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WATER FOOTPRINT OF A DECENTRALISED WASTEWATER TREATMENT STRATEGY BASED ON MEMBRANE TECHNOLOGY

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INTRODUCTION

In recent years, the consumption of water and energy resources has increased significantly, which suggests that this trend will continue in the coming decades. Water reuse can help increase available water resources by recovering internal water from the anthropogenic cycle while avoiding the use of freshwater from the natural cycle [1]. However, it should be noted that wastewater reclamation can be complex, costly and resource-intensive due to the combination of advanced treatment processes to achieve the required effluent quality. Also, certain environmental indicators could be negatively affected by the selected advanced treatment system [2]. Water availability per capita per year in Turkey is about one-fifth of that of water-rich countries, being lower than the world average [3]. Therefore, Turkey must improve water availability in order to improve the quality of life of its population, since the results of various studies estimate that by 2023 the amount of water available will be less than 1,000 m^3/(inhab·year). With this perspective, the reuse of wastewater for irrigation purposes in Turkey has been approached with untreated or partially treated wastewater or after mixing with river water. In recent years, the implementation of membrane bioreactor (MBR) technology in wastewater treatment plants is mainly due to the advantages it offers such as compact and simple design, adequate control of biomass, high hydraulic efficiency, the possibility of increasing treatment capacity, as well as the high quality of the effluent [4,5]. Finally, the MBR system allows direct use of the effluent for reuse (e. g. irrigation of agricultural land or recharge of aquifers [4]. The selection of the most appropriate membrane technology based on submerged, hollow fibres or flat sheet systems, should be made in terms of technical feasibility and the environmental impact associated with its implementation and operation. To do so, one of the most outstanding tools is the Life Cycle Assessment (LCA), which has been described by ISO 14040 standards. The current life cycle inventory only provides the volume of freshwater used with limited information on its origin (resource type) and none on its destination (volume, quality and point of discharge) [6]. The ReCiPe methodology in LCA is currently the only one that presents the "freshwater depletion" indicator that simply expresses the total amount of water used and for which no standardisation factor is available. Beyond the conventional impact categories included in LCA, it would be advisable to complement any life cycle analysis with the quantification of all the potential impacts derived from water use [7]. The main objective of the study is the environmental assessment of a rotary vacuum MBR system, located on the university campus of METU (Ankara, Turkey), accounting for the water reused as an environmental benefit on the footprint of water scarcity, using the AWARE methodology. In particular, the interest of this study lies in describing the environmental performance of the reuse of treated water for irrigation of the green areas of the campus.

DESCRIPTION OF THE MBR FACILITY

The technological solution for biological wastewater treatment is a submerged rotary membrane vacuum bioreactor designed for a capacity of 2000 hab-eq [8,9]. The plant consists of two tanks and several peripheral equipment (Figure 1). The two tanks are divided by a wall, which in turn connects the two tanks through five holes at the bottom of the wall that separates them. The volume of the first tank is 85 m^3 and is used for sludge aeration (biological treatment). The second tank is 23 m^3 and is used to house the membrane unit. The wastewater from the residence halls and the academic area is collected in a 10 m^3 storage tank and pumped to the treatment plant. At the inlet of the aeration tank, a screw-type sieve separates wastewater from materials larger than 3 mm.

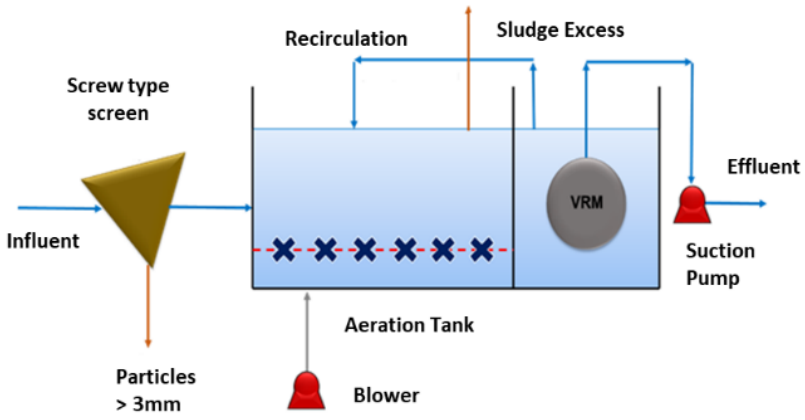

Figure 1. Flow diagram of the water treatment plant with the membrane unit.

