Sirisha Korrai[1], B. Vinay Sagar[2], Madhavi Earle[3]*, Sangeetha Sankhyayani Achanta[4], Hemanshu Mediboyana[5]*

*[1]*Department of Basic Sciences & Humanities, Vignan's Institute of Information Technology (A), Duvvada, Visakhapatnam-530049, India; [2]Department of Environmental Sciences, Andhra University, Visakhapatnam, India; [3*]NSRIT College, Visakhapatnam, Andhra Pradesh, India; [4]Department of Environmental sciences, Archarya Nagarjuna University, Andhra Pradesh, India; [5]Centre for the Environment, Indian Institute of Technology, Guwahati, Assam*

Scientific paper
ISSN 0351-9465, E-ISSN 2466-2585
https://doi.org/10.62638/ZasMat1172

Zastita Materijala 65 (4)
724 – 733 (2024)

Evaluating the water quality of a Kondakarla Ava Lake for Agricultural Endeavours in Visakhapatnam, India

ABSTRACT

Global population growth is placing a pressure on freshwater resources. Freshwater resources are becoming scarcer in terms of both quantity and quality due to the rising demand. Assessing water quality of surface water bodies for irrigation is essential as water with poor quality can pose health risks. The study involved observing the physicochemical parameters of Kondakarla Ava Lake from six different sampling locations. The study revealed that it could not use directly for drinking purposes as per NSFWQI. According to parameters like RSC, SAR, PI, % Na, and IWQI, water quality is appropriate for irrigation. It is further strengthened by the USSL diagram showing that the Kondakarla Ava Lake samples fall under the categories C3S1 and C4S1, which indicates that water has low sodium peril and high to very high salinity. The Wilcox diagram showed the grouping of the samples under three categories: excellent, good to permissible, and doubtful.
***Keywords:** Eutrophication; Potability; Water Quality Index; Overall Index of Pollution; Principal Component Analysis; Irrigation.*

1. INTRODUCTION

Water considered the most precious resource on the planet, plays an indispensable role in human survival. Although about 70% of the earth's surface is surrounded by water, only 3% of it is considered to be freshwater which is suitable for human use. And it is estimated that approximately 0.4 percent of the earth's usable and drinkable water is shared among the 7.8 billion inhabitants.

Deep down from the history of human civilisation, surface water bodies like rivers and lakes are prone to heavy pollution as they are easily accessible for waste disposal. Natural and anthropogenic processes significantly influence the surface water quality [1]. Industrialisation, urbanisation, and modern agricultural practices drastically impact on water quality [2, 3, 4, 5, 6, 7]. In the recent decade, there has been a considerable enhancement in the population and their utilisation of resources, generating sewage and its run-off, proportionally increasing the nutrient inputs for Eutrophication [8].

Water quality and loss of dire habitats and other pollutants in the water bodies generate immense stress on the aquatic ecosystems resulting in the deterioration of the biodiversity, which might ultimately decrease the life quality for the local inhabitants [9]. With the ever-increasing human interferences and the ill effects of pollution, it is obligatory to determine water quality before it is deemed fit for human use.

To assess the quality of these water bodies, some frequently used Water Quality Index (WQI) in open domains are as follows [10]. Surface water is considered as an essential resource for irrigation, making it easier to cultivate crops nearby. A sizable area of land may benefit from using lake water for irrigation, which would raise agricultural productivity and sustain local lives. Furthermore, the necessity of sustainable water management techniques is highlighted by the relationship between environmental protection and agricultural activities. The long-term sustainability of agriculture and the health of ecosystems and societies depend on a harmonious balance between environmental preservation and productivity.

A technique such as SAR (Sodium Absorption Rate) is the additional index used to evaluate the suitability of water used in irrigation [11]. Statistical approaches were employed to endow with

*Corresponding author: Madhavi Earle and Sirisha Korrai
E-mail: siritejvardhan07@gmail.com
Paper received: 17.04.2024.
Paper accepted: 22.05.2024.

representative and reliable chemical analysis of the water quality. The non-linear nature of the environmental information formulates spacio-temporal differences in water quality, which are usually difficult to interpret [12]. In this study, we made use of multivariate statistical tools like Correlation and Principal Component Analysis (PCA) as these are extensively used as unbiased techniques for the study of water quality facts for deriving important conclusions [13 &14].

2. METHODOLOGY

2.1 Study area

Kondakarla Ava wetland is one of the leading natural freshwater lakes of Andhra Pradesh and is 50 km southwest of Visakhapatnam, India. It lies between 17º 35' 30" N, 17º36º02''N latitudes, and 82º 59' 27" E and 83º 01' 02" E longitudes (Fig 1).

Figure 1. Study area

The Kondakarla Ava wetland is a share of the Sarada riverine structure and is categorised as a perpetual, warm, eutrophic shallow freshwater lentic body. The total water spread of the Kondakarla Ava wetland is about 753.93 hectares, with a self-catchment area of about 2538.19 hectares. The twelve-monthly rainfall in the present study area is about 955 mm, with mean temperatures varying from 23.5^0 C to 31.2^0 C.

