*Indian J. Applied & Pure Bio.* Vol. 40(2), 1242-1252 (2025).

**ISSN: 0970-2091**
**A Web of Science Journal**

# Evaluation of water quality index (WQI) of drinking water sources in streams of Sukhia Pokhari, Darjeeling, West Bengal

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## Abstract

Water, like air, is an indispensable and precious natural resource on this planet. Water greatly impacts human livelihoods, including health, economy, food, energy, environment and social impacts. Sukhia Pokhari, a small town in the Darjeeling district of West Bengal, is bestowed with an intricate network of freshwater perennial torrential streams, which constitute an important source of drinking water. The present study aims to determine the acceptability of drinking water sources from Sukhia Pokhari. A water quality index (WQI) gives a single value based on several parameters expressing the overall water quality at a specific location and time. The WHO (World Health Organisation) and BIS (Bureau of Indian Standards) ratings were used to evaluate the WQI and the water quality for the water sources. Based on weighted arithmetic WQI values, surface water falls under the projected area of Sukhia Pokhari into the category of excellent water (ranging from 0-25). However, water abuse remains a major challenge, therefore, improvement in local government and public participation in maintaining drinking water quality through intensive and inclusive awareness programs is needed.

**Key words:** Drinking water quality, WQI, WHO, BIS, Physico-chemical analysis.

Water, food and fresh air are the necessities for the survival of all living beings, and no life can exist without water[26]. It is one of the most essential substances available on earth and is an elixir of life[7]. As life originates from water, it is called the "mother of all living world"[13]. It is used not only for drinking but also is fundamental for the sustenance of environmentally dependent livelihoods such as agriculture, industrial activities, transportation, energy production, waste disposal, and food extraction[29]. Therefore, sustainable development will not be possible without adequate quantity and quality of freshwater[16].

Many water sources have been subjected to water deterioration associated with human activities, including urbanisation, cleaning, washing, bathing, agricultural waste runoff, religious and cultural activities, etc. Lakes in the Himalayan region are known for their picturesque beauty and are one of the most important water sources, along with springs. However, potable water availability has always been a major problem in many areas of the Himalayan region, including Darjeeling Hills.

The water quality is characterised by its physical (colour, odour, taste), chemical (pH, turbidity, total solids, hardness, alkalinity, presence of metallic or non-metallic salts), and biological properties of water. The water quality characteristics in complicated data sets are difficult to understand[1,2]. The water quality index (WQI) is essential to summarise complex water quality parameters and simplify communication for all concerned bodies for immediate remedial action [23,25]. However, selecting parameters is critical and needs care, particularly conside ring sources and time. Accordingly, the present study attempted to develop a drinking water quality index for the study areas for the first time.

The concept of WQI to represent gradation in water quality was first proposed by Horton[12] in the United States. WQI is commonly used across continents such as Europe, Africa, and Asia[33]. This study employs the established definition of WQI in the Indian context from the Bureau of Indian Standards views[4], so the predicted WQI values are easily compared to other Indian cities and towns[6].

In the present study, various parameters of the drinking water samples from five different sites at Sukhia Pokhari were analysed bi-weekly for six months, following the standard methods. They were compared with standard values to determine the drinking water quality. The study aimed to analyse various physicochemical parameters and determine the water's suitability for drinking purposes using the Weighted Arithmetic Water Quality Index (WA WQI). The study also compared the results from the monsoon and post-monsoon.

*Study area :*

The study was carried out in Jorepokhrari Lake and four major perennial streams of Sukhia Pokhari of Darjeeling district (Figure 1), which lies in latitude: 26° 59' 54.222" and longitude: 88° 10' 1.0128" in the high mountain ranges of Eastern Himalayas and composed of plateaus, valleys, ridges and hills. This region has various climatic conditions, and the average annual precipitation is recorded at 257.6 cm. Three seasons are observed: summer (between April and June), rainy season (between July and September), and winter season (the longest, spanning the months of October to March). Annual mean maximum temperature is 14.9 °C, and annual mean minimum temperature is 8.9 °C.

