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Glocal assessment of integrated wastewater treatment and recovery concepts using partial nitritation/Anammox and microalgae for environmental impacts

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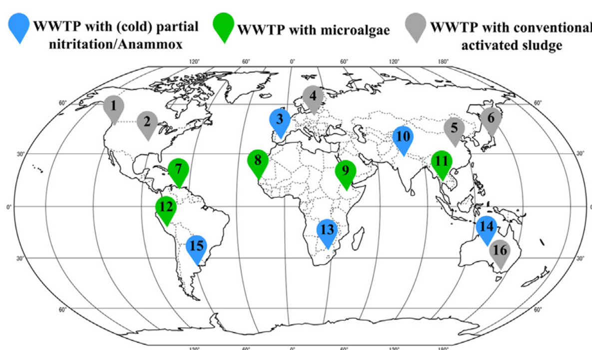
HIGHLIGHTS

- Applicability of new wastewater treatment concepts is strongly location dependent.
- Microalgae post-treatment is suitable for large scale plants in tropical climates.
- Microalgae have potential for resource recovery, but the area requirement is high.
- Feasibility of microalgae treatment mainly depends on the wastewater composition.

GRAPHICAL ABSTRACT



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ABSTRACT

This study explored the feasibility and estimated the environmental impacts of two novel wastewater treatment configurations. Both include combined bioflocculation and anaerobic digestion but apply different nutrient removal technologies, i.e. partial nitritation/Anammox or microalgae treatment. The feasibility of such configurations was investigated for 16 locations worldwide with respect to environmental impacts, such as net energy yield, nutrient recovery and effluent quality, CO_2 emission, and area requirements. The results quantitatively support the applicability of partial nitritation/Anammox in tropical regions and some locations in temperate regions, whereas microalgae treatment is only applicable the whole year round in tropical regions that are close to the equator line. Microalgae treatment has an advantage over the configuration with partial nitritation/Anammox with respect to aeration energy and nutrient recovery, but not with area requirements. Differential sensitivity analysis points out the dominant influence of microalgal biomass yield and wastewater nutrient concentrations on area requirements and effluent quality. This study provides initial selection criteria for worldwide feasibility and corresponding environmental impacts of these novel municipal wastewater treatment plant configurations.

1. Introduction

Municipal wastewater is commonly treated by conventional activated sludge (CAS) systems. However, these CAS systems cannot be considered sustainable because most of the organic matter is aerobically

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mineralized and the treated water is not reused. Moreover, a cost-effective technology that can recover valuable nutrients, such as nitrogen (N) and phosphorus (P), from dilute wastewater streams still remains a technological challenge. Therefore, in recent years new municipal wastewater treatment plants (WWTPs), which combine treatment with recovery of these resources (Fernández-Arévalo et al., 2017; Khiewwijit et al., 2015b; McCarty et al., 2011) were proposed. In addition, a mathematical programing based optimization framework/criteria was also developed to manage the complexity of the design problems for a new WWTP (e.g. Bozkurt et al., 2015; Hauduc et al., 2015; Chhipi-Shrestha et al., 2017a; Chhipi-Shrestha et al., 2017b). Numerical simulation, based on literature information and experimental data, can be used to assess the feasibility of such novel treatment and recovery concepts. Khiewwijit et al. (2015b) used this approach to evaluate two novel WWTP configurations (Fig. 1A) that have the potential to maximize energy and phosphorus recovery under Dutch conditions. They also compared these configurations to the CAS system (Fig. 1B).

Given the composition of the wastewater, light intensities and temperatures at different locations around the world, each of these two configurations can be evaluated with respect to their impact on the environment. More specifically, the effluent of a WWTP with remaining N, P and chemical oxygen demand (COD) is an input to the receiving water body, e.g., a lake, river or canal, thus affecting the water quality of the surrounding environment of the WWTP (see, e.g., Wang et al., 2017). Furthermore, the CO_2 emission from the WWTP, as a result of the oxidation of organic matter in the wastewater and other steps in the wastewater treatment, contributes to greenhouse emissions (Bridle, 2007; Snip, 2010; Das, 2011; Gupta and Singh, 2012).

In this study, given the local conditions of a WWTP in terms of hydraulic and organic load, light and temperature, we aim to find a configuration that not only reduces the negative pollution effects of municipal WWTP's on the environment, but also recovers nutrients and energy to a large extent. The calculated mass and energy flows can subsequently be used as fluxes through the boundaries of a WWTP to evaluate the local effects of WWTP's on the surrounding environment.

