



Info-package 3

Water Reclamation Operators

Fact Sheet 3.5 – Phosphorus recovery in water reuse.

Reclaimed water quality requirements

Contaminants of emerging concern

Potential Antibiotic resistance and health impacts linked to irrigation with reclaimed water

Key for success in Israel and Cyprus

Phosphorus recovery in water reuse

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This document is part of 5 factsheets in Info-package 3 addressed to water reclamation operators, that describe innovative methods to recover phosphorus from waste water, in its liquid and solid forms, for its use in agriculture.

INTRODUCTION

1. RichWater

The RichWater technology combines an efficient water treatment at low-cost, using a Membrane Bioreactor (MBR) with a mixing station for obtaining the optimal water and nutrients combination and a control system and monitoring with different water, plant and soil sensors. This combination allows offering a source of pathogen free water and in situ response to the watering demand and fertilization of each type of plant and soil. The Treat & Reuse MBR is designed to have a perm-selective membrane, which serves as a barrier that allows selective extraction of compounds from a wastewater stream. This characteristic allows the system to have in the effluent, or liquid phase, the highest possible concentration of Phosphorous and Nitrogen (Nitrate NO_3^-).

2. High Rate Algal Ponds (HRAP)

An alternative for taking the wastewater to the plants is to take the plants to the wastewater. Algal ponds and macrophyte wetlands are already in widespread use for wastewater treatment and if harvested, require less than one-tenth of the area to recover phosphorus, compared to terrestrial crops/pastures. The algal biomass grown to recover phosphorus from wastewater can be utilized in several ways such as, fertilizer or as a food source in its own right. Plant biomass also has the potential to be used in other added value products such as, human food supplements, cosmetics and extraction of high value cellular components, all of which applications represent a saving of mined phosphorus resources. However, these more specialized products generally require specific strains of algae to be grown, rather than the mixed cultures typically found in wastewater treatment systems.

3. Struvite production

Phosphorus is a key factor causing water eutrophication. On one hand, it is a non-recyclable, nonrenewable, and quite valuable resource. On the other side, the intensive livestock farming is a pillar industry in agricultural economy and an important way to increase rural incomes. However, it usually produces large amount of livestock wastewater containing high concentration of phosphorus. If this wastewater was not treated reasonably, it would not only lead to the pollution of water eutrophication, but also waste nonrenewable resources and would become one of the major contributors to phosphorus loss.

1. RichWater

1.1. Technology:

The MBR used in RichWater is a system of low energetic consumption designed for the treatment module of residual waters in a way that the nutrients (Phosphorous and Nitrogen mainly) stay even after the treatment, while the pathogens are purged (with a disinfection system). The mixing station receives an adequate combination of water and water coming from the MBR, which is transferred to the fertigation module (drip irrigation). The adequate level of mixture is determined via soil nutrient sensors. The main module is specifically designed for water treatment, which is composed of a MBR for low-cost water treatment and a disinfection system, which provide a pathogen free effluent. This technology had been developed after 5 years of research and it is specifically focused on trying to find an innovative water treatment plant destined to agricultural watering. RichWater's point of view allows to achieve meaningful water and fertilizer savings in agriculture. The water treatment plant operators using this system, will have the possibility to offer a new product to their potential clients: watering water rich in nutrients and free from pathogens. The farmers will have an ensured and constant water source, which in arid regions is highly beneficial. The implementation of the system in the agricultural production process supposes a more sustainable use of water resources, a saving in costs of fertilizers and water and the possibility for the fruit/vegetables producers to adjust the fertigation level depending on their concrete necessities using a mixture of water and treated water:

