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ENVIRONMENTAL EVALUATION OF DIFFERENT WASTEWATER TREATMENT SYSTEMS: ACTIVATED SLUDGE, UASB AND STABILIZATION PONDS IN LATIN AMERICAN AND THE CARIBBEAN

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ABSTRACT

Environmental evaluation of water treatment systems was developed for three technologies of wastewater treatment: activated sludge, upflow anaerobic sludge blanket reactors (UASB) and stabilization ponds. Life Cycle Assessment (LCA) was developed for 9 scenarios (S1 to S9) for the current situation in the Latin America and the Caribbean (LAC). Results show that S2, S5 and S8 (stabilization ponds) have greater impacts in global warming potential (GWP) and photochemical oxidation due to CH4 emissions from anaerobic ponds, likewise S1, S4 and S7 (activated sludge) have impacts in acidification and abiotic resource reduction due to electricity consumption in the aeration tank. Scenarios with UASB reactors have lower impacts in GWP and medium on formation of photochemical oxidants.

INTRODUCTION

With 33% of the renewable water resources of the world, Latin America and the Caribbean (LAC) is the continent with the highest water availability; its 3100 m^3 of water per capita per year, doubles the global per capita average (World Bank, 2004). Although the region has experienced an increase in drinking water coverage from 90% in 2000 to 94% in 2011 (World Health Organization, 2013), 35 million people still lack access to water. Sanitation coverage is limited to 82%, resulting in 106 million inhabitants without access to sanitation facilities (WHO, 2013).

A growing concern is related to the absence of an integrated management of the resource An important element in this approach is the need of sound, appropriate investments in infrastructure for wastewater treatment systems. In this context it is necessary to identify the more sustainable treatment technologies for the region.

There are few published LCA studies on wastewater treatment systems for some particular cases such as Benetto et al. (2009) which develops a comparative LCA in an office building in Luxembourg; Hospido et al. (2004) and Rodriguez-Garcia et al. (2011) carried out studies for some regions of Europe, but the region of LAC has been poorly studied

The aim of this study is to present a Life Cycle Assessment for wastewater treatment systems in LAC by analyzing the effect of each unit process within the more representative treatment technologies in the LAC region, based on 9 scenarios.

METHODS

Technologies selection and definition of 9 scenarios

The representative configurations of wastewater treatment plants (WWTP) for LAC were selected according to the findings of Noyola et al. (2012), based on a sample of 2774 WWTP in six LAC countries (Brazil, Chile, Colombia, Guatemala, Mexico and the Dominican Republic). As a result, the treatment systems considered were: activated sludge (extended aeration and conventional processes), stabilization ponds, upflow anaerobic sludge blanket reactors (UASB), and trickling filter as a post-treatment for UASB. The model considered that 80% of biogas from UASB reactors is collected and burned.

The environmental effect of each unit process was analyzed considering three flows: small, medium and large; the former within a range from 0.1 to 25 L s^{-1}, the medium from 25 to 250 L s^{-1} and the latter from 250 to 2500 L s^{-1}, resulting in 9 scenarios (Table 1).

Table 1: Treatment scenarios considered for the LCA

Small flow	**Medium flow**	**Large flow**
S1. Extended aeration	S4. Extended aeration	S7.Conventional Activated Sludge
S2. Stabilization ponds	S5. Stabilization ponds	S8. Stabilization ponds
S3. UASB + Trickling filter	S6. UASB + Stabilization ponds	S9. UASB + Activated Sludge

The sludge treatment option varied depending on the scenarios: S1, S3 and S4 considered a simple drying bed; S2, S5, S6 and S8 dried their sludge in the same pond (once isolated from the treatment system); S7 had a mesophilic anaerobic sludge digester followed by a centrifuge for dewatering; S9 considered a centrifuge for dewatering.

Functional unit

In this work, the functional unit was defined as the treatment of 1 m^3 of wastewater municipal over 20 years considering specific effluent and biosolids quality.

The effluent quality was defined as BOD (biochemical oxygen demand) of 30 mg L-1 and TSS (total suspended solids) of 30 mg L-1 according to an analysis of the discharge standards of the region. The quality of the resulting sludge was defined in accordance with the regulations for application of biosolids to agricultural lands "Class B" of the United Stated EPA regulations (USEPA, 1992, 1999), considering that in the region only some countries have biosolids standards and the majority of these regulations are based on those of EPA.

