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Evaluation of Physio-chemical Properties and WQI of the Drinking Water in Urban Area of Bilaspur, Chhattisgarh, India

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Authors' contributions

This work was carried out in collaboration among all authors. Author ST collection and analysis of sample, author BPS designed the study, Author Kamesh performed statistical analysis and wrote the draft of manuscript, authors SM and PPS read and approved the final manuscript and authors Ruby and TJ managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study was estimating the physicochemical parameters of water and preparing the water quality index for drinking water in a residential area of Bilaspur city. Fifty water samples were collected from ten sites and analyzed six parameters of water quality by using the portable multi-parameter water quality meter (Hanna Instruments: HI98194). The results of water quality were statistically

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different for sites ($p<0.001$). During the study, the average water pH (8.326±0.67), water temperature (27.349±0.207 °C), dissolved oxygen (7.775±0.034 mg/l), total dissolved solids (526.46±0.781mg/l), electrical conductivity of water (391.6±0.79 mg/l), and oxygen reduction potential (-32.715±0.21 mV) were recorded. The positive correlation was observed between EC and TDS (r = 0.935) and pH and ORP (r = 0.802), while the negative correlation was observed between DO and temperature. The range of the WQI was observed to be 383.67 to 530.87, and there was a statistically difference at for sites ($p<0.001$).

Keywords: EC; sustainable environment; TDS; urban water quality; water monitoring.

NOMENCLATURE

ORP	:	*Oxidation Reduction Potential*
DO	:	*Dissolved Oxygen*
WQI	:	*Water Quality Index*
EC	:	*Electrical Conductivity*
TDS	:	*Total Dissolved Solids*
ANOVA	:	*Analysis of Variance*
WHO	:	*World Health Organization*
BIS	:	*Bureau of Indian Standards*
mV	:	*Millivolts*
mg/l	:	*Milligram per Liter*
µS/cm	:	*MicroSiemens per Centimeter*
mg g^{-1}	:	*Milligram per Gram*
0C	:	*Degree Celsius*
Mm	:	*Millimeter*

1. INTRODUCTION

Water, the essence of life, is a vital resource on earth. 70% of the earth's mass is water, a constituent of living things, of which 2.8% is freshwater (20% groundwater) and the remaining 97.2% is saltwater [1]. Ground and surface water have been exceptionally used for drinking purposes in urban areas. Water quality has been affected by human activities such as agricultural practices, urban solid waste disposal, and improper disposal of industrial effluent [2]. Quality of water influenced human health [3,62,63,64,65]. Inappropriate uses and unsustainable waste management techniques are causing the water quality to worsen in cities [4,5,6,59]. The trouble is getting dangerous because water treatment is either nonexistent or insufficient. Pollutants pass through sewage systems and contaminate surfaces and groundwater [7,8,9,10]. Polluted water has caused 2.2 million deaths, of which 1.4 million are children, and the number of patients suffering from waterborne diseases has been increasing worldwide [11]. A healthy and balanced world is strictly dependent on the supply of clean and safe water [12,13]. In the meeting of UN members (held in September 2015), for the 2030 Agenda, adopted the sustainable goal “Ensure availability and sustainable management of water and sanitation for all” [14,15]. Minimising the water contamination and uses for drinking is the first priority for the nation [16]. Water quality parameters consist of physical, chemical, and microbiological characteristics, including pH, turbidity, dissolved oxygen, total dissolved solids, oxidation reduction potential, temperature, hardness, electrical conductivity, etc. [17,18,19].