2.2. Sample collection and Physico-chemical *analysis*

The water samples were collected in a pre-cleaned polyethylene bottle for six months (i.e., Pre-monsoon (March to May, 2023) and Post-monsoon (October to December, 2023) from six different sampling locations. To obtain the lake's overall water quality, consider the mean values independently in pre-and post-monsoon seasons. A continuous lake water quality monitoring was done in both seasons, which involved a comprehensive physicochemical analysis. The analysis of essential cations (Ca^{+2}, Mg^{+2}, K^+, Na^+) and anions (Cl^-, SO_4^{-2}, NO^{3-}, PO_4^{3-}) and other general parameters like pH, Temperature, BOD, DO, TS, TSS, TDS, and TH were conducted using standard analytical procedures as stipulated by APHA (2005) [15]. Each parameter was examined thrice for consistency in the obtained values. The irrigational Water Quality Index, Sodium Absorption Rates (SAR), and Percent Sodium (% Na) were investigated in all collected samples to check the suitability for irrigation.

In contrast, assessing its suitability for drinking, NSFWQI was used along with a comparison of observed values with that of the Bureau of Indian Standards (BIS 1998). The Overall Index of Pollution (OIP) was utilised to analyse the overall quality of lake water. *Evaluation of potable water quality comparison with standards stipulated by BIS, 1998.* The observed physicochemical values were compared with the criteria specified by the BIS[16], 1998, to acknowledge their usage for drinking purposes.

2.3 National Sanitation Foundation Water Quality Index (NSFWQI)

Water quality valuation can be used as a tool to provide valuable facts for strategic planners and decision-makers [8]. WQI is a sole entity that converts detailed water quality data into a simple form that generally helps express the overall water quality in a particular region at a specific period.

By calculating the NSFWQI, the suitability of the water sample for human consumption can be determined. Horton [17], has suggested the first WQI followed by other indices, which included the National Sanitation Foundation (NSF) by the US, which is putative as a more user-oriented WQI based on the opinions of experts or panellists [18]. The NSFWQI, employed to estimate the water quality of Kondakarla Lake, is precisely expressed as:

$$NSFWQI = \sum_{n=1}^{n} (SI_i)$$

Where SI_i=Sub index for i^{th} water quality parameter and was calculated by using the Equation 1 below:

$$SI = W_i q_i \qquad (Eq\ 1)$$

Where

W_i= Relative Weight (in terms of importance) associated with water quality parameters which is given Equation 2:

$$W_i = \frac{W_i}{\sum_{n=1}^{n} Wi} \qquad (Eq\ 2)$$

and qi = quality rating and it is measured by using Equation 3:

$$q_i = (C_i / S_i) *100 \qquad (Eq\ 3)$$

For the study, standard software is employed to calculate NSFWQI [19]. The scores range from 0 to 100. The WQI scores were categorised into five types as Excellent; Good; Medium; Bad; and Very Bad, usually meant to summarise the water quality of that particular area.

2.4. Overall Index of Pollution (OIP)

For the valuation of overall surface water quality in Indian conditions, Sargaonkar and Deshpande in the year 2003 [20], developed a unique index named Overall Index of Pollution (OIP), based on a general classification scheme. Water quality is classified into five classes as follows in Fig. 2. The index was calculated using the following scientific expression:

$$OIP = \sum_{i=1}^{n} \boldsymbol{Pi/n}$$

Where

Pi = Pollution Index of ith parameter; n = number of parameters.

Pi=Vn (observed value of the parameter)/Vs (standard value of the parameter.

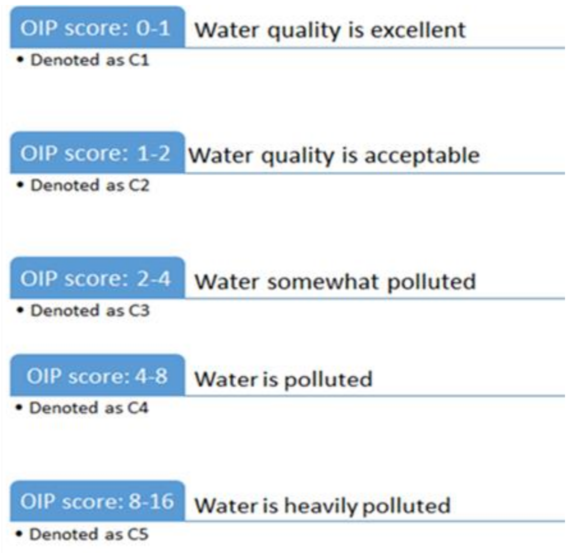

Figure 2. OIP score

2.5. Evaluation of irrigation water quality

The appropriateness of surface water for irrigation was evaluated by using different types of indices like Residual Sodium Carbonate (RSC), Sodium Percentage (Na%), and Sodium Adsorption Ratio (SAR), Permeability Index, Chloride and Electrical Conductivity (EC). The irrigation water classifications, based on the above physicochemical and statistical parameters, are represented in Table 1.

2.6. Permeability and Infiltration Hazard

The ubiquitous water quality factor governing the regular rate of water penetration is the relative and absolute concentrations of cations that include Na^+, Mg^{2+}, and Ca^{2+} in the water, also acknowledged as the Sodium Adsorption Ratio (SAR). The SAR value of irrigation measures the relative quantities of Na^+ to Ca^{+2} and Mg^{+2} and is calculated using the formula given by Richards in the year 1954. The procedure is represented below:

$$SAR = \frac{Na^+}{\sqrt{\frac{(Ca^{2+}+Mg^{2+}}{2}}}$$

where ion concentrations are in milliequivalents per litre (meq/l) units.

Water quality is considered excellent for irrigation if the values range below 10.

