Risk Analysis of Water Reuse for Industrial Cooling Water Consumptions

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Abstract: Limited qualified water resources have necessitated industries to use unconventional water resources such as wastewater. The aim of this study is to evaluate the risk of using urban treated wastewater to replace freshwater as a water source of cooling systems for industrial cooling water consumptions considering three main risks: corrosion, scaling, and biofouling. To perform this research, a risk analysis framework has been developed in three stages: identification of risks and the influential parameters, evaluation of the consequences of failure, and calculation of the probability of failure. The identified parameters were weighted using a paired comparison matrix, and the consequences of failure have been calculated using defined criteria. Questionnaires were used for scoring risks. In this research, the Isfahan Mobarakeh Steel Complex was chosen as the case study. The results of the risk assessment indicated that biofouling failure had the largest score. Furthermore, among the influential major failures, ammonium, phosphate, and chlorine, respectively, had the maximum risk. Based on the results, the developed framework can be used for ranking the risks of using urban treated wastewater instead of freshwater in industrial cooling systems.

Introduction

Severe water shortage is one of the global challenges threatening human life (Karagiannis and Soldatos 2008). Reduction of natural water resources such as drying lakes and rivers and the decline groundwater resources and the quality reduction and disruption to water supplies are among recent environmental challenges (Hadipour et al. 2016). On the other hand, urbanization, population growth, industrial development, and the change of people’s lifestyle have led to growing water demand. All of the mentioned factors can exacerbate water supply challenges (Kayhanian and Tchobanoglous 2016).

As one of the developing countries located in dry and semidry regions, Iran is a country whose annual average scaling is less than one-third of the average scaling in the world (Madani 2014). On the other hand, in recent decades in Iran, sustainable management of water resources has not been a priority, which has resulted in the severity of the water deficit crisis (Kayhanian and Tchobanoglous 2016). Furthermore, the inevitable industrial development in this country has led to the use unconventional water resources in industries.

Reusing wastewater is considered as a strategy for sustainable management of water resources around the world (Miller 2006; Asano et al. 1996). Nevertheless, wastewater may be largely used as an alternative source of water for agricultural irrigation. The concern about using wastewater for agricultural irrigation is related to the introduction of unknown pathogens and chemicals into food, which can cause unknown diseases for farmers and product consumers (Shuval et al. 1997; Keraita and Drechsel 2016).

Therefore, wastewater reuse in other applications like industry is more sustainable as a matter of health (Eslamian et al. 2013). Among the industries, utility power plants, oil refineries, petro-chemical, and steel industries are among those proposed for water reuse considering their huge water consumption. Cooling purposes account for the largest water volume required by industries. Although wastewater reuse in industrial cooling water usage is a suitable decision for sustainable management of water resources (Eslamian et al. 2013), it has some risks. Integrated risk analysis is one of the solutions for safe reuse of treated wastewater.

Previously, statistical methods have been used to assess reuse of treated wastewater in cooling systems. Zhang et al. (2014) proposed a statistical model to evaluate the probability of scaling and corrosion in power plant cooling systems across multiple samples of water sources (freshwater and treated wastewater). The Langelier Saturation Index (LSI) and the Aggressive Index (AI) were computed to determine the probability of corrosion and scaling. Results show that secondary treated municipal wastewater is the best source to be used as cooling system makeup water. However, this study does not consider the biological problems, which are the most important threat in the reuse of municipal wastewater in a cooling system.

A pilot-scale cooling system was designed to evaluate of changing water conditions and to test control strategies for corrosion, scaling, and biofouling due to reuse of treated municipal wastewater as cooling system makeup water (Chien et al. 2012b). Researchers on this pilot-scale system showed that recirculating cooling systems using treated municipal wastewater causes severe scaling (Chien et al. 2013) and biological growth is one of the major associated challenges (Chien et al. 2012a).

Researchers have used various methods for risk analysis of water and wastewater infrastructure. They are different in scope and...