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Yanthan, Senchumbeni
Department of Chemistry, National Institute of Technology Nagaland

Akito I Sema
Department of Chemistry, National Institute of Technology Nagaland

Das, Deepak
Department of Chemistry, National Institute of Technology Nagaland

Bhattacharyya, Jhimli
Department of Chemistry, National Institute of Technology Nagaland

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Assessment of water safety and associated health risks of Nagaland's capital, Kohima: A physico-chemical and statistical investigation

Senchumbeni Yanthan, Akito I Sema, Deepak Das, Jhimli Bhattacharyya*
Department of Chemistry, National Institute of Technology Nagaland, Dimapur, Nagaland–797103, India
Presenting and first author's email: ysenchum@gmail.com
*Corresponding/senior author's email: jhimli@nitnagaland.ac.in

Abstract: *Access to quality drinking water is a must for every individual however with increasing urbanization and development, water pollution has been on the rise in the past decades. This study aims to assess the drinking water quality collected from the capital city of Nagaland, India and analyzes the parameters that may be responsible for water contamination. Collected water samples were analyzed using Statistical analysis and the Water Quality Index concerning thirteen parameters namely pH, temperature, TDS, EC, DO, TH, Ni, Al, SO_4^{2-}, PO_4^{3-}, Ca, Mg, and TOC. As per the analysis, all the parameters were under the permissible limits as suggested by the BIS. The major concern is the high concentration of Aluminium which poses a risk for causing Alzheimer's disease. Hence such research is crucial to formulate designs for prospective water management which is possible only by obtaining detailed data of the water condition for the concerned areas.*

Keywords: Nagaland; North-eastern India; water safety, health hazard; pollutants.

1. INTRODUCTION

The availability of clean water is a significant public health issue [1]; researchers worldwide are constantly looking for more practical and affordable solutions to provide the general people with clean and improved water [2-5]. In developing nations like India, natural water shortages, insufficient sanitation facilities, and a lack of access to clean drinking water are all significant problems [6]. Besides these, water contamination usually arises from geographical, geological as well as anthropogenic conditions [7]. In this research, the main area under study is the state of Nagaland which is one of the 28 states in India.

With a total size of 16,579 square kilometers, Nagaland is situated in the north-eastern part of India. Its boundaries are as follows: 2506′ N to 2704′ N latitude; 93020′ E to 95015′ E longitude. With an average annual rainfall of about 2600 mm, the state has sub-tropical to moderate temperate monsoon climatic conditions. Spring, stream, and well water serve as the main sources of drinking water in rural areas where well-managed water transportation systems and related infrastructure are not accessible. Rivers and streams, which significantly rely on the amount of yearly rainfall, are the main water sources of Nagaland. This study's key hypothesis is that by testing the water's quality, we can determine whether it is fit for residential use. Since the research region is comprised of Kohima, it is essential to assess the drinking water quality status of the various water bodies that are present there to ensure that the area's population have access to clean drinking water. To determine the various physico-chemical characteristics of water from different sources and to compare the values obtained with the permissible limit of drinking water quality set by the Bureau of Indian Standards (BIS 1991) [8], we thus envisaged the evaluation of drinking water quality from different sources such as river, well, and stream water available in Kohima.

Though Nagaland is a very important bio-geographic region of North-eastern India and very rich in biodiversity, proper quantitative water maps, water quality data with quantitative, reliable, and scientific are still limited in number. It's a place for ethnic tribal population with rich traditional values. However, due to rapid urbanization and increased population, the environmental quality, especially the water quality is getting compromised fast. Overall awareness and understanding about such alarming condition is still missing among the common mass. This study will assist in finding a few key physico-chemical characteristics that demonstrate high water quality indices. The study's analysis of various pollution sources and heavy metals may aid in addressing pollution issues by raising public awareness of the need to prevent further contamination of this kind and the local population can implement the management program and recommended procedures essential for accessing better quality of drinking water. Furthermore, the study's findings will be helpful to the media, organizations, academics, water treatment facilities, municipalities, and those who make policy decisions.

2. MATERIALS & METHODS

2.1 Description of the sampling area

The samples were collected mainly from the capital of Nagaland, Kohima. Samples were collected and tested from the various spots with varied water sources. The areas considered for this study were the hilly regions where people relied mostly on natural sources like rivers and streams for water. The collection of samples was carried out from the primary sources in order to authentically analyze and present the data for the various samples.