2.7. Percent Sodium (% Na)

The sodium content in the irrigation waters is further expressed in terms of % Na (amounts expressed in meq/l) and this is computed using the below method:

$$\% Na = \{(Na^+ + K^+) / (Ca^{+2} + Mg^{+2} + Na^+ + K^+)\} * 100$$

2.8. Residual Sodium Carbonate (RSC)

Richards, 1954 [21] determined the harmful effects of carbonate (CO_3^-) and bicarbonate (HCO_3^-) on irrigation water; stated as Residual Sodium Carbonate (RSC), which is computed using the below method where ion concentrations are represented in meq/l:

$$RSC = (CO_3^- + HCO_3^-) – (Ca^{+2} + Mg^{2+})$$

2.9. Permeability Index (PI)

The soil permeability usually influences the proper usage of water for irrigation, which generally depends on the concentrations of cations like Na^+, Ca^{+2}, and Mg^{+2}along with anions like HCO_3^- present in the soil. The formula used to compute the Permeability Index was put forward by [22] Doneen (1964) is as follows:

$$PI = \{(Na+ + \sqrt{HCO_3^-}) / (Ca^{+2} + Mg^{+2} + Na^+)\} * 100$$

2.10. Irrigational Water Quality Index (IWQI)

Further, a complex irrigational water quality examination was carried out using the Irrigation Water Quality Index (IWQI), which uses various irrigation water quality indicators, which were further generalised and then presented in a single value (ranges from 0 to 100)- as in Table.2.

To process this index, we depend on the standards stated by the FAO paper No. 29 [23,24] along with a few specifications on the local studies. Qi value was intended using the below equation:

$$Q_i = q_{imax} - \left\{\frac{[(x_{ij} - x_{inf}) * q_{iamp}]}{x_{amp}}\right\}$$

Where q_{imax} is regarded as the maximal value of q_i for the class; x_{ij} is the measured value of chemical parameters; x_{inf} is termed as the minimal limit of the class to each parameter belongs; q_{iamp} is class amplitude; and x_{amp} is upper limit of the last class of each parameter. Finally, Irrigation Water Quality Index (IWQI) has been estimated using the below equation:

$$IWQI = \sum_{i=1}^{n} Qi * wi$$

IWQI is termed as a nondimensional index of irrigation water quality which usually ranges from 0 to 100, where Qi is the quality measurement of the parameter, (i^{th}) a number from (0 to 100) is a function of its concentration. Wi is the normalised weight of the i^{th} parameter.

3. RESULTS AND DISCUSSION

3.1. Parameters for drinking water quality assessment

The examination of the surface water quality of the lake is essential for the maintenance and existence of aquatic flora and fauna. The minimum, maximum, mean, and standard deviation values of each parameter in pre and post-monsoon for each station are depicted in Table 2.

Ca^{2+} and Mg^{2+} ions are probably due to the leaching of the minerals like dolomites, limestone, anhydrite and gypsum [25].

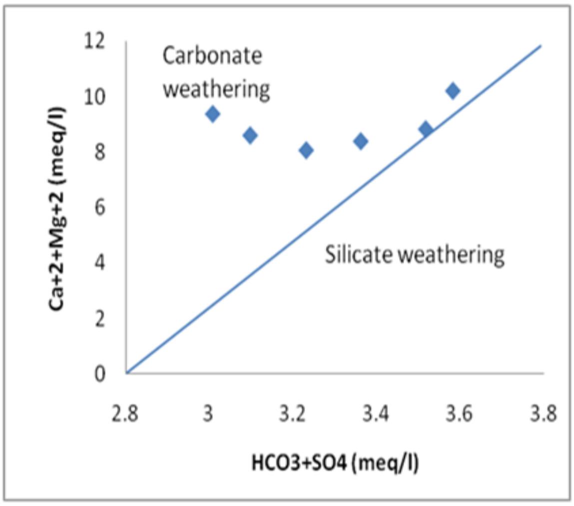

Figure 3. Scatter plot for Ca^{2+}+ Mg^{2+} VsHCO_3^-+SO_4^-

Table 1. The organisation of water for irrigation purposes based on physicochemical and statistical parameters

	Range in meq/l	Quality concerning the suitability for irrigation
Sodium Adsorption Ratio (SAR) (Richards, 1954)	0-10	Excellent
	10-18	Good
	18-26	Fair
	Above 26	Poor
Residual Sodium Carbonate (RSC) (Richards, 1954)	<1.25	Good
	1.25-2.5	Medium
	>2.5	Bad
Percent Sodium (% Na) (Wilcox, 1955)	<20	Excellent
	20-40	Good
	40-60	Permissible
	60-80	Doubtful
	>80	Unsuitable
Permeability Index (PI) (Doneen, 1964)	>75	Class I – Good
	25-75	Class II –Suitable
	<25	Class III – Unsuitable
Chloride (Cl^- in meq/L) (Doneen, 1958)	>5	Class I – Good
	5-10	Class II –Hazardous
	<10	Class III – Very Hazardous
Electrical Conductivity (EC, µS/cm|)(Wilcox, 1955)	<250	Excellent
	250-750	Good
	750-2250	Permissible
	2250-5000	Doubtful
	>5000	Unsuitable
Irrigation Water Quality Index (IWQI)	80-100	Class I - Excellent
	60-80	Class II - Good
	45-60	Class III - Permissible

In particular, calcium can also be attained from the cation exchange process [26]. A scattered diagram (Fig.3) of Ca^{2+} + Mg^{2+} Vs. HCO_3^- + SO_4^{2-} [27] reflects that majority (i.e., five out of six samples) of the collected samples of the study area drop above the equi-line, which indicates that carbonate weathering plays a significant role in supplying these ions to the Kondakarla lake.

