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Life cycle assessment of an industrial-scale petrochemical wastewater treatment plant

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ABSTRACT

Petrochemical industries produce a huge amount of wastewater during the production of various petrochemical products. The generated wastewater must be properly treated before being released into the environment because it contains harmful chemical compounds that affect human health, the aquatic ecosystem, and the environment. However, studies on the lifecycle assessment of petrochemical wastewater treatment processes on energy recovery are rare. This paper aims to evaluate the environmental impact of an industrial-scale petrochemical wastewater treatment plant (PWWTP) in the Malaysian state of Pahang using a life cycle assessment (LCA) method. The goal of this LCA study was to assess the environmental benefits and drawbacks of an existing treatment plant where greenhouse gas emissions are released directly into the air. In addition, the environmental impacts of the existing treatment plant were compared with those observed in an ideal case in which the methane gas is reused as an energy source. The 2001 version of the Center of Environmental Science-Leiden University (CML2001) impact assessment method was employed using GaBi 9 software, which entailed the analysis of the operational, sludge landfilling, and sludge transportation phases of the treatment process. Among the inventory components, the wastewater (direct emission) showed the highest eutrophication potential (EP) and global warming potential (GWP) in both the actual and hypothetical cases. In contrast, the electricity generation inventory component caused an increased acidification potential (AP) in the case of the existing treatment plant. Most of the global warming potential impact from the treatment results from the anaerobic digestion process. Other indirect global warming potential impacts from the chemical consumption (34.7 kg CO_2-eq) and solid sludge transport (13.7 kg CO_2-eq) are minimal compared to the treatment and electricity consumption impacts. The second most relevant source of the environmental impact of the treatment plant is electricity generation, which has impacted many categories. Acidification potential (89.2%), fossil abiotic depletion (59.4%), marine ecotoxicity (52%), human toxicity (45%), photochemical ozone depletion, and global warming (15%) are the main impact categories that significantly contributed by electricity consumption by the plant. Simple integration of the anaerobic digestion in the secondary treatment stage with the energy recovery unit reduced the total environmental impact by 30%. The results demonstrate that the least environmental impact was registered for the case where the methane gas produced from the anaerobic digestion is reused, indicating that the use of clean energy can reduce both the overall environmental burden and the treatment plant's operational costs.

1. Introduction

For efficient functioning, many industries require a significant volume of water. These businesses use water extensively in a variety of processes, including distillation, liquid-liquid extraction, washing activities, and cooling systems. For instance, the petroleum industry's manufacturing and processing facilities require about 3 m^3 of water for every megawatt hour of electricity generated (Programme, 2009) (see page 43). Recent data for the global energy sector indicates that the energy production process from fossil fuels consumed roughly 192 Billion m^3 of water in 2021 and is predicted to consume 172 Billion m^3 of water in 2030 (Payne et al., 2024) (see page 63). This

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