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Environmental benefits to society and sustainability aspects of wastewater treatment processes

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Summary of key findings

The aim of this study is the investigation of sustainability aspects of the wastewater treatment in Eindhoven, the Netherlands. The assessment involves the application of a Life Cycle Analysis (LCA) to the Eindhoven wastewater treatment plant (WWTP) for the year 2013 and the subsequent weighting of the LCA impact categories using shadow prices. Using the economic concept of shadow prices, the estimated environmental damage (or 'cost') can be an indicator of the environmental losses for the local society regarding its present and future emission goals. The results also provide some interesting insight on the most "costly" operational processes in environmental terms and can facilitate the proposal, prioritisation and assessment of improvement measures to be applied in the system.

Background and relevance

Various United Nations agencies, along with many individual nations, local governments and corporations have now adopted sustainable development as an overarching goal of economic, social and environmental development (OECD, 2006). Definitions of the concept of sustainable development vary; however, following the Brundtland Report (WCED, 1987), sustainable development is the "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs". Viable answers based on economic, social and environmental considerations will accordingly be necessary.

Economic activities will almost always have a certain by-product of stress on man or the environment (Vos et al., 2007). Externalities are described as side-effects of an activity that influence the welfare of others and that are not being taken into account in the (monetary) valuation of its costs and benefits (de Bruyn et al., 2010). They are typically said to be negative, for example, upstream diversion of water or the release of pollutants from an urban wastewater system reducing the downstream quality. They could also however be positive, such as recharge of the groundwater aquifer as a result of water reuse. While economic externalities are associated to costs to producers and consumers (upstream and downstream), environmental externalities refer to costs to public health, welfare and ecosystems (OECD, 2010). Despite of the growing interest in this concept, the estimation and inclusion of these externalities is not yet very common in economic feasibility studies of activities with environmental effects (Hernández-Sancho et al., 2010).

The valuation of environmental quality (and environmental externalities by extension) aims to express the value society puts on said quality in monetary terms for purposes of assessment and internalisation (de Bruyn et al., 2010). However this is a largely ambiguous undertaking, mainly hindered by the fact that in many cases no market exists for elements such as water quality or pollution (OECD, 2006). An array of different methodologies for the quantification of the value of environmental externalities has been developed in the field of economic theory. One of which is the concept of shadow prices.

These prices can provide an indication of the value society puts on a particular externality, be it positive, for example groundwater recharge, or negative, for example CO_2 emissions (de Bruyn et al., 2010). They can be assigned to pollutants and emissions, environmental impacts and environmental quality in order to assess the merits (or benefits) of a project for society (Curry, 1987). In this manner, shadow prices can provide valuable input into the decision-making process in various ways: to determine the possible income that can be gained in case of privatisation of some resources (Molinos-Senante et al., 2010); used by authorities as informational means to set rates for the use of environmental services and compare the current rates with the marginal generated revenue (Färe et al., 2001); to analyse the social effects of an investment project and compare environmental impacts alongside other monetised costs and benefits by assigning them a monetary value (Curry, 1987); to help the public recognise the benefits generated as a result of environmental improvement programs (Molinos-Senante et al., 2010); and to assign a relative weight to each of the environmental impacts identified in environmental analyses, such as Life Cycle Assessments (LCAs), Environmental Impact Assessments (EIAs) and benchmarking exercises (de Bruyn et al., 2010).

In this study, we employed shadow prices, developed by De Bruyn et al. (2010), to assign relative values perceived by the Dutch society as weights on impacts, estimated through a Life Cycle Assessment (LCA) applied on the wastewater treatment plant (WWTP) of Eindhoven for the year 2013. Weighting is an optional step of the Impact Assessment stage during a LCA, but it can be used to include societal preferences of the various impact categories and convert and aggregate the results into a single indicator. Using shadow prices, the estimated environmental damage (or 'cost') can be an indicator of the environmental losses for the local society regarding its present and future emission goals (Howarth et al., 2001; Vos et al., 2007). Shadow prices as weighting factors have the additional advantage of conforming with other market instruments and integral analyses enabling the decision maker to compare the financial costs and benefits of an action to its environmental impacts (Vos et al., 2007). The study aims to: investigate the life cycle impacts of the operation of the Eindhoven WWTP; and demonstrate how regional societal values regarding the environment can be a valuable tool to support decisions made by water management agencies through ranking impact categories, and estimating total environmental costs and benefits.