Membrane modules are made of polyether-sulfone (PES) and are characterized by their flat type with a pore size of 0.038 µm and a total surface area of 540 m^2 [8,9]. There is the membrane support which is driven by an electric motor that gives the rotation speed to the filter support unit, creating a cross-flow on the surfaces of the membrane modules together with a coarse aeration from the bottom of the modules.

RESULTS AND DISCUSSION

The functional unit is the quantitative reference against which the results of the environmental profiles are presented. Based on studies that consider the reuse of treated wastewater [10,11], the functional unit is defined as 1 m^3 of treated wastewater. Previous studies of conventional treatment plants have determined that the environmental impacts of the construction and dismantling phases are lower than those of operation and maintenance [10,12] with a contribution of around 25-35% of the total impact in certain impact categories, such as global warming potential [13]. In this case study, the construction phase of the plant will be included, since it may be an important parameter to be taken into account in decentralized systems and MBR systems on an industrial scale. The AWARE methodology indicates the remaining water available in a river basin relative to the world average, after meeting the demands of humans and aquatic ecosystems (1/AMD). What is being assessed at this point is the water scarcity footprint, i. e. the potential for water deprivation to other users, regardless of who is using it, in a given geographical area, Turkey. To date, no work has been published applying the AWARE methodology for assessing the water scarcity footprint to wastewater treatment systems. Other methodologies have been applied to determine the water footprint, such as ReCiPe, but they have limitations. For example, in the study by [14], they consider desalination of seawater, which had a benefit in this category, since seawater is not considered an infinite water source and therefore its consumption has no impact. Therefore, centralized systems that do not have water reuse have a greater negative effect than decentralized systems that reuse water, as they involve an increase in the exploitation of freshwater resources. Table 2 shows the results obtained for assessing the water footprint of the MBR system. As was the case for the other impact categories, the construction of the plant infrastructure and the electrical consumption during the operation of the plant are the stages that imply greater water consumption and therefore an increase in the water footprint. On the other hand, the reuse of treated water to irrigate the green areas of the university campus led to a negative water footprint, in other words, we are avoiding depriving other users of 48.31 m^3 of water per m^3 of treated water. If treated water were not to be reused, the water footprint would increase to a value of 7.50 m^3 of water equivalent.

Table 2. Evaluation of the water footprint, using the AWARE method, of an MBR system with decentralized strategy

PROCESS	m^3 world eq
NaOCl (15%)	$5.65\cdot10^{-4}$
Cationic polyelectrolyte	$3.07\cdot10^{-4}$
NaOCl Transport	$5.84\cdot10^{-6}$
Sludge Transport	$2.90\cdot10^{-3}$
Plant Infrastructure	5.07
Membrane Construction	$4.09\cdot10^{-3}$
Electricity for Aeration	1.36
Electricity for the Membrane	1.04
Electricity for the Centrifuge	$2.03\cdot10^{-3}$
Irrigation reuse	-55.81
Incineration	$2.08\cdot10^{-2}$
Reuse	-48.31
Non-reuse	7.50

CONCLUSIONS

The construction phase of a decentralized strategy plant based on Membrane Bioreactor technology acquires importance in the impacts associated with the analyzed categories of global warming, eutrophication potential and water footprint, which were typically considered negligible in the accounting of the impacts associated with energy consumption during the operation of an MBR. The reuse of treated water represents a considerable improvement in the water footprint of the process according to the AWARE category. The construction phase is the disadvantage of the decentralized system, but it also allows the reuse of treated water and improves the water potential of a country at risk of water shortage.

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