Implementation of microalgae-based recovery facility to improve circularity in urban wastewater treatment

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Highlights:

- **Climate change and its relationship with water availability.**
- **Current European legislation on minimum requirements for water reuse and updated legislation on wastewater treatment.**
- **Effluent treatment based on microalgae has shown promising results.**

Keywords: Wastewater treatment; microalgae; circular economy

INTRODUCTION

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The effect of the climate crisis on the world is becoming increasingly evident. One of the consequences of this phenomenon is water scarcity (IPCC, 2023). The wastewater sector in Europe is going through an important transition period with the recently approved Regulation (EU) 2020/741 dealing with minimum requirements for water reuse and the update of the Wastewater Treatment Directive 91/271/EEC (under development). To meet these new requirements and improve their energy and environmental efficiency, wastewater treatment plants (WWTPs) need to be upgraded and operated as water resource recovery facilities (WRRFs). Recently, the integration of microalgae cultures in the wastewater sector has increased considerably due to their promising results in nutrient recovery, pollutant removal and because they are considered a sustainable treatment. Moreover, algal biomass is a sustainable source of a variety of organic compounds that can be used as biofuels, biofertilizers and others. Each sewage's characteristics can influence microalgae growth significantly due to variable nutrient concentrations, nitrogen species, presence of toxics, competition with bacteria, etc. Concerning economic aspects, selecting the most appropriate sewage stream could improve process

performance using less capital and operational expenses. The overall aim of this study is to assess the feasibility of different alternatives for combining microalgae cultivation with conventional activated sludge systems and to implement the most suitable option on a pilot scale.

METHODOLOGY

The study compared the operating expenses (OPEX) related to the facility's energy demands, reagent use and sludge production in four theoretical scenarios. Scenario 0 consists of the normal winter operation of an activated sludge (AS)-based WWTP located in the city of Falconara Marittima, Italy. This Scenario 0 was simulated using DESASS® software (IIAMA - DESASS (upv.es)) and real data from this WWTP. It was then compared to three other different scenarios, in which the AS system was theoretically coupled with microalgae cultivated in raceway pond (RW) for treating different sewage flows: primary effluent (*Scenario 1*), secondary effluent (*Scenario 2*) and centralized (*Scenario 3*). The performance of the microalgae was simulated using data from the literature (data not shown). A pilot-scale microalgae cultivation system was also implemented, consisting of a 1.25 m^2, 10 cm deep RW tank. It was operated for 70 days feeding the primary effluent at a variable hydraulic retention time (HRT) in the range of 2.5 to 4.5 d.

RESULTS AND CONCLUSIONS

Scenario 1 appeared as the most suitable option, showing significant percentages of reduction in energy demand (28%), chemicals (50%) and sludge production (25%). This is the only Scenario that would also reduce the hydraulic loads fed to the sludge reactor, as the influent flow would be divided between microalgae and AS system, whereas the other Scenarios correspond to post-treatment of effluents from conventional secondary treatment.

Regarding the pilot RW, it was able to remove nutrients below current European legal discharge limits for mid-size WWTPs during most of the period, except at the end of the study, when increasing nitrogen and phosphorus loading rates hindered the microalgae culture to accomplish these treatment goals (Figure 1). This was related to a slow response of the feed control system, which is going to be improved in the next pilot studies for achieving the appropriate quality in the effluent at long-term.

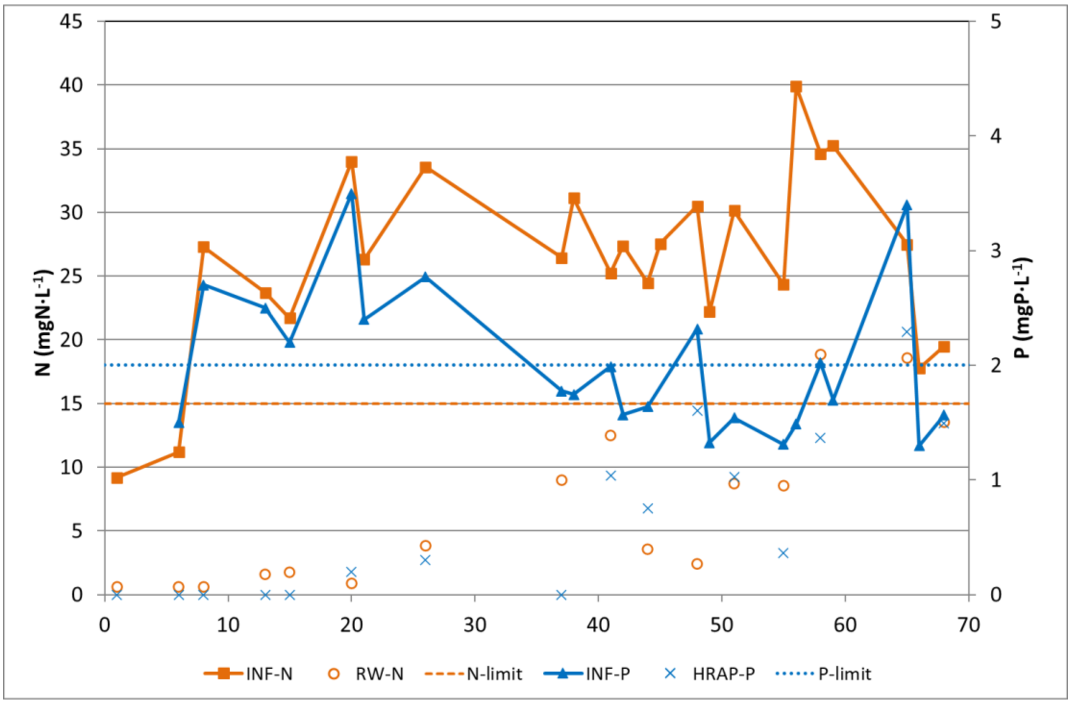

Figure 1 - Nutrient concentrations during the continuous operation of the pilot-scale HRAP

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