Physics and Chemistry of the Earth 50–52 (2012) 92–97

Contents lists available at SciVerse ScienceDirect

Physics and Chemistry of the Earth

journal homepage: www.elsevier.com/locate/pce

Determination of characteristics and drinking water quality index in Mzuzu City, Northern Malawi

Elijah M.M. Wanda *, Lewis C. Gulula, Gift Phiri

Mzuzu University, Department of Chemistry, P/Bag 201, Luwinga, Mzuzu II, Malawi

A R T I C L E I N F O

Article history:
Available online 25 September 2012

Keywords:
Domestic water quality
Electrical balances
Mzuzu City
Water quality index

A B S T R A C T

An assessment of characteristics and chemical water quality index (WQI) of water supplied by the Northern Region water Board (NRWB) in Mzuzu City was carried out in order to ascertain the quality of water for domestic purposes. The WQI offers a single number that expresses overall water quality for a water sample based on several water quality parameters. In this study raw water and 72 tap water samples were collected monthly between March and September, 2011 and analyzed for major ions, pH, total dissolved solids (TDSs), electrical conductivity (EC), turbidity, total hardness (TH), suspended solids (SSs) and alkalinity using standard methods. The quality and accuracy of the chemical data was assessed by checking electrical balances. The calculated electrical balance errors were found to be less than ±10%, which meant the results were reliable. Based on the Sawyer and McCarty TH classification, 100% of the samples were soft waters (TH < 150 mg/L). Nitrates, which registered medium or average WQ-rating of 69.77 and WQ-rating range of 52.06–86.94, were observed to have significantly affected the overall water quality index of the treated water since the rest of the parameters registered good–excellent WQ-ratings (average WQ-rating: 80.21–97.87). The pH, which is used to determine suitability of water for various purposes, ranged between 6.40 and 6.90 and registered a good water quality rating (WQ rating range: 72.73–87.02) for both raw and treated water. Raw water registered an overall medium water quality rating of 62.67%. Overall, 91.67% of the samples registered a good water quality rating (WQI range: 80.28–88.80%) and 8.33% registered a very good water quality rating (WQI = 90.07%). The results suggested substantial water treatment by the NRWB since the treated water is protected with some negligible degree of impairment that rarely departs from desirable levels of domestic water quality. It is recommended that the WQI should be adopted as a tool to monitor and establish trends in quality of water supplied by the NRWB since it is a composite index that turns complex water quality data into an aggregate rating that reflects the combined influence on the overall water quality as opposed to the univariate water quality assessment approaches such as the Malawi Bureau of Standards.

1. Introduction

Water quality assessment can be defined as the evaluation of physical, chemical and biological nature of water in relation to natural quality, human effects and intended uses. A water quality index (WQI) is one of the most effective tools to ascertain the quality of water for domestic purposes. A number of water quality indices have been developed to summarize water quality data in an easily expressible and easily understood format. Basically, the WQI is a summative index that incorporates data from multiple water quality parameters that reflects the combined influence on the overall quality parameters (Tiwari and Mishra, 1985). The parameters are weighted according to their perceived importance to overall water quality. The WQI is calculated as the weighted average of all observations of interest (Pesce and Wunderlin, 2000; Stambuk Giljanovik, 2003; Sargaonkar and Deshpande, 2003; Liou et al., 2004; Tsegaye et al., 2006). The computed WQI is intended to provide an easy to understand ranking of water quality on a rating scale from 0 to 100. Higher values of the WQI indicate better quality water and lower values show poor quality water. The WQI helps in interpreting the quality of water in a single numerical value (Horton, 1965; Brown et al., 1970; Dinius, 1972; Lohani and Todino, 1984). The WQI can indicate the degree to which the natural water quality has been affected by anthropogenic activity. The WQI also quantifies the extent to which a number of water quality measures deviate from ideal concentrations and may be more appropriate for summarizing water quality conditions across a range of water types and over time. The WQI can thus tell us whether the overall quality of water poses a potential threat to various uses of water, such as drinking water supplies.

* Corresponding author.
E-mail addresses: elijahwanda@mzuni.ac.mw, elijahwanda@gmail.com (E.M.M. Wanda).

1474-7065/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.pce.2012.09.004

Several researchers have used the WQI to assess quality of water resources elsewhere (Bhatt and Pathak, 1992; Kumar and Shukla, 2002; Patil et al., 2006; Sindhu and Sharma, 2007; Santosh and Shrihari, 2008; Ramakrishanaiah et al., 2009; Samantray et al., 2009). However, scant attempts have been made to assess the water quality index of water resources in Malawi. The present study was aimed at evaluating variations in water quality and assessing the characteristics and WQI of water supplied by the Northern Region water Board (NRWB) in Mzuzu City in order to ascertain the quality of water for domestic purposes based on standard formula (Oram, 2012; House and Ellis, 1987) and using the Malawi Bureau of Standards drinking water quality specifications as a criterion against which the quality of water for domestic use was evaluated.

