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Influence of data collection schemes on the Life Cycle Assessment of a municipal wastewater treatment plant

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ABSTRACT

A Life Cycle Assessment (LCA) of a municipal wastewater treatment plant (WWTP) was conducted to illustrate the effect of an emission inventory data collection scheme on the outcomes of an environmental impact assessment. Due to their burden in respect to data collection, LCAs often rely heavily on existing emission and operational data, which are gathered under either compulsory monitoring or reporting requirements under law. In this study, an LCA was conducted using three input data sources: Information compiled under compulsory disclosure requirements (the European Pollutant Release and Transfer Registry), compliance with national discharge limits, and a state-of-the-art emission data collection scheme conducted at the same WWTP. Parameter uncertainty for each collection scheme was assessed through Monte Carlo simulation. The comparison of the results confirmed that LCA results depend heavily on input data coverage. Due to the threshold on reporting value, the E-PRTR did not capture the impact for particulate matter emission, terrestrial acidification, or terrestrial eutrophication. While the current practice can capture more than 90% of non-carcinogenic human toxicity and marine eutrophication, an LCA based on the data collection scheme underestimates impact potential due to limitations of substance coverage. Besides differences between data collection schemes, the results showed that 3–13,500% of the impacts came from background systems, such as from the provisioning of fuel, electricity, and chemicals, which do not need to be disclosed currently under E-PRTR. The incidental release of pollutants was also assessed by employing a scenario-based approach, the results of which demonstrated that these non-routine emissions could increase overall WWTP greenhouse gas emissions by between 113 and 210%. Overall, current data collection schemes have the potential to provide standardized data collection and form the basis for a sound environmental impact assessment, but several improvements are recommended, including the additional collection of energy and chemical usage data, the elimination of a reporting threshold, the expansion of substance coverage, and the inclusion of non-point fugitive gas emissions.

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1. Introduction

Life Cycle Assessment (LCA) has in recent years gained interest from the wastewater and sewage sludge treatment sector (Friedrich et al., 2007; Corominas et al., 2013a,b; Yoshida et al., 2013a,b,c). An LCA aims to quantify, organize, and translate environmental emissions from all involved processes into one or multiple environmental impact indicators. LCAs have been used, for example, to assess alternative wastewater and sewage sludge treatment technologies from an environmental point of view, thereby enabling the quantitative evaluation of trade-offs (e.g. nutrient recovery versus health risk, upgrade of nutrient recovery versus energy, and chemical consumption).

One of the most critical issues in performing an LCA is establishing reliable inventory data. In practice, generating site-specific monitoring data for all substances known to cause adverse health and environmental impacts is prohibitively expensive, and in many cases it is not even feasible, despite the fact that data gaps relating to flows between unit processes and emissions into the environment introduce epistemic uncertainty in LCA results and therefore a systemic underestimation of environmental impacts (Finnveden, 2000; Huijbregts et al., 2001). Hence, the integrity of the LCA depends largely on the utilization of currently available operational and emission data and the assumptions made to fill data gaps (Bjorklund, 2002; Huijbregts et al., 2001; Reap et al., 2008). The question remains as to how significantly the outcome of an LCA study depends on available data (e.g. source, quantity, quality) and the assumptions made to close obvious data gaps.

Due to the nature of the operation, pollution control facilities such as wastewater treatment plants (WWTPs) already collect a range of data concerning flows and emissions as part of everyday operational schemes and in order to fulfill public reporting obligations. In Denmark, as also is the case in many other countries, specific plants are approved or licensed subject to the fulfillment of certain emission standards. Actual emissions, for example the quality of treated wastewater prior to discharge, must be monitored and reported regularly. Yet, limitations in line with such data lie in substance coverage, since not all substances known to have adverse environmental or health impacts are regulated, while some emission pathways are also exempted from the requirement. In addition, these monitoring data are often not organized or made easily accessible to the public.

In Europe, industrial entities - including WWTPs - of a certain size are required to report environmental emissions and transfers of pollutants via air, water, and waste to the European Pollutant Release and Transfer Register (E-PRTR). This web-based register, which is aimed at informing the public about the release of pollutants from industrial facilities, replaces and improves upon the former EPER register implemented under Council Directive 96/61/EC and later codified as 2008/1/EC (EEA, 2013). Currently some 28,000 industrial facilities report their environmental data to the E-PRTR every three years. A threshold for minimal production capacity applies, though the European Commission assumes that the E-PRTR covers 90% of industrial emissions for 91 substances in Europe (Wursthorn et al., 2011). Adopting an institutionally backed data collection scheme such as E-PRTR for LCA would not only reduce the burden of data collection, but also ensure the standardization of data collection and reporting schemes across industrial sectors, as well as provide timely inventory updates. These changes would expand the application of LCAs by evaluating data coverage and quality captured by current data collection schemes that require sector-by-sector evaluations.

Hence, the goal of this study was to illustrate in a quantitative way how the basis of inventory data affects the outcome of a WWTP LCA by using a specific WWTP located in Copenhagen, Denmark, as a case study. We used three levels of information for establishing inventory data, from using routinely reported data to using data from an advanced, specific monitoring campaign performed at the plant over more than one year. We used: (L1) the E-PRTR reporting guideline, (L2) emissions monitoring mandated by Danish regulations, and (L3) emissions data from a state-of-the-art measurement campaign. This study evaluated on-site emissions from WWTPs, as the current E-PRTR does not require industry practitioners to report on energy and material consumption. However, in order to place the results into the perspective of a conventional LCA, emissions from up- and downstream processeswere included in one scenario (L3+). The propagation of uncertainties was also conducted, in order to evaluate the influence of variations in measurements on the outcome of LCA.

2. Methods

The study follows the four steps defined in the ISO standard 14040 (2006), namely goal and scope definition, a Life Cycle Inventory (LCI), a Life Cycle Impact Assessment (LCIA), and the interpretation of results. This section details the first three steps and a review of the uncertainty analysis methods used herein. The results and their interpretation are presented in Section 3. The paper focuses on the three data collection schemes, while detailed documentation on the assumptions and parameter values is provided in supporting information (SI).

2.1. *Goal and scope*

The objective of this study was to assess the possibility of adopting the current compulsory environmental disclosure requirement (E-PRTR) when conducting a wastewater LCA, by quantifying potential environmental impacts associated with the operation of Avedøre WWTP, located southwest of Copenhagen, Denmark, under the three input data collection schemes. The reasons for conducting the study included methodological development, and the implications of the results were limited to the discussion on the viability of emission data collection schemes. Since the E-PRTR requires only on-site emissions from WWTPs, an assessment of the construction and demolition phases was not included in this study.

The system under study is an urban WWTP serving 265,000 inhabitants (SI-1) and is equipped with primary and secondary wastewater treatment systems utilizing advanced nitrogen