HYBRID WORKSHOP

Circular management of sludge and biosolids

CIRCULAR SLUDGE

8-9 November 2024 - Chania, Greece

https://circularsludge.gr/workshop

PROGRAM

09:00-09:10	**The concept of circular management of sludge and biosolids** Alexandros Stefanakis, Technical University of Crete, Greece
09:10-09:20	**DIALKOP project: optimization of Sludge Treatment Reed Beds for sludge treatment and reuse of biosolids** Ioannis Asimakoulas, Technical University of Crete, Greece
09:20-09:30	**DIALKOP project: production of biochar and compost from sewage sludge for agronomic applications** Panagiotis Regkouzas, Technical University of Crete, Greece
09:30-10:10	**Operational strategy, reuse of biosolids and environmental performance of Sludge Treatment Reed Bed systems based on 36 years of experience** Steen Nielsen, WSP Denmark
10:10-10:40	**Challenges, opportunities and pathways for circular management of biosolids in Australia** Glenn Dale, Verterra Ecological Engineering, Australia
10:40-11:00	Coffee break
11:00-11:20	**Constructed Wetlands for Sludge Treatment in Catalonia: technical insights, economic feasibility, and biosolids applications** Enrica Uggetti, Polytechnic University of Catalonia-BarcelonaTech, Spain
11:20-11:40	**Enhancing Fertility of Barren Soils: A Circular Economy Approach by Utilizing Biochar and Earthworms** Petros Kokkinos, Hellenic Open University, Greece
11:40-12:00	**Nutrient Mining: A Circular Food System for Sustainable Cities** Dominic Clyde-Smith, University College London, UK
12:00-12:20	**The Biosolids Observatory project** Hubert Brunet, EFAR, France

12:20-12:40	**Circular (Bio-)Economy: Perspectives and successful examples of bio-waste** George Banias, CERTH, Greece
12:40-13:40	Lunch break
13:40-14:00	**Nature-Based Solutions for Urban Wastewater and Sludges Treatment in Sicily, Italy** Alessia Marzo, University of Catania, Italy
14:00-14:20	**Hydrothermal Technologies for the Valorization of Waste: Theory and Applications** Stergios Vakalis, University of the Aegean, Greece
14:20-14:40	**Experiences with constructed wetland systems for sewage sludge dewatering in southeastern Poland** Krzysztof Jóźwiakowski, University of Life Sciences in Lublin, Poland
14:40-15:00	**Assessment of Compost Stability: Key Indicators for Sustainable Sludge and Biosolid Management** Christina Chroni, Harokopio University of Athens, Greece
15:00:16:00	**Round table** *"Reuse of sludge and biosolids: we know the benefits - can we overcome the barriers?"* trigger by Alexandros Stefanakis
Saturday 9/11, 10:00-17:00 **Site visits to the pilot facilities for sludge management at the (1) Wastewater Treatment Plant of Chania, (2) Waste Management Plant and Compost Facility of Chania,(3) Technical University of Crete campus**	

Project Coordination

ΠΟΛΥΤΕΧΝΕΙΟ ΚΡΗΤΗΣ
TECHNICAL UNIVERSITY OF CRETE

LABORATORY OF ENVIRONMENTAL ENGINEERING AND MANAGEMENT

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ABSTRACTS

Operational strategy, reuse of biosolids and environmental performance of Sludge Treatment Reed Bed systems based on 36 years of experience.

Steen Nielsen, *WSP Denmark*

Sludge Treatment Reed Beds (STRB) or Sludge Treatment Wetlands (STW) - A NATURE-BASED TECHNOLOGY - have been used for dewatering and mineralization of sludge from Wastewater Treatment Plants (WWTP) and Water Works (WW). A full-scale STRB system consists of multiple dewatering basins. Feed sludge is loaded into a basin, where solids are captured on the surface of the filter media. Long-term sludge reduction takes place in planted basins through a combination of dewatering (gravity draining, evapotranspiration) and mineralization of organic solids in the sludge. The pilot studies have been developed for design and dimensioning the STRB systems. A STRB operational cycle consists of four primary phases: (1) commissioning, (2) normal operation, (3) emptying and final disposal of sludge residue and (4) re-establishment of the system. During an operational cycle, the basins in the STRB are emptied in shifts to prevent a situation where all basins need to be emptied or commissioned at the same time. An operational cycle is completed when all beds have been emptied. Basins can receive sludge for 10 to 20 years; at which time it must be emptied. The dried biosolids would ideally be land-applied once removed. Treatment of sludge in STRB system provides substantial environmental, economic, and operational benefits compared to mechanical sludge dewatering solutions such as belt presses and centrifuges. STRB's require less energy, no chemicals, reduce sludge volume, reduce internal pollution, and produce biosolids with up to 20-40% dry solids content or possibly more, depending on the climate conditions and sludge quality.

