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Connection of neighboring wastewater treatment plants: economic and environmental assessment

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ABSTRACT

This paper explores the potential of integrated management of neighboring wastewater treatment plants (WWTPs). The novelty lies in the integration of environmental aspects, with the application of life cycle assessment (LCA) methodology, together with economic criteria for the selection of best alternatives. A case study illustrates how the connection of neighboring wastewater systems by constructing an extra pipeline provides positive results in the economic assessment, and in the majority of the LCA categories used in the global environmental assessment. The consideration of local environmental constraints suggests that the usage of the connection should be limited to periods when the minimum ecological flow in the river section between the discharges of the two WWTPs is maintained. In this particular case, the scenario that promotes the usage of the connection between the two WWTPs (but with some restrictions in dry weather periods) is preferred because it provides cost savings of 45,053€·year^{-1} and satisfies environmental criteria. A scenario analysis has been conducted to evaluate the influence of the pipe length on both economic and environmental aspects and the influence of individual cost terms on the economic assessment.

1. Introduction

Public or private companies operating wastewater systems are facing the challenge of reviewing their practices in terms of environmental and economic performance. Most of the studies resulting from such reviews focus on optimizing single wastewater systems, typically without considering the effects on the receiving media. However, recent water directives define that measures at a river basin scale, as the optimization of environmental performance and economics should be conducted for multiple wastewater systems in the same river basin and should take into account the impacts on the receiving media. The consideration of the specific characteristics of the receiving water bodies in the management of WWTPs is needed if aiming to minimize the impact on water bodies and fulfill the Water Framework Directive objectives of good environmental (i.e., ecological and chemical) status (Corominas et al., 2013a). This is especially relevant in semi-arid regions (such as the Mediterranean) with low river flows and significant contribution of WWTP discharges.

Some studies can be found in the literature evaluating the integrated management of multiple facilities from an environmental and/or economic point of view. The study of Thames Water (Dennison et al., 1998) on biosolids management showed that environmental impacts (by using life cycle assessment - LCA) influenced more the decision rather than capital costs. Lundie et al. (2004) performed an LCA for Sustainable Metropolitan Water Systems Planning evaluating the integrated management of 31 wastewater systems, but no economical assessment was present in the paper. Yuan et al. (2010) demonstrated through a cost-effectiveness analysis, but without using a life cycle approach, that sharing WWTPs in an industrial Park in China was a better option compared to independent operation of several WWTPs. Similarly, cost-effectiveness of integrated operation of two neighboring WWTPs together with the receiving water body impact was demonstrated using deterministic models for predicting water quality without including LCA criteria (Benedetti et al., 2009; Devesa et al., 2009; Prat et al., 2012). Finally, there are some works with the aim of improving the environmental performance of the integrated urban water cycle (from drinking water

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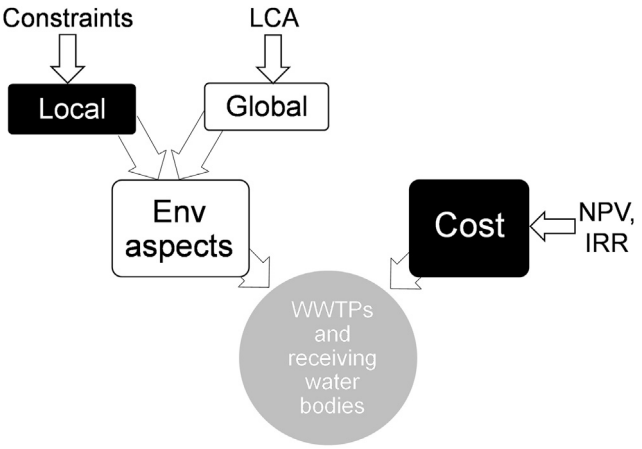

Fig. 1. Methodological approach proposed in this paper (the novelty is the inclusion of environmental local constraints and environmental assessment of urban wastewater systems, together with a cost assessment). NPV: Net Present Value; IRR: Internal Return Rate.

production until wastewater treatment), proposing a procedure for the selection of sustainability indicators (Lundin and Morrison, 2002), analyzing different future scenarios (Lundie et al., 2004; Lassaux et al., 2007; Friedrich et al., 2009), identifying weaknesses to the current situation and proposing improvements (Mahgoub et al., 2010; Lemos et al., 2013), focusing on the water supply plans (Muñoz et al., 2010), evaluating sustainability of a Mediterranean city (Amores et al., 2013) or comparing different cities with different locations and specificities (Uche et al., 2013). However, none of these studies combined environmental and economical aspects in the assessment.

