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Life Cycle Assessment of water treatment: what is the contribution of infrastructure and operation at unit process level?

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ABSTRACT

In the literature, Life Cycle Assessment studies of drinking water production systems do not show or fully clarify the contribution of the specific unit processes, of the plant infrastructure and of sludge spreading to the overall generated environmental impact. Nevertheless, these constitute key issues for the optimization and management of such plants. This article aims at providing a consistent and up to date assessment based on detailed operation and infrastructure design data at unit process level for two complex plants located in France. At the single score level, the study shows that the complexity of the treatment chain is not a reliable indicator of its environmental footprint. The overall generated impact is driven by the consumption of fossil resources, mainly related to electricity and activated carbon production. These consumptions are mainly concentrated at the settling and distribution unit processes. The contribution of infrastructure to the single score varies from 4% to 11%, with steel usage being the main contributor. The importance of toxicity generated by sludge spreading is still unclear because of the insufficient degree of precision and consistency of the assessment. In particular, significant variability of the toxicity of heavy metals is observed, ranging from 0.10 to 0.55 millipoints/kg sludge.

1. Introduction

Life Cycle Assessment (LCA) is a widely accepted methodology for the evaluation of the potential environmental impacts of human economic systems, with two key features: i) comprehensiveness: it accounts for the whole life cycle, from cradle to grave, related to the studied system; ii) multi-criteria analysis, as it evaluates a broad range of environmental impacts. LCA was originally developed to allocate environmental pollution of production activities to specific products and commodities (attributional approach), for comparative purposes, in order to support product labelling and development. For the past decade, LCA methodology, both regarding the data inventory and impact assessment steps, has evolved to increase the robustness and the reliability of results and to allow its application to respond to broader societal and policy related questions, e.g. regarding biofuels (consequential approach). Applications to industrial processes, and particularly (waste) water treatment, have been developed more recently and can be placed somewhere in between the two approaches from a methodological perspective. Unfortunately, published LCA studies lack transparency and still suffer of methodological limitations, inconsistencies and incompleteness, which possibly lead to the misinterpretation and finally misuse of the results.

This paper aims at presenting a consistent application of LCA for the assessment of two existing complex water treatment plants, focussing mainly on two elements that have not been comprehensively addressed in the literature to date: i) the importance of infrastructure as compared to the operation phase, at the level of each unit process composing the treatment chain instead of the overall plant; ii) the effective contribution of waste generated by the plant, particularly the contribution of mineral sludge spreading to the overall environmental impact of the plants. In a companion paper (Igos et al., 2013), the problem of fair comparability between LCAs of alternative water treatment plants is addressed. The interest of studying two specific water treatment plants mainly relies on the high quality inventory data that have been collected, especially given that comparable data are not available in current LCI databases.

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A review of existing LCA studies on water treatment has been published recently by Bonton et al. (2012). In the reviewed studies, the impact related to the infrastructure of the plants accounts for less than 15% of the impact of the operation phase (in some cases less than 5%). Similar conclusions were drawn by Godskesen et al. (2011). Conversely, the end of life of mineral sludge from the treatment is often neglected or omitted in the published literature, whereas abundant literature is available regarding the environmental assessment of sewage sludge spreading, e.g. Lederer and Rechberger (2010), Hospido et al. (2010), Pradel et al. (2010) and Langevin et al. (2010). Bonton et al. (2012) highlight significant impacts related to ecotoxicity due to sludge spreading, which is directly related to aluminium emissions to soils. However, the study did not consider that aluminium was inventoried in the metal form, whereas the ecotoxicity impact in the Life Cycle Impact Assessment (LCIA) method used (Impact2002+) applies only to aluminium ion. As a result, the impact of aluminium is overestimated and the actual significance of sludge spreading is still unclear.

