ELSEVIER

Journal of Environmental Management 82 (2007) 1–12

Journal of Environmental Management

www.elsevier.com/locate/jenvman

Influence of alkalinity, hardness and dissolved solids on drinking water taste: A case study of consumer satisfaction

Jie-Chung Lou*, Wei-Li Lee, Jia-Yun Han

Institute of Environmental Engineering, National Sun Yat-Sen University, Kaohsiung, Taiwan, ROC

Received 26 January 2005; received in revised form 21 November 2005; accepted 23 November 2005
Available online 8 May 2006

Abstract

Two surveys of consumer satisfaction with drinking water conducted by Taiwan Water Supply Corp. are presented in this study. The study results show that although a lot of money was invested to modify traditional treatment processes, over 60% of local residents still avoided drinking tap water. Over half of the respondents felt that sample TT (from the traditional treatment process) was not a good drinking water, whether in the first or second survey, whereas almost 60% of respondents felt that samples PA, PB, CCL and CT (from advanced treatment processes) were good to drink. For all drinking water samples, respondent satisfaction with a sample primarily depended on it having no unpleasant flavors. Taiwan Environmental Protection Administration plans to revise the drinking water quality standards for TH and TDS in the near future. The new standards require a lower TH concentration (from currently 400 mg/L (as $CaCO_3$) to 150 mg/L (as $CaCO_3$)), and a lower TDS maximum admissible concentration from the current guideline of 600 to 250 mg/L. Therefore, this study also evaluated the impacts on drinking water tastes caused by variations in TH and TDS concentrations, and assessed the need to issue more strict drinking water quality standards for TH and TDS. The research results showed that most respondents could not tell the difference in water taste among water samples with different TDS, TH and alkalinity. Furthermore, hardness was found to be inversely associated with cardiovascular diseases and cancers, and complying with more strict standards would lead most water facilities to invest billions of dollars to upgrade their treatment processes. Consequently, in terms of drinking water tastes alone, this study suggested that Taiwan Environmental Protection Administration should conduct more thorough reviews of the scientific literature that provides the rationale for setting standards and reconsider if it is necessary to revise drinking water quality standards for TH and TDS.

Keywords: Consumer satisfaction; Questionnaire; Regulation; Blind test

1. Introduction

Kaohsiung City, with an area of 153,6029 km^2 and a population of 1,508,000, is the second largest city in Taiwan. The city has moderate weather year round with average temperatures ranging from 18.6 °C in February to 28.7 °C in June and relative humidity varying from 60% in March to 81% in August.

In Kaohsiung city, the government-owned Taiwan Water Supply Corp. (TWSC) supplies drinking water to about 98.8% of the city population. Cheng Ching Lake Water Works (CCLWW) and Cou Tan Water Works (CTWW), owned and operated by TWSC, are two major suppliers of drinking water to Kaohsiung city. The water sources of these two water works come from the nearby rivers and lakes that have been severely polluted by both industrial and domestic wastewaters. Removing hardness, alkalinity, and metabolites of algae or other microorganisms (e.g. 2-MIB, geosmin) from raw water was beyond the treatment capabilities of the traditional water treatment process used by these two water works (Fig. 1a), and the finished drinking water from these two water works contained an unpleasant flavor. Consequently, many local residents constantly complained not only about the disagreeable drinking water taste but also about teapot scaling problems owing to high hardness. A poll (Lou and Han, 2002) showed that 42.8% of residents never drank tap

*Corresponding author. Tel.: +886 7 5254410; fax: +886 7 5254449.
E-mail address: loujc@mail.nsysu.edu.tw (J.-C. Lou).