Challenges, opportunities and pathways for circular management of biosolids in Australia

Glenn Dale[1,2,3,4], Laura McCallum[1], Mieke Elder[1,2], Peter Schulze[1], Belinda Whybrow[1] and Rusty Mark[2]

[1]Verterra Ecological Engineering. [2]BYV Organics Pty Ltd. [3]Queensland University of Technology. [4]University of Southern Queensland

Biosolids are a rich source of plant macro and micro-nutrients and organic carbon. Modern guidelines for beneficial use, closely following US EPA Part 503, were introduced in Australia in the year 2000. Over the same period, source control of sewer discharge has improved, and since 2010, direct beneficial use in agriculture of dewatered cake (typically 17 to 20% solids) has been the dominant management pathway. In 2023, 95% of biosolids were beneficial, with 88% used in agriculture.

However, although use in agriculture has been safely managed over the past 25 years, and dewatered biosolids are widely favoured by farmers as a cost-effective alternative to mineral fertiliser, often delivering superior crop productivity, direct use of dewatered cake is facing many emerging challenges, leading to the need to identify alternative management pathways.

With increasing population density in rural areas, odour is a growing issue. This, combined with the cost and emissions intensity of transporting high moisture content product over large distances (up to 300km) has directed research and development into processing dewatered biosolids via pathways such as controlled aerated static pile composting to eliminate odour, improve handling properties, reduce moisture and produce a value-added product.

However, increasing awareness and regulation of emerging contaminants such as PFAS is now limiting options to high-temperature thermal treatments, generally requiring energy intensive pre-drying.

In addition, proposed regulation for other emerging contaminants such as triclosan, galaxolide and microplastics is further challenging and limiting post sewage treatment plant processing options. In turn, regulatory uncertainty is leading to decision paralysis among water utilities faced with the need to make decisions about multi-hundred-million dollar plant upgrades and treatment process investments.

At the same time, the growing adoption of regenerative land management practices and increasing focus on improving soil health, set against the rapidly rising and volatile cost of mineral fertilisers is creating increasing demand for biosolids use in agriculture. In addition, new income opportunities are arising, with the world's first soil carbon sequestration project under a regulated carbon scheme, employing biosolids as the "eligible management activity", being registered in 2023.

The intricate web of biosolids management challenges being faced in Australia, opportunities being explored and likely pathways for future management will be discussed with reference to the experience of Verterra, BYV Organics and trends across the wider industry.

Constructed Wetlands for sludge treatment in catalonia: technical insights, economic feasibility, and biosolids applications

Enrica Uggetti, *Polytechnic University of Catalonia-BarcelonaTech, Spain*

Wastewater Treatment Plants (WWTPs) generate a substantial amount of sludge as a byproduct of the wastewater treatment process. Sludge Treatment Wetlands (STWs) have emerged as an effective, sustainable method for managing and treating this sludge, producing biosolids suitable for agricultural use. Over the past 20 years, more than 30 STWs have been constructed and operated in WWTPs across the Catalonia region of Spain, serving populations ranging from 350 to 3,500 population equivalent (PE). The growing interest in these systems arises the need for clear guidelines on their proper management, including feeding strategies, rest periods, and the application of the final product (biosolids). This study focuses on three key aspects: i) optimizing the final rest period, ii) conducting an economic comparison of different treatment scenarios, and iii) evaluating the potential applications of biosolids as soil amendments, biofertilizers, and biostimulants. The results related to the final rest period show that, in the Mediterranean Region, a 6-months of rest period starting in summer is optimal for STWs to produce biosolids with characteristics suitable for safe reuse as bio-based fertilizers. The economic study, conducted over a 20-year lifespan and comparing STWs and centrifuge-based systems for populations ranging from 500 to 10,000 PE, revealed that despite higher initial investment costs, STWs are the more cost-effective solution, with total costs ranging from €0.06 to €0.21 per cubic meter of wastewater treated. Finally, preliminary tests on the biosolids properties demonstrated their strong potential as soil amendments, biofertilizer properties comparable to compost or digestate (tested on radish, grass, and lettuce), along with the presence of phytohormones exhibiting biostimulant properties

Enhancing fertility of barren soils: a circular economy approach by utilizing biochar and earthworms

