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Mathematical Computation of Water Quality Index of Vea Dam in Upper East Region of Ghana

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Abstract

The objective of the study was to calculate the Water Quality Index (WQI) of Vea Dam in Upper East Region of Ghana in order to assess its suitability for drinking purposes. Water samples were collected from the Vea Dam in sterile bottles (1 litre capacity) under aseptic conditions. The samples were put in ice chest containing ice and then transported to the laboratory for analysis. Samples were assessed for ten (10) physico-chemical parameters namely pH, Electrical Conductivity, Total Dissolved Solid, Total Hardness, Nitrates, Sulphates, Chlorides, Calcium, Dissolved Oxygen and Biochemical Oxygen Demand. The calculation of the WQI was done using weighted arithmetic index method. The WQI was found to be 54.21 indicating clearly that untreated water from the Vea dam is of poor quality and must therefore be treated before use to avoid water related

diseases. We therefore strongly recommend that education on water related diseases should be intensified in the villages near the dam to stop the residents from resorting to the untreated water from the dam as their source of drinking water especially when they go to their farms.

Keywords: Water Quality, Water Quality Index, Physico-Chemical Parameters, Weighted Arithmetic Index Method

Introduction

Water is a chemical compound with the chemical formula H_2O. Water covers 71% of the Earth's surface (CIA, 2014) and is vital for all known forms of life. Water quality refers to the chemical, physical and biological characteristics of water (Diersing and Nancy, 2009). It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose (Johnson et al., 1997). In order to keep the health of any aquaculture system at an optimal level, certain water quality indicators or parameters must be monitored and controlled. A water quality index (WQI) summarizes large amounts of water quality data into simple terms (e.g., excellent, good, bad, etc.) for reporting to managers and the public in a consistent manner (Hulya, 2009). A water quality index provides a single number that expresses overall water quality at a certain location and time, based on several water quality parameters. WQI can be used as a tool in comparing the water quality of different sources and it gives the public a general idea of the possible problems with water in a particular region. The indices are among the most effective ways to communicate the information on water quality trends for the water quality management (Jagadeeswari and Ramesh, 2012).

The Vea Dam which was built in 1968 serves as the major source of water for residents of Bolgatanga Municipality in Upper East Region of Ghana. Water from the dam is treated by the Ghana Water Company Limited (GWCL), stored in reservoir tanks and then distributed to residents through distribution pipe lines. However, some residents in villages near the dam resort to the untreated water from the dam as their source of drinking water especially when they go to their farms. The objective of the study therefore was to calculate the Water Quality Index (WQI) of water from the dam in order to assess its suitability for drinking purposes.

Materials and Methods

Water samples were collected from the Vea Dam in sterile bottles (1 litre capacity) under aseptic conditions. The samples were put in ice chest containing ice and then transported to the laboratory for analysis. Samples were assessed for ten (10) physico-chemical parameters namely pH, Electrical Conductivity (EC), Total Dissolved Solid (TDS), Total Hardness (TH), Nitrates, Sulphates, Chlorides,

Calcium, Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) following the procedures outlined in the Standard Methods for the Examination of Water and Wastewater (APHA/AWWA/WEF, 1998). However, pH was measured in situ using a portable pH meter.

The calculation of the WQI was done using weighted arithmetic water quality index which was originally proposed by Horton (1965) and developed by Brown et al (1972). The weighted arithmetic water quality index (WQI_A) is in the following form:

$$WQI_A = \sum_{i=1}^{n} w_i q_i / \sum_{i=1}^{n} w_i \quad (1.1)$$

where n is the number of variables or parameters, w_i is the relative weight of the i^{th} parameter and q_i is the water quality rating of the i^{th} parameter. The unit weight (w_i) of the various water quality parameters are inversely proportional to the recommended standards for the corresponding parameters. According to Brown et al (1972), the value of q_i is calculated using the following equation:

$$q_i = 100\ [(V_i - V_{id}) / (S_i - V_{id})] \quad (1.2)$$

where V_i is the observed value of the i^{th} parameter, S_i is the standard permissible value of the i^{th} parameter and V_{id} is the ideal value of the i^{th} parameter in pure water. All the ideal values (V_{id}) are taken as zero for drinking water except pH and dissolved oxygen (Tripaty and Sahu, 2005). For pH, the ideal value is 7.0 (for natural/pure water) and a permissible value is 8.5 (for polluted water). Therefore, the quality rating for pH is calculated from the following equation:

$$q_{pH} = 100\ [(V_{pH} - 7.0) / (8.5 - 7.0)] \quad (1.3)$$

where V_{pH} = observed value of pH.