0301-4797/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jenvman.2005.11.017

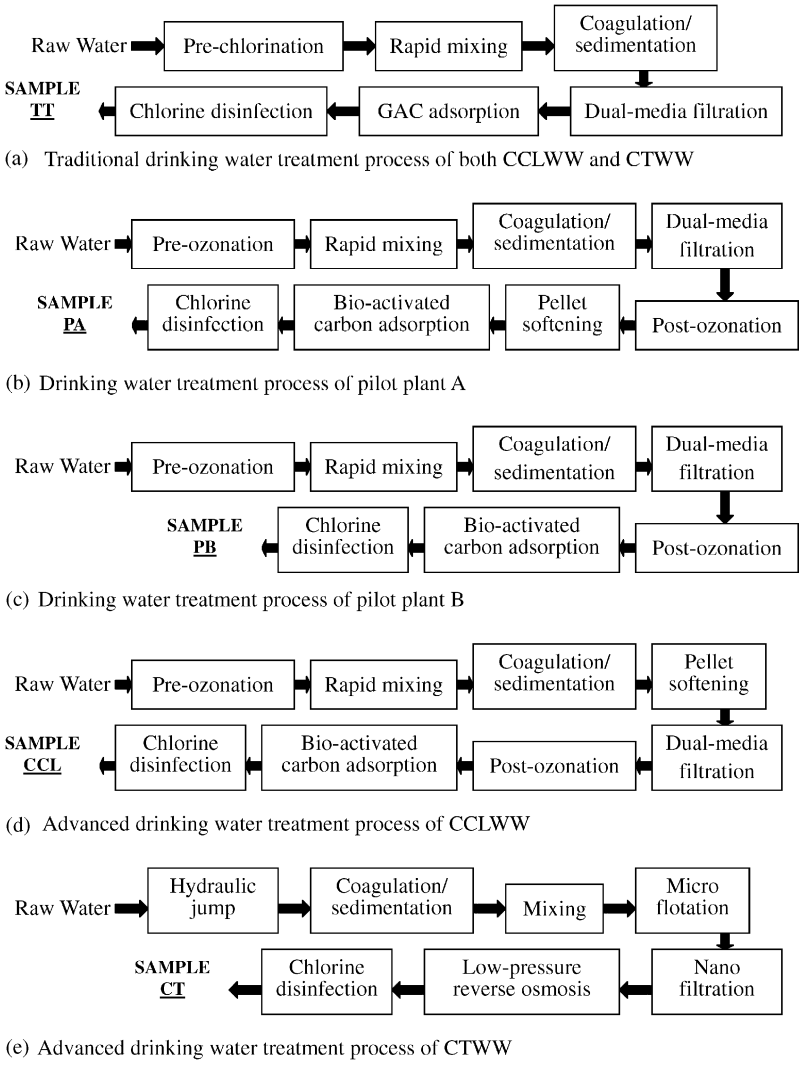

Fig. 1. Different treatment processes associated with five drinking water samples.

water, and almost 80% treated their tap water (e.g. boiled, reverse-osmosis filtered, activated-carbon adsorbed, or other methods) before drinking it in Kaohsiung City.

To improve the finished drinking water quality of CCLWW and CTWW, TWSC decided to upgrade the water treatment processes of these two water works from the current conventional processes to advanced ones. In 1998, TWSC built two pilot plants to simulate the optimal advanced treatment processes. Treatment units of these two pilot plants included pre-ozonation, pellet softening, post-ozonation, and biological activated carbon adsorption (Fig. 1b and c). The functions of pre-ozonation are to oxidize odor and color-causing compounds, interfere with the metabolism process of algae, and alter the surface characteristics of suspended solids to increase coagulation efficiency. Pellet softening (also known as fluidizing bed crystallization, FBC), as a substitute for traditional rapid mixing, coagulation, sedimentation and sludge dewatering, is used to remove hardness in drinking water. The advantages of pellet softening include high efficiency, low capital cost, low operation and maintenance (O&M) cost and low energy consumption. Following post-ozonation to absorb smaller organic compounds oxidized by post-ozonation, a biological activated carbon (BAC) bed was designed because during chemical oxidation, degradation was seldom completed and numerous compounds generally remained, potentially causing bacterial regrowth in drinking water distribution systems (Camel and Bermond, 1998). These pilot plants were proved to perform well in removing organics, reducing THM and enhancing biostability (Lai et al., 2002). However, if local residents are not satisfied with the water taste, they will refuse to drink the water. Moreover, many consumers will link the presence of offensive tastes or odors with the possibility of a health risk (Jardine et al., 1999) though an unpleasant taste in water does not necessarily indicate that the water is unsafe to drink. Still, many consumers switch to bottled water for their drinking needs (Khiari et al., 1999). To assess consumer preferences and attitudes regarding drinking water produced by the pilot plants, a survey of consumer