2.2 Physico-chemical measurements

Water quality parameters like pH, Total Dissolved Solids (TDS), Electrical Conductivity (EC), and Temperature were measured with the help of Portable pH meter (HI98127) and Groline TDS/EC/Temperature meter (HI98318). In addition, the data obtained was cross-checked using an HM digital AP-1 TDS and EC tester. A multi-parameter photometer (HI83399) was used for the detection of various inorganic salts and ions. TOC (Total Organic Content) was determined using Shimadzu TOC Vcph analyzer. All the instruments were calibrated using the set of calibration solutions. Following the standard procedures from the American Public Health Association (APHA) book [26], the Winkler method with azide modification and EDTA titration methods were utilized to check the concentration of Dissolved Oxygen (D.O.) and Total Hardness. All the chemicals used were of analytical grade and were obtained from Sigma-Aldrich.

2.3 Sampling methods and analysis

Water samples were collected from 7 different wards of Kohima. One litre of Tarson LDPE bottles were used to store the water samples and two litres of each sample were collected from all the sampling points. These samples were collected using thoroughly washed/sterilized bottles and were washed with the target water again before sampling. The samples' temperatures were determined on the spot and other parameters such as pH, TDS, and conductivity were analyzed promptly following sample collection as they are affected by the change in temperature. To preserve the samples for elemental analysis, 1 ml of concentrated HNO_3 was added to one of the bottles to reduce precipitation and adsorption on the container. The concentration of D.O. was determined on the evening of the sample collection. The GPS coordinates for the sampling region were recorded during sample collection.

2.4 Statistical and Water Quality Index analysis

The statistical data for the entire set of water samples were computed using IBM SPSS Statistics version 25 software.The Pearson correlation matrix was used to assess the relationships between the water qualities for 13 parameters.

In an effort to assess the suitability of water sources for human consumption, the Water Quality Index (WQI) has been computed [9]. A Water Quality Index (WQI) denotes a single value that indicates the overall water quality at a specific location and time. In this case, all thirteen parameters were considered for WQI calculation. It was calculated using the weighted arithmetic index method [10].The WQI is calculated using the expression given in Equation 1

$$\mathrm{WQI} = \frac{\Sigma Q_n \times W_n}{\Sigma W_n} \qquad (1)$$

Where,

Q_n is quality rating of the n^{th} water quality parameter and it is obtained using the Equation 2

$$\mathrm{Q_n} = 100 \times \frac{(V_n - V_i)}{(S_n - V_i)} \qquad (2)$$

V_n is the estimated value of the n^{th} water parameter at a given sampling site.

V_i is the ideal value of the parameter taken as zero for all parameters except for pH and Dissolved Oxygen (D.O). Ideal Value for pH = 7 and D.O = 14ppm.

S_n denotes the standard permissible limits for the parameters.

W_n of equation 1 can be determined using the Equation 3

$$\mathrm{W_n} = \frac{K}{S_n} \qquad (3)$$

K in equation 3 is the constant of proportionality and is given by the Equation 4

$$\mathrm{K} = \frac{1}{\Sigma(1/S_{n=1,2,3......n})} \qquad (4)$$

WQI can be calculated using Equation 1 and the obtained value can be correlated by comparing with the values presented in Table 1.

Table 1: Water quality range as per the Water Quality Index

Water Quality Index	Water Quality Status
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
>100	Unfit for consumption

3. RESULTS AND DISCUSSION

3.1 Physico-chemical analysis

The detailed physico-chemical analysis of the water samples collected from Kohima, the capital of Nagaland is presented in Table 2. The results have been discussed with respect to the standards of the BIS (Bureau of Indian Standards).

Table 2: Data of the analyzed parameters for Kohima district

Sample / Parameters	1	2	3	4	5	6	7
pH	7.7	6.2	6.4	7.1	6.8	5.9	6.1
Temp	16.3	15.1	15.8	17	14.2	16	15.9
TDS (mg/L)	309	250	430	514	220	288	408
EC (in µS/cm)	589	480	832	988	432	563	770
DO (in ppm)	7.4	7	4.9	7.2	7.7	7.8	6.9
TH (in ppm	351	475	703	551`	399	570	665
Ni (in ppm	0.008	0.014	0.012	0.006	0.01	0.012	0.013
Al (in ppm)	0.4	0.07	0.02	0.19	0.02	0.33	0.02
SO_4^{2-} (in ppM)	34	27	53	29	22	38	42
PO_4 (in ppm)	0.05	0.01	0.05	0.03	0.04	0.03	0.06
Ca (in ppm)	1	41	49	43	57	62	142
Mg (in ppm)	23	21	45	34	14	24	30
TOC (in ppm)	0.83	0.94	2.93	1.36	1.69	1.09	1.83

3.1.1 pH

In the determination of water quality, the pH of a water sample is very important because of the fact that it tends to affect chemical reactions related to solubility and metal toxicity [11, 12]. It causes the leaching of toxic metals into the water that could be hazardous and can disturb the aquatic habitat. During the study, the pH of the samples was found to be in the range of 5.9 to 7.7. Most of the samples were found to be well within the limits set by the BIS (pH 6.5-8.5) however one sample (pH 5.9) was found to be below the permissible limit.