Ekavi Aikaterini ISARI[1], Charilaos Stefanou[1], Theofylaktos Sidiropoulos[3], Eleni Grilla[1], Petros Kokkinos[1], Konstantinos Komnitsas[2], Ioannis K. Kalavrouziotis[1]

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In recent years, the urgent need to improve soil fertility, combat desertification, and restore and safeguard biodiversity has become critical in the pursuit of environmental sustainability. BioCom project: “Improving the fertility of barren soils with the combined use of earthworms and biochar for the production of products of high nutritional and agronomic value. Application of technology in pilot stage.”, aims to promote research and the development of innovative practices in sustainable intensive agricultural production, through the application of technology at a pilot stage.

BioCom's work packages include: 1) the design, and test operation of a humification bioreactor pilot plant, 2) the production of biochars from different raw plant residual materials (olive branches and walnut shells), as well as from biosolids, through slow pyrolysis in the presence of inert N2 gas at temperatures of 300-400°C, and their evaluation as soil improvement materials, 3) the evaluation of barren soil mixed with biochar at the optimum rate in terms of toxicity for horticultural spinach cultivation in a greenhouse, 4) the full-scale bioreactor function: barren intensively cultivated soil samples containing biochars will be converted into fertile, through the biological action of earthworms (Lumbricus rubellus), 5) the evaluation of soil bioreactor material and the degree of humification of the biological process, 6) greenhouse assessment tests for the production of spinach, 7) the evaluation of the proposed technology: both the produced enriched soil and the cultivated spinach will be characterized, through different analytical techniques, 8) the techno-economic evaluation and market research to document the need of organic soil conditioners use.

The management of both agricultural waste and sewage sludge is currently problematic. The innovation of BioCom concerns the economic utilization of by-products (waste) and the organization of a cooperative scheme. Although biochar and earthworms have been applied for soil remediation, their combined application for improving soil fertility has not been holistically evaluated in the context of sustainability. Findings support that the simultaneous application of biochar and earthworms, can be a dynamic model for soil bioremediation.

Nutrient mining: a circular food system for sustainable cities

Dominic Clyde-Smith, *University College London, UK*

Urban regions face critical challenges such as limited land availability, energy shortages, importing of food with large ecological footprints, linear use of water and its nutrient leakage. The Food-Energy-Water (FEW) Nexus, which links these resources, is increasingly strained by linear systems of resource use that generate significant ecological and water footprints. Cities dispose of valuable nutrients embedded in organic waste streams, such as food waste, urine and biosolids, without harnessing their full potential. Anaerobic Digestion (AD) offers a means to recover energy from organic waste, but the nutrient-rich digestate typically has limited urban applications. This project seeks to address these issues by integrating AD with vertical hydroponic systems to create a circular, resource-efficient urban food system.

The research explores the potential of combining micro-scale AD, in-vessel composting, and gasification with vertical hydroponics to optimize nutrient recycling from biosolids. In doing so, it aims to close the nutrient loop within the urban FEW nexus. By leveraging the space efficiency of vertical farming, hydroponics allows the recovery and reuse of nutrients in cities, reducing the footprint of food production and contributing to sustainable urban resource management

A smart, decentralized system will be designed, incorporating advanced monitoring and AI-driven control algorithms to optimize nutrient flows, manage fluctuating environmental parameters, and minimize greenhouse gas emissions. The project will evaluate the system's performance at both laboratory and pilot scales, assessing its technical, environmental, social, and economic impacts. Additionally, it will explore the marketability of such systems in addressing key agricultural challenges, including the rising costs of fertilizers, climate change, and the need to reduce food miles.

The broader goal is to establish a Total Controlled Environment Agriculture (TCEA) system that integrates AD and hydroponics, offering a sustainable solution to urban food production. By reducing reliance on imported fertilizers and produce, such as soybeans, this project aims to enhance local food security, minimize environmental degradation, and contribute to the circular economy. The integration of AD and hydroponics presents an innovative approach to nutrient mining from waste streams, aligning with the United Nations Sustainable Development Goals (SDGs) and providing a model for future urban agriculture systems globally.

The Biosolids Observatory project

Hubert Brunet, *EFAR, France*

Biosolids land application is currently, and from far, the major route in the EU for sludge management. Indeed, this solution has many advantages such as nutrient recovery, carbon sequestration and the improvement of soil production capacity. Nevertheless, biosolids may contain contaminants from domestic, commercial and industrial discharges into the sewer system. Due to legitimate concerns regarding the protection of human health and the environment it is essential to have a recent and comprehensive overview of the biosolids quality at a European level. The purpose of the Biosolids Observatory is to collect, package, transport and analyse representative samples from a significant number of sewage treatment plants located in different EU countries. The resulting data can be used to feed risk assessment studies but also to better understand the potential impacts of the potential revision of the regulatory framework, notably the 86/278/EEC Directive.

