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Water Quality Assessment of Jonha's Waterfall Ranchi, Jharkhand Using Multivariate Statistical Technique

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***Abstract*: The Jonha waterfall in Ranchi, Jharkhand, has become significantly contaminated due to tourism and human activity. The availability of high-quality drinking water and wastewater treatment is determined by the findings of the water quality examination. This study explores the physico-chemical and microbacteriological properties of water from Jonha's waterfall in Ranchi, Jharkhand, India. Water samples were taken from the waterfall's upstream and downstream regions for research purposes. The physico-chemical and microbacteriological parameters were investigated using Indian Standards methods (IS:3025). The results are compared to the Bureau of Indian Standards' current list of acceptable values (BIS-2012). Several statistical matrices were utilized to estimate the water quality. Numerous hydrological factors were evaluated to determine the water quality of Jonha's waterfall, with some falling below and others exceeding the permissible threshold. The obtained results help to preserve the quality of the water reservoir while also demonstrating the feasibility of managing inefficient extraction structures.**

Keywords: Waterfall, Physico-chemical constraints, Statistical tools, Water Quality.

I. INTRODUCTION

Water is necessary for life on earth and the most valuable natural resource. Water has an important role in the development of the financial systems of numerous sectors, including agriculture and other businesses. Water accessibility from both groundwater and surface water resources has recently become a major challenge. Anthropogenic activities have caused a decrease in the quality of water resources, posing a significant public health risk. Over the last decade, the increasing number of tourists visiting Jonha falls has resulted in increased anthropogenic activity as well as serious environmental contamination of the falls. Water and prawn samples observed experimentally from the Olumirin waterfall in Erin-Ijesa, Nigeria (Oyekanmi et al. 2017). They employed a conventional approach for physico-chemical examination of water samples. In addition, for prawn sample analysis, population index ratios were employed. Furthermore, they discovered that spatial and seasonal variations in water quality affect the quality and number of prawns in the cascade. The quality of water samples discussed from Gunung Belumut and Gunung Lambak waterfalls (Zakiah et al. 2022). They employed bio-monitoring technologies and the Average Score Per Taxon (ASPT) approach to assess ecosystem balance and macro invertebrate diversity in relation to water quality. It was also discovered that upstream water quality is generally superior to downstream. Water samples from three different locations (upstream, waterfall, and downstream) for the Koban Rondo waterfall in Pujon, Malang, Indonesia, and utilized a descriptive quantitative method to described the water quality status (Hussen et al. 2019). Furthermore, they employed statistical techniques to examine the water quality and discovered that the waterfall was unsuitable for tourist, fishing, and crop irrigation. The water quality of five distinct groundwater and municipal water samples from Kalar Syedan, Rawalpindi, Pakistan was assesed (Sehar et al. 2011).

However, the standard approach was utilized for physico-chemical examination of water samples, whereas the most probable number (MPN) method was used for microbiological analysis.They examined the data and discovered a discrepancy in the groundwater sample from municipal water, indicating the presence of pollution in groundwater. The hydrological parameters of water samples collected from the Rawanduz River and Gali Ali Beg waterfall in Iraq's Kurdistan region (Hanna et al. 2019). They were calculated the Canadian Council of Ministers of the Environment's Water Quality Index (CCME WQI) to assess water quality. According to the acquired data, both water samples are graded as unsatisfactory for drinkable purposes. The investigation of bacteriological characteristics of water samples from Khumbu Valley, Sagarmatha National Park, Nepal (Nicholson et al. 2016). Some of the physical parameters were determined to be within the WHO guidelines range, but the summer water sample had a greater level of E-coli and coliform bacteria than the winter sample. In addition, surface water contains more E-coli and coliform bacteria than groundwater. The physico-chemical examination of water samples from the village of Barwari Bala, Duhok, Kurdistan Region, Iraq (Ameen 2019). Water quality index (WQI) techniques based on specific parameters were utilized to analyze the individual pollutant parameters, and we discovered a large deviation in parameters from their averaging values. The overall results indicated that the physico-chemical parameter has no negative consequences, but it has negative impacts over a lengthy period. The investigation of hydrological characteristics of the spring water used for drinking in the Beni-Mellal Atlas Piedmont (Morocco) (Barakat et al. 2018). To ascertain the physicochemical and microbiological characteristics of water samples, they used the Water Quality Index (WQI) approach. According to the analytical results, a spring water sample is safe to drink and falls within the BIS legal limits; nevertheless, certain water samples that beyond the BIS permissible limits include fecal contamination. The physical and chemical properties investigated for spring and borehole water samples from Robe Town, Oromia, Ethiopia (Shigut et al. 2017). They followed American Public Health Association (APHA) standard protocols to analyze the physico-chemical properties of water samples. Borehole water samples had the greatest pH, iron, and manganese concentrations when compared to spring water. The results reveal that spring water sources were more desirable than borehole water samples. . The physical and chemical quality of water samples evaluated from Arbaminch, Ethiopia (Reda 2015). The experimental procedure was used to evaluate the physico-chemical parameters, and the results were compared to the World Health Organization (WHO), Indian Standards Institute (ISI), Standard Organisation of Nigeria (SON), and United Nations Environmental Protection Agency (USEPA) standards. Except for fluoride, which exceeded the WHO and SON maximum standard value, other parameter values were found to be within allowed limits.Spring water and waterfalls are the principal sources of water for potable, agricultural, and household use in the neighboring region of Jonha, Ranchi. Water quality is evaluated using certain physico-chemical and microbiological characteristics. The current study aims to estimate the water quality of Jonha waterfall by analyzing its physico-chemical and microbiological parameters using standard/experimental procedures. The findings of the major physico-chemical and microbiological parameters were compared to the BIS allowed limit for appropriate potable water use. Additionally, statistical matrices are employed to determine the variation of each parameter. The current study's findings are important for monitoring water resources and detecting changes in water quality metrics.