Bilaspur is the second largest city of the Indian states of Chhattisgarh and known as the city of festivals. About 2.5 lakh people live in the city, which sharply increased in 2022 to about 3.4 [20]. Increasing population around the city creates huge pressure on water sources, which results in a decreasing groundwater level. The Arpa River is the main river that passes between the city. It is also the headquarters of South East Central Railway and South Eastern Coalfield Limited. Due to the enormous number of coal mines near the city, coal-based major and minor industries (thermal power plants, iron melting industries, etc.) that are existing in the surroundings of the city and disposing of their effluents without proper management techniques. Hence, the ground and surface water quality have been affected by it. The present study shows the physiochemical quality of drinking water of different sites in Bilaspur city (India) and to ensure that the water is either safe for drinking or not.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted during the period of March to June 2023. Water samples were collected from the different residential areas of Bilaspur city (Table 1). It is situated at 22.09^0 N 82.15^0E and has an average elevation of 264 meters above sea level. The climate of the area is tropical; the average temperature and rainfall ranged from 20.37^0C to 35.75^0C and 764 mm recorded, respectively.

Table 1. Shown sites for water sample collection

Sites	Place	Latitude	Longitude	Source of water
S1	Koni	22.134125 N	82.123842 E	Tube well, water tank
S2	SECL, Indira Vihar colony	22.106386 N	82.147844 E	Water tank
S3	Lodhipara	22.100774 N	82.140638 E	Water tank
S4	Ashok Nagar	22.102597 N	82.152661 E	Water tank
S5	Satyam Chowk	22.078887 N	82.156474 E	Water tank
S6	Mangla Chowk	22.091352 N	82.127432 E	Water tank
S7	Seepat Chowk	22.095562 N	82.144719 E	Water tank
S8	Devkinandan chowk	22.088342 N	82.148754 E	Water tank, tube well
S9	DFO, colony	22.083050 N	82.140649 E	Water tank, tube well
S10	Birkona	22.140783 N	82.154384 E	Water tank, tube well

2.2 Water Sampling and Analysis

Fifty samples of water were collected from ten sites, and five replications for each site were analyzed. The six parameters of water quality were analyzed (including temperature, electrical conductivity, pH, total dissolved solids, dissolved oxygen, and oxygen reduction potential) using a portable multi-parameter water quality meter (Hanna Instruments Model: HI98194).

The WQI has been measured as per the drinking water quality standards recommended by the Bureau of Indian Standards (IS-10500:2012). The weighted arithmetic approach was used to create the water quality index, and that equation has been completed into three steps, which are given below:

To calculate the unit weight (*Wi*) factors from each parameters by using the formula [21,22]:

$$Wi = \frac{K}{Sn} \tag{1}$$

Where, *Wi* = unit weight of i^{th} parameters

$$K = \frac{1}{\Sigma(\frac{1}{Sn})}$$

K = proportion constant, *Sn* = standard desirable value of the i^{th} parameters

To calculate the sub-index value *Qi* value by using the formula [50]:

$$Qi = [\frac{(Vo-Vi)}{(Sn-Vi)}] * 100 \tag{2}$$

Where, *Vo* = concentration of i^{th} parameters at a giving sampling sites, *Vi* = ideal value of i^{th} parameters in pure water.

To calculate the water quality index by using the formula [21,22]:

$$WQI = \frac{\Sigma\, Wi * Qi}{\Sigma Wi} \tag{3}$$

With the exception of pH, dissolved oxygen, and temperature, all ideal values (*Vi*) for drinking water are assumed to be zero [23]. The ideal value of pH is 7.0, while the maximum acceptable pH is 8.5 for drinking water. Similarly, for dissolved oxygen, the permissible limit is 5 mg/l, while the ideal value is 14.6 mg/l. The permissible limit of water temperature ranges from 25 to 280 °C, and the ideal value is 250 °C. Thus, effective values for water temperature, pH, and dissolved oxygen were calculated using these formulas [23]:

$$Q_{pH} = [\frac{(VpH-7.0)}{(8.5-7.0)}] * 100 \tag{4}$$

$$Q_{DO} = [\frac{(VDO-14.6)}{(5.0-14.6)}] * 100 \tag{5}$$

$$Q_{T} = [\frac{(VT-28)}{(25-28)}] * 100 \tag{6}$$

Where V_{DO} is observed value dissolved oxygen, V_{pH} is observed value of pH and V_T is observed value of temperature.

