

Life Cycle Assessment Applications in Wastewater Treatment

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Introduction

Life Cycle Assessment (LCA) is a technique to assess all potential environmental impacts of any action and covers the entire life of the product; the study begins with raw material acquisition through production, use, and disposal [1]. A life-cycle uses the “cradle-to-grave” approach, and identifies energy use, material input, and waste generated from the acquisition of raw materials to the final disposal of the product. The facility at which this is conducted will benefit from the identification of the areas where environmental improvements can be made. Its principles and requirements are defined by ISO 14000 series standards [2,3] and consist of four main activities: goal and scope (ISO 14040), inventory analysis (ISO 14044), impact assessment (ISO 14044), and interpretation (ISO 14044).

Although LCA is generally used for the production phase, it is also applied to the global environmental analysis of a wastewater treatment operation. The environmental assessment of wastewater treatment technologies has been realized with the LCA technique. Corominas et al. [4] reported that LCA applied to wastewater treatment is a field with 17 years of experience and more than 40 studies have been published in international peer-reviewed journals using an array of databases, boundary conditions, and impact assessment methods for interpreting the results since 1990s.

The wastewater treatment plants help us to protect the environment, but in contrast to their main commissioned purpose, they can damage the environment through energy consumption, greenhouse gas emission, the utilization of chemicals, and some toxic material outcomes. Among them energy consumption is one of the most important issues in treatment plants. In wastewater treatment plants, huge amounts of energy are usually consumed and the amount of energy needed for operations varies depending on effluent characteristics, treatment technology, required effluent quality, and plant size [5]. Energy is required at every stage of the treatment plant, including pumping, mixing, heating, and aeration. The wastewater treatment plants should be designed and operated considering the amount of energy consumption. The one of the largest energy consumers in the treatment plant are aeration equipment [6]. Conventional activated sludge or aerated lagoon wastewater treatment processes can efficiently remove organic pollutants, but the operation of such systems is cost and energy intensive, mainly due to the aeration and sludge treatment associated processes [7]. Anaerobic treatment is generally a more environmentally friendly treatment technology than aerobic treatment due to its low solids generation rate, low electrical energy requirements and the production of a usable biogas [8]. Even though anaerobic degradation results in greenhouse gas emissions, these emissions and the energy requirements of the treatment systems could be reduced by the generation energy from biogas. So, when deciding on the treatment and disposal options in wastewater treatment plant design, all impacts should be taken into consideration. For example, water reuse is a very popular approach to protect natural water sources and it is thought to be an environmentally friendly application. However, in water reuse applications, generally high quality water is required, and therefore water reclamation facilities generally include additional advanced treatment technologies, which can consume large amounts of energy.

In this case, LCA can be used for the assessment and the comparison between the different techniques.

Although most of the LCA studies focused on the energy consuming [9-12] there are also some studies evaluating greenhouse gas emissions [13,14], toxicity [15,16], and eutrophication [15,17]. Muñoz et al. [15] use LCA for the comparison of two solar-driven advanced oxidation processes, namely heterogeneous semiconductor photo catalysis and homogeneous photo-Fenton, both coupled to biological treatment, are carried out in order to identify the environmentally preferable alternative to treat industrial wastewaters containing non-biodegradable priority hazardous substances. In LCA, global warming, ozone depletion, human toxicity, freshwater aquatic toxicity, photochemical ozone formation, acidification, eutrophication, energy consumption, and land use were taken into consideration. Depending on the assessment results, an industrial wastewater treatment plant based on heterogeneous photo catalysis involves a higher environmental impact than the photo-Fenton alternative. Zhang et al. [9] applied LCA to illuminate the benefits of a wastewater treatment and reuse project in China. Energy consumption was used as the sole parameter for quantitative evaluation of the project. As a result of the LCA analysis of the case project in Xi'an, China, it was revealed that the life cycle benefits gained from treated wastewater reuse greatly surpassed the life cycle energy consumption for the tertiary treatment. Other researchers from China investigated the environmental impacts associated with the treatment of wastewater in a wastewater treatment plant (WWTP) in Kunshan, China by Life Cycle Assessment. SimaPro 7.0 software was used in this study and the construction phase, operation, and maintenance phase; sludge landfilling and the transportation of chemicals to the WWTP were all taken into consideration. The LCA results of Kunshan WWTP taking renewable energy (wind power) as the energy source proposed that enhancing the effluent quality will decrease the environmental impact [18]. Amores et al. [19] employed the Life Cycle Assessment methodology to carry out an environmental analysis of every stage of the urban water cycle in Tarragona, a Mediterranean city of Spain, taking into account a water supply system of a city considering water abstraction, potable water treatment, distribution network, wastewater treatment, reclaimed water, and desalination. They compared three scenarios: 1) current situation, 2) using reclaimed water and using desalination plants, 3) reclaimed water to supply water during a drought. In all three scenarios the main source of impact was the energy consumed through the collection and intermediate pumping of freshwater.

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As indicated by Corominas et al. [4], different methodologies have been applied at LCA studies and there is variability in the definition of the functional unit and the system boundaries, the selection of the impact assessment methodology and the procedure followed for interpreting the results. It is important to use same functional unit to compare the alternative options. The functional unit is defined by the service provided by the system being studied and further shaped by the goal of the study [20,21] and selected depending upon the aims of the study [22]. The volume unit of treated wastewater and one dry ton of sludge are commonly used for wastewater treatment and sludge handling and disposal processes, respectively [9,13,22,23].

The system boundaries determine which unit processes shall be included within the LCA [2]. In the inventory analysis, allows of materials and energy across the system boundary are quantified [21]. Some of the studies cover only the operation phases [11] the others cover the construction phase [9,24] or the disposal and transportation phase [13,18]. In LCA studies, so many kinds of life cycle assessment methods, such as Eco Indicator 99, EDIP 96, EPS and Ecopoints 97 [22], and commercial software, such as SimaPro [18,25], Umberto 5.5 [26], and Gabi [27], has been used.

Conclusion

In conclusion, the benefits and harms of each application should be investigated in detail and among the alternative treatment methods, the most environmentally friendly treatment options, especially the least energy consuming techniques, should be selected and applied. In order to design and construct the most appropriate wastewater treatment plants, it would be useful to use the LCA approach and different environmental impacts of wastewater treatment plants should be identified by the LCA method. Further analysis should be carried out on life cycle impact assessment of wastewater treatment techniques.

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