LCA Case Studies

Life Cycle Assessment of Water from the Pumping Station to the Wastewater Treatment Plant

Stéphane Lassaux*, Robert Renzoni and Albert Germain

University of Liège, Laboratory of Industrial Chemistry, Allée de la Chimie, B6, 4000 Liège, Belgium

* Corresponding author (St.Lassaux@ulg.ac.be)

Abstract

Goal, Scope and Background. The goal of this study is to determine the environmental impact of using one cubic metre of water in the Walloon Region. The whole anthropogenic water cycle is analysed, from the pumping stations to the wastewater treatment plants. The functional unit has been defined as one cubic metre of water at the consumer tap. This study was carried out in the context of the EU Water Framework Directive. It is part of a programme called PIRENE launched by the Walloon Region to fulfil the requirements of this Directive.

Methods. A model of the whole anthropogenic water cycle in the Walloon Region was developed. The model is mainly based on site-specific data given by the companies working in the field of water production and wastewater treatment. It was used to assess the environmental impact from the pumping station to the wastewater treatment plant using the Eco-Indicator 99 methodology. Eco-Indicator 99 has been adapted in order to better take into account environmental impact of acidification and eutrophication. Characterisation factors have been calculated for COD, nitrogen and phosphate emissions. From the reference model, different scenarios have been elaborated.

Results and Discussion. On the basis of the inventory, the environmental impact of five scenarios has been evaluated. Acidification and eutrophication is the most important impact category. It is mainly caused by the wastewater that is discharged without any treatment, but also by the effluent of the wastewater treatment plant. So, this impact category has the lowest environmental load when the wastewater treatment rate is high. For the other impact categories, the impact generally increases with the wastewater treatment rate. During wastewater treatment, energy and chemicals are indeed consumed to improve the quality of the final outputs, and thus to reduce the environmental impact related to acidification and eutrophication. A comparison between the scenarios has also shown that the building of the sewer network has a significant contribution to the global environmental load and that the stages before the tap contribute less to the environmental impact than the stage after the tap.

Conclusions. The three stages that contribute significantly to the global environmental load are: water discharge, wastewater treatment operation and, to a lesser extent, the sewer system. The results show that the wastewater treatment rate must be as high as possible, using either collective or individual wastewater treatment plants. Even a small water discharge without any treatment has a significant environmental impact. Operation of the wastewater treatment plants must also be improved to reduce the environmental impact caused by the effluent of the plants. For new wastewater treatment plants, building plants treating nitrogen and phosphorus should be encouraged. A sensitivity analysis was conducted and showed that the results of the study were not very affected by a modification of key parameters. Impact assessment using the CML methodology has confirmed the results obtained with Eco-Indicator 99.

Keywords: Anthropogenic water cycle; environmental impact; life cycle assessment; wastewater treatment plant; water

Introduction

In 2000, the EU Water Framework Directive was adopted. This directive sets ambitious objectives to ensure that all waters (rivers, lakes, coastal waters and groundwaters) meet a ‘good status’ by 2015. To achieve the requirements of this Directive, a programme called PIRENE (Programme Intégré de Recherche ÉNvironnement-Eau) was conducted by 18 teams from different Universities and Research Laboratories from the Walloon Region in Belgium. The goal of this programme was to develop the necessary tools for the Walloon Region to ensure an integrated management of water. Our team was in charge of the life cycle assessment of water. Some data give an illustration of the complexity of this task: more or less 400 million cubic metres of water are pumped each year in the Walloon Region, more than 100 wastewater treatment plants are in use.

Life cycle assessment has already been used to study particular processes of the anthropogenic water cycle, mainly in the field of wastewater treatment and sewage sludge management. Tillman et al. [1] analysed different alternatives for municipal wastewater systems for two cities in Sweden. A study of Hospido et al. [2] showed that water discharge and sludge application to land are the main contributors to the environmental load of a municipal wastewater treatment plant. Concerning sewage sludge, Suh et al. [3] presented a comparison of alternative wastewater sludge treatment scenarios. This point was also developed by Houillon et al. [4] who compared six wastewater sludge treatment scenarios (agricultural spreading, fluidised bed incineration, wet oxidation, pyrolysis, incineration in cement kilns and landfill) focussing on energy and emissions contributing to global warming. There are very limited references considering the whole water cycle from the pumping station to the wastewater treatment plant. Balkema et al. [5] tried to identify sustainable treatment options for domestic water including water supply in their system boundaries, but it was done indirectly by offering the possibility to use different water qualities.

1 Goal and Scope

The goal of this study is to determine the environmental impact of using one cubic metre of water in the Walloon Region from the pumping station to the wastewater treatment plant. The function is production, distribution and treatment of water in the Walloon Region. The functional
unit is defined as 1 cubic metre of water at the tap of the consumer. The analysed processes are:

- Water catchment (from ground and surface waters)
- Water treatment
- Water supply
- Sewer system
- Collective and individual wastewater treatment plant
- Wastewater sludge treatment
- Water discharge (without treatment)

For each of these processes, building and operation of the installations are studied. After evaluation of the environmental impact of a reference scenario, it will be possible to develop other scenarios reflecting different management options.

2 Description of the System

The reference scenario is based on data coming, on one side, from the companies working in the sector in the Walloon Region (water producers and suppliers, wastewater plants, ...) and, on the other side, directly from the Walloon Region public offices. The reference year is the year 2000.

2.1 Water balance in the Walloon Region

It is necessary to establish a balance of water flows in the Walloon Region in order to determine equivalent volumes for each stage of the water cycle. One cubic metre of water at the production is indeed not equal to one cubic metre at the tap. There are leaks during the water supply and there are also unregistered flows (e.g. for the fire department). Similarly, the consumption of one cubic metre of water at the tap doesn’t mean that one cubic metre will be treated in the wastewater treatment plant (WWTP).

The water flow balance in the Walloon Region for the year 2000 (data mainly from [6]) lies at the basis of a diagram (Fig. 1) representing volumes equivalent to one cubic metre at the tap for each stage of the water cycle. Thus, on this diagram, it’s possible to see that it’s necessary to catch 2.47 cubic metre of water to finally have 1 cubic metre at the tap, but that an important part of the water extracted is exported to other regions in Belgium. After the tap, the major part of the water (0.78 cubic metre) is going to the sewer system. However, only a part is collected (0.70 cubic metre) and only a small part is treated in a wastewater treatment plant (0.29 cubic metre). The rest, except 0.01 cubic metre which goes to an individual wastewater treatment plant (Indiv. WWTP), is not treated, and directly rejected in the ecosystem. Besides wastewater, other types of water, like rainwater, are flowing through sewers and wastewater treatment plants. This contribution is taken into account and is represented in grey on Fig. 1.

The different processes on this diagram are presented in the next paragraphs.

![Water flow balance relative to one cubic metre at the tap in Walloon Region](image)