https://chemclassjournal.com/
ChemClass Journal Vol. 9 Issue 2 (2025); 417-428
e-ISSN:3092-8214 p-ISSN:3092-8206
DOI: https://doi.org/10.33003/chemclas-2025-0902/169

Assessment of the Physico-Chemical Parameters of Wikki Warm Spring Water at Yankari Game Reserve in Bauchi State, Nigeria

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Abstract

The physicochemical parameters and heavy metals present in the Wikki Warm Spring water at Yankari Game Reserve, Bauchi State have not been thoroughly investigated. This lack of information hinders a comprehensive understanding of the water quality in this natural resource. The ecological and human balance of the reserve may also be at risk due to the possible presence of heavy metals in the water. The study considered three separate locations of the Wikki warm spring water, Yankari Game Reserve, Bauchi State, and investigated the levels of selected heavy metals and physicochemical properties of the water and sediment. The physicochemical parameters were analyzed using appropriate standard methods, and heavy metals were analyzed using Atomic Absorption Spectrometry (AAS). The results of the physicochemical analysis indicated that most of the parameters were below the WHO (2008) allowable limit. The mean concentration of Lead (Pb) in both the water and sediment samples were above the recommended maximum permissible limit WHO (2008). Similarly, the Pb mean concentration ± standard deviation of source sample, middle sample, end sample and sediment samples are (0.223±0.0788, 0.379±0.0917, 0.200±0.0052 and 0.233±01050) mg/L respectively; Pb in the water samples were above the allowable limit value of 0.05 mg/L indicating pollution. The high lead content in the water suggests that it may not be entirely safe for residential use and that residents and the society at large are at risk of environmental health problems.

Keywords: *physicochemical parameters, heavy metals, Wikki Warm Spring, Samples of water, Yankari Game Reserve Bauchi State.*

Introduction

One of the most significant and prevalent elements in the environment is water. It is essential to the life and flourishing of all living things on earth. Currently, the only planet with almost 70% water is earth. However, it is heavily contaminated with various dangerous pollutants as a result of the growing human population, industrialization, agricultural fertilizer use, and human activity. The human population contracts a variety of water-

borne illnesses as a result of drinking water contamination, it is imperative that the quality of drinking water be monitored on a regular basis. It is difficult to understand the biological phenomenon fully because the chemistry of water reveals much about the metabolism of the ecosystem and explain the general hydro - biological relationship [1].
An essential component of disease prevention and life quality enhancement is the availability of high-quality water. Natural water contains different types of impurities are introduced in to aquatic system by different ways such as weathering of rocks and leaching of soils, dissolution of aerosol particles from the atmosphere and from several human activities, including mining, processing and the use of metal-based materials [2].

Government agricultural revolution's greater usage of metal-based fertilizer may cause metal pollution concentrations in freshwater reservoirs to continue rising as a result of water runoff. Also, fecal pollution of drinking water causes water born disease which has led to the death of millions of people [3]. Due to undesirable changes in the physical, chemical, and biological properties of the air, water and soil, people everywhere are in grave danger. These are related to animal and plants and finally affecting on it [4]. Industrial development (either new or existing industry expansion) results in the generation of industrial effluents, and if left untreated results in water, sediment and soil pollution [5]. Having mainly excessive amounts of heavy metals such as Pb, Cr and Fe, as well as heavy metals from industrial processes are of special concern because they produce water or chronic poisoning in aquatic animals. High levels of pollutants mainly organic matter in river water causes an increase in biological oxygen demand [6], chemical oxygen demand, total dissolved solids, total suspended solids and fecal coli form. They make water unsuitable for drinking, irrigation or any other use (Hari and Nepal).

The trends in developing countries to use sewage effluent as fertilizer has gained much acceptance as it is considered a source of organic matter and plant nutrients and serves as good fertilizer. Farmers primarily focus on general advantages, such as enhanced agricultural output, economical water sources, efficient effluent disposal, and nutrient and organic matter availability; however, they are often unaware of detrimental effects, including heavy metal soil contamination, crop issues, and health-related quality concerns.

