantification methods of these pollutants must be developed into sludge, soil, water and vegetables matrix. Quantification methods include (i) extraction of the pollutants from sludge/soil, water and vegetables matrix, (ii) separation by LC or GC, and (iii) analysis by mass spectrometry. The communication will discuss developed quantification methods (Table 1) and will present characterization of 160 Walloon sludge samples with the quantification results.

Table 1. Emerging pollutants families confirmed into Walloon sewage sludge: extraction and quantification techniques

Substances families	***Extraction***			***Quantification***
	Water	**Sludge/Soil**	**Vegetables**	**Technique**
Alkyphenols	SPE	SLE	SLE	LC/MS
Phtalates	SPE	SLE	SLE	GC/MS
Perfluorinated	SPE	SLE	SLE	LC/MS
Pharmaceuticals	SPE	PLE	PLE	LC/MS
Personal care				
Triclosan	LLE	PLE	SLE or PLE	GC/MS
Tonalide/Galaxolide	LLE	PLE	SLE or PLE	GC/MS
UV filters	LLE	PLE	SLE or PLE	GC/MS
Tertiary butylphenols	LLE	PLE	SLE or PLE	GC/MS
Parabens	SPE	SLE or PLE	SLE or PLE	LC/MS

MICROPLASTIC IN SEWAGE SLUDGE - AN EXTRACTION METHOD AS A PRE-TREATMENT STEP FOR THE ANALYSIS OF MICROPLASTIC

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Keywords: sewage sludge, microplastic, Fenton-reaction

In Europe, 9.7 million tons of sewage sludge are annually produced. Almost 40 % of this is used for material recycling in agriculture [1]. Studies show that sewage sludge from wastewater treatment plants concentrates more than 90 % of the microplastic, defined as particles smaller than 5 mm, supplied [2], [3], and thus acts as a source of micropollutants in the terrestrial environment. Therefore, based on the Fenton process, a well-known wet-oxidative process for sewage sludge conditioning, cf. Kemicond process [4], a plastic-friendly method for the disintegration of microplastic particles, defined smaller than 5 mm, from sewage sludge was evolved as a pre-treatment step for further microplastic analysis with spectroscopic methods.

In laboratory experiments are investigated the effects of variation of temperatures, pH-values, quantities and concentrations of iron sulfate-solution ($FeSO_4$), and different amounts of hydrogen peroxide (H_2O_2) on the degree of digestion of the organic components of sewage sludge from municipal wastewater treatment plants as well as on microplastic.

With the optimum H_2O_2/COD and Fe^{2+}/H_2O_2 ratios of 13.7 g/g and 0.01 mol/mol, respectively, at a pH-value of 4.0 and a temperature of 23 °C, COD degradation of more than 50 % and, thus, the greatest effectiveness of the Fenton oxidation process could be observed. In particular, a suitable extraction method has been designed with the help of the implementation of the above mentioned fixed ratios to the respective COD values of the sewage sludge, which prevents the destruction of the microplastic particles. Furthermore, the Fenton reaction kills the germs and significantly improves the filtration properties of the sewage sludge.

This research work took place within the frame of project ”Strategies for the reduction of urban plastic emissions into limnic systems (PLASTRAT)” funded by the German Federal Ministry of Education and Research (BMBF) as part of priority research program ”Plastic in the Environment – Sources • Sinks • Solutions”.

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OPTIMIZATION AND ECONOMIC ASSESSMENT OF AN ENVIRONMENT-FRIENDLY *IN SITU* ENZYMATIC BIODIESEL PRODUCTION METHOD FROM URBAN SEWAGE SLUDGE

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Keywords: sewage sludge, biodiesel, enzyme, *in situ* conversion, economic assessment

In the context of the 2020 climate change and energy package adopted by the EU, the Directive 2009/28/CE establishes a mandatory target of at least 10% of renewable fuel in the transport sector. Biodiesel, one of the most promising renewable fuels, is obtained from lipid sources. At present, the main obstacle to its widespread production and commercialization is the need to use costly edible oil as feedstock, the cultivation of which competes with human food production.