2.3 Statistical Analysis

A one-way ANOVA was performed at the 5% level of significance to analyze the variation in sampling sites for parameters using SPSS software (IBM 20.0). The matrix correlation was performed to determine the relationship among the parameters of water quality**.**

3. RESULTS AND DISCUSSION

3.1 pH of Water

The water pH is altered through electrolysis, or the splitting of the water molecule into hydrogen and hydroxide ions with an electric current. The pH of water indicates its acidity and basicity, and the scale of pH is <7.0 for acidic, 7.0 for neutral, and >7.0 for salinity or alkanity [59,60]. It detects the ratio of free hydroxyl and hydrogen ions present in water. The water pH was statistically significant differ (p 0.001) in sites. The higher water pH values received 9.3±0.03 for S1, followed by S2 >S3 >S10 >S4 >S5 >S6 >S9 and S8. The lower water pH was observed at 7.89 ± 0.11 for S7 (Table 2). Two sites, S1 and S2, showed pH values of water more than 8.5, which is not considerable for drinking while other sites are safe. A study was reported in drinking water pH about more than 7.40 [24,25,26]. Significantly higher or lower pH can be harmful for the human body and not safe for drinking purposes. High pH results in an unpleasant taste; it reduces the efficacy of chlorine disinfection, necessitating the use of extra chlorine. Metals and other materials corrode or dissolve in low-pH water [26,27].

3.2 Water Temperature

Water temperature is a significant influence on drinking water quality. High temperatures increase the viscidity of drinking water sharply. When temperature rises from 5 to 25°C, the level of viscosity will fall by approximately 40%, thus lowering flow resistance. It also has effects on the mobility of copper ions, the degree of deterioration, the dissolution of metal structures, the overall chlorinated breakdown, and the production of disinfection products [28,29]. Drinking water should have an ideal temperature of 25°C, as per the World Health Organization [30]. They reported the negative correlation between dissolved oxygen and water temperature, and the dissolved oxygen of water decreased with increases in the water temperature [31,32]. The observation showed the water temperature significantly differs at the (*P* = 0.001) level of significance. S6 received the highest water temperature at 28.86±0.17°C, followed by S7> S3> S5> S8> S4> S9> S10> and S1. The minimum temperature of water was recorded 26.38±0.25°C for S2 (Table 2). A similar report was found for the water temperature of Wondo Genet city, which ranges between 28°C and 29°C [31]. The acceptable drinking water temperature limit of WHO is 25–30°C. A water temperature range of 29°C was reported for drinking water in Nigeria [33]. The drinking water temperature in tropical countries could be even higher; the city of Cali (Colombia) ranges of water temperatures between 25^{0}C and 28^{0}C [29].

3.3 Dissolved Oxygen

All aquatic species depend on dissolved oxygen. Whenever dissolved oxygen within water remains unsaturated, atmospheric oxygen can enter a water body; likewise, aquatic plants may produce dissolved oxygen during photosynthesis [34,35]. The dissolved oxygen of water is inversely proportional to the water temperature; when the water temperature increases, the dissolved oxygen decreases. DO level is the sign of water self-purification [36]. The dissolved oxygen of water for study areas was significant and differed at the (*P* = 0.001) level of significance. The highest dissolved oxygen (mg/l) was received 8.14±0.02 mg g-1 for S2, followed by S7> S10> S9> S4> S8> S3> S5> and S7, while the lowest was 7.22±0.02 mg g-1 for S6 recorded (Table 2). Bwire et al. (2020) reported the dissolved oxygen of 6.38 mg/l at a temperature of 26.57 °C for domestic drinking water [37].

