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Monitoring and modeling of trihalomethanes (THMs) for a water treatment plant in Istanbul

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Abstract

Because of increasing concern for both microbial control and disinfection by-products (DBPs) formation, water utilities are strictly examining and optimizing disinfection practices. In this study, modeling of trihalomethanes (THMs) formation at processed water of the Kagithane water treatment plant in Istanbul City was conducted. Data for THMs and other water quality and operational parameters were generated through a 12-month sampling program between January and December 2003. A multiple linear regression model was developed to predict THMs concentrations in processed water. Routinely measured parameters including total organic carbon (TOC), pH, temperature, and chlorine dose were used to develop the model for the prediction of THMs. Both pH ($r = 0.963$) and temperature ($r = 0.921$) were found to be the parameters of the highest statistical significance as predictors for THMs occurrence. The regression analysis resulted in a model that is directly applicable to the chlorination of raw waters. This indicated that the linear models developed could be used to estimate THMs concentration for different water quality and treatment processes with different operational conditions.

Keywords: Disinfection by-products (DBPs); DBP models; Trihalomethanes (THMs); Processed water; Water treatment, Istanbul

1. Introduction

Disinfection is the most important process in the treatment of drinking water supplies since it removes or inactivates pathogenic microorganisms responsible for waterborne diseases such as cholera and dysentery [1]. Chlorination is a widely used disinfection method because of its very efficient and cost-effective properties [2].

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Almost all municipal water supply systems in Turkey also use chlorine for water disinfection. However, it was discovered that the use of chlorine as an oxidant or disinfectant posed potential health risks due to the formation of carcinogenic halogenated organic compounds known as disinfection by-products (DBPs) [3,4]. Among DBPs found in chlorinated water, trihalomethanes (THMs) have been the focus of particular attention because they are considered potentially carcinogenic for the bladder [5]. The United States Environmental Protection Agency (USEPA) [6] has defined the hazardous classes for different DBPs among THMs, HAAs and inorganic DBPs; $CHCl_3$, $CHBr_2Cl$ and $CHBr_3$ were classified as possible carcinogens to humans. Also, recent studies have suggested links between adverse reproductive outcomes and exposure to THMs during pregnancy [7,8].

Concerns about health risks associated with THMs have prompted several industrialized countries to establish maximum acceptable levels for THMs concentrations in drinking water [9]. The US EPA developed the Disinfectants/DBP (D/DBP) Rule in 1998 to set a maximum contaminant level (MCL) of 80 μg/L for THMs in drinking water [10]. Moreover, recently most of the European countries regulated THMs in their water at the MCL of 100 μg/L [11]. However, up to now, there is no MCL for DBPs, especially for THMs in Turkish Drinking Water Regulations (TS-266) [12].

THMs formation during water treatment processes is important and needs to be monitored. The modeling of THMs consists of establishing empirical or mechanistic relationships between THM levels in treated water and the water quality and water treatment operational control parameters (such as chlorine dose applied, temperature, pH).

The model equations developed for chlorination were based on raw water chlorination and not chlorination of treated waters (e.g., coagulated-settled waters or granular activated carbon (GAC)-treated waters), which are most appropriate for prechlorination [13]. Efforts are currently underway to develop predictive equations based on reaction kinetics of DBP formation that will be appropriate to coagulated-settled waters and may remove some of the restrictions regarding boundary conditions [14]. The progress in development of new models by Abdullah et al. [15], Elshorbagy et al. [16], Golfinopoulos et al., [17], Golfinopoulos and Arhonditsis [18], Gallard and Gunten [19], Milot et al. [20], and Sohn et al. [21] have contributed to explaining the effect of water characteristics on THM formation as well as to optimize the coagulation process which is essential for water treatment.

This paper presents the development of a linear multi-parametric THM predictive model with a particular focus on the Kagithane Celebi Mehmet Han water treatment plant (KWTP) in Istanbul, Turkey, which supplies the water needs of more 1 million people on the European side. The model was based upon raw water characteristics; e.g., TOC, pH, temperature and sum of applied pre- and final chlorine doses, to predict the THMs in processed water. The developed model was then validated using THM data sets obtained from the same treatment and from the Buyukcekmece water treatment plant that has different raw water characteristics and treatment plant configuration than in Istanbul. The major importance of the developed model is that it was the first investigation in this field in Turkey where most of the water treatment plants apply prechlorination.

2. Materials and methods

2.1. Description of water treatment plant

In this study, KWTP, which supplies the water needs of more than 1 million inhabitants, and is operated by the Istanbul Water and Sewerage Administration, was selected to monitor and model THMs formation. The KWTP receives surface water mainly from the Alibeykoy