Urban sewage sludge generated in wastewater treatment plants (WTTPs) is a low-cost lipid feedstock available in large quantities. Moreover, its management represents a major cost in WWTP operations. In Belgium, Walloon urban WWTPs produced around 49,000 tons dry matter (DM) of sludge in 2014 (Société Publique de Gestion de l'Eau (SPGE)). In this context, the aim of the project BioBoS (ISSeP, Belgium) is to develop an approach to produce biodiesel using sewage sludge as feedstock.

The common approach to produce biodiesel from sludge is a two-step process: (i) extraction of lipids from dewatered or dry sludge using organic solvents, and (ii) transesterification/esterification of extracted lipids to fatty acids methyl esters (FAMEs) under acid catalysis. The main challenge for full-scale production is an efficient lipid extraction. To avoid energy-consuming dewatering or drying steps, extraction should be carried out from wet sludge. The main drawbacks of direct liquid-liquid extraction of lipids are that it has been poorly explored until now and that the residual sludge is contaminated with organic solvents, limiting the valorization potential.

The high free fatty acid content of sewage sludge lipid fraction (30-50%wt) does not allow the use of base-catalyzed transesterification. Acid catalysts are then commonly used, sulfuric acid being by far used the most often. But this kind of catalyst has many disadvantages. One solution to overcome its drawbacks is to use *in situ* enzymatic conversion from wet sludge. Extraction and conversion are combined in a single step and the acid catalyst is replaced by an enzyme. The catalytic properties of immobilized lipases (involved in fat metabolism) have received growing consideration in recent years in industrial processes (mainly food, pharmaceuticals and personal care products production). The main drawback is the high cost. In order to reduce this cost, liquid lipases can be used. But the available literature is scarce.

The purpose of the present study is to present the results of the optimization of an *in situ* enzymatic conversion of sewage sludge to biodiesel with the commercial liquid enzyme Eversa® Transform 2.0 (Novozymes) at a laboratory scale, and to propose a first economic assessment of the corresponding industrial process.

PULSE PROCESS: RECOVERY OF PHOSPHORUS FROM SLUDGE AND ITS PRODUCT QUALITY ASSESSMENT

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Keywords: leaching, reactive extraction, speciation model, quality assessment

In the framework of the Phos4You (P4Y) project funded by Interreg North West (NW) Europe 6 different Phosphorous(P)-recovery technologies will be demonstrated. The University of Liège is developing one of the processes, called PULSE (Phosphorus ULiège Sludge Extraction) process, to recover P from fully or partially dried sewage sludge. The PULSE process is a modification of the PASCH process developed at RWTH Aachen to extract P from sewage sludge ashes [1]. In the PULSE process P is recovered from partially or fully dried sludge using acidic leaching. Purification of the leach liquor will be carried out by reactive extraction to separate P and other nutrients from co-leached metals. Finally, depending on the leaching and extraction approach used above, the final product of the PULSE process can either be obtained as phosphate salt or phosphoric acid. Nevertheless, production of novel P products requires a novel standardized methodology for its quality assessment and valorisation on the market. In the first part of the research, the experiments for the unit operations of the PULSE process are conducted at lab-scale and metals, P and other macronutrient content in each step of the process sequence is monitored and benchmarked against the legislative limits. Comparison of the standardized sludge digestion method with nitric acid and/or *aqua regia* with modified sulphuric and hydrochloric acid will be conducted in order to establish a standard for sludge characterization especially for heavy metals determination. The data obtained for the different process options of each unit operation are evaluated using the methodology of 'Cascaded Option Trees' [2] to select the most feasible and optimum option. A solid-liquid equilibrium speciation model developed in MATLAB is further used for optimizing process parameters. In the second step, the PULSE process will be demonstrated on a pilot-plant scale at 4 different locations in NW Europe. The novel P product will be thoroughly analysed using quality methods selected by project partners responsible for quality assessment in the P4Y project for P availability and inorganic characterization, which provides feedback to the technology producer for improvement.