Research has proven that long term use of this sewage effluent for irrigation contaminates soil and crops to such an extent that it becomes toxic to plants and causes deterioration of soil [7]. This contains a significant quantity of potentially hazardous chemicals, including soluble salts and heavy metals such as Fe^{2+}, Cu^{2+}, Zn^{2+}, Mn^{2+}, Ni^{2+}, and Pb^{2+}, and of course addition of these heavy metals is undesirable. Plants can accumulate heavy metals in their tissues in concentrations above the permitted levels which is considered to represent a threat to the life of humans, and animals feeding on these crops which may lead to contamination of food chain, as observed that soil and plants contained many toxic metals, that received irrigation water mixed with industrial effluent [8]. The concentration of different chemical elements, which are primarily determined by the geological facts of the specific area, determines the quality of ground water. One of the main reasons why surface and ground water are becoming contaminated is industrial waste and municipal solid waste.

Excessive levels of heavy metals make accessible water unfit for human consumption in many regions of the nation. Due to rainwater release and water constraint, the situation deteriorates during the summer. One of the primary health issues is the presence of heavy metals, metal ions, and hazardous microbes in water supplies used for drinking and household reasons. The recent research in Haryana (India) concluded that it is the high rate of exploration then its recharging, inappropriate dumping of solid and liquid wastes, lack of strict enforcement of law and loose governance are the cause of deterioration of ground water quality [9].

The majority of rivers in emerging nations' cities are the result of industrial wastewater discharges. Africa and Asian countries experiencing rapid industrial growth and this is making environmental conservation a difficult task [10]. Many trace metals in very low concentrations can be found in seawater. Due to the extremely low quantities of numerous significant trace elements, this matrix presents difficulties for the analytical chemist.

Materials and Methods

All the chemicals used in this work were of analytical grade.

Overview of the Research Area

Yankari Game Reserve is situated in northeastern Nigeria, near the southern Sudan Savannah. It is approximately 2,244 km² in size. It is made up of well-established woodland patches interspersed by Savannah grassland. It is also a region of rolling hills, with Kariyo Hill, the highest point at 640 meters above sea level, primarily between 200 and 400 meters. It is located in the south-central region of Bauchi State, between latitudes 9°50' N and 10°32' E. There are four springs in the Yankari Game Reserve: three warm springs and one cold spring.

While Dimil is the only cold spring in the reserve, Wikki, Mawulgo, and Gwana are the warm springs. The park contains three natural springs, the most well-known of which is the Wikki warm spring.

Figure 1: Yankari National Park map displaying the Wikki Camp's location

Collection of Water Sample

Three locations were chosen to collect water samples for the physico-chemical examination from Wikki warm spring water at the Yankari Game Reserve in Bauchi State, Nigeria. Water samples (approximately 1000 mL each) were collected from three sites which are the source, middle and end. The polypropylene (1 L) sample bottles were then transported to the laboratory, labeled appropriately, maintained airtight, and stored in the refrigerator awaiting further examination.

Methodology

Physico-Chemical Analysis

The pH Assessment

A digital pH meter (Model No PHX 1400, Analab Scientific Instrument India) was used to measure the pH. After being turned on, the meter was given five minutes to warm up. A buffer solution was then used to standardize it. After that, the electrode was submerged in the water sample, and a measurement was made. Before taking another measurement, the electrode was cleaned with deionized water [11].

Determination of Conductivity

A DDS-307 Conductivity Meter was used to measure the conductivities of the water samples. After turning the meter on, it was calibrated at 25°C using 0.1M KCl. The electrode was then immersed into the water sample and conductivity reading of each sample was recorded [12].

Determination of Total Hardness of water

First, a conical flask was pipetted with 10 cm³ of water sample. Three drops of Erichrome Black T indicator and 1cm³ of buffer solution (NH_4Cl) with a pH of 10 were added to the flask. After that, the mixture was titrated with 0.0IM ethylenediamine tetra acetic acid (EDTA) until it turned blue instead of wine red. The procedure was repeated two more times to obtain the average titre value. The permitted conversion factor, 44.892, was multiplied by the obtained titre value to determine the total hardness, which was then stated in milligrams per liter (mg/L). The remaining samples underwent the same process [13].

Determination of Turbidity

A digital turbidity meter (2100AN HARCH Model) was used to measure the turbidities of the water samples. The water samples were mixed with clean deionized water, which was used to normalize the meter. The turbidity reading of each sample was then recorded [14]. The result was recorded in Nephelometric Turbidity Unit (NTU).