3.4 Electrical Conductivity

Electrical conductivity (µS/cm) of water for different sites differed significantly at the (*P* = 0.001) level of significance. S9 recorded a higher electrical conductivity of water for 686.95 µS/cm followed by S5> S1> S4> S7> S6> S8> S2> S3, while the lowest was 357.4 S/cm for S10 observed. Pure water is an excellent insulator but nevertheless a strong conductor of currents [60,61]. As the ions in the water increase, the electrical conductance also increases. EC in water is often determined by the concentration of dissolved suspended particles in water [31,38,39]. The present study reported that the electrical conductivity ranges from 569 to 569 µ*S*cm^{-1}. 300 µScm electrical conductivity of the water is an acceptable limit for drinking. An investigation reported a higher range of EC for drinking water quality in the city of Pogradec, Albania [40]. Similar data was reported for a for a higher range of EC 770 µ*S*cm^{-1} [41,42,43].

3.5 Total Dissolved Solids

The TDS (mg/l) of water varied statistically (*P* = 0.001). The maximum TDS was observed 496.2±0.58 mg/l for S5, followed by S9> S4> S1> S7> S2> S6> S8 and then S3. The 239.6±0.68 mg/l for S10 was observed as the as the minimum water total dissolved solid (Table 2). The entireties of the dissolved components in water that remain dehydrated are known as total dissolved solids. Soluble salts compose almost all of the nonvolatile or fixed components of TDS that exist in natural waters [44]. This part might be known as water salinity. Inland water salinity tends to contain four major cations (Ca, Mg, Na, and K) and three anions (bicarbonate, sulphate, and chloride) [43,45]. The TDS ranges between 500 and 2000 mg/l, which is the maximum permissible limit [46]. These limits are not always observed, however, and many municipalities use water containing from 2,000 to 4,000 mg/l TDS [47]. Present study maximum TDS observed 496 mg/l for drinking water. A similar investigation was reported of TDS for surface drinking water >490 mg/l [48,49,50].

3.6 Oxidation Reduction Potential

Electrons are transferred among atoms, molecules, or ions in a process known as a redox reaction. The electrical force generated within water in the presence of an oxidant or reductant is determined by the test ORP [51]. Drinking water should have an ORP of about -50 mV. When ORP is positive, situations are oxygenating; often used as a gauge for disinfectant concentrations in untreated discharge water, like chlorine. The ORP was influenced by the existence of chlorine water, which can cause value to move towards positive [52,53]. The correlation between ORP and pH was also reported by Vongvichiankul et al. (2017); the degree of deference was decreased with increasing pH [54]. The present study observed the ORP (mV) of municipal tap water was significant and differed for sites at the (*P* = 0.001) level of significance (Table 2). The range of ORP was recorded from -38.65 (S10) to -22.82 (S1). A similar result was reported by Luccarini et al. and Azis et al. [55,56].

The correlation between the physiochemical parameters of water quality has been analyzed using a correlation matrix in MS Excel (Table 3). The correlation value was categorized into four classes: very strong correlation (r value greater than 0.75), moderate correlation (r value between 0.50 and 0.75), lower correlation (r value between 0.30 and 0.50), and week correlation (r value is <0.30). Present results showed significantly strong positive correlation between EC and TDS (r = 0.935) and between pH and ORP (r = 0.802). A moderate positive correlation was recorded between DO to pH (r = 0.524) and ORP (r = 0.467), between ORP to EC (r = 0.316) and TDS (r = 0.475). While the strong negative correlation was recorded between DO and temperature (r = -0.987). Comparison between mean study values with different parameters of quality of water and Bureau of Indian Standard (2022) as shown in Fig. 1.