In the presentation, the concept of the PULSE process will be explained along with the results from the lab experiments and evaluation of process options. The concept of solid-liquid equilibrium speciation model and its application to optimize the PULSE process operation will also be presented. The relation between the quality of the P source and P product will be showcased. Further comparison of the quality of PULSE product with the regional and EU regulations on P fertilizers will also be presented.

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STRATEGY AND CONCEPT-APPROACH FOR THE RECOVERY OF PHOSPHORUS AT ONE OF THE LARGEST SEWAGE SLUDGE PRODUCERS IN GERMANY

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Keywords: waste water treatment, P-recovery, sludge strategy, phosphorus balance, concept approach

The Emschergenossenschaft (EG) and Lippeverband (LV) manage together as waterboards in combined administration approximately 60 wastewater treatment plants with a capacity of 7.2 million population equivalents. The EG and LV treat the wastewater of about 3.6 million people, and produce nearly 90.000 Mg DM/a sewage sludge, which must be disposed and recycled adequately. Due to the new German fertilizer regulation, the operators of the wastewater treatment plants are looking to re-position themselves strategically in order to meet all the standards.

The challenge for EG and LV is try to compensate the decrease in the use of sewage sludge in agriculture activities through thermal treatment capacities and to integrate the mandatory P-recovery from 2029/2032. For this purpose, the legislators have set a deadline to reach this proposition by the year of 2023. However, which market and technical possibilities for P-recovery exist? How is possible to integrate the different phosphorus recycling pathways into the sewage sludge treatment? How are the phosphorus recovered products introduced into the other value chains? All these questions are not trivial for many sewage sludge producers. Therefore, as one of the biggest disposal and sludge producers in Germany, EG and LV joined forces with other partners in Europe and created the project Phos4You (INTERREG-V B North West Europe) to answers all these questions.

Initially, a comprehensive basic evaluation was carried out which included the site-specific potentials, the logistics on sewage sludge treatment and the current pathways of sewage sludge use. Having done this work, future operational changes will need to be addressed and taken into consideration. Moreover, any existing operational influence (room for maneuvers) is as well taken into consideration. As mentioned before, the focus is set on the future strategy for sewage sludge disposal.

Nowadays, the market in Germany is quite volatile and many stakeholders are putting themselves into a position to ensure the mid-term disposal security for the coming years. The first concept approaches for P-recovery are based on the Phos4You technology demonstrators [1] and the study of different business cases. This presentation is intended to show the basic approaches, methods and tools to address the P value chain in the best-structured way.

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TOWARDS QUALITY CONTROL OF FEEDSTOCKS FOR BIODIESEL PRODUCTION: THE CASE OF URBAN SEWAGE SLUDGE

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Keywords: sewage sludge, lipids, feedstock analysis, biodiesel, quality control

In the context of the 2020 climate change and energy package adopted by the EU, the Directive 2009/28/CE establishes a mandatory target of at least 10% of renewable fuel in the transport sector. Biodiesel, one of the most promising renewable fuels, is obtained from lipid sources. At present, the main obstacle to its widespread production and commercialization is the need to use costly edible oil as feedstock, the cultivation of which competes with human food production.

Urban sewage sludge generated in wastewater treatment plants (WTTPs) is a low-cost lipid feedstock available in large quantities. Moreover, its management represents a major cost in WWTP operations. In Belgium, Walloon urban WWTPs produced around 49,000 tons dry matter (DM) of sludge in 2014 (Société Publique de Gestion de l'Eau (SPGE)). In this context, the aim of the project BioBoS (ISSeP, Belgium) is to develop an approach to produce biodiesel using sewage sludge as feedstock.

