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An integrated modeling approach to optimize the management of a water distribution system: improving the sustainability while dealing with water loss, energy consumption and environmental impacts

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Abstract

There is a strong link between water and energy in municipal water systems then the Alliance to Save Energy coined the term "Watergy" [1].
Each component of the integrated water system contributes differently to the energy balance. With regard to urban water distribution systems (WDS), the pumping energy cost represents the single largest part of the total operational cost, also magnified by every litre of water lost to leaks. Even a small increase in operational efficiency may result in significant cost savings to the water industries.
Therefore the inefficient management of water distribution systems results not only into depletion of water resources but also into energy consumption that increase CO_2 emissions related also to the treatment of water volumes greater than needed, with use of excessive chemical components and consequent higher environmental global impact.
The research outlined in this contribution was born with the aim to develop appropriate methodologies and tools to support the optimization of the WDS performance, in terms of water saving and reduction of energy consumptions and consequently environmental impacts. The integration of advanced WDS hydraulic modelling with a material and energy flow analysis is proposed

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herein, where the output of the hydraulic simulations permits to get more accurate input for a metabolic analysis of the system. Next phases of this research will test the integrated model under different scenarios, aimed at quantifying the environmental impact of different WDS management solutions by means of selected indicators.

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Keywords: Water distribution system; metabolic analysis; energy consumption; leakages; environmental impacts

1. Introduction

The current state of many existing urban water distribution networks is inadequate to cope with the change of the conditions that drove their design: primarily the ageing of infrastructure, population growth, increasing of urbanization but also the more recent factors of climate change and environmental pollution. The main problem is represented by the increasing of water losses and, consequently, the loss of energy (and cost of energy) spent for pumping, treating and conveying that water [1]. The inefficient management of the water resources means increase the risk of supplying insufficient quantity of water of inadequate quality to users.

Therefore, it is required, according with the Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000, an integrated water cycle management tacking into account efficiency, effectiveness and economic criteria. Effectiveness requires providing a specified amount of water with sufficient pressure, and efficiency means doing it at the lowest cost [2]. There is then a necessity to develop methodologies and tools to support efficiency and safety of water distribution system (WDS).

The paper presents the ongoing research of a more comprehensive project, which aims at coupling the advanced hydraulic analysis of a WDS with the resources input-output analysis of the water supply system. The main objective of such research is provide methodologies and tools for the optimization of the performance of the WDSs, in terms of water saving and reduction of energy consumption and consequently environmental impacts.

1.1. Relationship between water losses and energy

The possible connections (nexus) between water and energy are vast and ever changing, but the knowledge of these links in both the production and consumption of water is necessary for optimizing the impact of using these resources [3]. The Alliance to Save Energy coined the term "Watergy" to describe the strong link between water and energy in municipal water systems [1].

In the last decades, the electricity prices is increased causing the major interest of water utilities to energy recovery and saving by searching for optimal solutions for energy management in integrated water systems. Each solution is linked to water system characteristics and, in particular, to the resources availability and quality, to the network topology, to the topography of served area and processes in the treatment plants. Each component of the integrated water system contributes differently to the energy balance and some procedures are currently available for identifying the best energetic configuration [1]. In the WDSs the large part of the total operational cost is represented by pumping energy cost which is also magnified by every liter of water lost to leaks before reaching the consumer. Water lost includes not only the value of water as limited resource but also the added value for the treatments to make water drinkable, then the expenses of treatment chemicals, the cost of running the distribution service and also social impact of leakages which might prevent for providing sufficient supply service to customers. . The presence of water losses also contributes to unnecessary capacity expansion, to the acceleration of infrastructure deterioration that means more risk of new leaks and then loss of energy related to increasing leaks, creating in this sense a vicious cycle. In addition, the energy wasted in leaks involves an environmental burden related to many impacts associated with energy production and consumption, including greenhouse gas (GHG) emissions, acid rain and resource depletion [4]. Therefore, even a small increase in overall operational efficiency may result in significant savings to the water industries.