3.2. National Sanitation Foundation Water Quality Index (NSFWQI)

This study's computed NSFWQI values ranged from 43 to 57 meq/l. From these calculated values, it was evident that the quality of this lake water during the study period was graded as a medium quality category in the sampling stations S1 and S2, while the rest (S3 to S6) were categorised as bad. Hence this lake water is not suggestible for direct consumption by humans (Table 3). The computed NSFWQI values were categorised into five types (Fig. 3).

3.3. Overall Index of Pollution (OIP)

To determine the overall status of the water quality, OIP is computed. The computed values showed that the lake is excellent. The observed OIP values were 0.53 and 1.41 (Table 4). As per the classification given by [28], the present lake water quality during the study period was labelled as C1 category for five samples (S1, S2, S3, S4, and S6); while S5 falls under the C2 category (Fig.2).

3.4. Parameters for irrigational water quality assessment

3.4.1. Sodium Absorption Ratio (SAR)

According to the classification (Table 3), the quality of the study area was Excellent during the study period. The computed values of SAR were observed to be 4.17 meq/l and 3.606 meq/l during the study period.

3.4.2. Percent Sodium (% Na)

The most widely recommended % sodium for water for irrigation purposes should not exceed 50-60 to prevent its detrimental difficulties on the soil. The computed values of PI were 55.04 meq/l and 59.9 meq/l during the study period.

3.4.3. Residual Sodium Carbonate (RSC)

The excess quantity of CO_3^{2-} and HCO_3^- is known as Residual Sodium Carbonate (RSC). The observed values of RSC in the selected area range from -5.19 to -7.24, i.e., all the values fall under the excellent and safe category for irrigation (Table 2 & 3).

3.4.4. Permeability Index (PI)

Na^+, Ca^{+2}, Mg^{+2} and HCO_3^- concentrations influence soil permeability [29]. Hence, the PI values were calculated using cations and anions to assess the water quality. The PI values in the present study ranged from 55.04 to 59.9, i.e., all the samples collected were suitable for irrigation (Tables 2 & 3).

3.4.5. Irrigational Water Quality Index (IWQI)

As per the classification (Table 2), all the samples in the present study area range from 70.23 to 84.79, i.e., they range from good to excellent for irrigation. The water quality is evaluated using different indices, and the data is presented in Table 3.

3.5. Correlation analysis

Correlation is a bivariate technique that signifies the association between two random variables, which provides a quick view of the water quality monitoring processes. Spearman's rank coefficients of correlation among twelve Physico-chemical parameters (i.e., EC, pH, Ca^{+2}, Mg^{+2}, Na^+, K+, HCO_3^-, Cl-, SO_4^{2-}, PO_4^{3-}, NO_3^- , K^+ and IWQI) was computed for analysis of correlation (Table 4), to identify the association between different random properties.

The highest correlation coefficients (nearer to -1.0 or +1.0) reflect the existing association between two variables. Suppose it is nearer to zero, demonstrating no connection among them [31]. In the present study, pH showed the most negligible correlation, while EC showed the highest correlation with maximum parameters. The rest of the parameters also exhibited a more or less strong positive correlation.

Table 2. Analytical results of the lake Kondakarla Ava

Parameters	Site 1		Site 2		Site 3	
	Pre-monsoon	Post – Monsoon	Pre-monsoon	Post - Monsoon	Pre-monsoon	Post - Monsoon
Temperature (oC)	26.3	30.5	26.5	27.5	25.2	27.5
pH	8.03	8.6	7.7	8.82	8.1	8.5
Turbidity (NTU)	7.8	8.4	6.9	7.6	7.4	8.2
EC (µS/cm)	476.6	520.4	433.2	498.1	467.2	514.1
Total Hardness (mg/l)	359.69	478.04	429.235	488.4245	351.6	412
Total Alkalinity (mg/l)	145.1	298.4	186.3	261.1	144.8	278.44

TDS (mg/l)	1020	1300	754	838	1121	1452
DO (mg/l)	8.1	11.6	8.2	12.4	8.4	10.4
BOD (mg/l)	2.8	10.3	1.9	7.2	3.9	10.2
Ca^{+2} (mg/l)	67.53	95.3	112.2	67.65	72.97	96.42
CaH (mg/l)	168.622	237.96	280.16	287.8	168.742	239.08
Mg^{+2} (mg/l)	46.4	58.3	37.1	49.3	46.52	59.42
MgH (mg/l)	149.07	240.07	191.07	203.01	191.19	241.19
Cl^- (mg/l)	89.3	164.1	43.4	101.3	89.42	165.22
HCO_3^- (mg/l)	152.3	201.2	152.3	196.6	116.41	202.32
SO_4^- (mg/l)	19.3	25.35	15.21	20.51	20.12	26.47
NO_3^- (mg/l)	1.12	3.34	2.14	1.14	0.65	4.46
PO_4^- (mg/l)	0.25	1.27	0.1	0.4	0.37	2.39
Na^+ (mg/l)	81.5	101.86	94.7	96.2	95.7	102.98
K^+ (mg/l)	18.3	34.6	10.2	21.3	19.14	35.72