Life Cycle Inventory

The Life cycle inventory (LCI) obtained for this work considered more than 40 chemical compounds emitted to air, water and soil, as well as raw materials and energy used. In this study, a representative electricity mix for LAC region was obtained from WB (2010): Coal 5.9%, Gas 20.9%, Oil, 14.6%; hydro,55.8% and nuclear, 2.8%.

The characterization of municipal wastewater influent was defined according to statistical analysis of the data collected within a sample of 158 WWTP as presented by Noyola et al. (2012). The sludge stabilization and subsequent disposal in soil was considered, with their corresponding emissions, taking into account their heavy metals content.

In this study, the CML2000 method was used to evaluate the impact categories: Abiotic depletion (AD), Acidification (AC), Global warming (GWP100), Eutrophication (EU), Photochemical oxidation (PHO), and Terrestrial toxicity (TT).

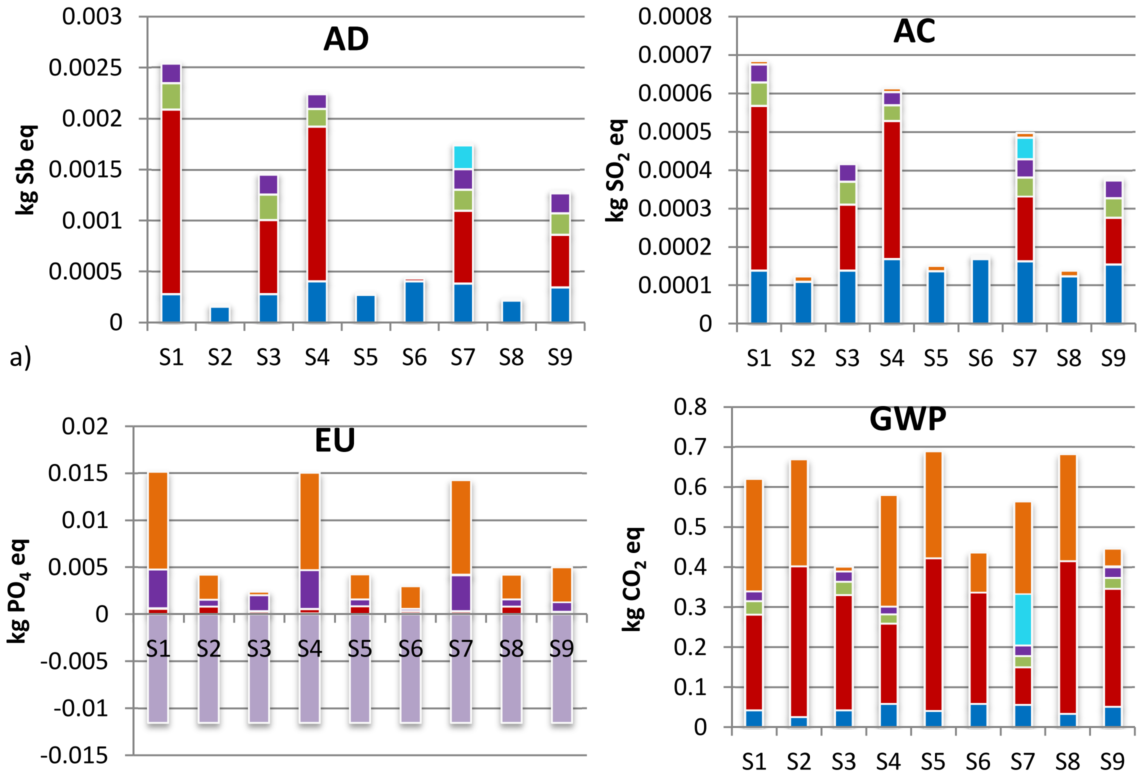
RESULTS AND DISCUSSION

Figure 1 shows the results of environmental performance for each unit process for the 9 scenarios.

