# Intermittent Urban Water Supply with Protection of Consumers' Welfare

Omid Bozorg-Haddad[1]; Sotudeh Hoseini-Ghafari[2]; Mohammad Solgi[3]; and Hugo A. Loáiciga, F.ASCE[4]

**Abstract:** Intermittent operation of water networks is prevalent in many developing countries. It is a practical method to continue operation of water distribution networks (WDNs) during unexpected water shortages. Implementation of intermittent water supply compels consumers to withstand periods of interrupted water supply. Intermittent operation increases operating and maintenance costs attributable to the damage of pipes and valves caused by water pressure fluctuations. This paper considers consumers' welfare and system depreciation simultaneously in a multiobjective optimization model for intermittent water supply in WDNs. The objectives of the optimization model are the improvement of water supply resiliency and the maximization of the mechanical reliability of WDNs. The optimization model is solved by means of the honey-bee mating optimization (HBMO) algorithm linked to WDN hydraulic simulator software. The model's performance is tested with several shortage scenarios in two different WDNs. The calculated results show the optimization model's capacity to determine optimal values of water supply resiliency, and demonstrate that consumers' welfare may conflict with the objective of mechanical reliability, giving rise to an optimization possibility tradeoff frontier. **DOI: 10.1061/(ASCE)PS.1949-1204.0000231.** *© 2016 American Society of Civil Engineers.*

**Author keywords:** Water distribution network; Multiobjective optimization; Intermittent water supply; Water supply resiliency; Mechanical reliability; EPANET; Honey-bee mating optimization (HBMO).

## Introduction

Water shortages due to hydrologic drought, natural disasters (e.g., earthquakes), conflicts (e.g., war) and intentional or accidental water pollution coupled with inadequate water-resources development may preclude the continuous operation of water distribution networks. One of the methods used to counteract urban water scarcity is intermittent water supply (Solgi et al. 2015). In addition, intermittent operation of water networks is common among developing countries (Ameyaw et al. 2013). A properly functioning water system is pressurized continuously and serves consumers without interruption. On the other hand, in an intermittent system the total amount of available water is less than consumers' demands, and operators have to cut the water supply to some parts of the network regularly (e.g., for a few hours daily). In intermittent water supply, customers' water needs are not fully satisfied. Most likely, the intermittent operation of distribution networks would cause adverse effects. When the intermittent operation of a network is inevitable, intermittent water supply must be implemented so that its adverse impacts are minimized.

Sashikumar et al. (2003) investigated the effect of initial filling of water pipes. Field experiments have shown that it may take even 1–2 h for air to be fully vented out of a water distribution system, after which hydraulic conditions stabilize. Andey and Kelkar (2009) conducted a study in four Indian cities to evaluate influence of intermittent water supply (IWS) and continuous water supply (CWS) on domestic water consumption. Soltanjalili et al. (2013) proposed intermittent water supply as a way to avoid severe water shortages. Solgi et al. (2015) developed an optimization model to consider the equanimity and justice of the water supply among consumers with the intermittent operation of water distribution networks.

Water distribution systems are essential components of urban water supply. Their design, operation, and calibration have been the subject of extensive research aiming at optimization their cost of operation and maximize serviceability (see recent work by Bozorg Haddad et al. 2008; Fallah-Mehdipour et al. 2011; Seifollahi-Aghmiuni et al. 2011, 2013; Sabbaghpour et al. 2012; Suribabu 2012; Babu and Vijayalakshmi 2013; Ezzeldin et al. 2014).

The Honey Bee Mating Optimization (HBMO) algorithm was developed by Bozorg Haddad et al. (2006). This algorithm has the ability to solve different engineering optimization problems with accuracy and efficiently. Many researchers have used the HBMO algorithm in various fields of water resources, e.g., water distribution networks, and they have proved that the HBMO algorithm has better performance than other algorithms, e.g., the genetic algorithm (GA) (Bozorg Haddad et al. 2006, 2008, 2011; Jahanshahi and Bozorg Haddad 2008; Karimi et al. 2013). Recently, the HBMO algorithm has been used for the optimal utilization of intermittent systems, and its good performance in solving such problems has been established (Soltanjalili et al. 2013; Solgi et al. 2015).

In intermittent systems, the pipes are empty during several hours of the day and hold water and air simultaneously. For this reason intermittent systems suffer from such problems as drastic pressure changes that cause damage to the network infrastructure, leading to

[1]Associate Professor, Dept. of Irrigation and Reclamation Engineering, Faculty of Agricultural Engineering and Technology, College of Agriculture and Natural Resources, Univ. of Tehran, Karaj, 31587-77871 Alborz, Iran (corresponding author). E-mail: OBHaddad@ut.ac.ir

[2]Dept. of Irrigation and Reclamation Engineering, Faculty of Agricultural Engineering and Technology, College of Agriculture and Natural Resources, Univ. of Tehran, Karaj, 31587-77871 Alborz, Iran. E-mail: Sotudeh.hoseini@ut.ac.ir

[3]Dept. of Irrigation and Reclamation Engineering, Faculty of Agricultural Engineering and Technology, College of Agriculture and Natural Resources, Univ. of Tehran, Karaj, 31587-77871 Alborz, Iran. E-mail: Solgi_Mohammad@ut.ac.ir

[4]Professor, Dept. of Geography, Univ. of California, Santa Barbara, CA 93106. E-mail: Hugo.Loaiciga@ucsb.edu

Note. This manuscript was submitted on November 19, 2014; approved on November 4, 2015; published online on January 7, 2016. Discussion period open until June 7, 2016; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Pipeline Systems Engineering and Practice***, © ASCE, ISSN 1949-1190.