The combination of both economic and environmental assessment criteria improves the decision making process (Rodriguez-Garcia et al., 2011; Chong et al., 2012). In some cases, higher environmental benefits are achieved without cost incremental (e.g. Dennison et al., 1998). In other situations, the achievement of higher environmental benefits supposes an additional cost (e.g. Sharma et al., 2009). In any case, economic assessment has to also be addressed from a Life-Cycle perspective, including both capital and operational costs. Hence, LCA-based Life Cycle Costing allows for an integrated environmental and economic assessment of different options, therefore enabling decision-makers to make the best overall decision, or to tackle trade-offs, if they exist, on a transparent basis (Rebitzer et al., 2003).

So far, none of the published studies evaluated the integrated management of WWTPs by combining environmental and economic aspects. Furthermore, in the real world of environmental issues, it is absolutely necessary to understand what would the impact of WWTP effluents be on the receiving environment at a local scale. Since the provision of a set of "accepted" characterization factors that can be applied at local scale is still a challenge (Corominas et al., 2013b) within the LCA community it is proposed in this paper to combine local and global environmental aspects within the analysis.

Therefore, the goal of this paper is to propose a methodology to evaluate the integrated management of neighboring WWTPs including economical and environmental (local and global) criteria. The usefulness of the proposed methodology is illustrated with a case study which compares the reference scenario (i.e., the independent operation of two existing WWTPs) against a proposal that involves the construction of a pipeline of ~1 km that connects them and allows sending wastewater from the upstream to the downstream WWTP.

2. Materials and methods

2.1. Proposed methodology

The proposed methodology for the assessment of integrated management of WWTPs and receiving water bodies combines: i) local environmental constraints (i.e. maintenance of the minimum ecological flow in the river into which the WWTPs discharge the treated water), ii) global environmental impact assessment through LCA applied according to the ISO 14040 (2006) standard; and iii) economic assessment, through the Net Present Value (NPV) and the Internal Rate of Return (IRR) for the different management options.

Fig. 1 shows the proposed methodology, which includes environmental local constraints together with global environmental assessment and cost assessment in urban wastewater systems decision-making.

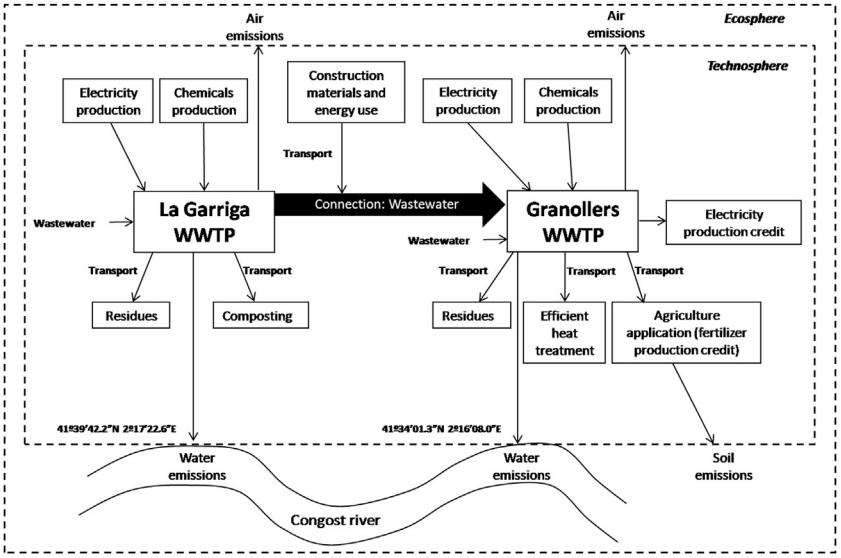

Fig. 2. System boundaries.