The scenarios S1, S3, S4, S7 and S9 have major impacts in AD because of their use of electricity, mainly in the aeration tank of the activated sludge process. Those systems involving stabilization ponds (S2, S5, S6 and S8) presents much lower impacts on this category (Figure 1a). Moreover, Figure 1b shows that S1, S3, S4, S7 and S9 have higher impacts in AC on the secondary treatment (59 to 83%) due to SO2 (68%) and NOx (31%) emissions in the electricity production with the given generation mix.

In each scenario, the impacts on EU have negative values (avoided or positive impact) due to the reduction of pollutants in the discharged treated wastewater. In fact, WWTP are built and operated in order to reduce this specific impact, among other public health related issues. However, S1, S4 and S7 present similar impact values as those avoided, resulting in nearly neutral processes for this specific impact category, mainly due to the contribution of sludge disposal (land application). The scenarios considered final water disposal to a river and shows minor impact (2 to 8%) for this operation. With the exception of S3, in all scenarios sludge disposal had higher EU impact than water discharge.

Scenarios S2, S5 and S8 have greater impacts (67%) in GWP, and particularly in PHO, due to CH_4 emissions from anaerobic ponds. Also, S1 and S4 have high impacts, as a result of the contributions of the aeration tank (50%) due to the emission of fossil CO_2 (91% of the total impact) produced for electricity generation. The pretreatment operation has a similar behavior in each of the scenarios, due to emissions of residues from the solid waste screening disposed in the landfill, mainly associated with dichloroethane emissions by 91%.



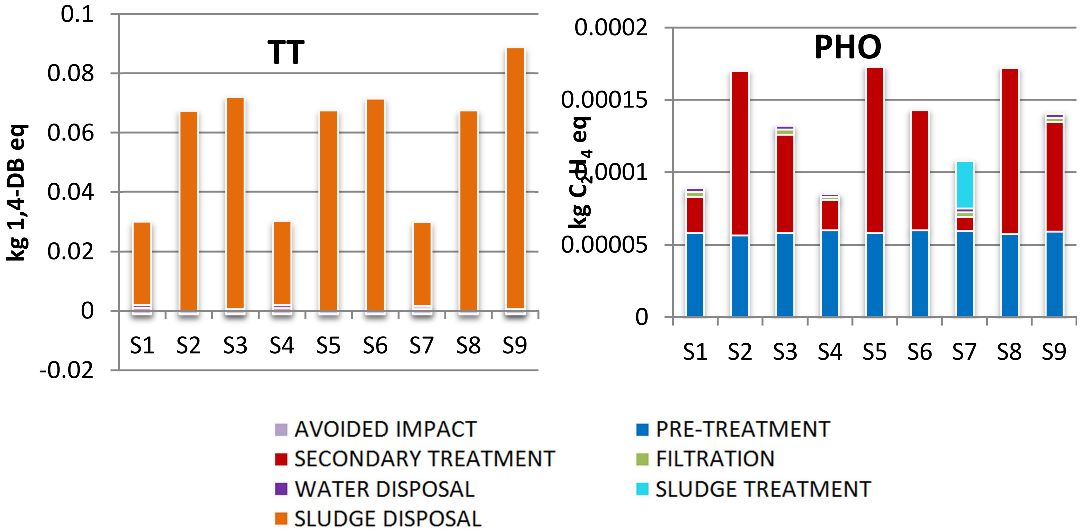


Figure 1. Environmental performance of the 9 scenarios

Sludge disposal in all scenarios is responsible for 95% of impacts in TT. The UASB scenarios (S3, S6 and S9) have major impacts in each flow size, due to the higher concentration of heavy metals in this kind of sludge, precipitated as metallic sulfides, which are disposed on soil.

CONCLUSIONS

The impact analysis of the contribution of each unit operation and process involved in each scenario allows to identify that scenarios with electricity use have major impacts in the categories of acidification, abiotic resource reduction and terrestrial toxicity. Anaerobic ponds have major impacts in the category of global warming and photochemical oxidation. However, UASB with biogas burning shows the lower impact on GWP. Furthermore, scenarios with UASB have greater impact on terrestrial toxicity category due to the concentration of sludge disposed in the soil. In the eutrophication category, scenarios with greater generation of sludge (involving the activated sludge technology) have the greater impact due to nutrients disposed on soil.

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