Determination of Total Dissolved Solid

A conductivity meter was used to measure the total dissolved solid. After selecting the total dissolved solid from the meter's programmed menu, 100 cm^3 of the sample was measured in to the beaker, and the electrode was added to the sample. The results of total dissolved solid were displayed and recorded. The Total Dissolved Solid was also measured using the gravimetric method, which involved evaporating the material for 2hrs at 200°C in an oven. This is to ascertain the accuracy of the above-mentioned method by comparing the two results no significant difference was recorded only that it has more time consuming as reported by [15].

Total Suspended Solid (TSS)

The sample is filtered, dried, and weighed using the total suspended solids method, a gravimetric technique, to ascertain the actual quantitative TSS. Following a one-hour drying process at 105˚C in an oven, Whatman filter paper was rinsed with distilled water and allowed to cool in a desiccator. A digital balance was used to measure its weight (W_1). A 50 mL water sample was filtered through paper and allowed to dry for an hour at 105˚C. The total suspended solids were computed using $(W_2 - W_1) \times 100$ mg/L, and the weight (W_2) of the filter paper holding the residue was noted.

Determination of Total Solid

The sum of the total suspended solids (TSS) and total dissolved solids (TDS) were used to get the total solid (TS).

Determination of Heavy Metals (Mn, Ni, Pb, Co, Cd, Zn):

Process of Digestion

The determination of heavy metals in water is often regarded as the movement of total suspended and dissolved metals (soluble metals). Consistent and reliable digestion techniques were employed in these situations to ensure the accuracy of the results obtained for the total metal content. To keep water samples from changing in composition, the water was digested right away after sampling.

Water Samples Digestion

Samples of 50 mL water were measured into a 100 mL beaker, and each sample was treated with 6 mL of concentrated nitric acid (HNO_3 65%), 3 mL of concentrated hydrochloric acid (HCl 35%), and 2 mL of peroxide (H_2O_2 30%). The digested samples were used to measure the individual metal concentrations in the water using AAS. Blanks were also made using the same procedure, but without the samples. The samples were loaded one at a time onto a hot plate, and the mixture was heated gradually until it evaporated to a volume of about 20 mL. The wall of the beakers was then cleaned with double distilled water (deionized water), and the filtrate was transferred to a clean screw-capped 60 mL polyethylene bottle [16].

Soil Sample Digestion

A 3.0 g sample of sieved soil was precisely weighed and then put into a 100 mL beaker. To every sample, 10 mL of (aqua regia), a mixture of concentrated hydrochloric acid and concentrated nitric acid in a 1:3 ratio, were added. White fumes were then seen after the sample was placed on a heating mantle in the fume cupboard. Then, 20 mL each of deionized water were added to the samples after they had finished digesting, and they were subsequently filtered. Next, 50 mL of deionized water was added to the filtrate. Ultimately, the diluted solution was poured into a tiny polyethylene bottle, and blanks were created using the same process but without the samples. The metals concentrations of samples were analyzed using A.A.S. (SHIMADZU AA-7000F, Japan).

Results and Discussion

The results of the analysis carried out were represented in Table 1a, Table 1b and Table 2.

Table 1a: Some Physico-chemical Parameters in Water of Wikki Warm Spring Water

Samples	pH	Conductivity (µS/cm)	Turbidity (NTU)	Alkalinity (mg/L)
Source	6.6	380	2.1	0
Middle	6.7	340	1.4	0
End	6.4	370	0.9	0
Sediment	8.1	3800	---	0
WHO (2008)	6.5 – 8.5	1000	5	---

Table 1b: Some Physico-chemical Parameters in water of Wikki Warm Spring Water

Samples	TSS (mg/L)	TDS (mg/L)	TS (mg/L)	Hardness (mg/L)
Source	1.1	1600	1601.1	330
Middle	1.0	1000	1001	120
End	0.8	400	400.8	118
WHO (2008)	5 – 10	1000	1000	10 – 500

Key = TSS: Total Suspended Solid, TDS: Total Dissolved Solid, TS: Total Solid WHO: World Health Organization

