Water Research 104 (2016) 231–241

Contents lists available at ScienceDirect

Water Research

journal homepage: www.elsevier.com/locate/watres

Up to what point is loss reduction environmentally friendly?: *The LCA of loss reduction scenarios in drinking water networks*

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ARTICLE INFO

Article history:
Received 29 January 2016
Received in revised form
23 May 2016
Accepted 11 July 2016
Available online 13 July 2016

Keywords:
LCA
Water loss reduction
Drinking water networks
Water resources
Urban water system

ABSTRACT

In a context of increasing water shortage all over the world, water utilities must minimise losses in their distribution networks and draw up water loss reduction action plans. While leak reduction is clearly an important part of sustainable water management, its impacts have to be reconsidered in a broader objective of environmental protection than strictly the avoided losses in cubic metres of water. Reducing the volume of water abstracted reduces also environmental impacts associated to water production (the operation and infrastructure needed for abstraction, treatment, supply). In the mean time, activities for reducing water losses generate their own environmental impacts, notably as a result of the work, equipment, and infrastructures used for this purpose. In this study, Life Cycle Assessment (LCA) was used to assess and compare two sets of environmental impacts: those resulting from the production and supply of water which will never reach subscribers, and those caused by water loss reduction activities. This information can then be used to establish whether or not there is a point beyond which loss reduction is no longer effective in reducing the environmental impacts of drinking water supply. Results show that the improvement actions that start from a low water supply efficiency are clearly beneficial for ecosystems, human health and preservation of resources. When seeking to improve the efficiency beyond certain values (about 65%), the uncertainty makes it impossible to conclude for an environmental benefit on all impact categories.

1. Introduction

Each year, more than 32 billion cubic metres of treated water are lost worldwide through leakage from drinking water distribution networks (Farley et al., 2008). According to these authors, saving half of this loss would supply water to 100 million people. Water loss is also a loss of profit for water utilities: the total cost for water utilities caused by Non-Revenue Water is estimated at $14 billion per year (Kingdom et al., 2006). Reducing water losses is therefore a great social and economical challenge. But reducing this waste of water resources is also an environmental issue considering that water scarcity affect a number of regions around the world, not only in arid areas, but also in more temperate regions (Lehner et al., 2006).

In France, to take into account this environmental challenge, specific regulations (Ecology, 2010) were introduced in 2010 with the aim of reducing losses from drinking water supply networks. Under the new regulations (Ecology, 2012), French water network managers are required to draw up water loss reduction action plans when the level of water lost from their networks exceeds a legally-defined threshold. Nevertheless at world scale, as in France, many regions have abundant water resources and deploying such a policy to entire countries leads to the following question: How severe are the environmental impacts of actions taken to reduce losses compared with the environmental benefits of water savings?

While leak reduction is clearly an important part of sustainable water management, its impacts have to be reconsidered in a broader objective of environmental protection. Activities aimed at reducing the volume of water abstracted can actually generate their

Abbreviations: ALC, Active leakage control; DMA, District metered area; TWP, Tap water production; FU, Functional unit; LCA, Life cycle assessment; LCI, Life cycle inventory (i.e. inventory of natural resources consumption and pollutants emissions); LCIA, Life cycle impact assessment; UWS, Urban water systems; Water supply efficiency, [1 − (loss volume per year / volume supplied to the network per year)].

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http://dx.doi.org/10.1016/j.watres.2016.07.025
0043-1354/

own environmental impacts, notably as a result of the work, equipment, and infrastructures used.

In this study, Life Cycle Assessment (LCA) was performed to assess and compare two sets of environmental impacts: those resulting from the production and supply of water which will never reach subscribers, and those caused by water loss reduction activities. This will provide a clearer indication of the environmental issues linked to losses from drinking water networks. This information can then be used to establish whether or not there is a point beyond which loss reduction is no longer effective in reducing the environmental impacts of drinking water production and supply.

LCA is a multi-criteria environmental impact assessment method used to quantify the potential impacts of human activities on ecosystems, natural resources, and human health. It involves assessing the impacts of natural resources being used, as well as environmental releases into air, water, and soil caused by the object studied during its entire life cycle, cradle to grave (i.e. from the time it is created up until the time it ceases to exist). At present, this method is commonly used for environmental evaluation, based on established international standards (ISO, 2006a) (ISO, 2006b).