The purpose of the present study is to evaluate the potential of Walloon urban sewage sludge for biodiesel production by means of a detailed characterization, and to develop a quality control program to apply to feedstock before conversion. Indeed, although biodiesel quality control is standardized (EN 14214), it does not address any feedstock analysis. However, the need for such analysis clearly stems from the wide variety of lipids sources that can be used for biodiesel production. Moreover, as sewage sludge quality is bound to seasonal, climatic, geographical and processing variations, it has to be assessed to ensure biodiesel quality.

Sludge samples were obtained from Walloon urban WWTPs (from 17,500 to 446,500 population equivalent) using an activated sludge process with or without prior primary settling. A list of parameters is proposed for the characterization of sludge samples and of the extracted lipid fraction (Table 1). Parameter values were analyzed in order to compare primary and secondary sludge potential for biodiesel production.

Table 1. Parameters proposed for sludge samples characterization

Parameter	Sample status	Method	Reference
Dry Matter Content	Wet sludge	Drying	ISO 11465
Water content	Wet sludge	External dilution	Karl-Fisher
Lipid content	Wet sludge	Gravimetry	Internal method
Organic carbon	Dry sludge	Sulfochromic oxidation	ISO 14235
Free fatty acid content	Extracted fraction	Colorimetric titration	NBN EN ISO 660
Saponification number	Extracted fraction	Colorimetric titration	NBN EN ISO 3657
Fatty acid composition	Extracted fraction	GC after derivatization	Internal method

UTILISATION OF SEWAGE SLUDGE IN COMBINATION WITH RECULTIVATION OF DEGRADED LANDS FOR IN-SITU PRODUCTION OF A SOIL SUBSTITUTE

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Keywords: 5 keywords: recultivation, in-situ production, economical, the most greenest technologie, green energy

Our invention relates to the creation of a soil substitute functioning similar to a natural ecological system, which enables the simultaneous execution of recultivation activities and bio waste treatment. Substantial parts of bio wastes and sewage sludge can be treated together with a simultaneous reclaiming of the degraded lands. Furthermore, the method enables the cultivation of arboreal and herbaceous plants for energy producing purposes on a surface specified and developed in the technology, which improves the cost efficiency and ecological advantages of the method.

By means of biological recultivation, a new surface is developed instead of the earlier degraded surface, the soil substitute of which – in comparison with other methods – starts to function within a short time (2 to 3 years) as a soil system of high water storage capacity with a high humus and nutrient content. The soil substitute established meets the plant requirements imposed on natural fertile soils.

It provides a solution for biological treatment and for utilising wastes that can be used for stabilisation as well as in the utilisation of communal wastewater sludge generated by wastewater treatment plants.

It is a great advantage of this utilisation method in comparison with using sewage sludge in agriculture that it does not become part of the food chain, the treatment can be sustained and repeated without the involvement of an increasing number of new areas, and it does not represent a biological hazard to the general public. It also eliminates the risk of pathogen microbes and eventual drug and chemical residues in the wastewater sludge.

Instead of a fast decomposition of organic materials in the wastewater sludge and in the utilised biological wastes, organic mineral complexes are generaterd, which allows higher degree of utilization of energy and nutrients stored in the organic material. This also results in a decreasing CO_2 emission.

Contrary to prior art technologies, it avoids transport and movement of humus or other topsoil to be produced or extracted elsewhere, and thereby it can achieve substantial cost saving in the implementation of recultivation. It also avoids environmental burdens stemming from transport missions.

VALIDATION OF A PILOT SCALE BELT FILTER FOR SLUDGE DEWATERING

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Keywords: waste water treatment sludge, conditioning, dewatering, convective drying

In order to valorise wastewater treatment sludge, drying has become an essential step. Indeed, it improves the mechanical, hygienic and thermal properties of the sludge. Unfortunately, the different stages of the sludge process have a significant impact on drying performance. The liquid sludge comes out with a dry matter content about 1% and is then flocculated (sometimes assisted by a coagulant) to improve its sedimentation properties. Then it is dewatered to reach 20% dry matter thanks to press belt filters. Finally they are dried to reach more than 90%.

