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Design of regeneration recycling water networks with internal water mains by using concentration potential concepts

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HIGHLIGHTS

- ▶ Design method proposed for regeneration recycling water networks with water mains.
- ▶ Process precedence order determined by values of Concentration Potential of Demands.
- ▶ Sources to form water mains determined by Concentration Potential of Sources.
- ▶ The final design can be obtained in a few iterations.
- ▶ The proposed method is simple and effective.

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ABSTRACT

This paper presents a new design method for regeneration recycling water-using networks with internal water mains by using the concentration potential concepts (Liu et al., 2009a. AIChE J. 55, 374–382). The precedence order of the processes is determined by the values of the Concentration Potential of the Demands (*CPDs*). The formation of the internal water mains is determined by the values of the Concentration Potential of the Sources (*CPSs*). An initial network with one regeneration unit is developed based on the concentration potential values. The final design can be obtained in a few iterations by adjusting the initial network. The results of the illustrated examples show that the designs obtained in this work are comparable to that obtained in the literature with computer programming methods. It is shown that the proposed method is simple and effective. It can be concluded that the concentration potential concepts are useful tools in design of water networks.

1. Introduction

Wastewater minimization has become a research focus because water conservation and reducing wastewater discharge are of great significance. Water system integration can reduce both freshwater consumption and wastewater discharge significantly by reuse, regeneration reuse/recycling of wastewater appropriately.

For water-using network design and targeting, the literature methods can be classified into pinch-based methods (for example, Wang and Smith, 1994; Kuo and Smith, 1998; Castro et al., 1999; El-Halwagi et al., 2003; Prakash and Shenoy, 2005; Foo, 2007; Tan et al., 2007; Kim, 2011), and mathematical programming methods (for example, Takama et al., 1980; Grossmann, 1985; Doyle and Smith, 1997; Alva-Argaez et al., 1998; Bagajewicz et al., 2000; Linke and Kokossis, 2004; Li and Chang, 2006; Teles et al., 2009; Poplewski et al., 2011).

In the work discussed above, the water-using units are connected with pipes directly. For a large petrochemical or chemical complex, the water network with many process units will be very complicated and difficult to operate and control. Moreover, the change of water flow rate or water quality in some processes might influence the others significantly.

To increase the flexibility of water networks, Feng and Seider (2001) introduced internal water main in water networks of single contaminant. Wang et al. (2003) proposed a concept of "water-saving factor" for design of the water networks of multiple contaminants with single internal water main. Wang et al. (2005) emphasized the significance of determining the location of the first internal water main, and discussed how to allocate the water streams of the internal water mains to subsequent processes. He et al. (2010) proposed a method based on the concentration potential concepts (Liu et al., 2009a) to design the

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water networks with two internal water mains. In their method, a conventional network was obtained with the concentration potential method (Liu et al., 2009a), and an initial structure of the internal water mains was developed based on the conventional network. The final design was obtained with a trial-and-error approach. Su et al. (2012) designed the water networks with single internal water main by using the concentration potential concepts (Liu et al., 2009a) as well.

When regeneration is introduced in a water-using network, both the freshwater consumption and wastewater discharge can be reduced significantly. To design the water networks with internal water mains involving wastewater regeneration recycling, Cao et al. (2004) proposed a method based on a trial-and-error approach to determine the structure and the concentrations of the regeneration water main. Feng et al. (2008) proposed a method for the design of optimal regeneration recycling water networks with internal water mains. They addressed that the relative importance of the objectives were freshwater consumption, regenerated water flow rate and contaminant regeneration load. The above objectives were optimized with a sequential optimization procedure.

There are a few papers addressing the design of conventional (without water mains) water-using networks involving regeneration unit. Ng et al. (2007) investigated the target of the water-using networks of single contaminant with regeneration unit placement. They proposed a numerical targeting procedure to locate the minimum regeneration flow rate for both fixed flow rate and fixed load problems. Liu et al. (2009b) proposed a simple method to design the water-using networks involving regeneration reuse. They addressed that a water-using network involving regeneration reuse can be formed by adding the regenerated source in the source streams of the network involving reuse only. The design of the water networks involving regeneration reuse could be carried out by using the design procedure proposed for the systems involving reuse only (for example, Liu et al., 2009a). Pan et al. (2012) proposed an iterative method for design of the water-using networks involving regeneration recycling based on the design procedure of Liu et al. (2009a, 2009b).