Table 2. Analyzed value of different samples for water parameters

Sites	pH	Temperature (^{0}C)	DO (mg/l)	EC (µS/cm)	TDS (mg/l)	ORP (mV)
S1	9.3 ± 0.03^{a}	26.56 ± 0.34^{de}	8.07 ± 0.04^{g}	586.2 ± 1.85^{c}	437.8 ± 1.16^{c}	-22.82 ± 0.25^{a}
S2	8.85 ± 0.04^{b}	26.38 ± 0.25^{e}	8.14 ± 0.02^{f}	475.6 ± 1.94^{g}	405 ± 1.55^{d}	-26.38 ± 0.21^{b}
S3	8.45 ± 0.06^{c}	27.77 ± 0.22^{b}	7.68 ± 0.01^{e}	391.6 ± 2.01^{h}	280.2 ± 1.77^{g}	-34.28 ± 0.13^{e}
S4	8.23 ± 0.08^{d}	27.18 ± 0.15^{bcd}	7.86 ± 0.01^{de}	574.8 ± 2.6^{d}	439.6 ± 1.66^{c}	-34.04 ± 0.36^{de}
S5	8.18 ± 0.06^{de}	27.55 ± 0.18^{b}	7.57 ± 0.14^{cd}	608 ± 3.75^{b}	495 ± 1.82^{a}	-32.28 ± 0.26^{c}
S6	8.17 ± 0.07^{de}	28.86 ± 0.17^{a}	7.22 ± 0.02^{bc}	527.2 ± 3.22^{e}	375 ± 2.02^{e}	-37.24 ± 0.23^{f}
S7	7.89 ± 0.11^{f}	28.51 ± 0.22^{a}	7.37 ± 0.02^{ab}	570.2 ± 2.15^{d}	409 ± 1.52^{d}	-33.44 ± 0.19^{d}
S8	7.95 ± 0.1^{f}	27.28 ± 0.2^{bc}	7.81 ± 0.02^{a}	494.2 ± 1.02^{f}	357.6 ± 1.69^{f}	-34.64 ± 0.19^{e}
S9	7.97 ± 0.07^{ef}	26.81 ± 0.11^{cde}	7.99 ± 0.03^{a}	686 ± 0.95^{a}	481 ± 1.45^{b}	-33.38 ± 0.11^{d}
S10	8.27 ± 0.05^{cd}	26.59 ± 0.23^{de}	8.04 ± 0.03^{a}	357 ± 2.55^{i}	240.4 ± 1.44^{h}	-38.65 ± 0.2^{g}

Mean±SE in the same column with different letters in superscript is significantly different (P = 0.001)

Table 3. Correlation matrix between physiochemical parameters

Parameters	pH	Temperature (0C)	DO (mg/l)	EC (µS/cm)	TDS (mg/l)	ORP (mV)
pH	1					
Temperature (0C)	-0.5165	1				
DO (mg/l)	0.524321	**-0.987**	1			
EC (µS/cm)	-0.13946	0.068883	-0.10866	1		
TDS (mg/l)	0.011174	-0.03286	-0.03423	**0.935806**	1	
ORP (mV)	**0.802626**	-0.47455	0.467226	0.316448	0.475399	1

