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Assessing wastewater treatment in Latin America and the Caribbean: Enhancing life cycle assessment interpretation by regionalization and impact assessment sensibility

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ABSTRACT

Life cycle assessment (LCA) was applied to evaluate two wastewater treatment plant (WWTP) scenarios in Latin America and the Caribbean (LAC): extended aeration (EA) and pond system (PS). The main goal was to compare the environmental performance of two WWTP technologies across all environmental impact categories in selected methods when developing new WWTP projects. As a complementary goal, we analyzed how regionalization enhances LCA interpretation through a case study illustrating the spatial variability of WWTP results for 22 Latin American and Caribbean countries.

A generic LCA relying on averaged primary data from 158 WWTPs was first performed based on three LCIA methodologies: ReCiPe, IMPACT World+ (IW+) and Impact 2002+. The results were used to identify the parameters that most influence the impact scores and test the sensitivity of the choice of LCIA methodology on the conclusions. While EA is the most impactful scenario for the human health (HH) and ecosystem quality (EQ) indicators according to Impact 2002+, ReCiPe considers it to be the least impacting option. This is mainly due to the fact that ReCiPe includes the contribution of global warming impacts at the damage level whereas IMPACT 2002+ does not. For the same reason, IW+ favours EA for the HH indicator, which is dominated by global warming impacts. However, for EQ, the PS scenario scores better because of the lower relative importance of global warming impacts (GWP) as compared to eutrophication impacts (FE) at the damage level. Both the IW+ and ReCiPe methodologies point to a trade-off between the two impact categories, which dominate the impact scores for this area of protection. A sensitivity analysis was therefore carried out at the inventory level considering regional grid electricity mixes and at the impact assessment level characterizing eutrophying emissions from WWTPs with the regional CFs for the 22 LAC countries provided by the IW+ model. Results from the IW+ analysis showed that the operating conditions of WWTP in countries where 43–80% of electricity is produced from fossil fuel tend to favour PS for the EQ and HH damage categories. Operating conditions in countries with an electricity mix of over 60% hydropower favour EA due to the significant decrease in greenhouse gas emissions for the EQ and HH damage categories. The location where a WWTP operates also influences the results of the impact assessment. For example, locations with higher eutrophication characterization factors such as Brazil, where the residence time of water is higher, do not tend to favour scenarios with higher eutrophying emissions such as EA with higher EQ impact scores as compared to PS. We concluded that regionalization, both of the inventory and characterization factors, show the potential for adding relevance and discriminating power to the LCA. To address regionalization it in standard LCA practice we propose a pragmatic and stepwise iterative approach that makes it possible to regionalize the greatest contributing inventory and the most impactful assessment flow. Nevertheless, it is important to note that we only addressed the uncertainty related to known spatial variability and that it may be of major interest to apply a similar stepwise approach to any other type of uncertainty.

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