In this paper, an iterative method is proposed to design the regeneration recycling water networks with internal water mains. In the design procedure, the processes are divided into three parts based on their concentration potential values and flow rates, as shown in Fig. 1. The processes in Part 1 use water from freshwater main only; the processes in Part 2 use water from the first internal water main; and the processes in Part 3 use water from the main before regeneration. The first internal water main is formed by the high reuse-possibility source streams, which have low *CPS* values. The water main before regeneration receives the outlet streams of the processes in Parts 1 and 2, and supplies water to the regeneration unit and to the processes in Part 3. Based on the three parts identified, an initial network can be developed. The final design can

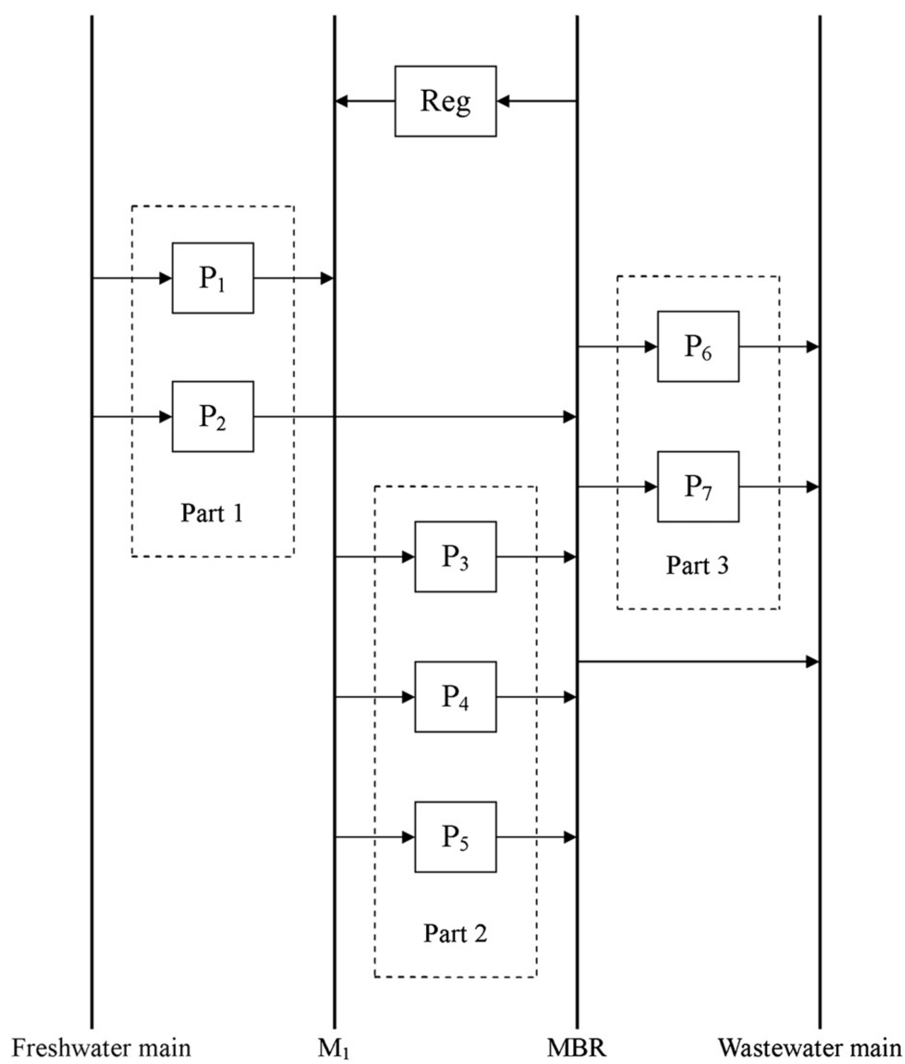

Fig. 1. An example of water-using network structure with internal water mains and regeneration unit.