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Integrated water resources management for emergency situations: A case study of Macau

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ABSTRACT

Integrated water resources management (IUWM) is a useful tool that can be used to Q6 alleviate water resource shortages in developing regions like Macau, where 98% of the raw water comes from mainland China. In Macau, scarce water resources deteriorate rapidly in emergency situations, such as accidental chemical spills upstream of the supply reservoir or salty tides. During these times, only the water from the two freshwater reservoirs in Macau can be used. In this study, we developed urban water management optimization models that integrated the raw water supply from the two reservoirs with various proposed governmental policies (wastewater reuse, rainwater collection, and water saving). We then determined how various water resource strategies would influence the urban water supply in Macau in emergency situations. Our results showed that, without imported raw water, the water supply from only the two Macau reservoirs would last for 7.95 days. However, when all the government policies were included in the model, the supply could be extended to 13.79 days. Out of the three non-conventional water resources, wastewater reuse is the most beneficial for increasing the Macau water supply, and rainwater collection also has great potential.

Introduction

The Macao Special Administrative Region, internationally renowned for its casinos and tourism, experiences water stress because of a lack of raw water combined with rapid economic growth in recent years. Although Macau has two storage reservoirs, the Macau main storage reservoir (MSR) and the Seac Pai Van reservoir (SPVR), it has virtually no conventional water resources, and 96% of the raw water supply comes from mainland China. Three water pipes transport raw water from the Zhuxiandong reservoir in Zhuhai to four water treatment plants in Macau (Fig. 1). The raw water in the Zhuxiandong reservoir is supplied from the Modaomen Channel by the HongWan pumping station. Non-conventional water resources, such as reused water and rainwater, are not widely exploited at present; Macau's wastewater reuse policy is still in its initial stages and the rainwater use rate was only 3.4% in 2012. The current, limited use of unconventional water resources maintains the fragility of the Macau water system, and means that it is particularly vulnerable in emergency situations, such as chemical spills and during the salt tide period.

Emergency situations in water supply systems have been reported by other researchers. Schade et al. (2015) reported that an industrial accident contaminated the public water supply of approximately 300,000 homes in and close to Charleston, West

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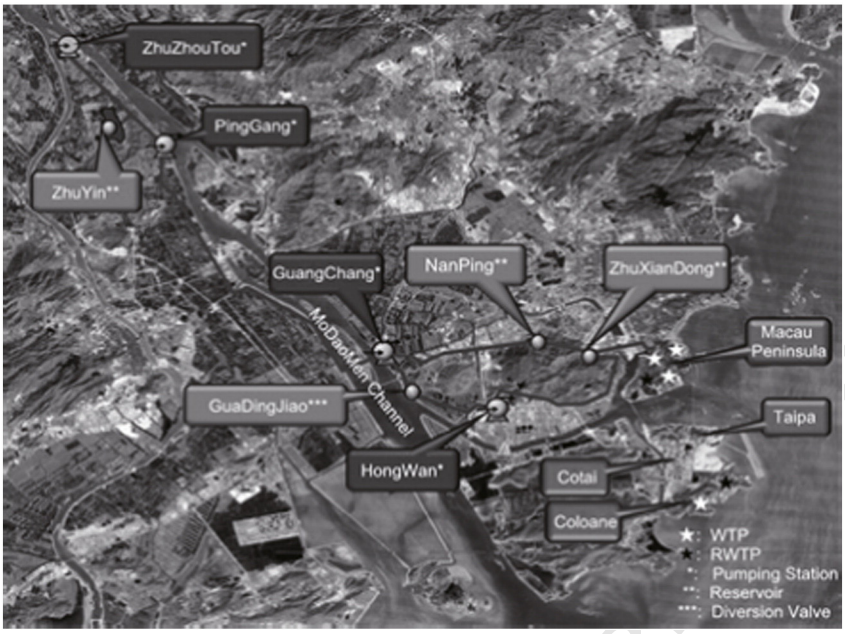

Fig. 1 – Raw water supply system of Macau.

Virginia. A fatal incident occurred in Longgang, a suburb of Shenzhen, when cyanide spilled into a sewer in 2007 and resulted in the death of two people. The Macao Water Supply Company Limited also experienced an exercises that chemical spill at the water treatment plant of the MSR in 2014. If the cyanide accidentally spills in the raw water from Modaomen Channel by the factory, the consequences could be disastrous, most of the fish and other aquatic organisms would die and the people around the river should evacuate immediately. Natural diffusion and dilution by environment itself would be the remedial way for serious cyanide spill. For Macau, it can mean that there may be no raw water in the water system except for the raw water in the two main Macau storage reservoirs. The severity of this kind of situation and the implications for daily life should be of concern to water users and the government; the safety and quality of the water supply should be a government priority. Another, unrelated problem is the salt tides that occur in urban water systems located in regions near tidal rivers. Vellinga et al. (2014) studied the discharge distribution and salt water intrusion in the Rhine–Meuse River delta network and found that the contribution of salt water to the total river flux strongly depended on the stage of the tide, but decreased rapidly upstream. The Macao Water Company and the government have moved the raw water intake from the Guangchang pumping station, to the Pinggang pumping station and the Zhuzhoutou pumping station, so that intake will be sourced further and further upstream. Furthermore, raw water has even been supplied from the Zhuyin reservoir to the Zhuxiandong reservoir (Fig. 1). In 2005, Macau residents rushed to purchase bottled water to neutralize the salinity of the water supply during a salt tide when the salt content reached 500 mg/L, which is twice the international standard.

In the situations given above (*i.e.*, chemical spills and salt tides), the number of days for which a normal water supply is available is a matter of great concern for water users and the government. Because the conventional water system has a limit on its available duration, Hamoda (2004) said non-conventional water systems have great potential and should be exploited. He figured that water reuse as non-potable water in agriculture is justified on agronomic and economic grounds. It will result in savings of fresh water and augmentation of water supply required for irrigation to overcome the shortage in food sufficiency. Besides, the reused water can also be used as potable water through the advanced treatment process. Government policies, such as wastewater reuse and rainwater collection, have been developed to enhance the non-conventional water resource supply in Macau. Water-saving policies can also strengthen the resilience of the water system. Methods like integrated urban water management (IUWM) are common and can help optimize the use of various water resources in urban water systems. This type of approach has been applied to alleviate water resource shortages and has been particularly successful in developing countries and in regions that have experienced high population and economic growth (Evans and Varma, 2009). Grit et al. (2015) studied IUWM and developed a method for identifying, bundling, and prioritizing measures that included resource orientation and cost-efficiency analysis. The IUWM method can be used to model and estimate the number of days that freshwater will last in emergency situations in urban water systems. Similar studies involving effective management of water resources in emergencies have focused on actions that using smart management coordinated various agencies. (Tiana et al., 2013). Rasekh and Brumbelow (2015) suggested that their optimized adaptive emergency response model could be a major component of an all-inclusive cyber-infrastructure to efficiently manage threats from contamination to urban water systems. The aim of this study was to model options that might enhance the overall efficiency of the water system by integrating aspects of governmental policies relating to the use of alternative water sources in emergency situations.

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