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Piggery wastewater treatment by solar photo-Fenton coupled with microalgae production

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ABSTRACT

Pig farming generates highly polluted wastewater that requires effective treatment to minimize environmental damage. Microalgae can recover nutrients from piggery wastewater (PWW), but excessive nutrient and turbidity levels inhibit their growth. Solar photo-Fenton (PF) offer a sustainable and cost-effective pretreatment to allow microalgal growth for further PWW treatment. This study optimized the concentrations of PF reagents to minimise water and nutrient inputs while maintaining microalgae-based treatment efficiency. PF trials were conducted in pilot-scale raceway ponds under solar radiation, testing different concentrations of $FeSO_4$ (4.48 and 8.95 mM) and H_2O_2 (77, 154, and 309 mM). Following PF, *Tetradesmus obliquus* was used in a biological treatment of PWW to recover the remaining nutrients. PF achieved high removal efficiencies for turbidity (97.6–99.5 %), total organic carbon (59.2–77.1 %), and chemical oxygen demand (83.8–94.7 %), but ammonium was not significantly removed. Phosphorus was almost completely removed through iron precipitation during neutralisation. Lowering the H_2O_2 concentration from 309 to 77 mM did not compromise removal efficiency but reducing $FeSO_4$ below 8.95 mM negatively affected the process. Consequently, 8.95 mM $FeSO_4$ and 77 mM H_2O_2 were selected for microalgae production. The pretreated PWW could be recycled at least once for microalgal production, without nutrient supplementation, improving biomass productivity and PWW treatment, especially targeting ammonium. Phosphorus supplementation, however, did not significantly boost biomass productivity or treatment efficiency. Moreover, the iron sludge generated from PF pretreatment contained enough NPK to be repurposed as an organic fertilizer boosting sustainable agricultural practices. These findings encourage further investigation of this emerging combined technology towards wastewater treatment at large-scale.

1. Introduction

Pigs are among the most widely distributed livestock, with annual pig production reaching almost 1 billion pig heads worldwide (FAOSTAT, 2024). Pig farming stands out as the largest polluter, accounting for 76.8 % of all livestock discharges (Deng et al., 2023). Piggery wastewater (PWW) contains high-load chemical oxygen demand (COD), nitrogen, and phosphorus, originating from pig excreta and animal feed waste. Furthermore, PWW exhibits high variability due to factors such as the size of the pig farm, water management for washing facilities, animal age, feed composition, and climate conditions (Maciel et al., 2024). The conventional treatment process includes a primary solid-liquid separation and a secondary treatment by anaerobic digesters or stabilisation ponds focused on the removal of organic matter, followed by land application. However, the long storage periods can generate high emissions of CO_2, methane (from anaerobic digestion), ammonia (by volatilisation), and hydrogen sulphide (from decomposition) (Nagarajan et al., 2019).

Many studies have shown that wastewater can serve as an inexpensive and readily available source of nutrients and water for microalgae

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