In a previous study [1], it was shown that drying performance could be improved by using a coagulant (PAX-14) and a cationic flocculant (HIB640) at a laboratory scale with a few grams of sludge. Since then, our research group is equipped with a pilot belt filter that allows to generate larger quantities of sludge in the laboratory with performances similar to those encountered in large scale wastewater treatment plants.

In this study, we will use the same polymers as in the previous work, i.e. HIB 640 which is a cationic cross-linked flocculant with high charge density often used in industry and PAX-14 which is polyaluminium chloride as coagulant. The conditioning is made online thanks to peristaltic pumps that inject and mix the different components. The belt filter is divided into two parts. The first one is a gravity drainage system that eliminates a large part of the free water. The second is the pressing area that compresses the sludge between two belts. These belts are wrapped around 5 rollers to optimize water extraction. The convective dryer is equipped with a measuring cell that can carry 1 kg of material and follows the loss of mass thanks to a weighting system to obtain the drying behaviour of the sample. Since sludge is a pasty material, it is first extruded into 10 mm diameter "spaghetti" to obtain a large exchange surface and a porous fixed bed. Moreover, the final sample is scanned by micro X-ray tomography to follow the modification of the internal structure of the sludge until the end of drying. First results indicate that the dewatering behaviour obtained with the pilot belt filter is in agreement with the real life performance; which promises a large number of future experiences. However, the influence of PAX-14 does not appear in the sludge dewatering efficiency with the belt filter pilot. This point needs to be further explored.

ACKNOWLEDGEMENT

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DEMONSTRATION OF A CONTINUOUS TORWASH® PILOT PLANT FOR SEWAGE SLUDGE TREATMENT

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Keywords: pilot, hydrothermal treatment, dewatering, biogas, pellets

Sewage sludge is a waste stream produced at urban wastewater treatment plants and is largely being disposed of by truck transportation and incineration. With existing technologies sewage sludge can be dewatered up to 22 wt.% dry matter which is quite low and therefore makes current method of disposal inefficient and unsustainable. ECN part of TNO has developed a hydrothermal treatment technology (TORWASH®) which is capable of improving the dewatering and the quality of sewage sludge as a fuel without the use of flocculants. Also, the mild thermal treatment conditions render the effluent digestible. Overall, TORWASH® can convert a wet waste stream that has no fuel value into gaseous and solid biofuels that can be used for the production of heat and power.

A continuous TORWASH® pilot plant at 50 L/h throughput was engineered, designed and constructed at ECN's facilities in the months January-June 2018. After functional testing, the pilot plant was transported and installed at the urban wastewater treatment facilities of the city of Almere in The Netherlands. Successful commissioning of the pilot plant was completed by August 2018.

The TORWASH® pilot was subsequently used within the framework of the Dutch subsidized project EnCore where tests were realized with sewage sludge, containing 3-6 wt.% dry matter. In this project, a pilot train (TORWASH® plant, filter press and effluent treatment) was installed on-site at the wastewater treatment facilities for the proof-of-concept. The sewage sludge after TORWASH® treatment was pressed into a solid cake containing 60-70 wt.% dry matter. This is in agreement with previously obtained results on lab scale and proves that the sewage sludge waste stream can be reduced by ~85%. Testing with the effluent treatment pilot showed that the chemical oxygen demand (COD) of the water stream could be converted by ~70% and the dewatered cake was pressed into pellets with a calorific value of 16-18 MJ/kg. The impact of this result is that the treatment of wastewater can become cheaper for citizens, and that wastewater treatment plants can become more sustainable by generating their own bio-based energy.

WET OXIDATION OF SEWAGE SLUDGE: A PROMISING TECHNOLOGY FOR SLUDGE MANAGEMENT

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Keywords: Wet oxidation, sludge, circular economy, hydrothermal treatment, waste recovery.