Parameters	Site 4		Site 5		Site 6	
	Pre-monsoon	Post - Monsoon	Pre-monsoon	Post - Monsoon	Pre-monsoon	Post - Monsoon
Temperature (ºC)	25.1	28.5	26.8	30.2	24.3	27.6
pH	7.8	8.2	7.89	8.4	7.5	8.21
Turbidity (NTU)	7.1	7.4	7.3	8.2	7.2	7.8
EC (µS/cm)	424.1	472.3	446.4	522.3	443.1	491.7
Total Hardness (mg/l)	431.2	474.7	354.4	441.1	414.7	472.4
Total Alkalinity (mg/l)	174.32	254.1	175.4	274.2	167.3	265.4
TDS (mg/l)	784	1021	1189	1302	1122	1347
DO (mg/l)	8.3	11.8	8.4	10.6	8.7	11.7
BOD (mg/l)	3.2	7.3	4.8	11.2	1.4	6.3
Ca^{+2} (mg/l)	113.6	116.7	69.85	99.62	114.3	100.74
CaH (mg/l)	281.56	285.4	170.942	242.28	174.062	245.4
Mg^{+2} (mg/l)	36.2	51.7	48.72	62.62	51.84	65.74
MgH (mg/l)	150.47	247.51	193.39	205.41	196.51	244.39
Cl^- (mg/l)	44.8	103.7	91.62	168.42	94.74	171.54
HCO_3^- (mg/l)	117.81	199	154.5	208.64	157.62	205.52
SO_4^- (mg/l)	16.61	22.91	22.32	29.67	25.44	32.79
NO_3^- (mg/l)	2.05	10.78	4.34	7.66	7.46	3.54
PO_4^- (mg/l)	1.5	2.8	1.21	5.59	1.22	1.54
Na^+ (mg/l)	82.9	98.6	97.9	106.18	101.02	109.3
K^+ (mg/l)	11.6	23.7	21.34	42.04	24.46	38.92

Table 3. Quality of water based on different indicators

	S1	Water quality-status	S	Water quality-status	S3	Water quality-status	S4	Water quality-status	S5	Water quality-status	S6	Water quality-status
NSFWQI	50	Medium	57	Medium	48	Bad	46	Bad	43	Bad	49	Bad
OIP	0.76	Excellent	0.53	Excellent	0.91	Excellent	0.99	Excellent	1.41	Acceptable	0.92	Excellent
IWQI	77.65	Good	70.23	Good	79.3	Good	74.42	Good	81.47	Excellent	84.79	Excellent
PI	59.16	Suitable	59.11	Suitable	59.51	Suitable	55.04	Suitable	59.9	Suitable	56.15	Suitable
RSC	-5.48	Safe	-5.19	Safe	-5.98	Safe	-6.78	Safe	-5.84	Safe	-7.24	Safe
SAR	3.895	Excellent	4.137	Excellent	4.167	Excellent	3.645	Excellent	4.226	Excellent	4.046	Excellent
Na%	46.81	Per-missible	49.54	Per-missible	48.16	Per-missible	44.54	Per-missible	47.95	Per-missible	45.33	Per-missible

Table 4. Correlation matrix for analysed parameters

	EC	pH	Ca^{+2}	Mg^{+2}	TDS	Na^{+}	K^{+}	HCO_3^-	Cl^-	SO_4^{2-}	PO_4^-	NO_3^-	IWQI
EC	1												
pH	0.331	1											
Ca^{+2}	0.824	0.006	1										
Mg^{+2}	0.742	-0.174	0.64	1									
TDS	0.871	0.124	0.871	0.973	1								
Na^{+}	0.916	-0.11	0.811	0914	0.981	1							
K^{+}	0.784	0.472	0.742	0.412	0.873	0.617	1						
HCO_3^-	0.947	0.227	0.631	0.88	0.911	0.874	0.747	1					
Cl^-	0.914	0.413	0.711	0.628	0.899	0.887	0.712	0.874	1				
SO_4^{2-}	0.875	-0.241	0.841	-0.852	0.926	0.712	0.624	0.799	0.742	1			
PO_4^-	0.041	-0.02	0.648	0.245	0.939	0.354	0.124	0.878	0.841	0.719	1		
NO_3^-	0.215	-0.041	0.731	0.124	0.901	0.133	0.233	0.851	0.872	0.784	0.471	1	
IWQI	-0.972	0.217	-0.871	0.947	-0.972	-0.974	-0.817	-0.896	-0.981	-0.857	-0.523	0.291	1

3.6. Principal Component Analysis (PCA)

Further analysis of factor loadings showed that EC, TH, TDS, BOD, TA, Ca^{+2}, Mg^{+2}, Na^{+}, K+, HCO_3^-, Cl-, SO^{42-}, PO_4^{3-}, and NO_3^- were found to be the major factors affecting the water quality in the selected area (Table 5). For factor 1, EC, TH, TDS, Mg^{+2}, Na+, K^{+}, HCO_3^-, Cl^- and PO_4^- showed high positive loading value (> 0.9). These are the most significant variables for the first factor and were mentioned to be the most responsible variables for pollution loads in the Kondakarla Ava Lake during the study period. Factor 2 is heavily loaded with TA, BOD, Ca^{+2} and Na^{+}, reflecting the influence of organic matter that may have intruded from domestic and agricultural run-off. High positive loading of Ca^{+2} and Na^{+} confirms the discharge of agricultural run-off [30]. The third factor is highly loaded with SO_4^- and NO_3^-, which is attributed to agricultural run-off associated with excessive usage of organic and chemical fertilisers.