*Selecting and testing water samples :*

Simana Road Water Source, Jorepokhari Lake, Debrepani Water Source, Parment

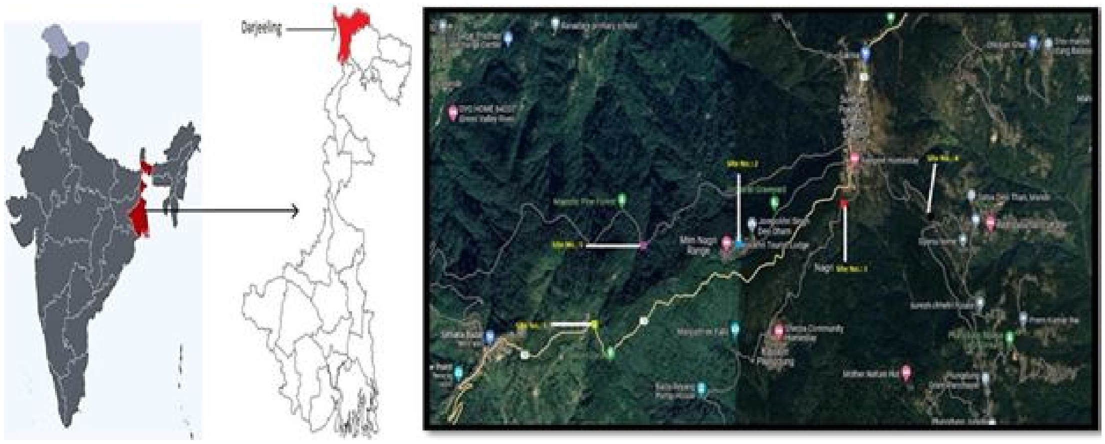


**Figure 1.** Map of study area showing respective sites of study. * Site 1: Simana Road Water Source; Site 2: Jorepokhari Lake; Site 3: Debrepani Water Source; Site 4: Parment Water Source; Site 5: Maneybhanjang Road Water Source.

Water Source and Maneybhanjang Road Water Source are the primary water supply sources for Sukhia Pokhari. A brief description of sampling sites for quantitative estimation of water quality parameters is presented in Table 1. The water samples were collected randomly from diverse areas to determine the WA WQI values. Figure 2 depicts the work technique in detail. The water sources for testing were chosen based on two criteria: 1) water used for drinking purposes and 2) water sources that are functional and operational throughout the year. The present study was conducted for 6 months (from June 2023- November 2023). Water sampling was carried out weekly throughout the study period. The water samples for physico-chemical analysis were collected in 2-liter polyethylene cans that were sterilised and pre-rinsed with distilled water. After sampling, the bottles were sealed, labelled, and immediately transferred to the laboratory for analysis.

Various physico-chemical parameters (total alkalinity, acidity, salinity, total hardness, DO, Free $CO_2$, calcium, magnesium, and chloride) of the water samples were analysed following the standard methods of Gupta[10]. The temperature, EC, TDS, and pH values were measured using a portable field thermometer, TDS meter, EC meter and pH meter. Finally, the WA WQI values were determined using the water quality parameters.

*Calculation of Unit Weight (Wi) :*

The unit weight (Wi) of each water quality parameter was calculated using the following formula: $\mathbf{Wi = k / Si}$

Where, K = Proportionality constant $= 1/\Sigma 1/Si$
Si = Standard desirable value of the $i^{th}$ parameter.

*Calculation of Sub Index (Qi) :*

The sub index Qi (water quality rating) was calculated using the formula:

**$Q_i = 100 [ (V_i–V_o / S_i–V_o)]$**

Where, $V_i$ = Concentration of $i^{th}$ parameters in the analysed water

$S_i$ = Standard desirable value of the $i^{th}$ parameter

$V_o$ = Actual value of this parameter in pure water

**Calculation of WA WQI :**

WQI was calculated using the following formula: **$WQI = \Sigma W_iQ_i / \Sigma W_i$**


Fig. 2. Protocol followed for determination of the water quality index.