Sustainability, circular economy and environmental issues in appropriate waste management are taking great interest in recent years. Along these lines, the sludge management from urban or industrial wastewater treatment plants is one of the most complex challenges associated with wastewater management. It is estimated that by 2020 the generation of sewage sludge in Europe will exceed 13 million tonnes per year [1]. The need to develop economically viable technologies to tackle this problem is essential. Wet Oxidation emerges as a promising technology, not only in the technical aspect, but as an economically feasible option. Urban sludge contains everything from microorganisms and pathogens to toxic compounds and emerging pollutants. The technology proposes to maintain the liquid phase using pure oxygen at high pressure and temperature (above 200 bar and 300ºC, respectively), so that the C-C bonds of these molecules are destroyed [2], obtaining easily biodegradable low molecular weight molecules, such as short chain fatty acids (mainly acetic acid), CO_2 and H_2O, as it is shown in Figure 1.

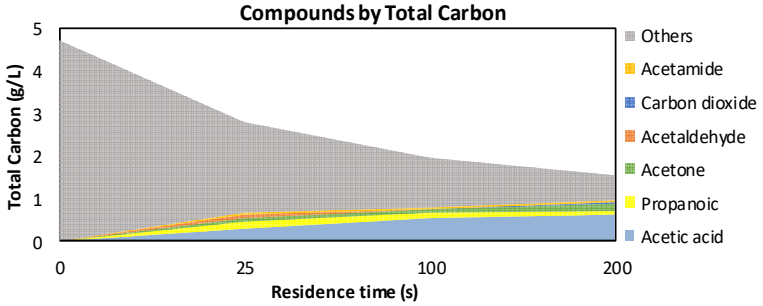

Figure 1. Compounds evolution based on total carbon.

Figure 2. Initial sludge vs treated sludge

This process requires in-depth research due to the high costs involved in scaling up and implementing a novel technology. The various effects of mass transfer, oxygen solubility, temperature, pressure, oxygen flow, residence time, as well as empirical kinetics have been analysed in the present study. In Figure 2, the difference between the original sludge (left) and the treated sludge (right) is shown as an example, in just a few minutes of reaction.

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CHARACTERIZING METAL CONTENT AND EXTRACTION POTENTIAL IN DOMESTIC SLUDGE – THE SUBLIMUS PROJECT

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Keywords: sludge, metals, precious metals, biolixiviation

This poster presents the first results of the SUBLIMUS project (BRIDGE2019-Innoviris). The objective of this project is to explore the potential of harvesting valuable metals (including precious metals like Au, Ag, Pt) present in urban wastewater treatment plant (WWTP) sludge. Although many recent studies point out the potential value of recycling metals from domestic sludges [1] [2] [3], the step towards an integrated industrial process has not been undertaken yet, mainly because of the sludge matrix complexity. Very first and explorative results of this project are presented here.

Firstly, various types of domestic sludge are analysed for their metal content and show that sludge is enriched in all metals and that highest contents are found in wet oxidized sludge (Techno-sand from WWTP Brussels North, Aquiris).

We then determined the mineralogical characteristics of Techno-sand and its "leachability" according to Tessiers' extraction protocol. Most metals are associated to silicate and phosphate minerals and are present in the most refractory remaining fraction.

Techno-sands were then used in a bioleaching experimental setup whereby the objective is to pre-clean the sludge matrix from the most abundant interfering metals (Cu, Zn, Pb, …). Various tests include the selection of appropriate bacterial strains and their acclimatization to the techno-sand matrix, the determination of optimal physicochemical conditions (pH, Temperature, …) for bioleaching, and the first evaluation of metal leaching efficiency in a bioreactor experiment.