Thus, the water is heavily polluted with organic and inorganic pollutants which are attributed to agricultural run-off or the dumping of domestic wastewater into the lake. The lake is eutrophic (heavily flooded with algal blooms) and is one of the evident factors for its deterioration.

3.7. United States Salinity Laboratory (USSL) Diagram

A total reflection of the effect of SAR & EC on the quality of soil is determined by the USSL diagram. The USSL graph for the present study samples shows that samples 1, 2, 4, 5, and 6, which account for about 83.33 %, fall under C3S1 (low sodium and high salinity category), and sample 3, which represents 16.6 % of the samples, fall under C4S1 (low sodium and very high salinity category). Thus, this diagram (Fig 3) shows that this water can be used for irrigation purposes, with frequent leaching, good drainage, and intensive management support.

Table 5. Factorial loads of Kondakarla Lake

Variables	F1	F2	F3
pH	-0.3611	0.255	0.21
EC (µS/cm)	0.942	0.032	0.014
Total Hardness (mg/L)	0.911	0.047	-0.022
Total Alkalinity (mg/L)	0.122	0.957	-0.735
TDS (mg/L)	0.9238	-0.536	0.321
DO (mg/L)	-0.9404	-0.447	0.112
BOD (mg/L)	0.7957	0.957	-0.7431
Ca^{+2}(mg/L)	0.472	0.914	0.176
Mg^{+2}(mg/L)	0.969	-0.386	-0.623
Cl^-(mg/L)	0.9293	0.447	0.1373
HCO_3^- (mg/L)	0.9973	0.764	-0.361
SO_4^-(mg/L)	0.223	0.112	0.947
NO_3^-(mg/L)	0.321	0.258	0.918
PO_4^-(mg/L)	0.971	0.291	-0.112
Na^{+} (mg/L)	0.952	0.912	-0.551
K^{+}(mg/L)	0.982	0.345	0.1373

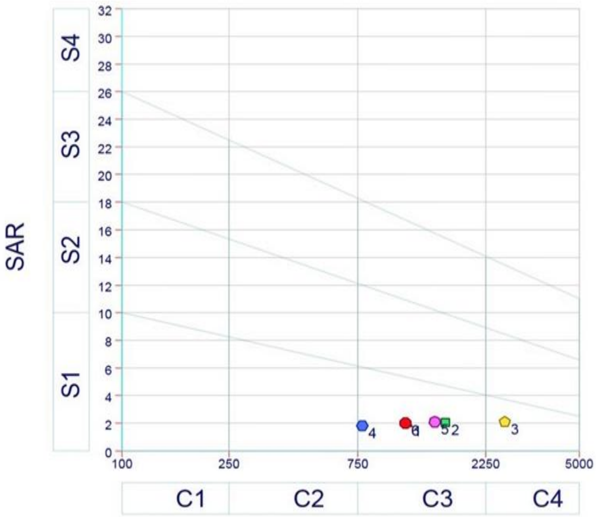

Figure 4. USSL Salinity diagrams indicating the classification of irrigation waters

3.8. Wilcox Diagram

Wilcox diagram represents the effect of % Na and EC on the soil and crops. As per the Wilcox classification (Fig 5), sample 4 falls under Excellent (16.66 %); samples 1,2, 5, and 6 (about 66.66%) fall under the good to permissible section, and sample 3 (16.66 %) fall under doubtful.

Thus, the study stated that as per the USSL diagram, the samples fall under highly saline to very highly saline, making them unsuitable for irrigation under normal conditions. In contrast, as per Wilcox classification, most samples drop below the good to permissible category.

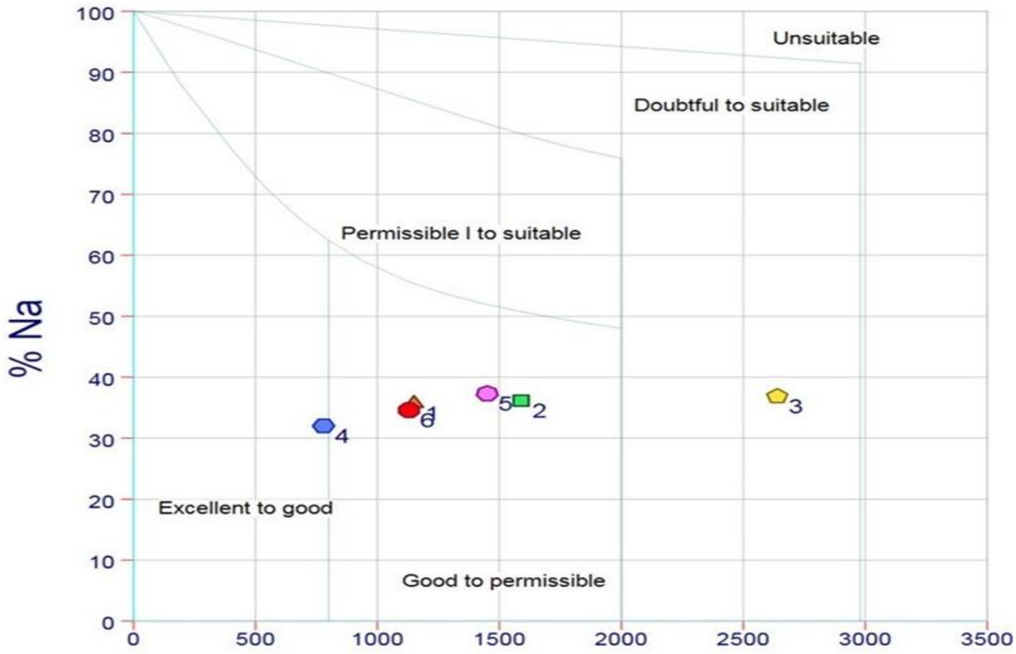

Figura 5. Wilcox diagram depicting the classification of irrigation water based on % Na and EC