For dissolved oxygen, the ideal value is 14.6 mg/L and the standard permissible value for drinking water is 5 mg/L. Therefore, its quality rating is calculated from the following equation:

$$q_{DO} = 100\ [(V_{DO} - 14.6) / (5.0 - 14.6)] \quad (1.4)$$

where V_{DO} = observed value of dissolved oxygen.

Table 1 below shows a classification of water quality, based on its quality index due to Brown et al (1972), Chatterji and Raziuddin (2002) etc.

Table 1 Classification of water quality based on weighted arithmetic WQI method

WQI	STATUS
0 - 25	Excellent
26 - 50	Good
51 - 75	Poor
76 - 100	Very Poor
Above 100	Unsuitable for drinking

Source: Brown et al (1972), Chatterji and Raziuddin (2002)

Results and Discussions

Table 2 below gives the observed values (v_i) of the ten (10) selected physico-chemical parameters of water samples (collected on 4th October, 2014), standard drinking water values (s_i) according to World Health Organisation (WHO, 1993), unit weights (w_i), water quality rating (q_i) and $w_i q_i$.

Table 2: Calculation of Water Quality Index (WQI) of the Dam.

Parameter	**Observed values (v_i)**	**Standard values (s_i)**	**Unit weights (w_i)**	**Quality rating (q_i)**	**$w_i q_i$**
pH	7.7	6.5 - 8.5	0.2190	46.67	10.2207
Electrical Conductivity	96.3 µS/cm	250 µS/cm	0.3710	38.52	14.2909
Total Dissolved Solids	45.0 mg/L	500 mg/L	0.0037	9.00	0.0333
Total Hardness	30.0 mg/L	300 mg/L	0.0062	10.00	0.0620
Calcium	10.3 mg/L	75 mg/L	0.0250	13.73	0.3433
Chlorides	3.1 mg/L	250 mg/L	0.0074	1.24	0.0092
Nitrates	1.7 mg/L	50 mg/L	0.0412	3.40	0.1401
Sulphates	8.0 mg/L	200 mg/L	0.0124	4.00	0.0496
Dissolved Oxygen	3.2 mg/L	5 mg/L	0.3723	118.75	44.2106
BOD	1.1 mg/L	5 mg/L	0.3723	22.00	8.1906
			$\sum_{i=1}^{10} w_i$ = 1.4305		**$\sum_{i=1}^{n} w_i q_i$ =77.5503**

The water quality index (WQI) of the Vea dam was then calculated using the weighted arithmetic index formula as follows:

$$WQI_A = \sum_{i=1}^{10} w_i q_i \,/\, \sum_{i=1}^{10} w_i = {}^{77.5503}/_{1.4305} = 54.21$$

This value (54.21) falls within 51-75 of the classification of water quality based on weighted arithmetic WQI method as given in Table 1. It follows that untreated water from the Vea dam is of poor quality and must therefore be treated before use to avoid water related diseases.

Conclusion and Recommendations

The objective of the study was to calculate the Water Quality Index (WQI) of Vea Dam in Upper East Region of Ghana in order to assess its suitability for drinking purposes. The water quality index (WQI) of 54.21 obtained is a clear indication that untreated water from the Vea dam is of poor quality and must therefore be treated before use to avoid water related diseases. We therefore strongly recommend that education on water related diseases should be intensified in the villages near the dam to stop the residents from resorting to the untreated water from the dam as their source of drinking water especially when they go to their farms.

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