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Assessment of irrigation water quality parametric indices of lake Gwakra, Gerie local government, Adamawa state, Nigeria

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ABSTRACT

The quality of water for irrigation is vital to productivity and quality of crops produced. In this paper, the water quality of Lake Gwakra for irrigation purpose have been assessed using the Arithmetic Mean Water Quality Index Method. The lake water samples during the irrigation period (January, February and March) of the dry season were collected using standard procedures. The samples were subjected to appropriate physicochemical analyses. Properties such as pH, EC, TD and DO were determined in-situ using the multi-probes meter. Concentrations of chemical *properties (Na, K, Mg, Ca,* Cl^-, SO_4^{2-}, CO_3^{2-}*)* were tested in the laboratory using the Atomic Absorption Spectrophotometer (AAS) machine. The important parametric indices that influence the quality of water for irrigation such as Permeability Index (PI), Sodium Percentage, (Na%) Residual Sodium Carbonate (RSC), Magnesium Hazard (MH), Kelly's Ratio (KR), Total Hardness (TH) and Potential Salinity (PS) were determined using appropriate mathematical formulae. The results showed that the physicochemical parameters were within the permissible limits for irrigation purpose as provided by WHO. Permeability Index (47%), Sodium Percentage (40.56%), Residual Sodium Carbonate(0.90Meq/l), Magnesium Hazard (43.69%), Kelly's Ratio (0.47 Meq/), Total Hardness (43.72 Meq/) and Potential Salinity (4.19 Meq/) were all within the safe limits for irrigation. Controlled use of agrochemicals in the Jibiro Watershed and the lake vicinity was recommended towards preservation of the lake's water quality for irrigation and other uses.

KEYWORDS
lake gwakra; irrigation; physicochemical parameters; permissible limits

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INTRODUCTION

For human survival, drinking, agriculture, and other economic activities, surface water is a vital natural resource. According to FAO figures, 40% of the crops are produced on 20% of the irrigated land (Tiri,2018). Lakes, water reservoirs, and streams are the foremost valuable source of beverage for the earth's population. Lakes in particular, as natural water resources have always been of great significance to mankind (Naresh, 2021). The livelihood of the citizenry and a couple of other living components depend upon natural lakes for beverage and agriculture & industrial activities.

The quality of the lake water is dependent on the geological structure over which it is situated and also on the anthropogenic activities surrounding it which may include construction, waste disposal, agriculture and other associated activities (Mehari and Mulu, 2013; Tank and Chippa, 2013).

As the water inputs from both surface and subsurface flows get into the lake, soluble and insoluble substances are added which in turn alter the quality of the lake for certain uses.

The major concerns in terms of water quality and quantity are due to the uneven distribution of water on the surface of earth and the rapid declining of fresh useable sources (Irfan et al., 2014). The quality of water influences its suitability for a particular use, i.e. how well the quality fulfills the requirement of the user. Water quality deals with the physical, chemical and biological characteristics of water in relation to all other hydrological properties (Shakoor, 2017). The characteristics of water quality have become important in water resources planning and development for drinking, industrial and irrigation purposes (Shakoor, 2015). Water quality is the basic criterion to judge the fitness of water for its proposed application for existing conditions. According to Rinke et al. (2013), it is very important to monitor short-term physico-chemical parameters at the catchment scale. Several scientists have advocated and expounded that water quality parameters for evaluating irrigation water quality include salinity hazard, water infiltration rates (sodium hazard), pH, carbonate and bicarbonates, and specific ion toxicities (Bauder et al., 2011; Al-Ruwaih and Shafiullah ,2017; Falowo et al., 2020), and concluded that irrigation water quality is evaluated based upon total salt content, sodium and specific ion toxicities. Almuktar et al. (2018), stated that irrigation water irrespective of its amount of chemical substances in solution has the potential to degrade the quality of the soils and reduce crop yield provided it is not compliant to irrigation standards. It is against this backdrop that this study aims at assessment of water quality parametric indices of Lake Gwakra for irrigation purpose in Gwakra Area.

STUDY AREA

Location and extent

The Gwakra Lake is the main destination of the Jibiro drainage system. The lake is situated on the right bank of the River Benue (Upper Benue Trough) at Gwakra, Girei Local Government Area of Adamawa State. It is located between latitudes 09°24'09"N and 09°25'07"N of the Equator and between longitudes 12°23'04"E and 12°24'11"E of the prime Meridian (Figure 1). It covers a total surface area of 1.41Km^2, with its surrounding flood plains making up the irrigation area.