Table-1. Description of the sites under study

| Site no. | Site name | Coordinate | Altitude (ft) | Use USE | Catchment area |
|---|---|---|---|---|---|
| 1. | Simana Road Water Source | 26°59`07.45``N 88°08`06.99`` E | 7500 | Drinking purpose. | Moderately dense vegetation and with no habitation around the stream. |
| 2. | Jorepokhari Lake | 26°59`27.41``N 88°09`23.96`` E | 7200 | Recreation, Drinking and Religious purpose. | Situated on the hilltop with tourist lodges, religious places and scarce habitation around the lake. |
| 3. | Debrepani Water Source | 26°59`32.83``N 88°09`57.07`` E | 6987 | Drinking purpose. | Moist vegetation with no habitation around the stream. |
| 4. | Parment Water Source | 26°59`44.84``N 88°10`01.95`` E | 7408 | Drinking and Washing purpose. | Very scanty vegetation with scarce habitation around the stream. |
| 5. | Maneybhanjang Road Water Source | 26°59`25.58``N 88°08`38.22`` E | 6325 | Drinking andReligious purpose. | The stream is surrounded by dense vegetation on the three sides; one side is exposed to the main road. |

Table-2 shows the average values of each metric and the Standard values[4,34].

***Temperature :*** The water temperature recorded during the present investigation varied in different months, ranging from 7.4°C to 24.4°C. In other words, temperature was based on seasons and showed monthly variations. Water temperature is of enormous significance as it regulates various abiotic and biotic activities of an aquatic ecosystem. Fluctuations in air and water temperature may be due to the influence of season, location, and difference in the time of collection[21]. High temperatures are known to alter the concentration of dissolved oxygen and other gases and may also change microbial colonies' activities[14].

***Electrical Conductivity (EC) :*** The electrical conductivity of water samples collected from the five sites had EC values ranging from 48 to 182 µS $cm^{-1}$ (Table-2). The conductivity of the samples, on average, showed values in the ranges of 50-80 µS during June - October 2023 and 80-102 µS $cm^{-1}$ in November 2023. Electrical conductivity measures the water's capability to transmit electric current and assesses water's purity[18]. As most of the salts in the water are in the ionic form, they can conduct current and are a very good measure of the total dissolved solids[32].

***Total Dissolved Solids (TDS) :*** TDS values ranged from 24 ppm to 92 ppm (Table 2). Site 3 had the highest TDS value. TDS recorded was low (24 ppm, site 2) in June-September and high (92 ppm, site 3) in October-November. Robinove *et al.*,[24] salinity classification shows that all water samples are non-saline. TDS comprises mostly inorganic salts and a small amount of organic matter[21]. It is an indicator of the overall water quality and is used to compare water quality over time. If TDS is higher, water cannot be used for drinking or construction as it affects palatability and strength and is also known to cause gastrointestinal irritation[19].

**pH *(Hydrogen ion concentration) :*** The pH of the water samples tested ranged from 6 to 8 (Table-2). The findings show that all of the water samples were within acceptable limits. The average pH values recorded in all the sites were mostly neutral. Water pH directly shows its acidic-basic nature and is considered a significant index in water quality assessment[11]. Though it does not directly affect health, all biochemical reactions are sensitive to pH variation[27].

***Total Alkalinity (TA) :*** The permitted limit for alkalinity is 200 mg/L, and in the absence of another water source, alkalinity up to 600 mg/L is suitable for drinking. Although most of the water samples' phenolphthalein alkalinity was zero, the examined water samples' total alkalinity ranged from 1.72 to 5.83 mg/L (Table-2). The total alkalinity of all samples was less than the allowable limit. The alkalinity of water is the measure of its capacity to neutralise acid and is characterised by the presence of hydroxyl ions capable of combining with hydrogen ions in solution. Therefore, it represents the major buffering capacity of water due to the presence of carbonate and bicarbonates[31].

***Acidity :*** The acidity of water samples ranged from 0.10 mg/L to 0.37 mg/L in all the sites throughout the study period (Table-2). Acidity values throughout the study period were low, and no significant variations were observed. The acidity of water is its quantitative capacity to neutralise a strong base to a designated pH. The acidity of water is significant because acids contribute to corrosiveness and influence certain chemical and biological processes. The measurement also reflects changes in the quality of the source water.

***Salinity :*** The Salinity of water samples collected from 5 different sites fluctuated between 0.031‰ to 0.098‰ in all the sites throughout the study period (Table-2). Salinity is an important and unitless quantity that measures the mass of dissolved salt in a particular solution. The suggested approach for determining salinity is to use indirect methods that involve measurements of other physical parameters such as conductivity, density, sound speed, or reflective index. In the current study, the argentometric method was employed to determine salinity. Salinity has no health-based value or recommendation.