2. Materials and methods

2.1. Goal and scope

The goal of this study is to carry out a consistent LCA of 1 m^3 of potable water produced by two existing water treatment plants, named Site A (maximum 40,000 m^3/day) and Site B (maximum 25,000 m^3/day) for confidentiality reasons (Fig. 1). The aim is to investigate the main processes contributing to the overall environmental impacts, at the level of each unit process of the

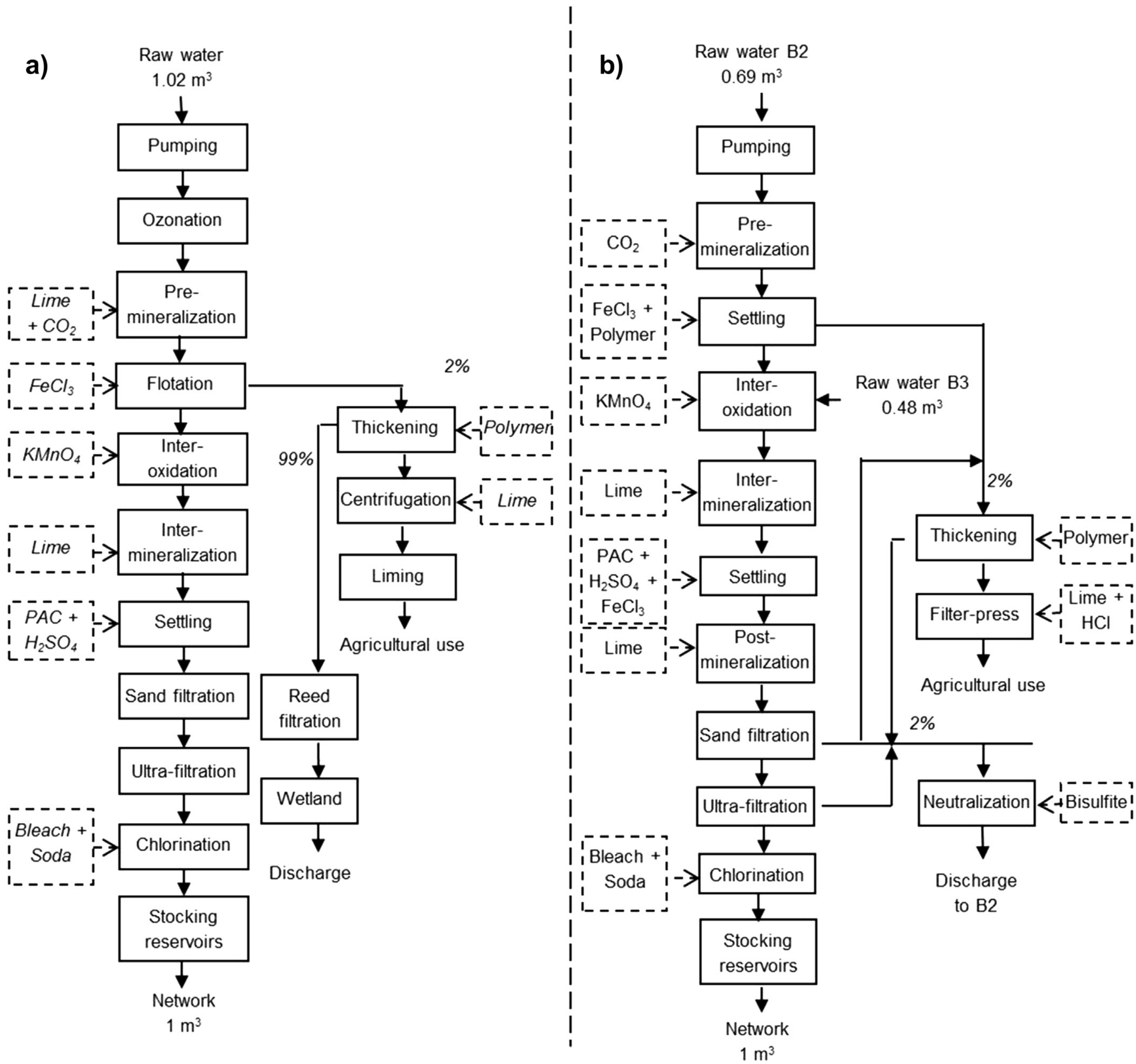

Fig. 1. Flow chart of the production of potable water for a) Site A and b) Site B. The reagents used for each unit process are in dashed boxes. Among them, PAC is powdered activated carbon.