The area has a humid tropical climate with distinct wet and dry seasons controlled by the yearly fluctuations of the Inter-Tropical Convergence Zone (ITCZ). The dry season which makes up the irrigation farming period runs from December to May. The lake area and its entire irrigable land is characterized by the Gleyic cambisols (FAO) or Typic topoqualfs (USDA)-213 soil type. This is a mineral hydromorphic and juvenile soil of recent riverine and lacusterine alluvium (Areola 1983). Its colour ranges from dark brown (10yr3/2) to very dark grey (10yr3/1) with loamy, sandy-loam and silty loam textural characteristics. The soil type is also of low to high cation exchange capacity with pH values ranging from 5.9 to 4.9 indicating slightly acidic to very strongly acidic conditions (Usman, 2005). Being characterized by high water-holding capacity and nutrients content (Usman, 2005) the soil type is naturally fertile enough to support substantial agricultural productivity.

The major sources of water for the lake are the Jibiro Drainage System and episodic inundations from the River Benue during flood periods. With a surface area of about 1.41Km^2 and a mean depth of 1.46m (Yonnana et al., 2015), the lake basin is capable of storing over 2.0mcm of water annually. which could support substantial irrigation agriculture and other socioeconomic activities as fishing and recreation

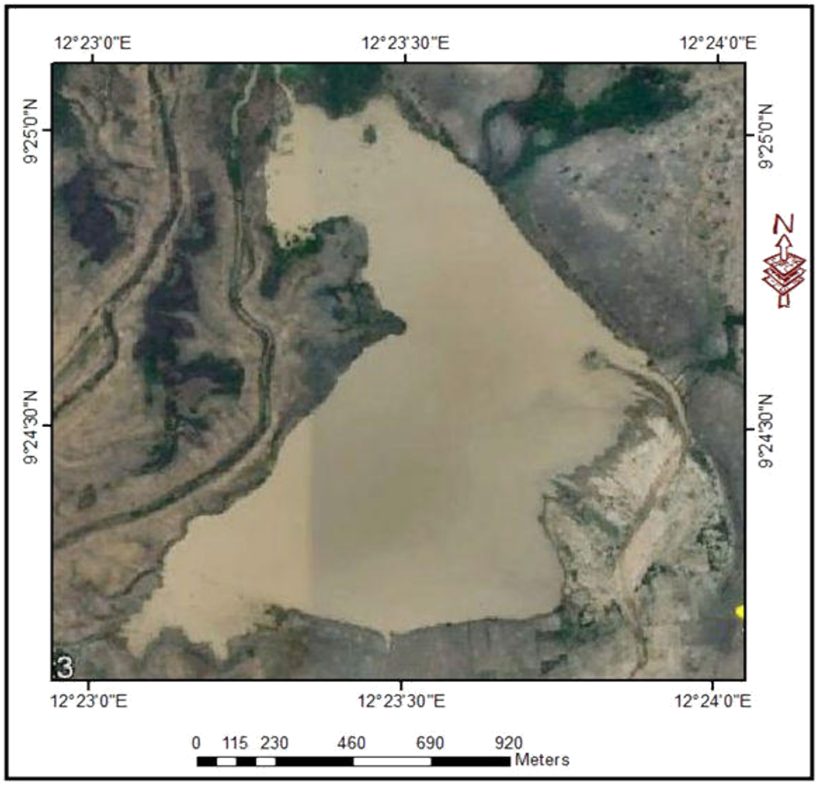

FIGURE 1: The Study Area.

METHODOLOGY

Samples Collection and Physicochemical Analyses

A total of nine (9) polyethylene containers (500ml) were used for collecting the water samples for the month of January, February and March respectively (3 containers for each of the month in dry season). The containers were properly washed, cleaned and rinsed with distilled water. At the sampling point, the containers were rinsed again with water from which samples were collected before they were later filled. The bottles were kept air tight and labeled properly for identification. Stoppering of the bottles was done quickly to avoid aeration during sampling. The technique of random sampling was applied in collecting the samples to make one composite sample because of numerous contaminants that could alter the quality of the water. All water samples were stored at a cool temperature of 4°C to inhibit the activities of microorganisms before transporting it to laboratory. Water quality sampling was carried out according to American Public Health Association (APHA; 2005). The samples were analyzed for physical and chemical parameters. pH, total dissolved solids (TDS), dissolved oxygen (DO), temperature, turbidity and electric conductivity were determined in-situ by using the multi-probes meter from Hydrolab Instrument. Chemical concentrations (Na, K, Mg, Ca, Cl^-, SO_4^{2-}, CO_3^{2-} and HCO_3^-) were tested by using the Atomic Absorption Spectrophotometer (AAS) machine.