Sampling Study Area

Jonha waterfall is located between 23°20′27″ north latitudes and 85°36′29″ east longitude in Ranchi Plateau of Jharkhand. Jonha waterfall, which emerges from the Raru and Gunga rivers, hangs above the master stream. The Jonha waterfall is located in Angara, Ranchi district, and falls from a height of 141 fit. Jonha waterfalls are located on the border of the Ranchi Plateau, also known as Gautamdhara Falls. Jonha waterfalls are bordered by green scrub and various vegetation. The moderately comfortable environment persists during the hot summer months. The sample study areas are depicted in Fig. 1.

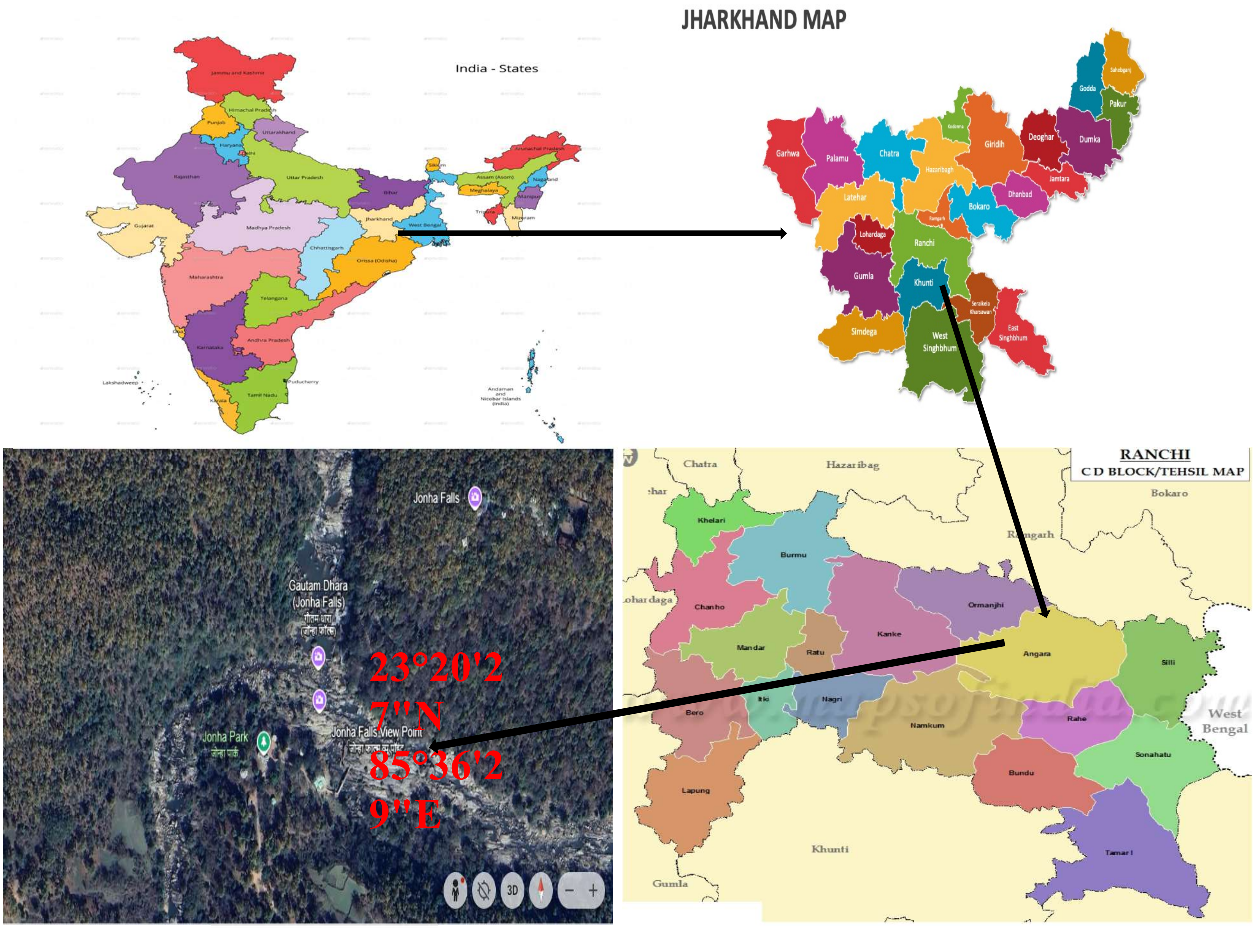
Water samples were collected from two different waterfall regions: the upper/source region and the bottom part of the waterfalls. The samples were placed in sterile plastic bottles that had been thoroughly cleaned, rinsed with deionized water, dried in a clean, controlled environment and sealed right away.Humans carry out more anthropogenic activities in the upper section of the waterfall than in the lower region. To investigate the impact of anthropogenic activities on water quality, samples were taken from two distinct parts of waterfalls, namely the upper/source region and the lower region.

