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Friends or foes? Monetized Life Cycle Assessment and Cost-Benefit Analysis of the site remediation of a former gas plant

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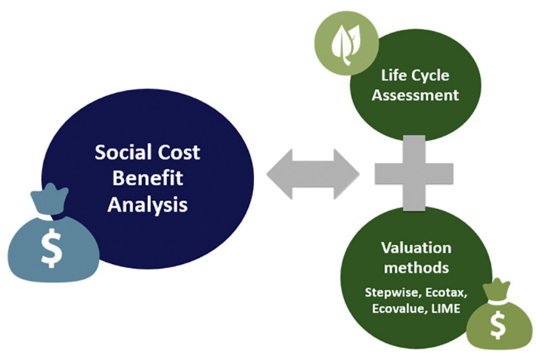
HIGHLIGHTS

- The paper shows a straightforward way to perform an LCA of a site remediation.
- The results of an LCA were monetized using different monetization techniques.
- A social CBA allowed to more accurately evaluate the societal profitability.
- Monetized LCA and social CBA can be combined for a more detailed assessment.

GRAPHICAL ABSTRACT



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ABSTRACT

Site contamination is a global concern because of the potential risks for human health and ecosystem quality. Every contaminated site has its own specific characteristics and the increased availability and efficiency of remediation techniques makes the choice of remediation alternative increasingly complicated. In this paper an attributional Life Cycle Assessment (LCA) of the secondary environmental impacts of a site remediation is performed and its results are monetized using two different monetization techniques, namely Stepwise 2006 and Ecovalue 08. Secondly, we perform a social Cost-Benefit Analysis (CBA) on the same case study using the same data sources. The case study used in this paper entails the soil and groundwater remediation of a tar, poly-aromatic hydrocarbons (PAH) and cyanide contamination of a school ground by a former gas plant. The remediation alternative chosen in this case study is excavation with off-site thermal treatment of the contaminated soil. The outcome of the social CBA, stating that the remediation project is socially beneficial in the long term, is critically compared to the outcome of the different LCA monetization methods. This comparison indicates that monetized LCA is a good complement to social CBA when it comes to the assessment of secondary environmental impacts. Combining the two methods provides decision makers with a more extensive and detailed assessment of the soil remediation project.

1. Introduction

During the past decades, soil contamination is more and more acknowledged as a problem all around the globe. In Europe alone, there are >2.5 million potentially contaminated sites of which 14% are expected to require remediation (Van Liedekerke et al., 2014). The cost of managing these contaminations is estimated at 6 billion euros annually (Panagos et al., 2013). The huge amount of contaminated sites that will have to be remediated in the coming years increased the attention for the secondary impacts (i.e. the environmental impacts caused by the site remediation activities themselves) of a site remediation.

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Although mineral oil and heavy metals are the main contaminants (60%) found on European contaminated sites, each contaminated site has its own specific characteristics and the range of potential contaminants is large. This site heterogenity as well as the recent focus on sustainable remediation has resulted in new developments and has stimulated technological innovations in site management and cleanup. The increased availability and efficiency of remediation techniques complicates the final choice between remediation alternatives. Life Cycle Assessment (LCA) can support site owners and remediation companies in the choice between remediation alternatives by taking into account primary (related to the contamination initially present on the site) as well as secondary (related to the remediation activities) environmental impacts. LCA as such has been used in several case studies to compare the secondary environmental impact of different remediation alternatives, but the technique has been critiqued within several fields of research for being too complicated, time consuming, and data demanding (Cappuyns and Kessen, 2012; Hoogmartens et al., 2014; Tufvesson et al., 2012). The present paper shows how an attributional LCA, assessing the secondary environmental impact of a site remediation study is not necessarily complicated.

A second well-known decision support tool is a Cost-Benefit Analysis (CBA). CBA is a well-developed tool to support the decision making process, but it has been applied only rarely to site remediation projects. In the literature, the value of CBA for site remediation has been recognized early on (Bonnieux et al., 1998) and is currently still considered to be valuable to the decision making process (European Commission, 2014; Guerriero and Cairns, 2011a, 2011b). Even though there has been high praise for the use of CBA, only limited full studies have been performed in the context of soil contamination (Lavee et al., 2012; Söderqvist et al., 2015; van Wezel et al., 2007; Volchko et al., 2017; Wan et al., 2016). The efforts made in the literature mainly focused on parts of a CBA, for example either on the costs or cost efficiency of a site remediation project (Forslund et al., 2010; Hamilton and Viscusi, 1999; Hylander and Goodsite, 2006; Lemming et al., 2010a; Van Liedekerke et al., 2014) or on the potential benefits of remediation (Bartke, 2011; Barton et al., 2010; De Romagnoli, 2011). Further, some limited CBA calculations have been performed within the bigger framework of sustainability studies for site remediation alternatives (Morio et al., 2013; Schädler et al., 2011).