Computation of Water Quality Parameters

From the values of physicochemical properties obtained, indices of the Irrigation Water Quality parameters were computed using the corresponding mathematical formulae presented in Table 1. sodium absorption ratio (SAR) was calculated; by the equation using the values obtained from $Na+$, $K+$, $Ca2+$, $Mg2+$, $SO_4^{2,}$ CO_3^{2} and HCO_3^-, in mg/l. Table 1 shows the mathematical formula used to determining the permeability index, (PI) soluble sodium percentage, residual sodium carbonate(RSC), magnesium hazard (MH), Kelly's ratio (KR), Total hardness (TH) and Potential salinity (PS) in accordance with (Paramaguru et al., 2016., Eaton, 1950). The analytical results of different water quality parameters were converted into a single value by the formulas presented in Table 1.

TABLE 1: The studied indices for water quality in lake Gwakra

Index	Formula	Reference
Sodium Percentage	$Na\% = \frac{Na^+ + K^+}{Na^+ + K^+ + Ca^{2+} + Mg^{2+}} * 100$	(Wilcox,1955)
Magnesium Hazard (MH)	$MH = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} * 100$	(Doneen, 1964)
Potential Salinity	$PS = Cl^- + \frac{1}{2} SO_4^{2-}$	(Doneen, 1964)
Total Hardness	$TH = Ca^{2+} + Mg^{2+}$	(Durfor and Becker,1962)
Kelly Ration	$KR = \frac{Na^+}{Ca^{2+} + Mg^{2+}}$	(Kelly,1940)
Sodium Adsorption Ratio	$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$	(Richards,1954)
Permeability index	$PI = \frac{(Na^+ + \sqrt{HCO_3^-})}{Na^+ + Ca^{2+} + Mg^{2+}} * 100$	(Doneen, 1964)
Residual Sodium Carbonate	$RSC = (HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$	(Richards,1954)

Source: Adopted from El-Amier et al., 2021

TABLE 2: Classes of used indices for Irrigation water qualities in the Study.

Parameter Index	Standard Value	Water Quality Status	Reference
Permeability Index (PI) %	PI > 75% PI = 25–75% PI < 25%	Suitable Moderate Unsuitable	(Das and Nag, 2015)
Sodium Adsorption Ratio (SAR)	SAR < 10 SAR = 10–18 SAR = 19–26	Excellent Good Doubtful/Fair Poor	(Richards, 1954).
Sodium percent (Na%)	Na% < 20 Na% = 20–40 Na% = 40–60 Na% = 60–80 Na% > 80	Excellent/Safe Good/Safe Permissible/Safe Doubtful/unsafe Unsuitable/unsafe	Richards, L.A., (1954) and Eaton, F.M.,(1950)
Residual Sodium Carbonate (RSC) (meq L/1)	RSC < 1.25 RSC = 1.25–2.50 RSC > 2.50	Good Medium Unsuitable	Eaton, F.M.,(1950)
Magnesium Hazard (MH) %	MH < 50% Suitable MH > 50%	Suitable Unsuitable	(Raghunath, 1987)

Parameter Index	Standard Value	Water Quality Status	Reference
Kelly's Index (KI)	KI < 1 KI > 1	Suitable Unsuitable	(Kelly1940).
Potential Salinity (PS) (meq L/1)	PS < 3.0 PS = 3.0–5.0 PS > 5.0	Excellent Good Injurious /Unsuitable	(Doneen, 1964)
Total Hardness (TH) (meq L/1)	0–60 61–120 121–180 >181	Soft Moderate Hard Very Hard	(Paliwal, 1972)
Irrigation Water Quality Index (IWQI)	WQI = 0–25 WQI = 26–50 WQI = 51–75 WQI = 76–100 WQI > 100	Excellent Good Poor Very Poor Unsuitable	(Durfor and Becker, 1962)

