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A life cycle assessment of conventional technologies for landfill leachate treatment

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Abstract
Landfilling of municipal solid waste is still one of the most diffused practices worldwide, generating long-term heavily polluted gaseous and liquid (*i.e.* leachate) emissions, causing environmental and especially human health concerns. Improvement of the methods for treating these emissions, particularly the leachate, is mandatory for increasing the sustainability of the entire waste management system. For this aim the environmental impact of conventional off-site technologies, based on co-treatment of leachate with civil sewage in wastewater treatment plants, was compared with advanced on-site technologies based on reverse osmosis and evaporation in a life cycle perspective. The model was built using mainly experimental and technical data from full-scale facilities. Human toxicity and freshwater ecotoxicity were the impacts most affected by the scenarios analysed. Average impacts were higher for the conventional off-site co-treatment in wastewater treatment plants, whereas impacts were lower for the advanced on-site treatment based on reverse osmosis. This result was largely influenced by the high incidence due to leachate transport for the off-site management scheme. Due to the high consumption of energy (*i.e.* 40kWh/m^3 electricity and 18.5 kWh/m^3 thermal heat) and chemicals (mainly HCl) the impact for the on-site evaporation system was always higher than for reverse osmosis and in some cases also for the conventional co-treatment with civil sewage sludge. The uncertainty analysis showed that pollutant emissions to water and emissions due to transport were affected by the highest errors, influencing in a major way the uncertainty of the impacts considered.

Keywords: Evaporation, leachate, life cycle analysis, reverse osmosis, wastewater treatment plant.

1. Introduction

Landfill disposal is still one of the most diffused options worldwide for the management of municipal solid waste (MSW) (Camba et a., 2014). As an example, at the EU28 level, 31% of the whole MSW (*i.e.* about 74 Mtonnes/year) is directly landfilled (ISPRA, 2015). Degradation of MSW is a long-term event, generating heavily polluted gases (*i.e.* landfill gas) (Barlaz et al., 2009; Chen and Lo, 2016; Di Maria et al., 2013a) and liquids (*i.e.* leachate) (Camba et al., 2014; Di Maria et al. 2013b), which are the main source of the environmental impact associated with this practice. Therefore it is of prime importance to identify more sustainable technologies for their treatment in order to reduce the environmental concerns of the entire MSW management system. In particular leachate can be considered a triphasic system with the characteristics of a heavily polluted wastewater (Schiopu and Graviliescu, 2010; Slack et al., 2005), entailing an important threat to human health, soil, and surface and ground water.

The most widespread options for leachate treatment can be classified as off-site and on-site treatments, which can also be referred to as conventional and advanced treatments, respectively (Renou et al., 2008). Among the conventional ones, leachate transfer for combined treatment with civil sewage in wastewater treatment plants (WWTP) is the most diffused (Wernet et al., 2016). However, due to the continuously more rigorous discharge standards and the ageing of landfill sites with more and more stabilized leachates, the capability of WWTP to remove some trace pollutants is limited (Papa et al., 2016). Furthermore off-site treatment costs are affected by both transport and

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