In the current paper we perform a full social CBA of a site remediation following a methodology commonly described in CBA literature. In such a social CBA, all impacts to society are included, and the Net Present Value (NPV) is calculated for a case study or a policy scenario including the direct and indirect financial costs and benefits as well as the health and environmental benefits and other relevant impacts. In the literature there is ambiguity about the terminology and definitions with respect to a CBA, which can be a private CBA or a social CBA. A CBA can either be a private CBA based on the viewpoint of one particular stakeholder (e.g. a firm, a homeowner or a local community) or a social CBA based on the viewpoint of society as a whole (i.e. all affected stakeholders). A private CBA thus takes into account all the costs and benefits of a particular stakeholder – also known as private agents - associated with the project. Other possible terms used in the literature for this type of analysis are financial appraisal or investment analysis (Prokofieva and Thorsen, 2011). In our assessment we aim to take into account all impacts for society as a whole and thus perform a social CBA. The case study that is used consists of an excavation and off-site soil cleaning of a former gas factory site in Belgium contaminated with tar and cyanide.

The main objective of the study is to critically compare the outcome of the social CBA to the outcome of different monetization methods, namely Stepwise 2006 and Ecovalue 08, which use the outcome of an LCA to calculate the monetary value of the environmental impact. The monetization of the results of an LCA is not frequently done within the context of site remediation (Lemming et al., 2010a), but occurs in other disciplines, for example consumer products, food (e.g. Weidema et al., 2008a, 2008b), construction works (Wu et al., 2005) and waste management approaches (e.g. Soares et al., 2013). The comparison of the monetized LCA results and those of the social CBA allows to evaluate similarities and differences between social CBA and monetized LCA. This evaluation is being done by identifying the elements that are not covered by the monetization methods mentioned above and their underlying assumptions. In the present paper we also evaluate whether monetized LCA and social CBA can strengthen each other in an overall assessment.

1.1. Case history and description

The case study assessed in this paper is the remediation of a former gaswork site located in Flanders (Belgium). In the 19th century gas factories were used to provide energy and lighten the city. These factories were therefore located near or in the city center and were partly bombarded during World War 1. The gaswork site investigated in the present study was operational in the late 19th century and the beginning of the 20th century. Other former onsite activities include a spinning mill, a gas plant, a gas holder, a dye house and a general workplace and warehouse. Later on the site was also used by the local government, as a garage housing a lubrication station, an underground gasoline tank of 4000 l, a repair workshop and a concrete goods factory until 1986. Currently the site is the location of a secondary school and the local fire department. After the remediation has taken place the use of the site will remain the same (Vinçotte, 2016, 2015).

The historic activities, mainly the production of city gas by heating coal without oxygen, caused a contamination of the soil and groundwater with tar, PAHs (Polycyclic Aromatic Hydrocarbons) and cyanide. The contaminants found during soil and groundwater investigation are mineral oil, BTEX (benzene, toluene, ethyl benzene and xylene), naphthalene, benzo(*a*)pyrene and cyanide (Table 1). The contaminants concentrations imply a risk to human health and this made the remediation of the soil and groundwater contamination a legal obligation. Up to a depth of 15 m the soil at the site is sandy, often containing debris. Underneath this first sandy layer there is a poorly permeable clay layer. From a depth of 32 m below surface a second permeable groundwater layer occurs. The depth of the superficial groundwater table lies between 1 and 2 m below soil surface and the groundwater flows towards the local river at approximately 100 m south of the contaminated site. The descriptive soil remediation analysis showed that there was no immediate risk (500 years) for contamination of the local river by the contaminated groundwater (Vinçotte, 2016, 2015).

1.2. Remediation technique

The remediation technique chosen for this case study is excavation and off-site cleaning of the contaminated soil. This remediation technique will remove the tar contamination until the residual amount of contaminants will no longer form a serious treath to human health or ecosystem quality. This is accomplished by excavating the pure tar and the tar contaminated soil and lowering the groundwater table to 5.5 m below surface. Afterwards the excavated parts of the site will be refilled with externally supplied clean soil. The source of the PAHs and cyanide contamination is removed, stabilizing the contaminated plume in the groundwater, by excavating and removing the first 70 cm of soil. From a depth of 70 cm to 2.5 m, the soil will be excavated and contaminant concentrations will be tested for each excavated batch of soil. Only the contaminated soil batches will be removed from the site and brought to an off-site soil treatment facility. Soil batches contaminated with tar are cleaned physiochemically while batches contaminated with cyanide are treated in an off site thermal cleaning facility. The uncontaminated soil will be temporary stored onsite and will be used to refill a part of the excavated site. Additional clean soil will be imported to refill the site fully. During the excavation of the soil the groundwater will be lowered to a depth of three meters below surface.