3.1.2 Temperature

The temperature for the water samples were measured on-site at the time sample collection. The temperature of the sample is affected by various factors such as season, time of the day, area etc. from which the sample is collected. Measuring temperature is essential as it can affect the values of several parameters studied in these analyses. The temperature of water sample analyzed was in the range of 14.2 to 17°C.

3.1.3 Total Dissolved Solids (TDS)

Total dissolved solid is the amount of solid present in water . The dissolved solid mainly includes sulfates, chlorides, nitrates,bicarbonates, carbonates, phosphate of calcium, magnesium, sodium, potassium along with traces of iron, manganese and other substances [13]. A significant level of TDS can make the water unpleasant to drink while an extremely low amount of TDS may cause the water to acquire a flat taste.The TDS values of the samples were in the range of 22 to 514mg/L. In this study, sample 4 from Kohima recorded the highest TDS value of 514 mg/L while the rest were all excellent and below the permissible limits of 500 mg/L.

3.1.4 Electrical conductivity (EC)

Electrical Conductivity (EC) is defined as the ability of water to conduct electrical current. It denotes the amount of dissolved minerals in the water. The analysis shows extensive variation in EC values which ranges between a minimum of 432 μS/cm and a maximum of 988 μS/cm. These analyses indicate that the water samples were not considerably ionized and thus had a lesser level of ionic concentration activity due to the presence of small, dissolved solids.

3.1.5 Dissolved Oxygen

DO is an important biological parameter that indicates the water quality level and organic pollution in the water[14].The DO values usually remain lower in areas where the rates of respiration and organic decomposition are high as compared to the areas with higher rates of photosynthesis [15].Lower concentration of dissolved oxygen can indicate excessive growth of algae (algal bloom)which is caused by the presence of phosphorus. Naturally, ground water has a low concentration of dissolved oxygen as compared to surface water [16]. Dissolved oxygen in the analyzed samples were found within the range of 4.9 to 7.7 ppm.

3.1.6 Total Hardness

In order to describe the effect of dissolved minerals like Ca and Mg, a parameter is utilized which is known as total hardness [17]. The study of this parameter is important as increased hardness causes change in the taste of water [18].Hardness may also be attributed due to the presence of additional components like sulfates or chlorides of iron, manganese, and aluminum[19, 20].EDTA titration method was used to determine the total hardness and they were found to be in the range of 399 to 703 ppm.Few of the samples exceed the permissible limits (600 ppm) set by the BIS like Sample 3(703 ppm) and 7(665 ppm) in Kohima.

3.1.7 Nickel

Nickel is usually present as the ion nickel hexahydrate $(Ni(H_2O)_6)^{2+}$in natural waters and its concentration varies depending on the type of soil, pH, and depth of sampling [21].The analyzed samples ranged between 0.008 to 0.014 ppm. None of the samples in Kohima exceeded the limit of 0.02 ppm. Nickel may cause eczematous flare-up reactions in the skin when ingested orally by nickel-sensitive individuals [22].

3.1.8 Total Organic Carbon (TOC)

Total Organic Carbon (TOC) is an analytical parameter that gives the concentration of organic carbon in a sample and may be used as a non- specific indicator for the purity of a water sample. TOC is being considered as an alternative to COD (Chemical Oxygen Demand) [23]. No desirable limits for TOC concentration has been set up by any regulating agency. The collected water samples had TOC ranging from from 0.8276 to 2.933 ppm.

3.1.9 Aluminium

The mineralogical conditions and geological aspect of an area greatly affects the concentrations of Aluminium in natural water. Aluminium concentration ranged from 0.02 to 0.4 ppm in the analyzed samples and three of the samples were found to have high levels of Al as compared to the permissible limit set by BIS (i.e 0.2 ppm). This result is concerning as studies proposed that prolonged exposure to a higher concentration of Al poses a risk for development of Alzheimer's disease in humans.

3.1.10 Phosphate

Phosphorous compound such as phosphates leads to the eutrophication of standing water which results in a lower concentration of dissolved oxygen in the water. Phosphates sources are usually anthropogenic resulting from detergents which are mostly present in waste and sewage effluent [24]. Two other significant sources of phosphorus in ground and surface waters are fertilizers and pesticides mainly used by the people in agriculture [25]. Phosphate levels in this study were in the range of 0.01 to 0.05 ppm which did not exceed the permissible limits of 1ppm according to BIS. It is necessary to check the phosphate levels of water as high phosphate levels can cause kidney damage, osteoporosis as well as digestive issues.