2. Materials and methods

2.1. Description of the study area

Malawi is situated in South East Africa and lies within the western branch of the East African Rift System and is located on 11°27′ South, 33°55′ East. Mzuzu City, which covers 48 km^2, is found on the northern end of the Vipya Plateau at altitude between 1300 and 1350 m above sea level in the northern region of Malawi in Mzimba District. Mzuzu City has a subtropical climate with a distinct rainy season during November–May and its average monthly rainfall ranges from 0.3 mm in August to 222 mm in January (Ministry of Water Development (MoWD), 2005). Most of the city lies in a gently sloping land with ridges and gullies to the east and south mainly on the edge of the Rift Valley escarpment. Mzuzu City is mainly underlain by alluvial and colluvial deposits with the higher ground composed of metamorphic gneiss. The soils are mainly ferruginous on the lower land. The City is mainly drained by the Lunyangwa River which runs east to west and its tributary is the Ching'ambo stream.

2.2. Sampling and sample preparation

A total of 72 water samples were collected monthly between March and September, 2011 from randomly selected taps from schools (3), churches (1), colleges (2), market places (4) and industries (2) located in eight suburbs within Mzuzu City. The eight suburbs are: Luwinga, Chiwanja, Chibavi, Katawa, Chiputula, Chimaliro, Zolozolo and Mzuzu Government, which are located at a distance (in various directions) of 26 km, 22 km, 23 km, 16 km, 20 km, 8 km, 18 km, <1 km from the main water treatment plant, respectively (Fig. 1). The taps located in schools, churches, colleges, market places and industries were selected for sampling in such a way that they best represent the service reservoirs available in Mzuzu City and that they also represent a larger cross section of users who could be at risk assuming incase the water is of poor quality. Mzuzu Government is served directly from the main water treatment plant, Luwinga suburb is served by the Mzuzu University service reservoir, Chiputula, Chiwanja and Chiwavi suburbs are served by the Nkhorongo reservoir whereas, Chimaliro, Zolozolo and Katawa areas are served by the Chimaliro service reservoir. Raw water was collected from the main water treatment plant intake. Sampling took place three times during dry season (August–September, 2011) and three times during the wet season (March–April, 2011).

The water samples were collected in triplicate in 1 L polythene bottles which were labeled accordingly, pre-washed with dilute nitric acid and rinsed three times with the water sample at time of sampling before filling to capacity. Samples collected were filtered using 0.45 μm filter paper and acidified with nitric acid for cation analyses to prevent precipitation of unstable metals that easily change their form when exposed to different environmental conditions and also prevents adsorption of some metals onto the surface of the container. For anion analyses, these samples were stored below 4 °C prior to analysis in the laboratory. For collection, preservation and analysis of samples, the standard methods (American Public Health Association (APHA), 1992 and Association of Official Analytical Chemists (AOAC), 1990) were followed.

2.3. Sample analysis

Samples were analyzed immediately after sampling right in the field for hydrogen ion concentration (pH), electrical conductivity (EC) and total dissolved solids (TDSs) using Hanna model HI-9812 pH-EC-TDS meter (Hanna Instruments Limited). The electrode of the meter was rinsed with deionised water before determining pH, EC and TDS of any subsequent sample to prevent inter-sample contamination (APHA, 1992).

The total concentrations of Na^+, K^+, Ca^{2+} and Mg^{2+} were determined using atomic absorption spectroscopy (Buck Scientific Model 200A) at specifics as follows: potassium (K) (769.9 nm), calcium (Ca) (422.7 nm), magnesium (Mg) (285.2 nm) and sodium (Na) (589.0 nm). Titrimetric methods were used to determine the concentrations of chlorides ($AgNO_3$), TH (EDTA), CO_3^{2-} and HCO_3^- (acid). The concentrations of SO_4^{2-} and NO_3^- were determined using UV–VIS spectrophotometer at 420 and 410 nm, respectively. The quality of the chemical data was assessed by checking ion balances.

2.4. Data analysis

Data collected using standard methods was entered in SPSS and R-programme where descriptive statistics were performed. The Sawyer and McCarty (1967) total hardness classification and Fetter (1990) TDS classification were used to determine the chemical characteristics of water in the study area. The water samples were also classified into water types based on the dominant anion (or cation) exceeding 50% of total anionic (or cationic) charge and presented on piper diagrams to determine hydrochemical faces of the water. The water quality rating q_i for the ith water quality parameters was obtained from the following equation:

$$q_i = 100(v_i/s_i) \quad (1)$$

where v_i is the value of the ith parameter at a given sampled site and s_i is the standard permissible value of ith parameter. This equation ensured that $q_i = 0$ when a pollutant (the ith parameter) was absent in the water while $q_i = 100$ if the value of this parameter was just equal to its permissible value for drinking water. Thus, the larger the value of q_i, the more polluted was the water with the ith pollutant. However, quality rating for pH required special handling. The permissible range of pH for the drinking water is 6.0–9.5. Therefore, the water quality rating for pH was computed using the following equation:

$$q_{pH} = 100[(v_{pH} - 6.0)/(9.5 - 6.0)] \quad (2)$$

where v_{pH} = value of pH. The weights for various water quality parameters were assumed to be inversely proportional to the recommended standards for the corresponding parameters by the following equation:

$$W_i = \frac{K}{S_i} \quad (3)$$

where W_i is unit weight for the ith parameter ($i = 1,2,3,\ldots,12$), K = constant of proportionality which was determined from the condition and $K = 1$ for sake of simplicity,