Source: Adopted from El-Amier et al., 2021

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Residual Sodium Carbonate (RSC) (meq L/1)	RSC < 1.25 RSC = 1.25–2.50 RSC > 2.50	Good Medium Unsuitable	Eaton, F.M.,(1950)
Magnesium Hazard (MH) %	MH < 50% Suitable MH > 50%	Suitable Unsuitable	(Raghunath, 1987)
Kelly's Index (KI)	KI < 1 KI > 1	Suitable Unsuitable	(Kelly1940).
Potential Salinity (PS) (meq L/1)	PS < 3.0 PS = 3.0–5.0 PS > 5.0	Excellent Good Injurious /Unsuitable	(Doneen, 1964)
Total Hardness (TH) (meq L/1)	0–60 61–120 121–180 >181	Soft Moderate Hard Very Hard	(Paliwal, 1972)
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Source: Adopted from El-Amier et al., 2021

RESULTS AND DISCUSSION

Physicochemical Properties of the lake

Understanding the intricate complexities of irrigation water quality and the much-desired role in ensuring soil fertility, and crop growth in addition to sustainable food security has been a burning issue for several decades in Nigeria and the global communities; steaming largely from dependence on poorly characterized and virtually unmonitored sources of water (Malakar et al., 2019). Thus, ensuring the long-term viability of irrigation water quality lies in the continual monitoring of factors not limited to the Physico-chemical parameter either from geogenic origin or from anthropogenic-related activities. The results in Table 3 are the highlights of the physicochemical parameters analyzed in water sampled from Lake Gwakra. The data shows a mean pH value of 7.67±0.05, an indication that the water is neutral-slightly alkaline (Belkhiri et al., 2017). The results are in agreement with the earlier assessment of lake water for drinking purposes by Yonnana *et al* (2015), reporting a pH of 7.83±0.06. The pH of the water is governed by the acid-based chemistry of dissolved ions. Ions such Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+} are predominant base-forming species (Bwatanglang and Magili, 2018), and the ion-exchange process between these ions influences the neutral-slightly alkaline pH dominance in the surface water (Tiri et al., 2019). Thus, from the results, it will suffice to conclude that Lake Gwakra consists of predominant base-forming species. These species are considered a predictor of the survival and growth of legumes, beans, rice, and must vegetable plants (Neilson et al, 2018)

Parameters such as sodium level, TDS, and electrical conductivity of irrigation water have been implicated as some of the main factors influencing irrigation water chemistry. Irrigation water with TDS below 1000 mg L^{-1} at alkaline-neutral pH and specific conductance below 1.5 mmhos/m is generally considered good quality. Above this trench were reported to increase the salinity and pore water concentration available for osmotic-roots uptake (Park et al., 2014). Electrical conductivity and TDS values are interrelated and serve as an indicator of saline water in absence of non-ionic dissolved constituents (Michael, 1992). In terms of 'Degree of restrictions on use for irrigation purposes; the TDS values <450, 450-2000, and >2000 mg/l represent 'none'; 'slight to moderate and 'severe (Islam and Shamsad, 2009). Based on the pH values established in this study and the resulting TDS value of 130±0.82 mg/l and EC 130±0.82 μs/cm, the water from Lake Gwakra is considered suitable for irrigation purposes. The TDS recorded in this study was observed to be higher than the 85.33±0.50 mg/l values reported in another study in 2015 (Yonnana *et al* (2015), this could be attributed to the continual tillage and other anthropogenic activity rightly observed and reported in the study area (Yonnana et al., 2015; Yonnana & Hyellamada, 2016).