After these very first investigations, future actions will concentrate on the optimisation of bioleaching techniques and the development of original methods to solubilize and selectively extract precious metals from solution. To be continued…

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APPLICATION OF PADDLE DRYERS FOR PIG MANURE DRYING: THE ANDRITZ EXPERIENCE

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Keywords: manure, sludge, thermal drying, paddle dryer

The Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources (the Nitrates Directive) aims to protect water quality across Europe by preventing nitrates from agricultural sources polluting ground and surface waters and by promoting the use of good farming practices [1]. The current limit of nitrates in water is 50 mg/L, what makes pig manure drying an essential step in manure processing.

In the present work, the application of a paddle dryer for pig manure drying is studied. The goal is to increase nutrients and organic matter concentration, reducing the volume for easier and cheaper transport, obtaining a dried, concentrated product with a moderate-high concentration of nutrients (N and P) [2].

The application of a paddle dryer for pig manure drying is proven to bring advantage to the thermal drying process. It is a continuous closed process, with product uniform treatment. The inertization is done via water evaporation, so no sweep gas is necessary. Another advantage of the paddle dryer is its small footprint, being much smaller than another types of dryer commonly used for sludge drying.

Tests with the Andritz Gouda Paddle Dryer (GPD) have shown that pig manure is suitable for drying with the GPD technology. For a drying purpose up to 15 wt % residual moisture, the results were satisfactory [3]. The produced amount of fines can be handled with a simple scrubber. The plastic phase, a critical problem in sludge drying process, did not cause instability in the process and the product encrustation was minimal. Further, the Andritz Gouda Paddle dryer safety concept, compliant with the ATEX directive, assures secure operation in pig manure drying.

For conclusive matters, this study presents a practical solution for pig manure treatment and compliance to the Nitrates Directive.

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OPTIMIZATION OF P RECOVERY FROM SEWAGE SLUDGE BY BIO-ACIDIFICATION

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Keywords: Phosphorus recovery, sewage sludge, struvite, bio-acidification

The increased demand for fertilizers and the rock Phosphorus (P) depletion has raised the awareness of the scientific community in the last decade, especially in Europe where the rock P is very limited. During this period, several European projects have been set up to find a sustainable solution for Phosphorus demand. The NEW Interreg project objective is to recycle and reuse the P from wastewater streams. The combination between IRSTEA's Bio-acidification/Bio-dissolution of P [1] and Veolia's STRUVIA process for P crystallization is studied to find an economical and environmental-friendly technology to close the P cycle.

In this study, the bio-acidification test using sugar/real Cosubstrate was studied, and compared to the chemical acidification and the biological P release of PAO, on the sewage sludge of a Wastewater Treatment Plan in north France. We also investigated the best location of the process in the WWTP line of treatment. The bio-acidification was studied on the sludge before and after the anaerobic digestion but with different Cosubstrate concentration; $0.5 g_{CODCosusbtrate}/g_{VM\ Sludg}$ before the digester to reach pH4.1, and $1 g_{CODCosusbtrate}/g_{VM\ Sludg}$ to reach pH 5 because of the high alkalinity of the digested sludge. The biological acidification allowed the dissolution of 40% of total P before anaerobic digestion and 37% after. The use of easily degradable Cosubstrates as a replacement for sugar gave similar results (pH=4.1) when the Cosubstrate was totally organic and for another Cosubstrate (VS=83% TS) the minimum pH obtained for the same Cosubstrate concentration was pH5.2. The acidification of the sludge to pH4.1 using hydrochloric acid permitted the dissolution of 40% and 58 % of P before and after the anaerobic digestion respectively. However the amount of acid added to the digested sludge to reach pH4 was two times more important than the amount used for the non-digested sludge.

This study have shown that the biological acidification of sewage sludge using easily degradable Cosubstrate is as effective as the chemical acidification for Phosphorus dissolution and is economically and environmentally more interesting. We also concluded that the best location to install this process is before the anaerobic digester to reduce the cost of the Cosubstrate and prevent the common problem of P precipitation in the digesters.