Table 2: Concentration of Heavy Metals in Water of Wikki Warm Spring Water

Heavy Metals	Concentration of Samples (mg/L)				WHO RMPL (ppm)
	Source	Middle	End	Blank sample	
Cd	0.009±0.0015	0.008±0.0012	0.005±0.0027	0.010±0.0020	0.05
Co	0.019±0.0088	0.020±0.0099	0.024±0.0067	0.026±0.0141	0.01
Mn	0.040±0.0081	0.031±0.0080	0.034±0.0037	0.041±0.0032	0.05
Ni	0.061±0.0053	0.040±0.0195	0.051±0.0012	0.089±0.0038	0.1
Pb	0.223±0.0788	0.379±0.0917	0.200±0.0052	0.163±0.0731	0.05
Zn	0.384±0.0023	0.524±0.0040	0.361±0.0013	0.594±0.0002	5.0

Key = WHO RMPL: World Health Organization Recommended Maximum Permissible Limit, Cd: Cadmium, Co: Cobalt, Mn: Manganese, Ni: Nickel, Pb: Lead, Zn: Zinc

Discussion

A water body's quality is determined by its physical, chemical, and biological components, all of which interact to affect its productivity. The results of the physicochemical parameters and heavy metals concentrations examined in the study area are shown in Tables 1a, 1b, and 2, respectively.

As shown in Table 1a, the physical analysis of pH produced a range of values. All of the samples have pH values that are below the allowable range.

The normalized capacity to conduct electricity is called electrical conductivity. The main factor influencing this is the dissolution of salts like potassium and sodium chloride. (SIT 2008).

Electrical conductivities obtained in this study were below maximum limit of 1000µS/cm prescribed by [17]. The values ranged from 340 - 3800 µS/cm. The highest value was recorded at sediment sample which found to be strong electrolyte and the lowest value was obtained at middle sample which is weak electrolyte respectively. This indicate that the presence of dissolved minerals in sediment sample is higher compared to other samples obtained. Although conductivity is not a human or aquatic health concern, but it serves as an indication of other water quality problems.

Low conductivity of some areas shows low dissolved salts in sites conductivity 340 µS/cm in middle, source and end, these conductivities indicate low dissolve salts like NaCl, KCl etc. by consideration of conductivity value obtain in sediment sample which is 3800 µS/cm, this sample has more dissolve salts than others, thus it conducts more electric current than other samples and also electrical conductivity is related to the concentration of iron (Fe) in water.

Turbidity is a measure of water clarity, how much the material suspended in water decreases the passage of light through the water, suspended materials include soil particles (clay, silt and sand), algae, plankton, microbes and other substances. Turbidity values were low for end sample 0.9 (NTU) and relatively middle sample 1.4 (NTU), but higher for source sample 2.1 (NTU).

Turbidity is a measure of how much light is interfered with, scattered, or absorbed, or how much transparency is reduced in water because of the presence of silt, clay, finely divided organic debris, plankton, or other microscopic organisms. The light transparency decreases as the turbidity value increases. The end sample exhibits high transparency due to its low turbidity value. The greater turbidity value in the source sample reflects the density of particles that blocks light from passing through.

Turbidity is mainly due to particles in suspension and therefore, typically corresponds to the total suspended solid concentration in a water, it may also be as a result of dissolve metals or dissolved organic matter (UNICEF 2008). By considering the result of Table 1a it indicates that all the values of the turbidity are within the limit of 5.0 (NTU) permissible of acceptable recommended values.

The total suspended solid of water samples was analyzed. The result in Table 1b shows some variation and range between 0.8 – 1.1 mg/L, the lowest value obtained in end sample with value of 0.8 mg/L. As indicated in Table 1b, total suspended solids (TSS), which assesses the transparency of the water sample, were higher in the Source sample (1.1 mg/L) than in the Middle sample (1.0 mg/L). TSS also provides a measure of the water's turbidity. A high TSS value as in source sample with value of 1.1 mg/L indicates an equally high turbidity. TSS highest value is due to siltation, deterioration, heavy precipitation and contribution from run offs and from surrounding land which carries mud, sand and other materials. The TSS values in this study were well within the permissible limits of 5 - 10 mg/L set by [18].

The amount of organic and inorganic materials dissolved in water is measured by the total dissolved solids (TDS) of water, which also indicates the salinity of groundwater. Except for one sample, as indicated in Table 1b above, the TDS values recorded at every sampling location were below the WHO (2004) allowable limit of 1000 mg/L. High TDS levels are a sign of possible problems and should be looked into further.