3.1.11 Sulphate

In nature, sulphate in water is mainly because of the presence of iron sulphide in coal and rocks which reacts with water and oxygen. Sulphate ions are produced in water when these pyrite wastes are chemically broken down. They are also found in minerals like barite, epsomite, and gypsum [26]. The analyzed samples were well under the permissible limits set by the BIS (200 ppm) and were in the range of 22 to 53 ppm.

3.1.12 Calcium and Magnesium

BIS has specified that the content of calcium and magnesium in drinking water should be below 200 and 100 ppm respectively. The concentrations of both Ca^{2+} and Mg^{2+} for the analyzed samples were found to be in the range of 1 to 142 ppm and 14 to 45 ppm which is under the permissible limits. The calcium concentration in groundwater is slightly greater as compared to surface water. Currently; there is no evidence of the impact on human health caused by the deficiency of Ca and Mg however studies suggest that stroke in postmenopausal women is reduced upon consumption of water which is high in calcium and magnesium [27]. Also, it was suggested that a person consuming water containing calcium has lesser chances of heart trouble or cardiac disorder as compared to a person drinking water without calcium content [28].

3.2 Statistical analysis between different parameters

Table 3 displays the detailed statistical analysis of the physico-chemical study i.e. mean, standard deviation, variance, range, minimum and maximum values for all the 13 parameters.

Table 3: Statistical data of the analyzed parameters

Water Parameters	Range	Min.	Max.	Mean	Standard Deviation	Variance
pH	1.8	6.9	7.7	6.6	0.638	0.407
Temp	2.8	14.2	17	15.76	0.892	0.796
TDS	294	220	514	345.6	107.2	11491.2
EC	556	432	988	664.86	203.28	41322.8
DO	2.9	4.9	7.8	6.99	0.979	0.958
TH	304	399	703	559.14	103.98	10812.8
TOC	2.105	0.827	2.933	1.522	0.7245	0.525
Ni	0.008	0.006	0.14	0.0107	0.0029	0.00
Al	0.038	0.02	0.4	0.15	0.16	0.026
Ca	141	1.0	142	56.42	42.62	1816.6
Mg	31	14	45	27.29	10.094	101.905
SO_4^{2-}	31	22	53	35	10.42	108.667
PO_4	0.05	0.01	0.06	0.039	0.017	0.0

3.3 Water Quality Index

The Water Quality Index (WQI) gives an idea about the overall quality of water by eliminating the excess amount of data and presents the results in a simplified manner. In this analysis, all the parameters were considered for calculating WQI. The values are represented in detail in Table4. WQI values for the samples range from 11.00 to 66.98 (Table 4) and fall in the categories of ‘excellent’ to ‘poor’. The quality of water samples can be interpreted with the help of the data given in the table below. The water samples analyzed in Kohima were found to be of excellent or good quality, with only two samples falling within the poor range. None of the samples exceeded the value of 100 which is deemed as water unfit for consumption. Higher level of Aluminium may be responsible for the poor quality of water and the higher value of WQI may be due to various parameters that exceed the permissible limits.

Table 4: Water Quality Index values for Kohima..

Sample no.	WQI - Kohima
1	66.98
2	20.88
3	13.52
4	34.14
5	11.00
6	59.04
7	13.63

Therefore, the overall characteristics of the water show ‘excellent’ and ‘good’ quality in terms of WQI.

4. CONCLUSION

The present study aims to evaluate the quality of water in Kohima, the capital city of Nagaland and to assess the parameters responsible for the poor quality of water. Following the correlation report, TDS and EC are significant physico-chemical parameters as they are associated with majority of the parameters that determine water quality. pH was well within the permissible range as suggested by the BIS and the D.O. of ground water was found to be less as compared to the surface water.TDS was well within the limits except for one sample;TH was high in some samples which were above the limits. Almost all of the parameters like TOC, sulphate, phosphate, Ca, and Mg of the water samples from Kohima were satisfactory however the high level of Al were concerning. The major issue is the high content of Al which can be dangerous if not checked properly.These high levels may mainly be due to the geological region of the districts however adequate measures and steps should be taken to tackle this matter. The overall characteristics of the water are shown as ‘excellent’ and ‘good’ quality as suggested by the Water Quality Index for Kohima district. Thus, this implies that the water samples collected from Kohima are suitable to be consumed directly however some components have to be treated before consumption. In conclusion, a need for innovation is observed to manage the emerging pollutants in order to address the water quality issue.

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