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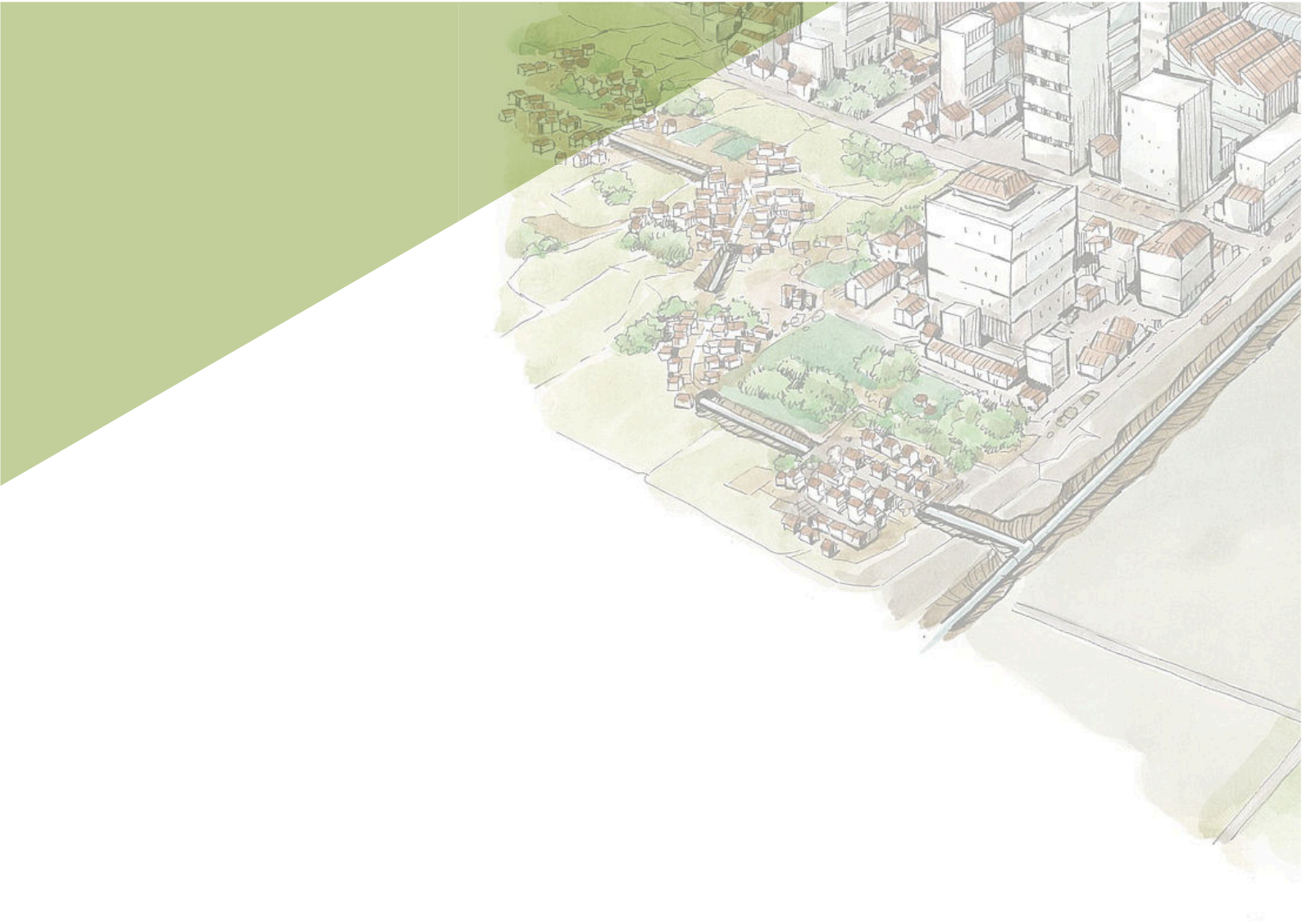

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