Participants in the Biosolids Observatory can be local authorities responsible for wastewater treatment, operators of wastewater treatment plants or companies specialised in the treatment, storage and land application of biosolids. Public and private entities involved in biosolids land application are committed to supplying farmers a product that can be safely used as a fertiliser or soil improver. This requires a detailed knowledge of the biosolids composition. Testing the biosolids for a large scale of compounds will allow to identify if their concentrations are in a standard range or at a high level. It will therefore provide important information on the need for further source control measures to reduce potentially harmful or unwanted contaminants in biosolids.

The Biosolids Observatory project is currently in a development phase corresponding to the selection of the parameters to be analysed and of a partnering laboratory. If you are interested in receiving more information on the Biosolids Observatory project, please send an email with your contact details to: biosolidsobservatory@gmail.com.

Nature-based solutions for urban wastewater and sludge treatment in Sicily, Italy

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Nature-based solutions (NBSs) can be considered as effective methods for wastewater treatment, such as Constructed wetlands (CWs), and for sludges treatment, such as Sludge Treatment Reed Beds (STRBs). There is an increasing interest in utilizing constructed wetlands (CWs) for the treatment of urban wastewater, as this non-traditional water resource is gaining significance for irrigation purposes. Furthermore, sludge management is a key issue in urban wastewater treatment, due to large amounts of sludge generated and to complex and expensive solid waste management. The use of STRBs may provide an efficacy opportunity to manage the sludge. This paper describes the use of CWs and STRBs, combined with conventional system, as NBS for wastewater and sludge treatment in Scicli, a small rural community located in Mediterranean region (Sicily). Furthermore, the effects of urban wastewater treated in the constructed wetland system was evaluated on zucchini (*var. Sayonara.*) and lettuce (*Lactuca var. Flavius*) in a split-plot experimental design for each crop.

CW system is employed as a secondary treatment of a portion of urban wastewater, about 30 m^3/day, effluent form primary sedimentation unit of the conventional wastewater treatment plant. CW system is a hybrid CW system, and it is made of three units connected in series: a horizontal subsurface flow bed (HF1) is followed by a vertical subsurface flow bed (VF) and by another horizontal subsurface flow bed (HF2). All CW units have been vegetated with *Canna Indica*. Currently, the STRB is being supplied with effluent from the hybrid constructed wetland system. However, it will soon transition to receiving about 2 m^3/day of sludge from primary sedimentation unit. At the inlet and outlet of each stage of the hybrid CW, the following physicochemical parameters have been evaluated: total suspended solids (TSS), BOD_5, COD, total phosphorus (TP) and total nitrogen (TN). Microbiological parameters, such as *E. coli* were also evaluated.

The preliminary results have highlighted average of TSS, BOD_5, COD, TN and TP removal performance of about 86%, 84%, 79%, 45% and 69%, respectively. The microbiological reduction rates, reported as *Escherichia coli*, were 3.4 Ulog From the crop yield data and other biomorphometric parameters recorded and evaluated, it is possible to state that domestic wastewater treated by a CW system is suitable for agricultural use.

This research was funded by Agritech National Research Center and received funding from the European Union Next-GenerationEU (PNRR – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.4 – D.D. 1032 17/06/2022, CN00000022)

Experiences with constructed wetland systems for sewage sludge dewatering in southeastern Poland

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The study will present experiences from implementing constructed wetland systems for dewatering of sewage sludge generated during the treatment of domestic wastewater in rural areas in south-eastern Poland. The first pilot installation was built in 2014 and has been used for dewatering of sewage sludge collected in a primary settling tank, which provides mechanical treatment of wastewater from a 6-people household. The area of the sewage sludge dewatering bed is 24 m^2 and giant miscanthus is planted on the bed.