To assess the impact of human activities on water quality, water samples were taken in sterilized plastic bottles from two distinct areas of the waterfall: the upper/source region and the lower region in December 2024. The top portion of the waterfall has more human activity than the lower region. Water samples were collected in sterilized plastic bottles that were completely immersed in the water sources, and the sterilized bottles sink into the water sources, opening the cap inside the water source and closing the cap again before bringing the bottle to the surface to minimize chemical and biological reactions. During the collecting process, digital equipment were used to measure the temperature, pH, electrical conductivity (EC), and total dissolved solids (TDS) of water samples. Furthermore, the remaining parameters were tested in the laboratory using established procedures.

II. Materials and Methods

The following laboratory methods were used to examine the physicochemical properties of the water samples indicated below. The temperature, hydrogen potential (pH), total dissolved solids (TDS), electrical conductivity (EC), and turbidity were all determined during sample collection. The different procedures/instruments were employed to measure the various parameters.

The temperature of the water in the field is measured with a mercury thermometer. The pH was measured using a digital pH meter (pH-009(I)A, Konvio Neer), while the TDS and EC were measured using digital TDS and EC meters (A-1 portable, Konvio Neer). Turbidity is measured with a nephelometry tube. According to IS:3025 (Part-34)-1988 RA 2003, nitrate (as NO_3^-) is assessed using a Merck Pharo 300, and fluoride (as F^-) is assessed using IS:3025 (Part-60)-2008. Chloride (as Cl^-) is measured according to IS:3025 (Part-32)-1988 RA 2003. Total hardness and alkalinity are tested using IS:3025 (Part-23)-1986 and IS:3025 (Part-40)-1991, respectively. Residual ammonia and chlorine are measured using the IS:3025 (Part-26)-1986 and IS:3025 (Part-34)-1988 methods. Table 1 shows the distinct physical parameter values for the upper/source and lower regions of waterfalls.



