LIFE CYCLE ASSESSMENT (LCA) AS A MEANS OF COMPARISON BETWEEN ACTIVE AND PASSIVE REMEDIATION TECHNOLOGIES FOR WASTEWATER AND CONTAMINATED SOILS

Extended abstract

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Background

Life Cycle Assessment is a powerful and widespread tool to evaluate the environmental efficiency of products and processes. An application is reported of the Life Cycle Assessment tool in an unusual field for this method such as the evaluation of remediation techniques for contaminated soils and water in order to understand the environmental impacts related with clean-up interventions.

The initial goal of the study was to assess technology-specific impacts of two different remediation systems, but soon the lack of appropriate tools to address the use of natural resources such as groundwater became self evident. The difficulty to address similar issues (i.e. land use) through the LCA methodology appeared in other fields of application too, suggesting the need to find new methodological tools to fill this methodological gap (Bayer and Finkel, 2006).

Objectives

In this case study it has been used to investigate the behavior of two different technologies for the remediation of polluted groundwater on a Life Cycle perspective (Lemming et al., 2010). The main focus of the LCA study was to address the environmental benefit deriving from the in-situ remediation operated by the PRB, which leaves groundwater in the aquifer instead of discharging it as surface water as the PTS does, thus allowing the conservation of a natural resource which cannot be restored in short periods.

Outline of the work

A first stage of the work has been dedicated to the Life Cycle Assessment of the two remediation technologies: a Permeable Reactive Barrier (PRB) built with the funnel-and-gate design (in-situ remediation technology) and a Pump and Treat System (PTS) using Activated Carbon (active remediation technology). The sizing and design of the PRB was based on an actual working plant while the sizing and design of the PTS is based on literature data.

The comparison of the environmental performance shown by the different technologies in the preliminary phase has lead to define critical impact categories for both and to tune the model and related assumptions according to observation and analysis of preliminary results.

A new implementation of the model has been set after an extensive evaluation of the influence of the groundwater resource depletion as a potentially-leading element and further development of this kind of analysis are planned for the research group.

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Methods

The passive nature of Permeable Reactive Barrier systems (PRB) implies greater material production requirements in the installation phase and significant reduction in energy related impacts (Higgins and Olson, 2009).

The barrier has been modeled according to the “funnel and gate” method. In a funnel-and-gate configuration, low permeability funnels direct ground water towards a permeable treatment zone or gate. The “funnel” typically consists of sheet pilings, slurry walls, or some other material and is preferably “keyed” into an impermeable layer (clay, bedrock) to prevent contaminant underflow. This funnel is emplaced to encompass and direct the flow of contaminated water to a “gate” or “gates” containing a permeable zone of granular Fe(0) or other reactive material (USEPA, 1998). In this case, zero valent iron (ZVI) was used as dechlorinating agent.

To allow comparison, assumptions have been made as follows: the functional unit has been identified as 1 m3 of treated groundwater; the expected lifespan of the technology has been set to 10 years; treatment efficiency has been supposed to match legal pollutant concentration requirements; the only contaminant taken into account is TCE; the special cement mixture used in the construction of the funnel (see inventory table) has been modeled according to standard bentonitic cement; the initial installed amount of ZVI is expected to be used for the whole plant lifespan.

The main impact categories affected by this technology are related to water, both directly as for the Ecotoxicity to water aspects and indirectly through human toxicity (Diamond et al., 1999; Zaitsev et al., 2010). The recycled cast iron production process accounts for the best part of the main impact categories, followed by the production of the bitumen mix for the funnel. The Italian electricity mix implemented affects the nuclear waste aspect, as previously stated. The Pump-and-Treat System has been modeled assuming the same treatment efficiency and volume of treated groundwater as the PRB. The contaminated groundwater is extracted through two wells, each one 17 meters deep, and pumped to the GAC vessels through two conduits for a total length of 20 meters. Each well is expected to pump out of the aquifer 1.8 L/s of contaminated groundwater. The daily flow (311 m3) through the GAC vessels is approximately 8 times higher than the groundwater flow taken into account for the LCA of the Permeable reactive barrier. It has to be noted that the pump and treat system works extracting groundwater and discharging it as surface water after treatment, thus consuming a non renewable (in the short-medium term) resource. The groundwater removal which is necessary for PTS remediation has been modeled in SimaPro including among the components of the process the use of a groundwater volume corresponding to the treated groundwater volume, and as a component of the waste scenario an equivalent volume of slightly polluted wastewater.

The main impacts related to the PTS system are ecotoxicity (both chronic and acute), for which the main contributors are the GAC production, human toxicity, mainly due to the construction processes, global warming and bulk waste, whose main contributor is the wastewater.

Results and discussion

Impacts related to the different technologies and sub-processes have been calculated through the implementation of the SimaPro model, with the EDIP97 method, which returns weighted results on 16 impact categories. The Pump-and-Treat System shows a poorer overall environmental performance compared to the PRB system, mainly due to the large contributions of the GAC production and wastewater disposal: in particular, human toxicity, bulk waste and global warming potential are the most unfavourable impact categories for the PTS. It has to be noted though that the PTS accomplishes its remediation objectives in a much shorter time than PRB (approximately 1.4 years against 10 years): it can be thus assumed that assessing its performance on a longer operation might show significant improvements, as the operation related processes are minor contributors to environmental impacts. As shown in Figs. 1-3 (values expressed in EDIP Points), the main impacts related to the PTS are attributed to the GAC production process and digging of the boreholes, while the ecotoxicity on water and toxicity on soil appears to be the most affected impacts categories.

![Fig. 1. Impacts of the Pump & Treat System, operation and disposal processes in the different impact categories (including long-term impacts)](Pt)
Life cycle assessment (LCA) as a means of comparison between active and passive remediation technologies

Fig. 2. Impacts of the Permeable Reactive Barrier, operation and disposal processes in the different impact categories (including long-term impacts) [Pt]

Fig. 3. Comparison between overall impact of PTS and PRB [Pt]

The Permeable Reactive Barrier shows worst environmental performance on ecotoxicity on water and toxicity to human health on water and soil, but, if compared with PTS technology on the same premises (i.e. same pollution conditions and same water volume to be treated), the overall impact remains 15% lower.

Concluding remarks

The designed case study of Life Cycle Assessment applied, on the same premises, on two different remediation technologies underlined the different environmental performance they provide, both in absolute value and relative distribution among the impact categories, but, most of all, it has given the opportunity to experiment a possible solution for a gap of the LCA model. In absence of an appropriate consideration of the negative impact deriving from the active remediation approach, which extracts groundwater from boreholes, changing the nature of the resource into surface water, the comparative study could not be complete. In this case, the readiness of the active technology in the remediation process is counterbalanced by this aspect, resulting in a positive comparative performance of the passive one, which preserves the groundwater resource’s (non-renewable in long-medium term) quantity while restoring its quality in observance of the contamination values established by law, which are stricter than the values established for surface water.

The opportunity to provide a correct and comprehensive account of the environmental costs and impacts of the groundwater resource depletion, caused by contamination and remediation technology to be applied, proved to be a key element in a decision support approach to Life Cycle Assessment and this study offers a first attempt to fill a gap into LCA modeling.

Keywords: active remediation technology, LCA, PRB, PTS, remediation technology
References