Irrigation water that has high sodium (Na^{+}) content readily displaces exchangeable cations, Ca^{2+} and Mg^{2+}, and the replacement of the cations by sodium. Sodium-saturated soil peptizes and loses its permeability, decreasing the soil fertility and suitability for agricultural purposes (Matthess, 1982). An increase in soil pH and reduction in the availability of phosphorous to plants due to high concentrations of Ca^{2+} and Mg^{2+} ions in irrigation water were also reported (Al-Shammiri *et al*., 2005; Khodapanah *et al.,* 2009),). The observed concentrations of Na (20.42±0.02 mg/l), Ca (24.62±0.02 mg/l), and Mg (19.10±0.01 mg/l) all fall within the acceptable limits required in irrigation water, indicating no restriction of use for irrigation purposes (Salifu *et al.,* 2017). Sulphates (SO_4^{2-}) salts at higher concentrations restrict calcium absorption by crops and disrupt the cationic balance by increasing sodium and potassium adsorption (El-Amier et al., 2021). Sulphates are formed through natural processes in surface waters, from industrial waste discharges, atmospheric precipitation, or fertilized-based sources (Khudair (2013). Other sources of induction into the water bodies could be from the oxidative decomposition of the sulfur compound by bacteria (Bwatanglang et al, 2020). Similarly, Potassium and Cl are constituents of fertilizer and common rocks (Taiwo, 2016; Falowo *et al.* (2017)). The presence of chloride ions could be anthropogenic-related or from the leaching of saline residues in the soil (Bwatanglang et al, 2020). High concentrations of K together with Mg impact severe effects on soil hydraulic and infiltration properties (Smith et al., 2014), as well as on water availability and plant growth (Oster *et al.*2016; Adegbola *et al.* 2021). The value of SO_4^{2-}(8.02±0.01 mg/l), K (9.40±0.14 mg/l), and Cl (0.18±0.01 mg/l) recorded in this study are within the acceptable limit (Salifu *et al*. 2017), indicating no threat while use for irrigation purposes. Bicarbonate, an important anion in irrigation water, required in moderate concentration is found in river Gwakra to fall within the permissible limit for irrigation ((95.47±0.03 mg/l). Bicarbonate availability in water regulates sodium hazard by establishing soluble sodium percentage equilibrium (Adegbola et al. 2019).

At near-neutral pH values, dissolved bicarbonate (HCO_3^-) is the dominant ion. This is in agreement with the pH of 7.6 reported in this study (Adegbola et al. 2019). The least abundant anion, CO_3^{2-} concentration is 2.63±0 mg/l.

From all the physicochemical indices discussed, it's clear that Lake Gwakra has an adequate environment for biological life to thrive. The hydrogeomorphic characteristics of the Lake as revealed in a study by Yonnana et al. (2015) show the lake to be of low relative depth, dominated by littoral plants, an indication that the lakes are exposed to high vertical circulation and mixing, adequate to aid the transfer of dissolved oxygen, surface temperature conditions and sunlight penetration making it possible for rooted aquatic fauna and flora and other biological species to thrive.

TABLE 3: Result of the Physico-chemical properties of Lake Gwakra and WHO standard

Parameter	WHO Standard	January	February	March	Mean &SD
PH	6.5-8.5	7.7	7.7	7.6	7.67±0.05
EC (µs/cm)	1000	129	130	131	130±0.82
TDS (mg/l)	500	87	86	85	86±0.82
Na+(mg/l)	200	20.4	20.41	20.44	20.42±0.02
K^+(mg/l)	12	9.2	9.5	9.5	9.40±0.14
Ca^{2+} mg/l)	75	24.6	24.64	24.61	24.62±0.02
Mg^{2+} (mg/l)	50	19.08	19.11	19.1	19.10±0.01
Cl-(mg/l)	250	0.19	0.17	0.18	0.18±0.01
$SO4^{2-}$(mg/l)	250	8.02	8.04	8.01	8.02±0.01
$HCO3^-$ (mg/l)	1000	95.47	95.43	95.5	95.47±0.03
$CO3^{2-}$(mg/l)	500	2.63	2.63	2.63	2.63±0

Source: Laboratory Test 2021

Irrigation Parametric Indices of the lake for Irrigation

The quality of water for irrigation purposes has a direct impact on the type of crops to be cultivated, the croup growth, fertility, and permeability of the soil. Irrigation parametric Indices such as Sodium Absorption Ratio (SAR), Magnesium Hazard (MH), Percentage Sodium (Na %), Permeability Index (PI), Potential Salinity (PS), Residual Sodium Carbonate (RSC), and Kelly's Ratio (KR),) interrelate with the physicochemical parameters to define the suitability of water for irrigation purposes. The availability of ionic salts traditionally estimated by the EC, the sodicity hazard estimated based on the concentrations of Na, Ca, and Mg, reflected in the sodium adsorption ratio (SAR) often provides a guide toward understanding the irrigation water quality (Oster *et al.*2016). For example, the effects of EC and SAR on soil permeability behave in two ways: Soil permeability increases with increasing EC, and decreases with increasing SAR. Conversely stabilized by the optimal combination of high EC and low SAR (Oster *et al.*2016; Smith et al., 2014). These indices as highlighted above were calculated and the results (Table 4) discussed with the view to ascertain the suitability of Lake Gwakra for irrigation purposes.