4.CONCLUSION

The study aims in determining the suitability of the lake water of Kondakarla Ava of Visakhapatnam for human consumption along with irrigation. The study found that the water is unsuitable for drinking depending on the NSWQI values, as they range from medium to lousy category. Based on values of RSC, SAR, PI, % Na, and IWQI, all the samples were detected to be appropriate for irrigation. This evaluation was further supported by obtained OIP values, in which all samples fall under the excellent category. The statistical analysis, including Principal Component Analysis and correlation analysis, stressed the influence of agricultural run-off and wastewater discharge as the primary source of pollution loads. The values plotted on the USSL diagram showed that the samples of the Kondakarla Ava Lake fall under the categories C3S1 and C4S1, which indicates that they are low sodium hazards and high to very high salinity. The Wilcox diagram, on the other hand, shows that the samples fall under three categories excellent, good to permissible, and doubtful.

Acknowledgements

The authors thank Andhra University for providinglaboratory space for analysis.

5. REFERENCES

[1] [1] T.G.Kazi, M.B.Arain, M.K.Jamali, N.Jalbani, H.I.Afridi, R.A.Sarfraz, J.A.Baig, A.Q.Shah (2009) Assessment of water quality of polluted lake using multivariate statistical techniques: a case study. Ecotoxicol Environ Saf. Feb; 72(2), 301-9.doi: 10.1016/j.ecoenv.2008.02.024. Epub 2008

[2] [2] H.P.Jarvie, B.A.Whitton, C.Neal (1998) Nitrogen and phosphorus in east coast British Rivers: speciation, sources and biological significance. Sci Total Environ, 210(211), 79–109. https://doi.org/10.1016/S0048-9697(98)00109-0.

[3] [3] A.R.Karbassi, S.MMonavari, G.R.NabiBidhendi, J. Nouri, K. Nematpour (2008) Metal pollution assessment of sediment and water in the Shur River. *Environ Monit Assess,* **147**, 107–116. https://doi.org/10.1007/s10661-007-0102-8

[4] [4] A.H.Mahvi, J.Nouri, R.Nabizadeh, A.A.Babaei (2005) Agricultural activities impact on groundwater nitrate pollution. Int J Environ Sci Tech, 2(1), 41–47. [Online]. Available: https://doi.org/10.1007/BF03325856

[5] J.Nouri, A.H.Mahvi, G.R. Jahed, A.A.Babaei (2008) Regional distribution pattern of groundwater heavy metals resulting from agricultural activities. Environ. Geo., 55(6), 1337-1343. [Online]. Available: https://doi.org/10.1007/s00254-007-1081-3

[6] V.Simeonov, P.Simeonova, R.Tsitouridou (2004) Chemometric quality assessment of surface waters: two case studies. Eco ChemEng, 11(6), 449–469.

[7] V.S.Simeonov, J.Samara, C.Zachariadis, G.Voutsa, D.Anthemidis, A.Sofoniou, M.Kouimtzis (2003) Assessment of the Surface Water Quality in Northern Greece. Water research, 37, 4119-24.[Online]. Available:
https://doi.org/10.1016/S0043-1354(03)00398-1

[8] P.R.Chaudhari, D.V.Ahire, V.D.Ahire, M. Chakravarty, S. Maity (2013) Soil Bulk Density as related to Soil Texture, Organic Matter Content and available total Nutrients of Coimbatore Soil. Int. J. Scientific and Res. Publications, 3(2), 67-75.

[9] J.A.Herrera-Silveira, S.M.Morales-Ojeda (2008) Evaluation of the health status of a coastal ecosystem in southeast Mexico: Assessment of water quality, phytoplankton and submerged aquatic vegetation. Marine Pollution Bulletin, 59(1-3), 72-86. [Online]. Available:
https://doi.org/10.1016/j.marpolbul.2008.11.017.

[10] T.Poonam, B.Tanushree, C. Sukalyan (2015) Water quality indices-important tools for water quality assessment: a review.Int. J. Adv. Chem., 1(1), 15-28.

[11] K.S. Srivastava, L.A. Ramanathan (2008) Geochemical Assessment of Groundwater Quality in Vicinity of Bhalswa Landfill.Delhi; India by Using Graphical and Multivariable Statistical Methods. Environmental Geology, 53, 1509-1528.

[12] W.Dixon, B.Chiswell (1996) Review of Aquatic Monitoring Program Design. Water Research, 30, 1935-1948.

[13] C.R.Surakasi, S.H.Doke (2019) Assessment of groundwater quality in the vicinity of landfill site: A case study of Dhapa landfill site, Kolkata. Applied Water Science, 9(2), 42-49. Available: https://doi.org/10.1007/s13201-019-1088-1.

[14] K.Singh, A.Malik, D.Mohan, S.Sinha (2004) Multivariate Statistical Techniques of the Evaluation of Spatial and Temporal Variations in Water Quality of Gomti River (India) – A Case Study. Water research, 38, 3980-92.[Online]. Available: https://doi.org/10.1016/j.watres.2004.06.011.

