LCA FOR EMERGING WASTE TREATMENT TECHNOLOGIES: THEORETICAL APPROACH AND PRACTICAL APPLICATION

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Our work is focusing on the assessment of the life cycle environmental performance of emerging technologies on waste treatment, by applying the LCA principles and tools (EASETECH, SimaPro). These technologies aim at the valorisation of waste for the production of bio-based products, the recovery of materials from waste and the optimization of established waste treatment technologies. A summarizing scheme including the feedstock types and the main processes used as well as the resulting products is illustrated in Figure 1. The technology readiness level (TRL) of the examined treatment schemes ranges between 3-6, while this diversification is also obvious within the treatment schemes themselves. The main aim for conducting LCA in all of the aforementioned emerging technologies is to timely inform the design and development process in order to support decision making for future investments. Such an LCA is frequently called *ex-ante* or *prospective*, as it provides preliminary results on the expected environmental impacts of technological innovations (Cucurachi et al., 2018). This is of significant importance, as decisions made at the early stages may highly influence the environmental impacts associated with the large-scale application of these technologies (Villares et al., 2017). Nevertheless, several challenges were identified when conducting the LCAs which were mainly related to the availability of data, comparability, scale up issues, and uncertainty (Moni et al., 2019). With respect to data availability, it is recognized that the lower the TRL the less abundant the data and subsequently the lower the robustness of the LCA results (Villares et al., 2017). This was particularly evident in the case of the air emissions generated during biological processes, as it was usually not in the scope of the technology validation phase to measure such emissions. For example, in the case of digestate treatment with microalgae for reducing its ammonia load, significant amounts of nitrous oxide are produced which are not currently monitored. To overcome this, the expected emissions were estimated based on stoichiometry and the limited literature on relevant case studies. Furthermore, in many cases, laboratory and pilot scale equipment does not reflect neither the complexity nor the efficiency of industrial scale equipment (Tsoy et al., 2021), and therefore are not comparable. For instance, for drying biomass an electric dryer was used during the tests in one of the pilots, while for the industrial design a rotary drum dryer fueled with biomass would be more appropriate. With respect to scale up issues, extrapolation of lab/pilot scale data is treated with caution, as the impacts of the industrial scale are not directly proportional. While in higher TRL processes, extrapolation may be safer to perform as in the case of biowaste pretreatment for fermentation in the bioethanol demo plant, in lower TRL processes scale-up issues are treated using thermo-dynamics, also considering similar existing processes and the best available techniques (BAT). In parallel, in the cases where the uncertainty remains high, sensitivity analysis is conducted for selected critical parameters.

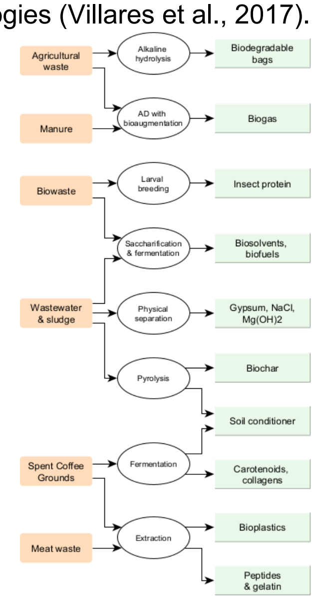

Figure 1: Overall scheme of case studies

Beyond the challenges mentioned, opportunities also rise when performing an ex-ante LCA. In specific, the need for the optimization of the identified environmental hotspots may shed light to unexplored opportunities, such as the recycling of high impact streams. This was the case for the recycling of ammonia used for the cultivation of ammonia tolerant mixed microbial cultures for the bioaugmentation of the anaerobic digestion process. Similar opportunity was identified with the use of CO_2 in the extraction of coffee oil for the production of bioplastics. As a result, a structured approach is proposed for dealing with such issues. Additionally, to demonstrate the effect of this approach, a comparison of the LCA results is made based on the available information at lab/pilot scale and the ex-ante insights gained.

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