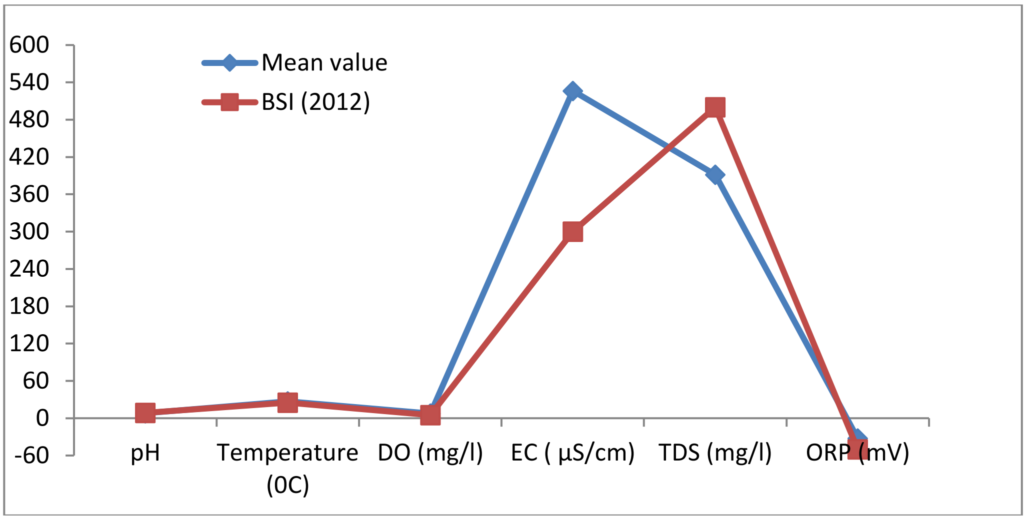

Fig. 1. Shown the comparison between mean values and BIS standard

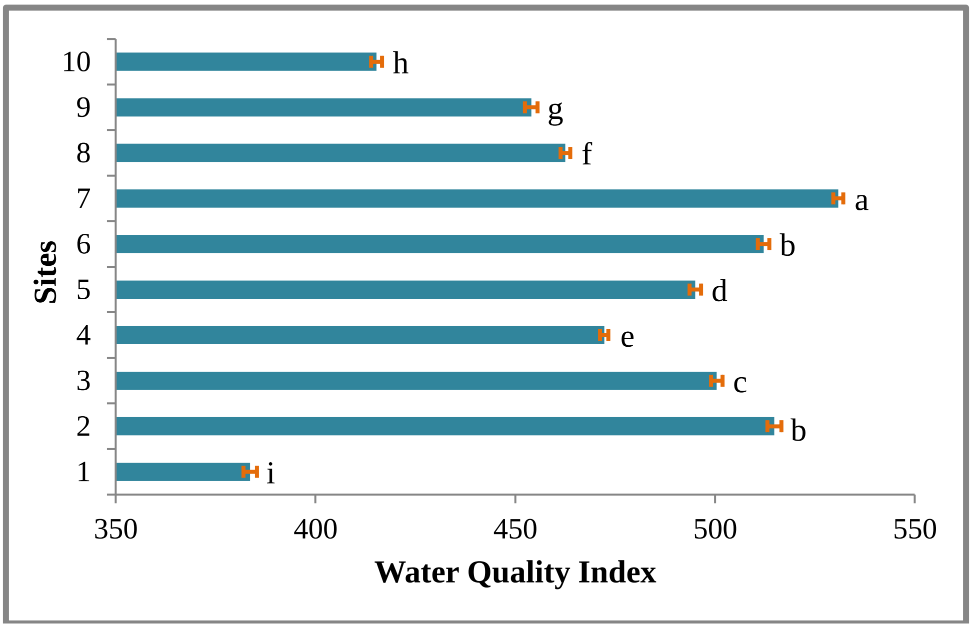

Fig. 2. WQI for different sampling sites

3.7 Water Quality Index

The water quality index of selected sites was analyzed on the basis of six types of water quality parameters, including pH, water temperature, dissolved oxygen, total dissolved solids, electrical conductivity of water, and oxygen reduction potential. A significant difference in WQI was at the (p 0.001) level of significance observed. The highest water quality index was at S7 for 530.87±1.25, followed by S2 (514.88±1.75), S6 (512.17±1.44), S3 (500.46±1.44), S5 (495.08±1.44), S4 (472.27±1.04), S8 (462.57±1.21), S9 (454.01±1.58), and S10 (415.3±1.37) (Fig. 2). While S1 showed the lowest water quality index value, about 383.67±1.69. Different researchers give different categorizations of water quality index. According to Al-Musawi et al. (2018), the WQI was divided into six categories, i.e., excellent (<50), good (50-100), poor (100-200), very poor (200-300), polluted (300-400), and very polluted (>400) [57]. This study revealed all the collected water samples fell into the polluted category and were not safe for drinking. Khudair Al-Musawi reported the WQI of the Tigris and Euphrates Rivers in Iraq was more than 300 for years from 2013 to 2014, which were not safe for drinking [58].

4. CONCLUSION

This research reveals fascinating investigations about the declining water quality in Bilaspur, (Chhattisgarh) urban areas. All the ten study sites were analyzed the physiochemical parameters of drinking water and compared with BIS (2012). However, electrical conductivity not in satisfactory level as per national standard, while the pH, TDS, DO, temperature and ORP values were within considerable limit. On the basis of selected physiochemical water quality parameters the water quality index (WQI) was fall into polluted category for all sites therefore it is unsafe for drinking.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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