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WATER QUALITY EVALUATION USING WEIGHTED ARITHMETIC INDEX METHOD IN THE VERI DAM OF GONDAL TALUKA, RAJKOT, GUJARAT INDIA

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ABSTRACT

Surface water quality plays a very important role in irrigation, domestic uses, drinking water supply and groundwater protection through recharge. An effort has been made to comprehend the water quality of Veri dam with the help of its water sampling, and their chemical analysis. The assessment of physiochemical parameters of dam water samples for drinking purpose, irrigation and municipal supply in urban city areas has been made using Weighted Arithmetic Quality Index. The present study was undertaken to evaluate the water quality of the Veri dam which located in the Gondal taluka of Rajkot District, Gujarat; and aerial extent lies between 22° 09' 33.05'' to 21° 53' 11.01'' North and 70° 44' 58.01'' to 70° 57' 38.29'' East. To collect the water samples an integrated method of sample collection was performed. Total 8 number of water sample collected during pre (March to May months) and post (September to November months) monsoon period of the year 2024. Temporal analysis of total 21 physio-chemical parameters were determined. Three parameters such as EC, pH and TDS were measured on site using digital and multifunctional water quality tester. The laboratory works for the others parameters were performed at P.G. Research Lab. Dept. of Agril. Chem. and Soil Sc., Junagadh Agricultural University, Junagadh, Gujarat. The determined analytical findings were compared with that of the permissible limit recommended by IS 10500:2012 (BIS, 2012). The study findings revealed that WQI values were found 38.31 & 49.94that defines the good quality condition of water during the pre- and post-monsoon seasons. From the study, it was also inferenced that the post monsoon water quality is going toward to poor condition that is the matter of concern.

***Key words*:**Surface water quality, Weighted arithmetic method, Veri or Sureswar dam

Introduction

Water is a critical resource for sustaining life, and its quality significantly influences ecosystem health, agricultural productivity, and human well-being. It is elixir of life, which is one of the most essential ingredients in multifarious facets of human life. The water resources have finite limits. It could be lost to contaminations and over exploitation as the ever-increasing population and industrial development, which will employ various pressure on the existing water resources (Bouwer, 1978; Pophare, 2019). Anthropogenic activities continue disturb our water quality; it remains a major problem globally (particularly concerning freshwater and human consumption) (Akhtar *et al.*, 2021). India is divided into twenty river basins. Each river that starts flowing meets at sea point. Out of twenty river basins, Ganga and Brahmaputra are the biggest and their surface water potential is 525 and 585 cubic km per year respectively, while Sabarmati has smallest 3.81 cubic km per year. Narmada river has 45.64 cubic km per year surface water potential. The total geographical area of Gujarat is 19.6 Mha which is 6 percent of the country. Out of the total, 9.5 Mha is under cultivation. There is a large scope and need for soil and water conservation measures in the state. The total population of the state is 6 crores according to 2011 census. From this 57.4 percent lives in villages and is closely related with agriculture (Patil *et al.*, 2009). Most of the watershed being ungauged, the availability of past records of rainfall, runoff, water quality, sediment and other required information are generally not available. In this situation, ungauged watershed remains unstudied by the researchers because of lack of good quality data as it becomes very difficult to develop working relationships between various variables for their assessment and use the available information in developing adequate and effective planning process. Dams are play a crucial role in water storage and management, particularly in regions with uneven rainfall distribution. However, these structures also alter natural water flow patterns, affecting water quality through sedimentation, nutrient accumulation, and biological processes. Understanding the water quality of dams is therefore essential to ensure their sustainable management and optimize their usage for drinking water supply, agriculture, and hydroelectric power generation. Globally, several studies have highlighted the pressing need to monitor and evaluate the water quality of dams. For instance, a study in the USA's Lake Mead dam revealed concerns about nutrient enrichment and algal blooms caused by anthropogenic activities and natural processes (Bennett *et al.*, 2013). Similarly, in Brazil, studies have demonstrated the impacts of sedimentation and organic matter decomposition on water quality in dams used for hydroelectric projects (Tundisiand Matsumura, 2008). In India, dams are critical for water resource management due to the country's dependency on monsoon-driven precipitation. Studies conducted on the Hussain sagar lake in Hyderabad and the Umiamdam in Meghalaya have shown the impact of urbanization, agricultural runoff, and industrial effluents on water quality. These studies emphasize issues such as elevated levels of nutrients, heavy metals, and biological contaminants, highlighting the urgent need for comprehensive water quality assessments and remedial measures (Reddy *et al.*, 2018; Lahon*et al.*, 2020). Despite significant research efforts, many dams in India remain understudied, particularly in terms of spatial and temporal water quality variations. This paper's prime thrust to analyze the water quality variability, examining key physio-chemical parameters and their variations across pre and post monsoon seasons. By the current findings, this study aims to provide insights into the factors influencing water quality and offer recommendations for sustainable management practices.