The permeability index (PI)

The permeability index (PI) as an irrigation index takes into account the Na^+, Ca^{2+}, Mg^{2+}, and HCO_3^- concentration of the soil. Based on the reference values in Table 2, and the estimated PI value of 47% (classified as moderate), suggest that the water is acceptable for irrigation purposes. As presented in Table 3, HCO_3^-, Ca^{2+}, and Na^+ are the predominant ionic species and their relative concentration levels were observed to determine the PI value recorded. Dissolution of carbonate and cation exchange processes were reported to influence PI of water (Xu et al., 2019).

As put forward earlier, sodium-saturated soil peptizes, rendered soil permeability weak, and decreases the soil fertility and suitability for agricultural purposes (Matthess, 1982). The hydraulic and infiltration properties of soil suffer similar setbacks at high concentrations of K^+ and Mg^{2+} ions (Smith et al., 2014). The precipitation of carbonate by denitrification reduces soil permeability by creating cementitious bonds at the particle contacts thereby reducing nutrient availability for plant growth (Rebecca 2018). However, based on the PI classification observed in this study, soil permeability and infiltration properties of Lake Gwakra irrigated soils are suitable for crop cultivation.

Sodium adsorption ratio (SAR)

Sodium (Na^+) to Ca^{2+} and Mg^{2+} proportion collectively referred to as Sodium adsorption ratio (SAR) are similarly used as indicators in analyzing the hydraulic conductivity, permeability, and the alkali/sodium level of water in the soil. The degree to which irrigation water tends to enter Na^+, Ca^{2+}, and Mg^{2+} ion exchange reactions usually result in deflocculation and loss of soil permeability (Egbueri et al., 2021). An elevated amount of sodium relative to Ca^+ and Mg^+, HCO_3^- and TDS are reported as limiting factors in soil aggregate formation, soil structure, infiltration, and plant-water accessibility (Malakar et al., 2019). This phenomenon creates a sodium risk, the hallmark which impairs soil permeability by Na-absorbed soil particles, increasing resistance to water penetration and hence the availability for crops-uptake (Egbueri et al., 2021). The SAR of the water samples from Lake Gwakra was observed to have a calculated value of 4.37 (Table 4), which according to Wilcox (1955) and Richards (1954), is excellent and suitable for irrigation purposes. The SAR as shown in Table 2, classify water into the following categories: excellent (SAR < 10), good (10 < SAR < 18), doubtful (18 < SAR < 26), and unsuitable (SAR > 26). To further underscore the importance of soil salinization and reduced crop productivity, the percentage of soluble sodium concentration often used to quantify the risk potential of Na (Sodium Hazard) is evaluated and presented in Table 4. As mentioned above, high Na^+ concentrations in irrigation water could impair Mg^{2+} and Ca^{2+} availability, leading to a reduction in soil permeability, and internal drainage capability of the soils (Egbueri et al., 2021). Sodium accumulation and deterioration of soil structure, infiltration, and aeration are typical characteristics associated with Sodium Percentage greater than 60% (Fipps, 2003). In this study the Na% was calculated as 40.56 %, and based on the classification depicted in Table 2 is Good/Safe for use for irrigation purposes.

Residual sodium carbonate (RSC)

Residual sodium carbonate (RSC) is an index used to elucidate the relationship of the quantity of carbonate and bicarbonate relative to that of calcium and magnesium as its affects irrigation water quality. The underlying effect shows that HCO_3^- at high concentration precipitate Ca^{2+} and Mg^{2+} and increases the chances of water hardness; making the water unproductive and unsuitable for irrigation (Egbueri et al., 2021). This chemistry also influences the pH of the water body especially in forming an alkali environment in a situation where Na combines with carbonate and saline when combined with chloride (El-Amier et al., 2021). As previously stated, high concentrations of K^+, Ca^{2+}, Mg^{2+}, and carbonate ions impaired the hydraulic and infiltration properties of soil (Smith et al., 2014) and the permeability (Rebecca 2018); retarding the emergence of seedlings (Xu et al., 2019). These phenomena are not likely to occur in Lake Gwakra, showing an RSC value of 0.90 meq L^{-1} (Table 4) and according to Table 2, RSC levels less than 1.25 meq L^{-1} are deemed safe for irrigation purposes (Eaton, 1950).