Jonha Waterfall

Fig.1: Sampling Study Area

TABLE 1
Physical parameters analysis of upper region and lower region of Jonha waterfalls

Test Parameter ⬇ / Sampling Location ➡	Upper region of waterfall	Lower region of waterfall	Standards permissible limit as per BIS (2012)
Temperature (^{0}C)	22.7	19.0	-
pH	8.3	8.8	6.5 -8.5
Electrical Conductivity (µs/cm)	192	191	300
Total dissolved solid(mg/l)	98.88	94.89	500
Turbidity(NTU)	5	5	1

Temperature - One significant factor influencing the effects of chemical and biological properties' solubility at water sources is temperature. The water samples from the upper and lower regions of the Jonha waterfall had recorded temperatures of 22.7°C and 19.0°C, respectively, throughout the investigation. The found temperature values for both upper and lower region of waterfall attain the temperature values beyond the room temperature.

p^{H} - The potential of hydrogen ions in a water sample is measured by the pH value. The concentration of water's acidic and alkaline characteristics is typically expressed using the term pH. The pH values of the water samples taken throughout the experiment were 8.3 for the upstream waterfall and 8.8 for the downstream waterfall. The acceptable pH range, according to the BIS allowed limit, is 6.5 to 8.5. The pH value downstream exceeds the BIS allowable limit based on the observed value.

Electrical Conductivity (EC) - The ability of water to transmit an electric current is determined by its electrical conductivity, which is a measurement that is dependent on the ion concentration and valencies. Another crucial technique for determining how many metal ions are dissolved in water is electrical conductivity. The EC values for the top and lower regions of the waterfalls in this investigation were 192 µs/cm and 191 µs/cm, respectively. Both the top and lower areas' obtained values fall inside the BIS allowable limit.

Total dissolved solids (TDS) - Total dissolved solids show how the water behaves in terms of salinity, which reveals the water's general quality. The TDS levels for the waterfalls' top and lower regions were found to be 98.88 mg/l and 94.89 mg/l, respectively. The measured TDS levels for both water samples fell under the BIS-recommended threshold for drinkable water.

Turbidity- One of the most important physical characteristics of water quality, or water clarity, is turbidity. The dispersion of solute particles and suspended solid particles in water bodies were both markedly impacted by turbidity. For both sampling points (upper and lower areas) of Jonha waterfall, turbidity was measured at 5 NTU and was determined to be within the acceptable range of the BIS standards limit.

The physical properties of the water samples from the Jonha waterfall are represented graphically to highlight how each parameter varies for the two water samples. Fig. 2 shows a comparison of the physico-chemical properties for the waterfall's top and lower areas. Each of the physico-chemical parameters for the various regions displays roughly the same value.

The many chemical components that are present in water are measured by the chemical criteria of water quality. These reveal the water's chemical makeup, including the presence of man-made and natural pollutants. Monitoring and evaluating these factors aids in determining if water is suitable for various uses and in spotting possible hazards to the environment and public health. Among the most significant chemical indicators of water qualities for upper and lower regions of waterfalls are tabulated in Table 2.

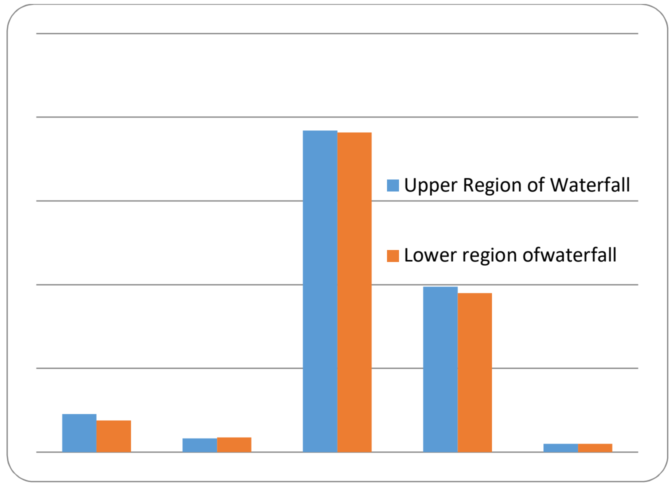


Fig. 2: The Comparison of distinct physico-chemical parameters for upper and lower region of Jonha waterfall

TABLE 2
Chemical parameters analysis of upper and lower regions of Jonha waterfalls in respect of standard BIS-2012 permissible limit

Test Parameter ⬇ / Sampling Location ➡	Upper region of waterfall	Lower region of waterfall	Standards Permissible limit as per BIS (2012)
Total Hardness (mg/l)	25	25	200
Chloride (mg/l)	150	200	250
Alkalinity (mg/l)	300	250	200
Residual chlorine (mg/l)	0.0	0.0	1
Iron (mg/l)	0.0	0.0	1
Nitrate (mg/l)	0.0	0.0	45
Fluoride (mg/l)	0.5	0.5	1
Phosphate ((mg/l)	0.1	0.5	5
Ammonia (mg/l)	0.0	0.0	0.5

Total Hardness - A crucial metric for assessing the quality of water is total hardness, which is often influenced by the concentration of calcium and magnesium salts in the water. Total hardness is the property of a water sample that raises the water's boiling point and inhibits soap lathering. The top and lower regions of the Jonha waterfall had a total hardness of 25 mg/l. The total hardness readings were within the normal BIS permitted limit when compared to the BIS allowable limit.