Usually, the presence of potassium, sodium, and chlorides causes high TDS levels; these ions have little to no short-term effects, but toxic ions (such as lead, arsenic, cadmium, and nitrate) can also dissolve in the water. Hard water is indicated by the highest TDS, which can produce an unfavorable taste that may be metallic, salty, or bitter. Additionally, it might signal the existence of hazardous minerals. Plankton, silt, leaves, industrial waste, and sewage are some organic sources of dissolved solids

The TDS value of water close to 600 mg/L is acceptable whereas those greater than 1000 mg/L is unpalatable for human consumption Middle sample and End sample showed TDS 1000, 400 mg/L respectively which are all below the standard values set by WHO (2004) but source sample showed value of 1600 mg/L which is above the limit. Certain treatments, including adding coagulants, could be necessary to make these waters fit for residential use.

Total solid in Table 1b was obtained by adding the total dissolve solid and total suspend solid. Total solid values obtained range between 400.8 – 1601.1 mg/L, the sample with lowest value of total solid is end sample 400.8 mg/L, this result shows that the value of TDS, the highest value was obtained in source sample with value of 1601.1 mg/L this was related to the high level of TDS and TSS. Furthermore, the water may contain pollutants that make it unsuitable for drinking, cooking, washing, irrigation, and other uses.

Total hardness, which is a measurement of the mineral concentration in a water sample that cannot be changed by boiling, is shown in Table 1b. The water sample had a total hardness of 118–330 mg/L. The total hardness in the water is the total soluble magnesium and calcium salts present in the water expressed as $CaCO_3$. In most natural water the predominant ions are those of bicarbonate associated mainly with calcium lesser degree with magnesium and still less with sodium and potassium. Water gets its overall hardness primarily from calcium and magnesium ions, however other cations including barium, iron, manganese, and zinc can also play a role. Hard water is generally undesirable because it forms precipitate with soap, produces scale in boilers point which is unsuitable for cooking. The Table 1b displays the total hardness, with the source sample having the highest value at 330 mg/L, followed by the intermediate sample at 120 mg/L, and the end sample at 118 mg/L. All of the concentrations found in this investigation fall below the 500 mg/L allowable limit set by Organization 2007.

According to Table 1b, the findings of the heavy metals' analysis of the Wikki warm spring water samples reveal that the highest level of Pb content is beyond the WHO's recommended maximum allowable limit. While all other samples with concentration of heavy metals (Cd, Co, Mn, Ni, Pb, Zn). Cd concentration is higher in source sample with value of 0.009±0.0015 mg/L followed by 0.008±0.0012 mg/L in middle sample while the end sample is below the limit. Mn and Ni concentration were also within the limit permissible range in all the samples respectively [19].

The use of water with lead ions can pollute the vegetables and can pose a significant risk to the consumers. A wide range of physiological, biochemical, and behavioral disorders that impact the kidney, liver, cardiovascular system, and central and peripheral nerve systems are known to be brought on by lead exposure in both humans and animals. The most important of all the heavy metals is lead since, even in trace amounts, it is toxic, widespread, and dangerous. Lead is a toxic metal whose high potency makes it a dangerous environmental threat to human health Nowadays, lead poisoning is quite uncommon, even though it can produce obvious sickness. Since lead is considered to have no necessary bodily functions, it can only cause harm when ingested through food, air, or water. Because it may build up in both individual organisms and entire food chains, lead is a very harmful chemical [20].

Conclusion

Assessing the concentration of several physicochemical parameters and heavy metals in water samples from Wikki warm spring water was the goal of this investigation. The findings indicate that, with the exception of a few physicochemical parameters, such as total dissolved solids (TDS) in the source sample and electrical conductivity in the sediment sample, which were above the WHO permissible limit, the concentrations of the majority of the water samples' Physico-chemical parameters, including turbidity, pH, total hardness, and electrical conductivity, were within the WHO permissible limit for drinking water.

The WHO-permissible standard for turbidity and overall hardness was met with the exception of Pd, which has a value above the WHO permitted limit, all water samples including the six chosen heavy metals Cd, Co, Mn, Ni, Pb, and Zn, and their quantities were within the acceptable range. The Wikki warm spring water samples analyzed have overall high-water quality, with the exception of a few lead and zinc physicochemical characteristics.

Acknowledgments

The authors express gratitude to the Federal University Dutse for providing a conducive environment and necessary facilities for carrying out the study.

Conflicts of Interest

There is no conflict of interest disclosed by the authors.

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