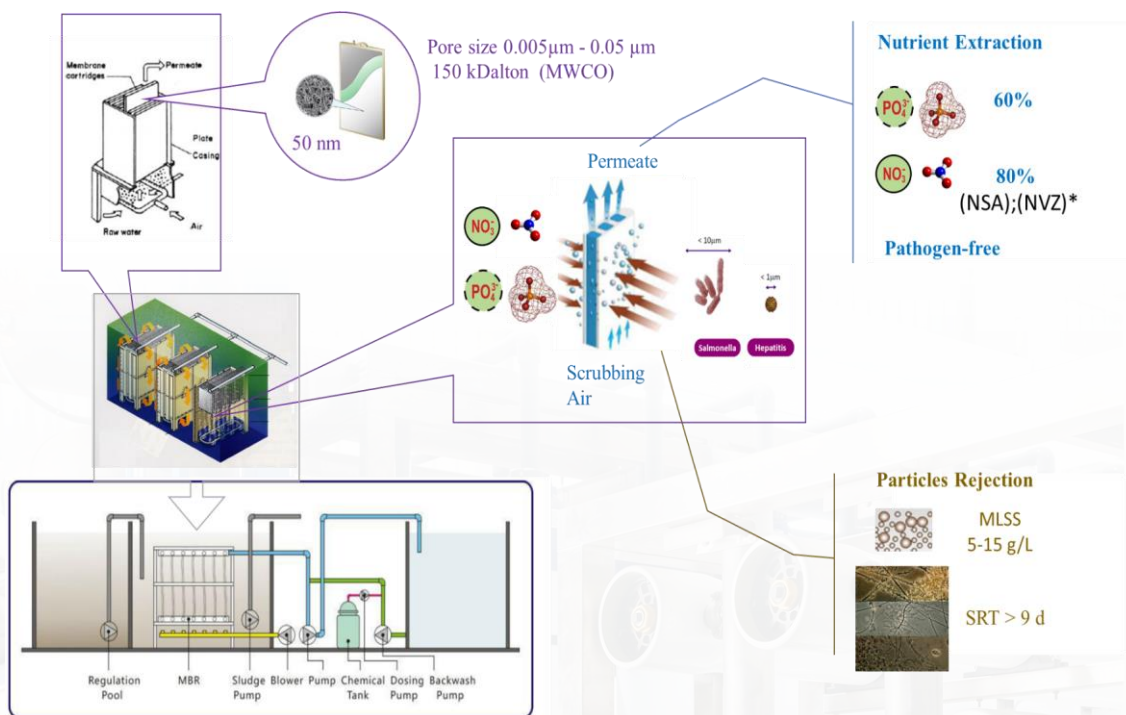


Figure 1: MBR system's functioning diagram

*Denitrification required in Nitrate Vulnerable Zone (NVZ) based on European Legislation limit of 50mg/L Nitrate (N).

1.2 Application in phosphorous recovery

Phosphorus is present in both organic and inorganic forms in municipal wastewaters. The typical generation of phosphorus in wastewater is 2.7-4.5 g/capita/day. The majority of phosphorus in municipal wastewaters is present as phosphate (PO_4^{3-}) which is soluble. The Treat Reuse MBR is designed to have a perm-selective membrane, which serves as a barrier that allows selective extraction of compounds from a wastewater stream [i.e., pore size 0.005µm and 0.05µm and molecular weight cut off (MWCO) of 150 kDalton]. This characteristic allows the system, to have in the effluent, or liquid phase, the highest possible concentration of Phosphorous and Nitrogen (Nitrate NO_3^-) due to extraction; experimental and practical results around 50-60% of phosphate in liquid phase after T&R MBR shows that the phosphate size (PO_4^{3-}) is smaller than the molecular weight cut off (MWCO) of membrane.



THIS PROJECT HAS RECEIVED FUNDING FROM
THE EUROPEAN UNION' HORIZON 2020 RESEARCH
AND INNOVATION PROGRAMME
UNDER GRANT AGREEMENT N. 818088



2. High Rate Algae Ponds (HRAP)

2.1. Technology:

HRAP system generally consist of three main parts: a primary settler, a shallow raceway or pond where microalgae grow and wastewater treatment is carried out, and a harvesting unit to recover the biomass and separate it from the water. Therefore, there will be two outlet lines, one for the clarified, treated water and the second for the biomass. The pond itself consists of an external and central wall, two raceways and reversals, and a paddlewheel, which makes the water flow to homogenize the mixed liquor, thus it all receives the same solar irradiation, and avoid microalgae culture settling as well. The HRAP system is divided in two independent ponds of 335 m² each, HRAP-1 and HRAP-2, working in parallel. They have 4 m of channels with 20 cm width walls. Both ponds have two baffles at the reversals and a tear (i.e., Turning vane) constructed in both ends of the central wall, in order to improve the hydraulic flow. Water depth is set to 30 cm, so that the total volume is 200 m³. The system operates under a hydraulic retention time (HRT) of 4 days, which could be optimized and modified depending on the results. Following this HRAP, each pond will be fed with 25 m³/day by means of two centrifugal pumps.