The analysis of the state of research shows a recent increase number of studies relating to the environmental impacts of drinking water production. (Lundie et al., 2004) have presented in 2014 one of the first LCA model of an integrated urban water and wastewater system. Ten years after (Loubet et al., 2014), conduct a comparative analysis of selected peer-reviewed literature dealing with urban water system and identify 18 LCA studies in which drinking water production (DWP) was included but without any thorough focus on loss reduction. In a very recent LCA study (Li et al., 2016), compares water supply alternatives from different sources (including water diversion options conducted at large scale in China). They highlight the embedded water loss that occurs during water diversion before water reaches the urban water system. In parallel, economic assessments of water loss reduction strategies were conducted, such as (Sturm et al., 2013) and, more recently (Cherchi et al., 2015), that investigate the cost and energy optimization of Drinking Water Distribution Systems. They point out the fact that minimization of water losses in water distribution systems and the implementation of pressure management strategies have a potential to improve the energy efficiency of the system.

In this research status context, the originality and significance of our work lies in the fact that none of these studies addressed the question of the actual environmental advantages gained from loss reduction using the holistic LCA approach.

2. Materials and methods

This study uses the general Life Cycle Assessment (LCA) framework and its four methodological stages (ISO, 2006a): (i) Goal & scope definition, (ii) Life Cycle Inventory (LCI) analysis, (iii) Life Cycle Impact Assessment (LCIA) and (iv) Interpretation of results. The first three stages and a specific section about studied scenarios are presented hereunder in the material and method section. The fourth stage (iv) will be presented in Section 3, 'Results and discussion'.

2.1. LCA goal & scope definition

Managers of Urban Water systems (UWS) often have to limit their water losses under targeted or legally-defined threshold that use the water supply efficiency indicator. Therefore, this study aims to assess the environmental benefit of reducing water losses for various level of efficiency. For that purpose, the environmental benefits resulting of the avoided tap water production (including abstraction, treatment and supply) will be compared to the environmental impacts associated a multi-year action plan that achieves an efficiency target.

Water loss reduction is not achieved through separate, uncoordinated actions, but by implementing a specific multi-year action plan, as defined in the dedicated guide for creating an action plan for this purpose (Renaud et al., 2014a,b). There are a number of actions that can be taken to reduce water losses (the guide lists 38). However, only actions reducing or stopping parasitic losses can lead to reduce the volume of water actually abstracted. Most others aim to improve operational efficiency and speed in dealing with failures, contributing indirectly to reduce water loss levels. Our study focuses on conventional action plans for water loss reduction implemented over a period of 5 years, made up of six actions commonly used in France (described in Table 1). These actions are combined in four scenarios of actions plans described in detail in paragraph 2.2. Each of these scenarios has five years duration and achieves a water supply efficiency target.

2.1.1. Functional unit

LCA is a relative approach, structured around a functional unit (FU) (ISO, 2006a). This FU defines what is being studied (i.e. the service provided by the studied system). All subsequent analyses are then relative to the chosen FU, such as inputs and outputs to and from the inventory (LCI) and consequently the impact assessment (LCIA). On the basis that the aim of an action plan is to reduce the abstraction of water by reducing losses, and in order to compare several scenarios in terms of their effectiveness in reducing them, the **FU selected was "avoided production of 1 m^3 of drinking water"** (i.e. water not abstracted from natural resources). To express the results of an action plan according to FU, impacts and water savings are assessed over a five years period (duration of an action plan scenario).

2.1.2. System boundary

As defined in (ISO, 2006a), LCA is conducted by defining a set of product systems as models that describe the key elements of the studied physical systems. The system boundary defines the unit processes to be included in the system and allows the listing of all interactions between the environment (the eco-sphere) and the system being studied (the techno-sphere). Based on our goal & scope, the system boundary is presented in Fig. 1. It includes all processes associated to tap water production (TWP), from the water resource to user gates as well as all processes required by water loss reduction action plans. Table 2 summarise the detail content and the boundaries of each actions and sub-actions implemented in scenarios.

2.2. Studied scenarios

2.2.1. Proposed approach for loss reduction scenarios

In order to assess the environmental benefit of reducing water losses for various level of efficiency (goal & scope of the study), four action plan scenarios were defined. Each scenario is a combination of selected actions (as defined in Table 1) implemented during a 5 years action plan. The 4 scenarios proposed in this study were inspired on a French water utility example (La Réole water utility, F33190 France, approximately 3500 subscribers).

To compare realistic scenarios of loss reduction and free us from local context specificities, we used the approach proposed in Fig. 2 starting by the selection of 6 common actions (Step 1). In Step 2, we define the first scenario based on actual observed situation and on a final efficiency of 62%. Then, we progressively increased the level of efficiency of each next scenario (Step 3) to achieve French legal thresholds (scenario 2 and 3) or the maximal efficiency according to technical considerations (scenario 4). Scenarios are constructed