***Total Hardness (TH) :*** Calcium and magnesium are the primary ions that cause hardness. The allowable overall hardness limit is 200 mg/L. The hardness of the water samples tested ranged from 11.6 to 27.4 mg/L. The maximum total hardness value was found at site 2 (Table-2). Without an alternate water source, $Ca^{2+}$ and $Mg^{2+}$ concentrations of up to 200 mg/L and 400 mg/L can be absorbed in groundwater. If these components are present in significant concentrations, they cause encrustation in the water supply structure and harm water utilisation. The results reveal that the TH is within the prescribed limits for drinking water standards[34]. Water is classified as soft, moderate, hard, or very hard by Durfor and Becker[9]. According to this classification, most samples fall into the soft category. Based on this classification, no water samples were either moderately hard or hard.

***Dissolved Oxygen (DO) :*** DO recorded during the study period showed a minimum value of 4.94 mg/L at site 2 in November and a maximum value of 9.79 mg/L at site 3 in August (Table-2). The permissible limit for dissolved oxygen is >6 mg/L [34]. DO is an important parameter in water quality assessment and reflects the physical and biological processes prevailing in the water. DO is required to convert one form to another by living organisms to maintain the metabolic processes and produce energy for growth and reproduction[15].

***Free Carbon dioxide ($CO_2$) :*** Free $CO_2$ during the study period ranged from 6.04 mg/L to 20.24 mg/L during October-November. Most months showed no free $CO_2$ except in October-November, which recorded $CO_2$ in all sites. Carbon dioxide ($CO_2$) is the natural component of all-natural waters[22]. In water, $CO_2$ originates from aquatic biota respiration, organic matter decomposition, and infiltration through the soil[28]. It contributes to the fitness of natural water as it buffers the environment against rapid shifts in acidity or alkalinity and regulates biological processes in aquatic communities[20].

***Calcium (Ca) :*** The calcium content detected in all the samples was found to vary from 4.01 mg/L (site 4) to 10.35 mg/L (site 2) during the study period. According to WHO[34],

Table-2. Average monsoon and post-monsoon values of the parameters at the study sites and comparison of the water quality parameters of different water sources of Sukhia Pokhari with drinking water quality standards[4,34]
*All parameters not assigned with values are in mg/L except pH.

| PARAMETERS | SITE 1 | | SITE 2 | | SITE 3 | | SITE 4 | | SITE 5 | | STANDARD Limit | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mon-soon | Post-mon-soon | Mon-soon | Post-mon-soon | Mon-soon | Post-mon-soon | Mon soon | Post-mon-soon | Mon-soon | Post-mon-soon | Highest Desi-rable | Maximum Permi-ssible |
| Temp. ($^oC$) | 13.80 | 12.40 | 17.14 | 14.47 | 16.02 | 13.72 | 15.43 | 13.77 | 14.50 | 12.70 | $6^oC$-$20^oC$ | $30^oC$ |
| E.C. ($\mu S\ cm^{-1}$) | 93.8 | 63.8 | 81.1 | 58.09 | 109.2 | 74.6 | 97.1 | 72.5 | 102.2 | 59.2 | 300 | - |
| T.D.S. | 53.7 | 32.1 | 41.8 | 28.3 | 71.9 | 36.6 | 50 | 37.2 | 55.9 | 34.5 | 50-150 | 500 |
| pH | 6.8 | 7.28 | 7.37 | 7.37 | 7.2 | 7.20 | 6.84 | 7.41 | 7.3 | 7.08 | 7.0-8.5 | 6.5-9.2 |
| Total Alkalinity | 4.04 | 2.75 | 4.95 | 3.37 | 3.44 | 2.64 | 3.87 | 2.84 | 3.78 | 2.67 | 200 | 600 |
| Acidity | 0.283 | 0.22 | 0.20 | 0.16 | 0.28 | 0.22 | 0.31 | 0.24 | 0.31 | 0.20 | - | - |
| Salinity | 0.049 | 0.068 | 0.044 | 0.063 | 0.054 | 0.08 | 0.052 | 0.067 | 0.055 | 0.065 | - | - |
| Total Hardness | 17.65 | 16.02 | 21.96 | 17.32 | 17.44 | 15.41 | 18.56 | 16.76 | 18.72 | 16.23 | 100 | 500 |
| D.O. | 7.68 | 6.12 | 7.76 | 6.05 | 8.29 | 6.85 | 7.79 | 6.01 | 7.66 | 6.59 | 6.5-8 | 3 |
| Free $CO_2$ | 10.47 | 8.61 | 15.06 | 10.62 | 10.48 | 8.01 | 10.69 | 9.19 | 11.38 | 8.92 | - | - |
| Calcium | 8.13 | 6.61 | 10.35 | 7.51 | 8.81 | 6.66 | 8.52 | 6.24 | 8.01 | 6.12 | 75 | 200 |
| Magnesium | 4.91 | 3.77 | 4.96 | 4.48 | 5.33 | 4.25 | 4.13 | 2.99 | 5.37 | 4.50 | 30 | 150 |
| Chloride | 16.67 | 9.71 | 20.53 | 13.64 | 18.48 | 12.15 | 16.52 | 12.50 | 16.98 | 10.40 | 200 | 600 |