Many years of research have shown that this plant is resistant to droughts and effectively supports the process of sewage sludge dewatering. Another facility for sewage sludge dewatering was implemented at the largest in Poland hybrid constructed wetland wastewater treatment plant (Q=180 m^3/d) in Białka at the Bialskie Lake. In the applied technology, sewage from the primary settling tank with a capacity of 30 m^3 is dosed once a week to 4 constructed wetland beds with an area of 100 m^2 (each) and planted with common reed. Initial results of sewage sludge tests indicate that it does not contain excessive heavy metal contents and have a favourable chemical composition, which allows it to be used as a fertilizer in agriculture. The last installation was built in 2023 at the hybrid constructed wetland wastewater treatment plant in Zawadówka (Q=74 m^3/d). In this system, sludge from the primary settling tank is dewatered in 2 beds with an area of 50 m^2 (each) planted with common reed and 2 beds with an area of 50 m^2 (each) planted with giant miscanthus. Initial experiences indicate that much better sludge dewatering occurs in beds with giant miscanthus. This plant has also much better growth throughout the year and is more resistant to high air temperatures in the summer - especially during periods of drought.

Work is currently underway to prepare a pilot installation for dewatering of sewage sludge generated during the treatment of dairy sewage. The test system is planned to be built at the wastewater treatment plant (with activated sludge) from a dairy plant belonging to one of the most well-known companies in Poland involved in milk processing.

Assessment of compost stability: key indicators for sustainable sludge and biosolid management

Christina Chroni, Harokopio University of Athens, Greece

The Circular Economy necessitates a shift in waste prevention and management policies, promoting processes and attitudes that conserve natural resources and reduce the environmental impact of human activity. Within this framework, there is a growing demand for sustainable, nature-based treatment and processing of sludge and biosolids. Composting has emerged as one of the promising options to maximize benefits and minimize risks. A key prerequisite for this approach to reach its full potential is a clear understanding of compost quality assessment. A common method for evaluating compost quality involves measuring the presence of beneficial substances or, conversely, specific contaminants, as these analyses are relatively straightforward. An increasingly prominent approach, however, centers on the stability and maturity of the composting substrate. To establish reliable stability indices—both as indicators of product quality and process progression—a range of physical, chemical, and microbiological parameters have been monitored across diverse composting feedstocks and conditions.

This presentation will highlight the evolution variations in microbial activity, assessed via respiration rate (SOUR test) and δ15N signature during the composting of various organic mixtures, to evaluate their potential as stability indicators. To support these findings, stability evaluation in this study also includes specific physical and chemical parameters (temperature, pH, electrical conductivity, moisture, and volatile solid content) and quantification of bacterial populations (total bacteria, total coliforms, and antibiotic-resistant bacteria).

DIALKOP project
«Management and utilization of sewage sludge in the circular economy using green technologies and methods»

The project (acronym: DIALKOP) studies a modern model for the management of biological sludge resulting from municipal wastewater treatment based on the circular economy, testing and using sustainable technologies such as constructed wetlands, methods such as composting and biochar production, and practices such as reuse in agriculture and wastewater treatment, towards the beneficial conversion and utilization of this valuable by-product.

The main goal of the project is to study and present a modern, innovative and integrated model of circular management and utilization of the sewage sludge produced at the wastewater treatment plants, as an holistic environmental solution to the existing management problem based on the circular economy principles.

The aim is to study different technologies and alternative methods in terms of their technical efficiency and suitability to reduce the environmental footprint of sludge management and convert this by-product into a useful material and biosolids. The new materials that will result from the tested processes are also studied for their suitability and improvement they bring in various reuse applications (agriculture, wastewater treatment).

Furthermore, the purpose of the project is to conduct a holistic evaluation of the model and the individual processes and methods, based on a series of studies that take into account environmental, economic and social criteria, in order to determine the benefits arising from the proposed circular management model.

The research of the proposed circular sludge management model and the different technologies and methods are of particular interest for all involved partners (TUC, DEYACH and DEDISA). TUC as the research body and provider of know-how will utilize the project to implement the model on a larger scale in other regions of the country. It will also promote the results to members of the scientific community, further cementing the institution's position as a pioneer in the development of ecological technologies.

In addition, the staff of the two public benefit companies-partners will gain new experience in the application of the studied technologies and methods: DEYACH for the operation and performance of the Sludge Treatment Wetlands, and DEDISA for the possibility of co-composting sludge and plant biomass. For DEYACH, the problems have to do with the technical difficulties and the frequent breakdowns of the mechanical equipment, the high operating costs and the unsustainable nature of the current strategy, as the smaller WWTP choose to transport the sludge to central facilities over long distances. Mechanical dewatering methods provide an incompletely dried non-stabilized product, unsuitable for reuse, which is why it is sent to the Chania Landfill, burdening its operation.

The project is financed by the Green Fund of Greece in the framework of Priority Axis 3: Research and Implementation, of the funding program: "Natural Environment & Innovative Actions 2022".

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