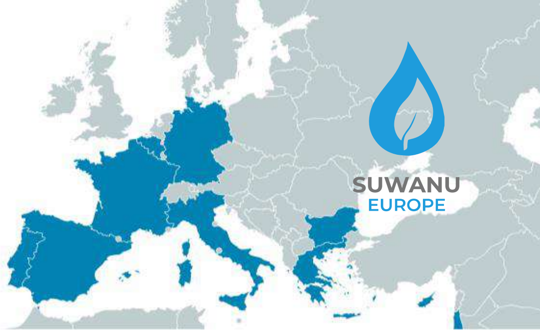
Sustainable **Water treatment** and
Agricultural reuse options in Europe



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 factsheet is part of a total of 5 factsheets in Info-package 3 aimed at water reclamation operators, that describe innovative methods to recover phosphorus, in its liquid and solid forms, from wastewater for its later 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 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 $NO3^{-}$).

2. High Rate Algal Pounds (HRAP)

An alternative for taking the wastewater to the plants is to instead 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 for a 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 the other hand, it is also 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 consume 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 gets 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 by a MBR for low-cost water treatment and a disinfection system, which provide a pathogen free effluent. This technology has 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 for water and fertilizer saving 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:

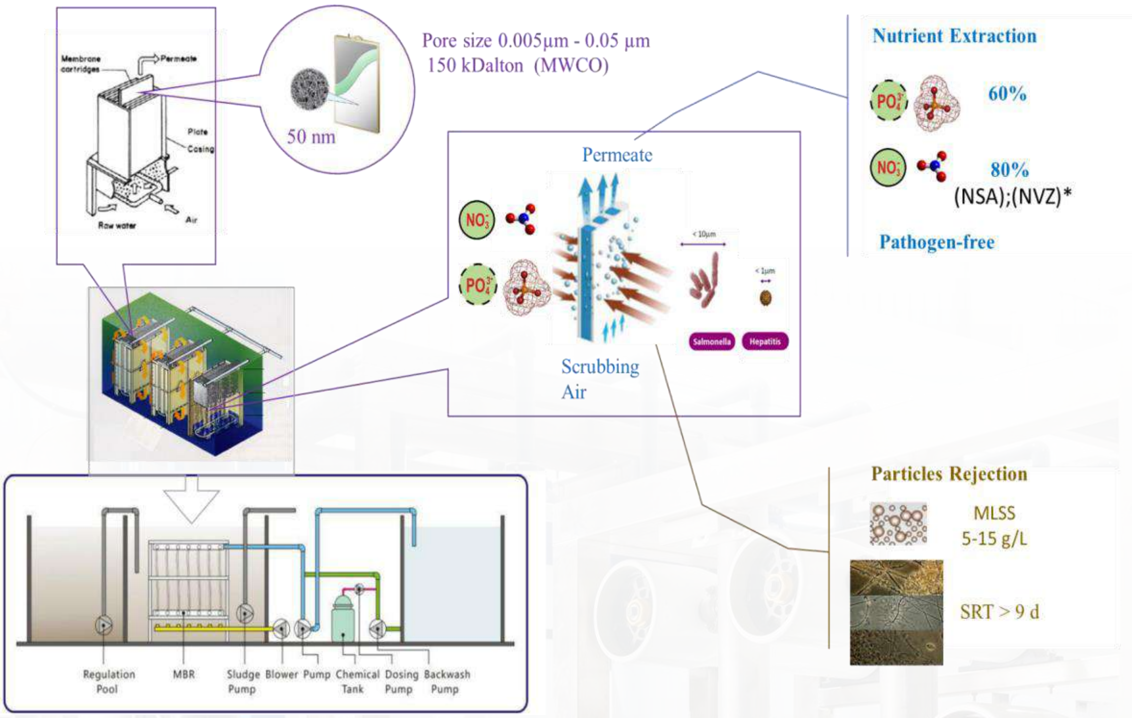


Figure 1: MBR system's functioning diagram

****Denitrification required Nitrate Vulnerable Zone (NVZ) 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 (Pore size around 0.005µm and 0.05µm and 150 kDalton. molecular weight cut off (MWCO)). 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.

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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 in order to homogenize the mixed liquor, so that it all receives the same solar irradiation, and to avoid the microalgae culture settling as well. The HRAP system is divided in two independent ponds of 335 m^2 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 constructed in both ends of the central wall, in order to improve the hydraulic behavior. Water depth is set to 30 cm, so that the total volume is 200 m^3. 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 m^3 /day by means of two centrifugal pumps.

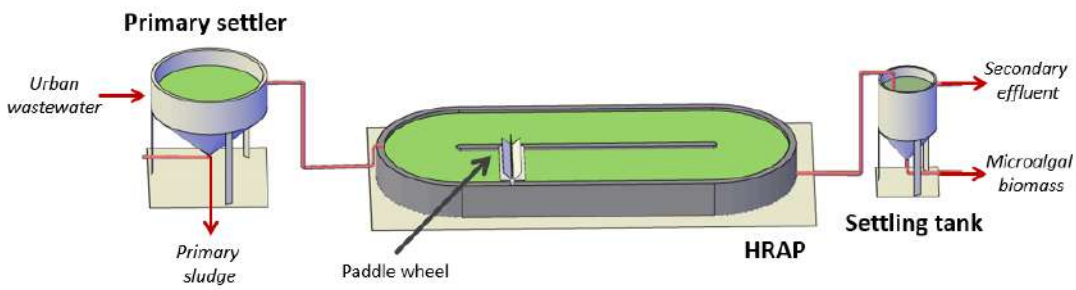

***Figure 2: Picture of*an HRAP montage**

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 has been compared to commercial fertilizer and it has shown a growth at comparable levels. However, overall these issues from harvest to application 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 will eliminate the CO_2 from the water. This water is then transported to the struvite reactor, where it will be mixed with NaOH and $MgCl_2$, 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: Sruvite production montage

3.2. Application in phosphorous recovery

The intensive livestock farming produces massive livestock wastewater with high concentration of phosphorus. Discharge of these compounds to surface water not only causes water eutrophication but also wastes phosphorus resources for plant growth. Therefore, it's necessary combining 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 by struvite production, 63,000 tons of P2O5 could be recovered, equaling to 16% of the phosphate rock production of the world. And 171 g struvite can be recovered from livestock wastewater per square meter 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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