Chloride (Cl^-) - In water bodies, chloride is typically the most prevalent ion, giving the water a salty flavor. Chloride concentration in water serves as a marker of sewage treatment-induced contamination. For the top water sample of the waterfalls, the chloride content value was 150 mg/l, whereas for the lower water sample, it was 200 mg/l. The chloride readings that were measured were found to be within the BIS standard limit.

Alkalinity - The presence of carbonate, bicarbonate, and sodium, calcium, and potassium hydroxide compounds causes water to be alkaline. Another definition of it is the concentration of water ions that neutralize hydrogen ions. Both the upper and lower Jonha waterfalls had alkalinity levels of 300 and 250 mg/l, respectively. The alkalinity values that were measured for both locations of the Jonha waterfall were found to be higher than the BIS's allowable limit.

Residual chlorine - The quantity of chlorine that is still present in the water after a predetermined amount of time or contact time is known as residual chlorine. The experiment revealed that there was no remaining chlorine in the upper or lower parts of the Jonha waterfalls.

Iron - The impact on water quality of iron-containing water with ferrous or bivalent (Fe^{++}) ions is dependent on the geological regions and other chemical components present in the water system. The experiment shows that there is no iron in the top or lower parts of the Jonha waterfalls.

Nitrate (NO_3^-) - Anthropogenic activities such as human and animal waste, sewage systems, open septic systems, and the extensive use of fertilizers by farmers in agricultural fields are the main causes of nitrates in water. The testing revealed that there was no nitrate in the top or lower portions of the waterfalls.

Fluoride (F^-) - High quantities of fluoride in water samples causes fluorosis and other skeletal (tooth and bone) disorders in humans being. Fluoride levels in the top and lower regions of the water fall were found to be 0.5 mg/l in the current investigation. Both regions' obtained values were judged to be within the BIS acceptable limit.

Phosphate (PO_4^-) – Water bodies may include phosphates as a result of fertilizers, industrial wastewater, household sewage, and agricultural activities. The phosphate content levels for the current water samples were determined to be 0.1 mg/l for the upper region and 0.5 mg/l for the lower region. The phosphate values that were obtained fell within the BIS standard allowed limit.

Ammonia - The aquatic ecosystem is impacted by the excess ammonia in the water bodies, which also raises the biochemical oxygen demand levels. The main sources of ammonia are animal waste emissions and overuse of fertilizer in agricultural fields. According to the experiment, there is no ammonia in either of the water resources.

For the upper and lower waterfall zones, Fig. 3 shows the graphical depiction of the comparative examination of the chemical parameters. Chloride and alkalinity readings for the lower portion of the Jonha waterfall are marginally lower than those for the upper portion, according to the variation of chemical parameters for the various areas of the waterfall's flow. But for the other parameters, the Jonha waterfall's upper and lower regions achieve roughly the same results.

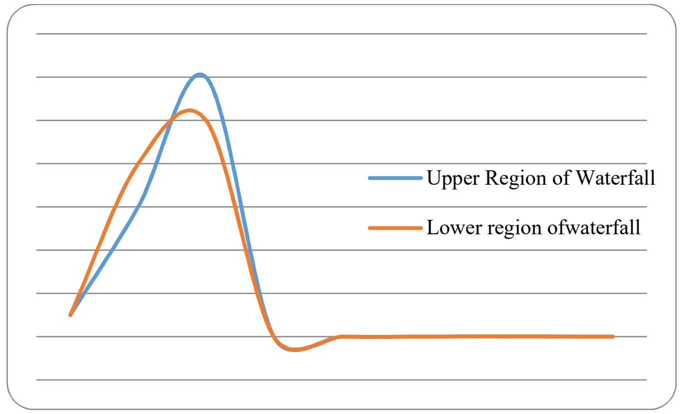


Fig. 3: The comparison of Jonha waterfalls' upper and lower regions' chemical parameters