Results

The studied system is the Eindhoven WWTP located in the southeast of the Netherlands and treats the wastewater of 750.000 inhabitant equivalents. The received wastewater is treated in three parallel lines, each consisting of a primary settler, a biological tank and four secondary settlers. The plant has a modified UCT (University Cape Town) configuration for biological COD, N and P removal. Approximately 660.000 m^3 of sludge is produced every year, roughly corresponding to 15.000 tons of dry matter content. To avoid odour nuisances, the sludge is not treated at the WWTP, but instead transported via a 7 km pipe system to a sludge processing installation near Mierlo. In Mierlo, the sludge is dewatered and then transported to an incineration facility. The system boundaries include the wastewater treatment, chemicals and energy used during the treatment, deposition of residues from water and the sludge treatment. For the sludge treatment, the dewatering installation and the sludge incineration facility were taken into account along with the chemicals and energy used at said facilities. The transportation of chemicals and dewatered sludge to the incineration facility were also included. No impact from the construction or maintenance of any of the facilities was considered. The functional unit is 1 m^3 of treated effluent water from the Eindhoven WWTP.

The data from the inventories were introduced into the Simapro 7.3.3 software, developed by PRé Sustainability, that allows for the modelling and analysis of complete LCAs in a systematic and transparent manner. To calculate the environmental impacts the ReCiPe Midpoint (H) (1.09) method was used (Goedkoop et al., 2009). The evaluated categories were: Climate Change, Ozone Depletion, Terrestrial Acification, Freshwater Eutrophication, Marine Eutrophication, Human Toxicity, Photochemical Oxidant Formation, Particulate Matter Formation, Freshwater Ecotoxicity, Marine Ecotoxicity.

To attach the relative socio-economic importance put to the various environmental impacts by the Dutch society, the shadow prices were then applied to the environmental impacts estimated in the Impact Assessment phase. The estimated environmental damages can therefore be an indicator of the environmental losses for the Dutch society regarding its present and future emission goals. The resulting costs can be broken down by impact category or by process (Figure 1).

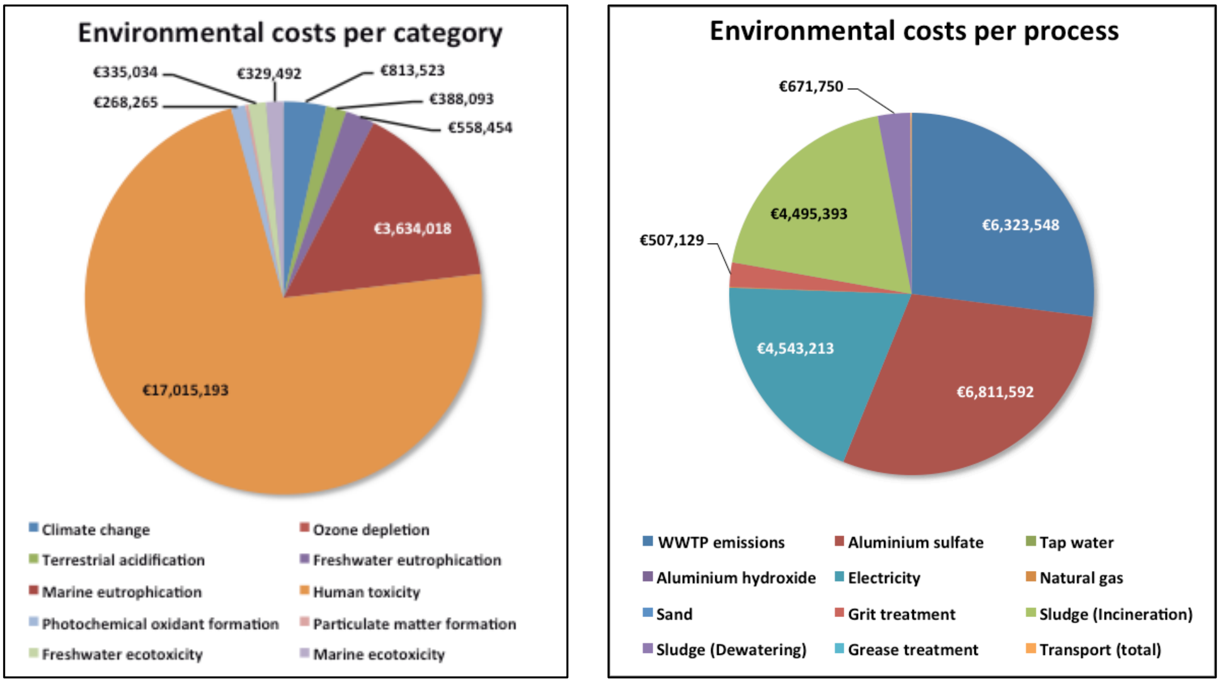

Figure 1: Estimated environmental costs per LCA impact category and per process.

Discussion

This is a preliminary investigation into a life cycle analysis of a WWTP using shadow prices to weight the LCA impact categories. The results provide some interesting insight on the most "costly" operational processes in environmental terms and can facilitate the proposal, prioritisation and assessment of improvement measures to be applied in the system. Future steps include the evaluation of said upgrade measures using the same methodology over a longer time-scale and bigger spatial boundaries.

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