Site 1: Simana Road Water Source; Site 2: Jorepokhari Lake; Site 3: Debrepani Water Source; Site 4: Parment Water Source; Site 5: Maneybhanjang Road Water Source.

the acceptable limit for calcium in drinking water is 200 mg/L, indicating that all sites had values within the tolerance limit. Ca is one of the major ions of fresh water[13]. It is an important element influencing the ecosystem's flora, which plays an important role in metabolism and growth[17]. It occurs in all kinds of natural waters and is non-toxic[3].

***Magnesium (Mg):*** $Mg^{2+}$ permissible limit is 30 mg/L. $Mg^{2+}$ concentrations ranged from 2.33 (site 4) to 6.36 mg/L (site 2). Based on the standard values of WHO[34], which is 150 mg/L, all sites were found to be suitable for consumption. The most abundant elements in water are calcium and magnesium. Calcium can be easily dissolved from carbonate rocks and limestones, or it can be leached from soils. However, the concentration of dissolved $Mg^{2+}$ in water is smaller than that of $Ca^{2+}$. Other sources largely include industrial and municipal wastes. $Mg^{2+}$ is a component of bones and is required for appropriate $Ca^{2+}$ metabolism. Its deficit can result in protein and energy malnutrition.

***Chloride ($Cl^-$) :*** The chloride concentration in the water samples analysed ranged from 7.83 to 23.80 mg/L. The permissible limit for chloride is 250 mg/L [34], indicating that the chloride content of the water sample was within the permissible limit. The highest $Cl^-$ concentration was found at site 2 and the lowest at site 5 (Table-2). Chlorides impart a salty taste to the water, indicating a significant source of pollution, especially of animal origin[13]. Chloride can be found naturally in stream water and comes from various sources such as weathering, leaching of sedimentary rocks, and seawater infiltration. The maximum chloride concentration in potable water is 250 mg/l. It tastes salty from 250 mg/l to 500 mg/l [32].

*Water Quality Index (WQI) :*

While numerous indices assess a region's drinking water security, the WQI is the simplest to compute[8]. This study calculates the WA WQI using critical water quality metrics. When choosing the criteria for water quality study, we prioritised those that were particularly troublesome for drinking water and were straightforward to quantify using minimum prerequisite. The WA WQI was calculated using the WHO[34] and BIS's[4] drinking water standard values.

Table-3. Classification of WQI[5]

| Water quality index | Water quality status |
|---|---|
| 0-25 | Excellent |
| 26-50 | Good |
| 51-75 | Poor |
| 76-100 | Very Poor |
| > 100 | Unfit for Consumption |

The minimum and maximum WQI for the water samples collected from 5 different sites are represented in Figure 3. In the overall study period, the lowest average value from the various sites was recorded in site no. 1 (12.75), designating it as "Excellent" quality (Range: 0-25), which indicated the site was far less contaminated when compared with the other sites[5] (Table-3). At the same time, the highest average value was recorded in site no. 2 (20.50), which was also designated as

