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Economic feasibility study for intensive and extensive wastewater treatment considering greenhouse gases emissions

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ABSTRACT

Economic feasibility assessments represent a key issue for selecting which wastewater treatment processes should be implemented. The few applications that exist focus on the positive economic value of externalities, overlooking the existence of negative externalities. However, wastewater treatment plants (WWTPs) consume a significant amount of energy, contributing to climate change. In this context, as a pioneering approach, greenhouse gas emissions (GHG) have been incorporated as a negative externality of wastewater treatment. Within this framework, this study aims to compare the economic feasibility of five technologies, both intensive and extensive, for small communities. The results show that both the investment and operation costs are higher for intensive than for extensive technologies. Moreover, significant differences in the value of negative externalities were observed. This study demonstrates that from an economic perspective, constructed wetland is the most suitable option for treating wastewater in small agglomerations.

1. Introduction

The achievement of the good ecological status of European water bodies specified by Directive 2000/60/EC (Water Framework Directive, WFD) is a challenge that must be addressed by European authorities before 2015. As reported for many River Basin Management Plans, one of the most common measures is to implement appropriate wastewater treatment systems in small agglomerations, i.e. urban agglomerations treating less than 1500 population equivalent (more information is available at http://circa.europa.eu/). The selection of the most suitable process involves many possible options, since a variety of objectives should be accomplished. Although a wide number of parameters must be considered, they may be categorized into three main groups: technical, economic and environmental.

The environmental impacts of wastewater treatment systems have been extensively investigated in the literature using the life cycle assessment (LCA) (e.g. Bargallo et al., 2006; Fuchs et al., 2011; Yildirim and Topkaya, 2012). In comparison, economic aspects have been traditionally considered through the financial assessment of facilities (e.g. Chen and Wagner, 2010; Wandl et al., 2006). However, a limited number of studies have examined both environmental and economic parameters together (e.g. Flores-Alsina et al., 2010; Rodríguez-Garcia et al., 2011).

Within the framework of environmental economics, since the 1980s, several methodologies have been developed aimed towards estimating the economic value of the environmental benefits of investment projects. The wastewater treatment sector has not escaped to this trend, with a significant number of studies being carried out to value the environmental benefits (positive externalities) associated towards preventing the discharge of pollutants (e.g. Godfrey et al., 2009; Hernández-Sancho et al., 2010).

The inclusion of environmental benefits in the assessment of the economic feasibility may be considered as a means of integrating economic and environmental variables in a single indicator, which primarily represents the net present value. Molinos-Senante et al. (2010) and Seguí et al. (2009) used a cost benefit analysis (CBA) to assess the economic feasibility of wastewater treatment projects, by considering both factors with market value and environmental benefits. Hence, the economic indicator of feasibility also provides information about environmental issues that were previously translated into monetary units. Despite theoretical developments

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(Hernández et al., 2006; Molinos-Senante et al., 2011a), it is considered that the assessment of the economic feasibility should include both positive and negative externalities; however, all empirical applications to date have primarily focused on positive externalities. In other words, it has been assumed that wastewater treatment is free of costs without market value (i.e. negative externalities).

Due to social and political concerns about climate change, there is growing interest in minimizing the consumption of energy in wastewater treatment plants (WWTPs). Energy consumption is twofold from the perspective of assessing the economic feasibility of the wastewater treatment process. On the one hand, it is an internal cost, since WWTPs operators must pay for the electricity consumed. On the other hand, and more interesting for our purpose, energy consumption is a negative externality, which should not be overlooked. WWTPs consume a significant amount of electricity (WERF, 2010), which involves the emission of greenhouse gases (GHG). The amount of energy needed for operating WWTPs depends on other factors of the implemented technology (Guimet et al., 2010). Hence, negative externalities of the wastewater treatment process vary depending on the technology being used. Although this issue has been overlooked in previous studies, it may play a vital role if the aim of the economic assessment is to compare technologies. In the context of small agglomerations, extensive technologies are generating interest as there are more environmentally friendly than intensive technologies (Yildirim and Topkaya, 2012). However, from an economic perspective, there remains little information about the differences between intensive and extensive technologies.

