Life Cycle Assessment of Small and Decentralized Wastewater Treatment Plants

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Abstract
The role of Wastewater Treatment Plants (WWTPs) in the sanitation of urban water and the protection of our water bodies has been paramount. The treatment process is not free of environmental impacts, as they are often reported as energy-intensive processes with significant CO_2 emissions; at the same time, depending on the process, treatment may result in the emission of various green house gases, such as CH_4 and N_2O. One of the methodologies used for the assessment of impacts associated with environmental issues of products and/or processes is Life Cycle Assessment (LCA), which takes into account the whole life cycle. LCA has been used as a tool for the environmental evaluation of WWTPs and has been shown to be helpful in designing control strategies in the treatment process. In this article, we use LCA to evaluate the Environmental Impact Assessment of six different wastewater treatment technologies that have been designed for installation in six small communities in the greater Larissa area in central Greece. Each small and decentralized wastewater treatment plant is designed to serve remote communities that range from 330 to 1070 population equivalents. A wide range of environmental impact categories is considered including global warming, acidification, eutrophication, human toxicity, etc. The potential of WWTP effluent reuse is examined whenever possible, taking into account regional factors and plant geographical location. Results obtained by SimaPro LCA commercial software show that LCA can be a valuable decision-support tools in assisting water companies reach a conclusion on which treatment technology is suitable, considering not only effluent quality and capital-operation and maintenance costs, but also environmental impact of each process, including the whole life cycle of the plant and long-term impacts.

Keywords
Life Cycle Assessment (LCA); wastewater treatment plants (WWTPs); environmental performance; Larissa; Environmental Impact Assessment (EIA)

BACKGROUND

According to the Urban Waste Water Treatment Directive (91/271/EEC), which concerns urban wastewater treatment and aims to protect the environment from the adverse effects of urban wastewater discharges, agglomerations of less than 2000 population equivalents (p.e.) are not required to have a sewerage network. In Greece, such small agglomerations are estimated to correspond to approximately 2.5 million p.e. What is required for these small communities is the implementation of "appropriate" wastewater treatment systems that will ensure the protection of receiving water bodies and groundwater. In the Municipality of Larisa in central Greece (162,591 inhabitants according to the 2011 Census), most people are served by advanced wastewater collection and treatment systems, with the exception of the small Municipal Unit of Koilada (3,169 p.e.). In the latter, inhabitants are served by septic tanks that have been proven insufficient in treating wastewater for the smaller communities; low depth of septic tanks leads to frequent overflows, while low soil absorbance results in groundwater pollution. To protect public health, the Municipal Enterprise for Water Supply and Sewerage of Larisa (DEYAL, www.deyal.gr) has decided to proceed with treatment works in the area and has conducted wastewater management studies for this purpose. The goal was to identify the optimum treatment technology scheme for the small remote communities of Koilada, since preliminary analysis showed that it would be too

expensive and inefficient to connect them to the central sewerage network of metropolitan Larissa. DEYAL has created an inventory of six different small and decentralized wastewater treatment systems that would be suitable to treat wastewater effectively, without requiring specialized scientific personnel for their operation and maintenance. The element of innovation in this effort was not under-estimated; with this initiative, DEYAL wishes to create a unique demonstration site for all these different treatment technologies operating well and successfully dealing with all issues associated with small and decentralized wastewater treatment systems. A list of local communities and proposed treatment technologies is presented in Table 1.

Life Cycle Assessment (LCA) is one of the methods used for the assessment of environmental impacts of a product or process, taking into account its whole life cycle (ISO 14040, 2006). It has been used as an environmental evaluation tool for control strategies in wastewater treatment plants (Meneses et al., 2015; Zang et al., 2015; Lorenzo-Toja et al., 2015, Breska et al, 2015), since although wastewater treatment facilities reduce pollution in the urban water cycle and improve water ecosystems, they also cause environmental impacts due to their high energy consumption, chemical use, sludge production and greenhouse gas emissions. In this article, we perform LCA for the six proposed wastewater treatment technologies and compare and contrast their environmental impacts.

Table 1. Local Communities in the Koilada Municipal Unit, populations and proposed treatment technologies (courtesy of DEYAL).

Local Community	Population	Design p.e.	Treatment Technology
Koilada	628	800	System of sub-surface, vertical and horizontal flow constructed wetlands
Amygdalea	336	430	
Eleytherai	520	660	Activated sludge with extended aeration and biological nitrogen removal
Loutro	332	330	Activated sludge with Sequencing Batch Reactors (SBR)
Rachoula	514	600	Moving Bed Membrane Reactor (MBMR)
Mandra-Koutsochero	839	1070	Rotating Biological Contactor (RBC)

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