Magnesium hazard

In the water body, calcium and magnesium exist in a state of equilibrium, however, in soil systems and an excess amount of Mg, their availability causes soil alkalinity and favors the adsorption of a large quantity of water between Mg and the soil particles. This change in soil chemistry reduces its infiltration ability and reduction in crop yield (El-Amier et al., 2021). Similarly reported to impaired soil architecture due to exchangeable Na ion in the irrigated soils (Zhang et al., 2021). Magnesium hazard as proposed by Szaboles and Darab (1964) describe the condition at which a high amount of Mg^{2+} in irrigation water can inflict harm to aquatic species and irrigated fauna and flora. However, in this study the concentration of Mg was observed to fall within the acceptable limits for irrigations purpose (Table 3), translating to no risk from MH having a calculated MH value of 43.69% for Lake Gwakra (Table 4), falling below the boundary value of <50 that are considered harmful and unsuitable for irrigation (Zhang et al., 2021). To reiterate more, water containing a high amount of Ca^{2+}, Mg^{2+}, Na^+, and HCO_3^- reduces soil permeability and retard crop yield.

Kelly's ratio (KR)

The severity and magnitude of the impact to the potential effect of sodium on the quality of irrigation water are referred to as Kelly's ratio (KR), which according to the inventor should not exceed 1. As presented in Table 2, a KI value less than one (KI < 1) is considered suitable, and a value greater than one (KI > 1) is considered unsuitable for irrigation (Kelly, 1963). The concentration of Na^+ as shown in Table 3 relative to Na% and RSC was observed to translate to the measured KI of 0.47Mg/l in Lake Gwakra. This suggests that the surface water from the lake is deemed fit for irrigation (El-Amier et al., 2021).

Potential Salinity (PS)

Consistent irrigation activities, influence SO_4^{2-} and Cl^- chemistry and hence the buildup of soil salinity especially in a situation where salt with low solubility precipitates and accumulates in the soil (Doneen, 1964; El-Amier 2021). This chemistry referred to as Potential Salinity (PS) was taken into account when measuring the suitability of water for irrigation purposes (Egbueri et al., 2021). The PS, as an indicator of the impact of Cl^- and SO_4^{2-} on irrigation water, is defined as the Cl^- concentrations plus half of the SO_4^{2-} concentration (Zhang et al., 2021). According to Doneen (1964) and presented in Table 2, irrigation water is considered excellent to good when the PS < 5, good to injurious (PS = 5–10), and injurious to unsatisfactory (PS > 10). High SO_4^{2-} concentrations increase Na^+ and K^+ adsorption, disrupt the cationic balance, and restrict Ca^{2+} absorption by crops (El-Amier et al., 2021). Chloride at higher concentrations, facilitate the mobilization of toxic metals through ion exchange and is further reported to promote the acidification process (Kaushal, 2009). The PS of the water samples from Lake Gwakra was measured at 4.19 Meq/l (Table 4), indicating that the Cl^- and SO_4^{2-} have no negative influence on the irrigation water. This is in line with their concentrations in the samples as shown in Table 3, falling within the acceptable limits set for irrigation purposes.

Total Hardness (TH)

Alkalinity influences the hydrochemistry of surface water and the hypodermic flow (Demetriades, 2011). The availability of alkaline earth ions (Ca^{2+} and Mg^{2+}) of weak acids (HCO_3^- and CO_3^-) and strong acids (Cl^-, SO_4^{2-} and NO_3) (El-Amier et al., 2021) leads to the hardness of water body, a process term Total Hardness (TH) of water. The TH is the sum of calcium and magnesium ions and salts or both. According to the result in Table 4, the surface water samples fall into the soft water category, showing TH of 43.72 Meq/l in Lake Gwakra. The maximum allowable limit of TH for irrigation purposes as described in Table 2 is 60 meq L-1.

CONCLUSION

The results show that all the physico-chemical parameters and the indices are within the permissible limit of World Health Organization (WHO). Sodicity were all within the permissible limit. It is therefore recommended that Periodic and timely implementation of suitable, appropriate, and consistent procedures to address any potential pollution should be adopted and there should be control on the use of agricultural chemicals so as to avoid contamination of the lake.

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