Against this background, the current study aimed to compare the economic feasibility of five technologies, both extensive and intensive, set-up for secondary treatment in small WWTPs. The integration of externalities in the evaluation also provides information related to the environmental performance of the technologies. Within this framework, we used the CBA tool as a decision criterion. Investment costs are predicted using cost functions, while operation and maintenance costs are based on real data from Spanish WWTPs. Positive externalities are represented by the environmental benefits derived from wastewater treatment, while GHG emissions are the negative externalities. Both types of externalities have been quantified in economic terms, and integrated in the economic assessment. The most innovative part of this research is the economic comparison of intensive and extensive technologies, and the integration of the economic value of GHG emissions into the assessment as a negative externality. The results of our research are expected to be of great use for decision makers as a decision support tool.

2. Material and methods

The cost benefit analysis (CBA) tool should be used to assess the economic feasibility of wastewater treatment technologies rather than traditional financial analysis. The main reason is that wastewater treatment involves significant environmental benefits that do not have market value. If economic feasibility is assessed through financial analysis, externalities derived from this process are excluded, whereas CBA includes internal and external impacts. Therefore, CBA reflects the true costs and benefits associated with wastewater treatment. Other reasons for selecting CBA as the preferred method are that: (i) it allows planners to take a long-term view of the project lifetime and (ii) it provides a project ranking, which, for all practical purposes, proves to be quite scientific and satisfactory.

Following Molinos-Senante et al. (2012), the net profit is the sum of internal and external benefits (Eq. (1)):

$$\mathrm{NP} = \sum B_{\mathrm{I}} + \sum B_{\mathrm{E}} \tag{1}$$

where NP is the net profit (total income − total costs), B_{I} is the internal benefit (internal income − internal costs) and B_{E} is the external benefit (positive externalities − negative externalities). A project is economically feasible if, and only if, NP $>$ 0. The best option is the project that offers the highest net profit.

All of the items considered in Eq. (1) must be expressed in present values. By means of a properly chosen discount rate, the investor becomes indifferent about cash received at different points of time. The net present value is calculated as (Eq. (2)):

$$\mathrm{NPV} = \sum_{t=0}^{T} \frac{\mathrm{NP}_t}{(1+r)^t} \tag{2}$$

NPV is the net present value, NP_t is the net profit at time t; r is the discount rate and T is the project lifespan.

2.1. Internal benefit

The internal benefit is the difference between internal costs and internal incomes. It can be calculated directly, since both components have market value. In a wastewater treatment project, internal costs are composed of the investment costs (IC) and operation and maintenance costs (OMC) of the facility.

Cost functions are a useful tool to quantify IC, as they show the relationship between the dependent variable (cost) and independent variables (a set of representative variables of the process). Therefore, cost functions are widely used to predict the IC of wastewater treatment projects (Gratziou et al., 2006; Nogueira et al., 2007; among others).

Although OMC may also be quantified by cost functions, as reported by Hernández-Sancho et al. (2011) and Papadopoulos et al. (2007), in our specific case study, it has been considered more appropriate to use real data from a sample of Spanish WWTPs. Taking into account that all the wastewater treatment technologies evaluated in this paper are already implemented in Spain, we assume that the data provided directly from the operating companies is more reliable than information provided by cost functions. In any case, if the proposed methodology is used to assess the economic feasibility of technologies, in which real data is not available, the cost function approach should be appropriate.

The term ‘internal income’ could include the potential revenues from the sale of regenerated water. In fact, in areas subject to the harsh conditions of water stress, water reuse is a highly valuable non-conventional water source. However, in most cases, the regeneration of water involves tertiary treatments aimed to obtain high quality effluents. As the aim of this work is to compare the economic feasibility of a selection of technologies for secondary treatment, it is assumed that treated water discharged into the environment is not reused without generating any internal income.

Nowadays, to promote more sustainable wastewater treatment processes, technical studies about the recovery of nutrients and energy from wastewater are being developed (Marti et al., 2010). However, their full scale implementation remains very limited (Cornel and Schaum, 2009). Hence, the possible revenues from the sale of these by-products have been not included in the economic feasibility assessment.

2.2. External benefit

An externality is an effect of a purchase or use decision by one party (or group of parties) on another party who did not have a