For instance, in Configuration 1 (Fig. 1A), the diluted organic matter in municipal wastewater, after screening and grit removal, is concentrated by a bioflocculation process (Faust et al., 2014). In experiments reported by Khiewwijit et al. (2015a), it was found that bioflocculation in a high-loaded membrane bioreactor (HL-MBR) could concentrate

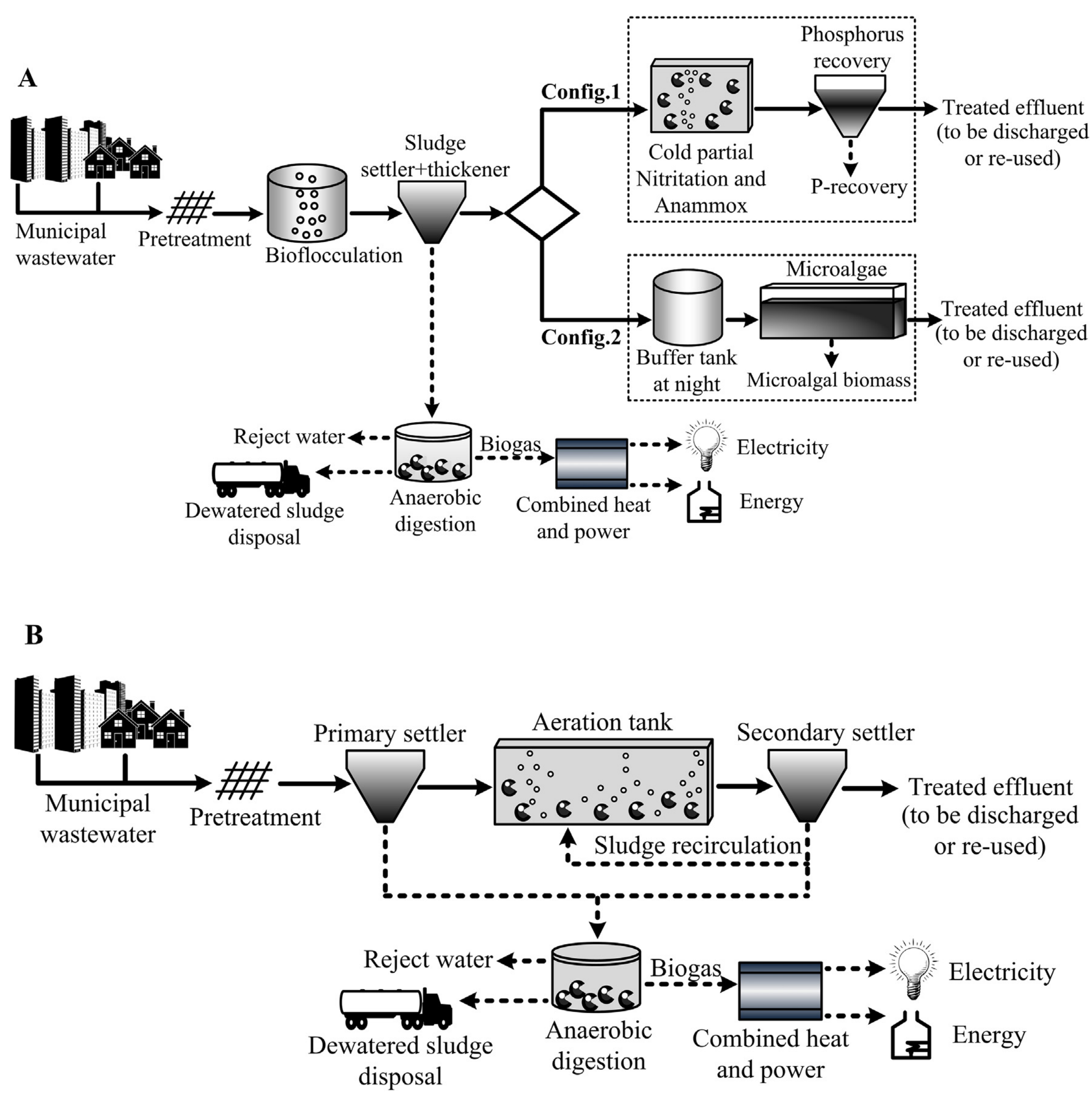

Fig. 1. (A) Two novel configurations for municipal wastewater treatment, suggested by Khiewwijit et al. (2015b), and (B) the CAS system. Solid lines indicate processes of the mainstream treatment and dashed lines indicate processes of the downstream solids treatment. ◇ is a decision block.