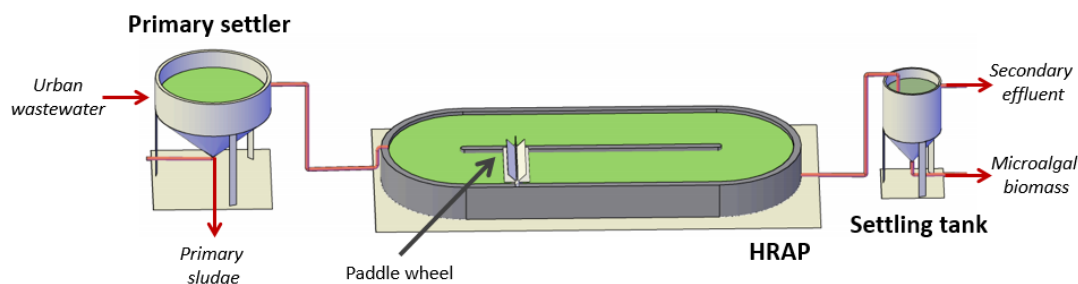


Figure 2: Picture of an HRAP montage

2.2. Application in phosphorous recovery

As we look out to a phosphate scarce future, algal based phosphorus recovery could significantly expand offshore. Around the world, there are massive discharges of wastewater directly to seas and oceans. Thus, installation of booms to form offshore floating pond systems around the naturally buoyant discharges from wastewater outfalls has been proposed. Optimizing for algal growth and harvesting from offshore systems may even present superior economics to 'on shore' algal cultivation, due to the absence of the highly significant land cost component. It has been shown that algal biomass can retain stored phosphorus for some days. Furthermore, with regard to its fertilizer potential, seedling growth using dried algal biomass was compared to commercial fertilizer and it has shown a growth at comparable levels. However, overall these issues from harvest to application, they are currently quite poorly covered by the literature for algae. Algae have been identified as making a good supplementary livestock feed, such as for chickens, due to their high protein content.



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3. Struvite production

3.1. Technology

Using the water from the first phase, it enters the CO₂ stripping unit, where the airflow eliminates the CO₂ from the water. This water is then transported to the struvite reactor, where it will be mixed with NaOH and MgCl₂, by mixing the phosphorous containing water with the NaOH and the Magnesium, the precipitation of struvite is forced. This struvite is transported to the settler with the water, where it will be separated, allowing the clear water to continue the treatment and collecting the struvite inside the settler.



Figure 3: Struvite production montage

3.2. Application in phosphorous recovery

The intensive livestock farming produces massive wastewater with high concentration of phosphorus. The discharge of these compounds to surface water not only causes water eutrophication but also misuses the phosphorus resources for plant growth. Therefore, it's necessary to combine the removal of phosphorus from livestock wastewater with its recovery and reuse as fertilizer. As a valuable slow-release mineral fertilizer, struvite production has become a focus in phosphorus recovery. It is reckoned that 100 m³ wastewater could form 1 kg of struvite. If all the wastewater in the world is treated for struvite production, 63,000 tons of P₂O₅ could be recovered, equaling to 16% of the phosphate rock production of the world. Additionally, 171 g of struvite per square meter can be recovered from livestock wastewater at most and the purity as high as 95% without washing. Therefore, recovery of struvite returning to the farmland is a developmental trend of struvite recovery technology.

Reference/further readings

1. Shilton, A. N., Powell, N., & Guieysse, B. (2012). Plant based phosphorus recovery from wastewater via algae and macrophytes. *Current opinion in biotechnology*, 23(6), 884-889.
2. Zhang, T., Jiang, R., & Deng, Y. (2017). Phosphorus recovery by struvite crystallization from livestock wastewater and reuse as fertilizer: A review. In *Physico-Chemical Wastewater Treatment and Resource Recovery*. InTech.

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THE EUROPEAN UNION' HORIZON 2020 RESEARCH
AND INNOVATION PROGRAMME
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