[15] APHA (2005) Standard Methods for Examination of Water and Wastewater. American Public Health Association, Washington, D.C.

[16] Bureau of Indian Standards (BIS) (1998) Drinking water specifications (revised 2003) IS:10500.

[17] R.K.Horton (1965) An index number system for rating water quality. J Water Pollut. Control Fed., 37(3), 300-306.

[18] R.M. Brown, N.J. McClelland, R.A. Deininger, R.G. Tozer (1970) Avater quality index--Do we dare? Water and Sewage Works, vol. 117, p. 339.

[19] B.Oram (2012) Water Quality Index Calculator. Field Manual for Water Quality Monitoring, Pennsylvania, USA.

[20] A. Sargaonkar, V. Deshpande (2003) Development of an Overall Index of Pollution for Surface Water Based on a General Classification Scheme in Indian Context. Environmental monitoring and assessment, 89, 43-67.[Online]. Available:
https://doi.org/10.1023/A:1025886025137

[21] L.M. Richards (1954) Diagnosis and Improvement of Saline and Alkaline Soils. Agriculture Handbook, No. 60, US Salinity Laboratory, USDA.

[22] L.D.Doneen (1964) Water quality for agriculture. Department of Irrigation, University of California, Davis.

[23] R.S.Ayers, D.W.Westcot (1999) The water quality in agriculture. 2nd ed., UFPB, FAO Irrigation and drainage, Campina Grande.

[24] R.S.Ayers and D.W.Westcot (1985) Water Quality for Agriculture. FAO Irrigation.

[25] N. Bhat, A. Bhat, S. Nath, B. Singh, D. Guha (2016) Assessment of Drinking and Irrigation Water Quality of Surface Water Resources of South-West Kashmir, India. Journal of Civil & Environmental Engineering, 6, 78-85.

[26] R.M.Garrels (1976) Survey of Low Temperature Water Mineral Relations in Interpretation of Environmental Isotope and Hydrogeochemical Data in Groundwater Hydrology, Vienna, International Atomic Energy Agency, p. 65–84.

[27] P.Datta, S.Tyagi (1996) Major ion chemistry of groundwater in Delhi area: Chemical weathering processes and groundwater flow regime. Journal of the Geological Society of India, 47, 179-188.

[28] C.N. Sawyer, P.L. McCarty (1978) Chemistry for Environmental Engineering. 3rd ed., McGraw-Hill Book Co., New York.

[29] S.K. Singh, P.K. Srivastav, D. Singh, D. Han, S.K. Gautam, A.C. Pande (2015) Modeling ground water quality over a humid subtropical region using numerical indices, earth observation datasets and X ray diffraction techniques, A case study of Allahabad district India. Environmental Geochemical Health, 37(1), 157–180.

[30] H. Juahir, S.M. Zain, M.K. Yusoff, T.I.T. Hanidza, A.S.M. Armi, M.E. Toriman, M. Mokhtar (2011) Spatial water quality assessment of Langat River basin (Malaysia) using environmetric techniques. *Environ. Monit.Assess.*, 173, 625-641.

[31] K.S. Srivastava, L.A. Ramanathan (2008) Geochemical Assessment of Groundwater Quality in Vicinity of Bhalswa Landfill.Delhi; India by Using Graphical and Multivariable Statistical Methods. Environmental Geology, 53, 1509-1528.

IZVOD

KUMULATIVNI PRISTUP ZA PROCENU KVALITETA POVRŠINSKE VODE JEZERA KONDAKARLA AVA, VISAKHAPATANAM, INDIJA

Globalni rast stanovništva vrši pritisak na slatkovodneresurse. Slatkovodni resursi postaju sve oskudniji u pogledu količine I kvaliteta zbog rastuće potražnje. Procena kvaliteta vode površinskih vodnih tela za navodnjavanje je od suštinskog značaja jer voda lošeg kvaliteta može predstavljati rizik po zdravlje. Studija je uključivala posmatranje fizičko-hemijskih parametara jezera Kondakarla Ava sa šest različitih lokacija za uzorkovanje. Studija je otkrila da se ne može koristiti direktno za piće prema NSFVKI. Prema parametrima kao što su RSC, SAR, PI, % Na I IVKI, kvalitet vode je odgovarajući za navodnjavanje. Dodatno je ojačan USSL dijagramom koji pokazuje da uzorci jezera Kondakarla Ava spadaju u kategorije C3S1 I C4S1, što ukazuje da vodaima nisku opasnost od natrijuma i visok do veoma visok salinitet. Vilcok dijagram je pokazao grupisanje uzoraka u tri kategorije: odlično, dobro do dozvoljeno I sumnjivo.
Ključnereči: *eutrofikacija, Potabiliti, Indeks kvaliteta vode, Ukupan indeks zagađenja, Glavni analiza komponenti, Navodnjavanje*

Naučni rad
Rad primljen: 17.04.2024.
Rad prihvaćen: 22.05.2024.

The ORCID Ids of all the authors are as follows:
1. Dr Madhavi Earle: https://orcid.org/000-0001-9945-0201
2. Dr SirishaKorrai: https://orcid.org/0000-0002-7215-8128
3. Dr B. VinaySagar: https://orcid.org/0009-0004-4522-9084
4. Sangeetha S Achanta: https://orcid.org/ 0009-0002-6342-1251
5. HemanshuMediboyana: https://orcid.org/ 0000-0002-0324-6909