Water quality is greatly influenced by microbiological factors, mainly because of their clear connection to environmental safety and human health. Water is contaminated, frequently from feces, when it contains dangerous microorganisms such bacteria (E. coli, Salmonella), viruses (hepatitis A), and protozoa (Giardia, Cryptosporidium). Vulnerable populations are especially at risk from this contamination since it can transmit dangerous waterborne illnesses like cholera, typhoid, dysentery, and diarrhea. E. coli and total coliforms are two examples of fecal indicator bacteria that are frequently used to evaluate the microbiological safety of water. Without adequate treatment, high concentrations of these microbes make water unfit for drinking and recreational use.

The water samples from the upper and lower areas of the Jonha waterfall are examined for micro bacteriological characteristics. The water system's contamination level is rising as a result of the unique microbiological parameters found in the bodies of water that have absorbed and adsorbed the unique passionate parameters. Table 3 contains the tabulated results of the micro bacteriological analysis for the upper and lower Jonha waterfall locations. The primary source of viral infections is fecal pollution, which therefore has important implications for the possibility of preserving water quality. Table 3 shows that Escherichia coli and total coliform were found in both the upper and lower regions of the water samples.

TABLE 3
Micro bacteriological analysis for upper and lower regions of Jonha waterfalls

Test Parameter ↓ / Sampling Location →	Upper region waterfall	Lower region waterfall
Escherichia Coli	Detected	Detected
Coliforms	Detected	Detected

Statistical Metrics

Standard Deviation and Standard Error Analysis

When evaluating the quality of water, standard deviation and standard error analysis are essential because they shed light on the dependability and variability of the data that is gathered. By measuring how water quality parameters (such pH, turbidity, or pollutant levels) spread or disperse around the mean, the standard deviation can be used to spot variations or irregularities in sample findings. The accuracy of the sample mean as a reflection of the actual population mean, however, is estimated by standard error. When used in combination, these statistical tools ensure data accuracy and facilitate well-informed decision-making, which raises the importance of water quality monitoring programs.

The following formula has been used to determine the standard deviation and standard error of the different parameters for the water sample of the upper and lower parts of Jonha waterfall Ranchi.

Standard Deviation $\sigma = \sqrt{\frac{\sum(x_i - m)^2}{n-1}}$ (i)

Where, x_i is represent the individual measurements, m is the mean value of the measurements and n is the number of measurements.

Standard Error $\sigma_x = \sqrt{\frac{\sigma}{n}}$ (ii)

TABLE 4
Standard deviation and standard error for the water samples of Jonha's waterfall Ranchi, Jharkhand

Parameters	Variance	Standard Deviation	Average ± Standard Error
Temperature (°C)	6.845	2.616	20.85±1.1437
pH	0.125	0.353	8.55±0.420
TDS(ppm)	7.98	2.824	96.885±1.884
EC (µs/cm)	1	1	191.5±0.77
Turbidity(NTU)	0	0	0
Total Hardness(mg/l)	0	0	0
Chloride(mg/l)	1250	35.355	175±4.204
Alkalinity(mg/l)	1250	35.355	275±4.204
Residual Chloride(mg/l)	0	0	0
Iron(Fe^-) (mg/l)	0	0	0
Nitrate(NO_3^-) (mg/l)	0	0	0
Fluoride(F^-) (mg/l)	0	0	0
Phosphate(PO_4) (mg/l)	0.05	0.223	0.075±0.334
Ammonia(NH_3^-) (mg/l)	0	0	0

The interpretation and dependability of the findings for the water quality evaluations of the water samples from Jonha's waterfall that are shown in Table 4. For both water samples, the statistical metrics have been computed with regard to each of the different parameters. The large range of water quality indicators can be found with help of these tabular values.

The standard deviation illustrates how different parameters vary with regard to their average value. In comparison to the other metrics, the alkalinity and chloride deviations are significantly observed. Each parameter's error from its average value is determined by evaluating the standard error. The pH value has the least amount of inaccuracy, but the chloride and alkalinity values have the largest error variance when compared to the other parameters. According to the results, many measures achieve noticeably lower error rates, preserving the water quality at Jonha waterfall. An insignificant standard error strengthens confidence in the data's representativeness, enabling accurate inferences and judgments.