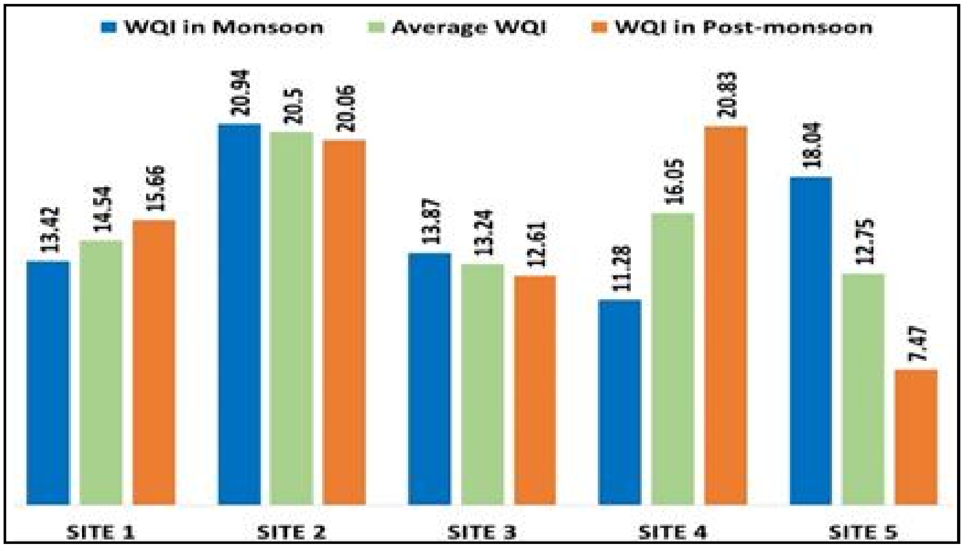


**Fig. 3.** Comparison of monsoon and post-monsoon water quality ratings of study sites using the weighted arithmetic WQI method. Site 1: Simana Road Water Source; Site 2: Jorepokhari Lake; Site 3: Debrepani Water Source; Site 4: Parment Water Source; Site 5: Maneybhanjang Road Water Source.

"Excellent" quality. WQI values were higher during the monsoon, with an average WQI of 15.51 compared to 15.33 after the monsoon. All sites under study showed "Excellent" water quality (Range: 0-25) throughout the study period.

Most natural water bodies that serve as a resource for drinking water supply contain sufficient nutrients that support the growth of various organisms[30]. In the present work concerning the physico-chemical analysis, some of the parameters, such as EC, TDS and Calcium showed lower values when compared with the highest desirable values, despite most of them being within the permissible limits prescribed by WHO[34] and BIS[4]. Many of the parameters were found to be present in the highest concentration in the monsoon than in post-monsoon seasons, indicating the sites were polluted during these months, which could be due to the influence of rains and the influx of waste materials, sewage or runoff from nearby areas coupled with other anthropogenic pressures.

The present study mainly evaluated overall drinking water quality, starting from the source. The results of the physico-chemical characterisation of all drinking water samples from 5 different sites revealed that the levels of all of the parameters analysed were within the safe limits prescribed by WHO[34] and BIS[4]. Variations observed in most parameters, especially dissolved oxygen, could be due to seasonal changes, including temperature fluctuations, rainfall, humidity, time of collection, and various other abiotic factors. Since water quality is critical in disease prevalence, the water sources should be protected and regularly monitored to formulate an action plan to prevent disease epidemics. The water quality index results showed that the samples collected from 5 different sites came under the class "Excellent", indicating that the water was of good quality for consumption. Although some of the parameters were quite low, all sites exhibited excellent water quality and were also acceptable for drinking since the values of the evaluated parameters fell within the tolerance limits. However, some preventive measures or precautions must be taken by the authorities to conserve water and ensure a protected drinking water supply to the public, as lack of adequate supply of good drinking water results in poor standards of personal hygiene and causes various diseases.

The study has certain limitations, for instance, the temporal fluctuations may cause the water quality to change. Nevertheless, the current analysis only evaluates the drinking water quality for a period of six months. Thus, it's possible that the study's findings don't reflect significant variations in the season's drinking water quality. Notwithstanding these drawbacks, overall, the study has aided in the creation of knowledge to support the sustainability of Sukhia town's drinking water system and its surroundings.

The authors are highly grateful and would like to thank the P.G. Department of Zoology, Darjeeling Government College, for providing the necessary laboratory facilities during this study.

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