Water Quality Index (WQI)

A key factor in consolidating extensive water quality data into a single, easily comprehensible numerical value that represents the general health and usability of a body of water is the Water Quality Index (WQI) calculation. Using this rating, water can be categorized as excellent, good, bad, or unfit for drinking or other uses.

The weighted arithmetic index methodologies are used to estimate the Water Quality Index (WQI) (Ramakrishnaiah et al. 2009). There are several water quality parameters that are closely monitored in order to evaluate the drinking water's quality and are given a weight. Each of the factors is given a different weight based on how differently it affects human health.

The W_i (relative weight) is computed by using the formula

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad \text{(iii)}$$

where

W_i is the relative weight.

w_i is the weight of the each selected water parameter

n is the number of parameter.

The quality rating scale q_i for each parameter is assigned by dividing its segmentation values in the respective water sample by its individual standard as per the drinking water guidelines prescribed by the BIS (2012) and outcomes multiplied by 100.

$$q_i = \frac{C_i}{S_i} \times 100 \quad \text{(iv)}$$

where

q_i is the quality rating.

C_i is the concentration of individual parameter.

S_i is the Indian standard drinking water for every parameter as per BIS limit.

Now we introduce $SI = w_i \times q_i$ (v)

Then Water Quality Index (WQI) determine as per the equation

$$WQI = \sum SI_i \quad \text{(vi)}$$

Where

SI_i is the subindex of i[th] water parameter, q_i is the quality rating of i[th] water parameter and n is the number of parameters.

The WQI parameters are categories into different categories whose ranges are as excellent water (WQI<50), good water (50 < WQI < 100), poor water (100 < WQI < 200), very poor water (200 < WQI < 300) and not suitable for drinking purpose (WQI > 300). The WQI are tabulated for upper and lower region of Jonha waterfall in Table 5.

TABLE 5
The WQI values for the upper and lower region of the Jonha Waterfall

Water Sample Region	WQI Value
Upper Region of Waterfall	92.17
Lower Region of Waterfall	83.70

As per the Table 5 the WQI values suggested that the both the upper and lower regions water samples were exist under the range of good water quality (50 < WQI < 100). On the other hand, the upper area water sample's WQI shows extremely high water quality. Fig. 4 shows a graphical representation of the WQI value for the upper and lower Jonha waterfall regions.

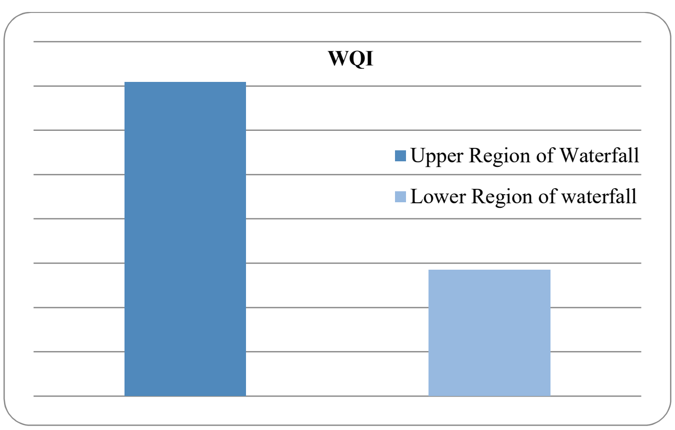


Fig. 4: The comparison of WQI between upper and lower region of Jonha waterfalls

Fig. 4 shows that, in contrast to the bottom portion of the waterfall, the WQI value for the upper portion of the waterfall reaches its highest value. However, both water samples are found to have good water quality.

III. Conclusion

The water quality at the Jonha waterfall's upper and lower locations is examined in this present paper. Tools and laboratory tests are used to study the various physical and chemical qualities. When compared to the bottom part of the waterfall's flow, the water quality in the upper section of the waterfall is slightly deteriorated due to the numerous human-caused activities that occur there. Physical characteristics of the water samples show essentially the same values in both the upper and lower regions of the waterfall, however chemical metrics such as chloride and alkalinity suggest slight changes between the two sections of the Jonha Waterfall. Every parameter showed minor fluctuations in standard error, with the exception of chloride and alkalinity, which showed more noticeable variations. In order to understand variability and data reliability, standard deviation and standard error were evaluated for their critical significance in water quality evaluation. The water quality index calculated for both regions indicated that the samples had good overall water quality. The results can support effective water resource planning and the maintenance of drinking water standards.

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