Material and Methods

Study Area Description

Gondal is largest taluka or tehsil followed by Upleta and Jetpur (in area wise) and falls under Rajkot district, Gujarat. Gondal is a city of about 1,15,000 residents; and about 1,75,000 municipality. The Veri dam or reservoir lies between aerial and elevation extent between 22° 09' 33.05" to 21° 53' 11.01" North & 70° 44' 58.01" to 70° 57' 38.29" East, and 255m to 107m resp. in the Gondal taluka. The dam receives averagely 650 mm of rainfall annually. Shallow to medium black calcareous and loamy soils are dominant (NABARD_PLP report, 2024). Generally, the electrical conductivity (EC) of the soils is less than 1.0 millimhos/centimeter and cation exchange capacity (ECE) varies between 30 and 35 me/100 grams of soil (Mohapatra, 2013). The dam also comes under the catchment area of Bhadar river basin which drains into it. The water of the dam firstly diluted into the Bhadar-I dam at Bandra village which has immense capacity in the Bhadar river catchment of Rajkot district, Gujarat. The outlet of dam drains into Bhadar river and works as its tributary system. The dam supplies the water to the

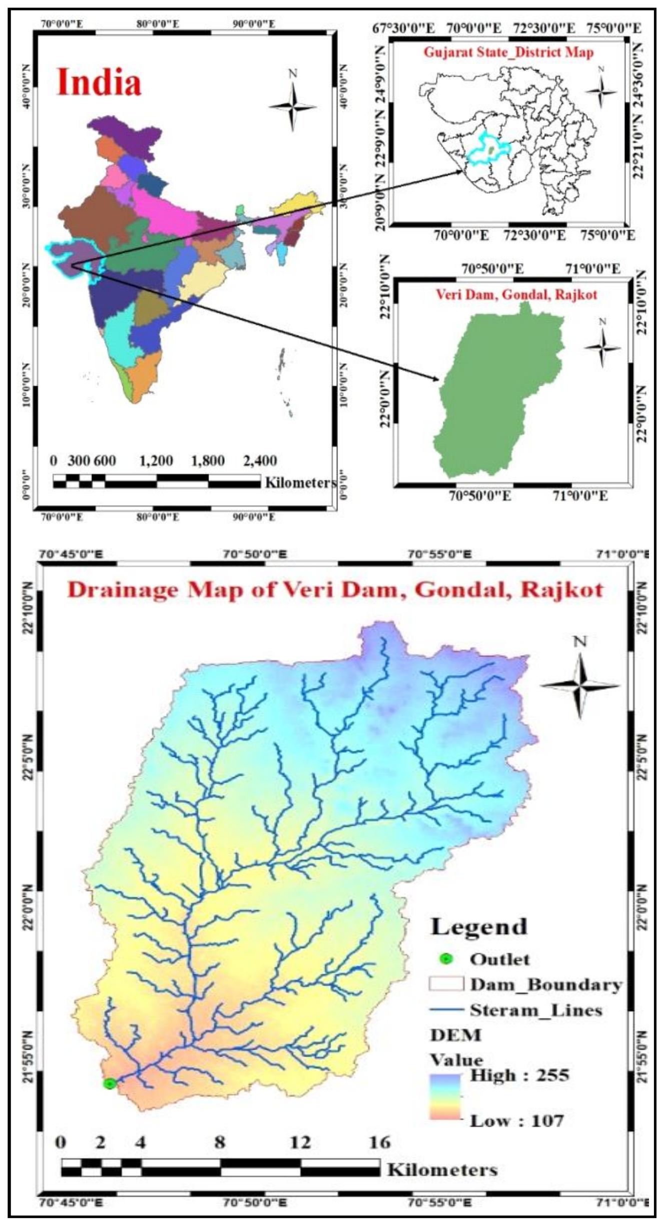

Fig. 1: Study area and drainage map.

Table 1: Salient feature of Veri dam, Gondal, Rajkot.

Sr. No.	Name of Irrigation Project	Veri Irrigation Project
1	River name	Veri river
2	Location	21° 59' 58.6' North Latitude 70° 48' 29.4' East Longitude
3	Total catchment area	178.42 sq. km
4	Grass Dam Capacity	4.59 M cum.
5	Live dam capacity	10.88
6	Top of Dam R.L.	145.58 m
7	H.F.L. R.L.	143.41 m
8	F.R.L.	142.04 m
9	Average annual rainfall	650
10	Maximum rainfall	1393 mm
11	Minimum rainfall	248 mm
12	**Earthen Dam Details:**	
a	Length	2383.54 m
b	Top of Dam in R.L.	145.58 m
c	Free Board	2.17 m
d	Maximum height from ground level	3.58 m
13	Water Supply for irrigation	Grass command area
14	**Masonry Dam Details:**	
a	Observed Maximum Flood Discharge	574.23 M cum.
b	Maximum Flood Discharge of Spillway	1642.36 $Meter^3$/Sec.

municipal corporation of Gondal Taluka for the drinking purposes in urban areas as well as releases water into the canal distributaries for the irrigation purposes to grow the agricultural crops in gross command area during the summer season period. Thus, dam uses for dual purposes and also contribute in ground water recharge. Veri dam receive water from Vachhapari and Gondali dams which are located in its upstream side. Gondaltaluka is renowned for its own chilli production (NABARD_PLP report, 2024). Some salient features are given below Table 1.

Collection of Surface Water Samples

Water sample collection practices were decided to collect during the pre and post monsoon period of the year 2024. The dam was considered as a trend station; and integrated method of water sample collection was done as per reported guidelines of Central Water Commission (CWC, 2020). During the pre-monsoon three times (once in a month) samples were collected between March to May, 2024 whereas in the post-monsoon twice in a month decided to collect between September to November, 2024. Total 8 number of samples were collected. For the laboratory work, the collected water samples were filter using 45 & 42 no. of Whatman filter paper to remove the foreign materials. The filtration practice was performed to prevent the choaking issue of thin tube or nebuliser of the analyser instrument.

Fig. 2: Water sample collection, water filtration and preservation work (left to right side).

Table 2: Standard guideline to determine the water quality parameters.

Sr. No.	Parameters	Method	Instrumentation	Reference
Primary Parameters				
1	pH	Electrode method	Model No. BLE-9908, Gaby Digital Water Quality Tester	Sorensen (1909), EPA (1993)
2	Electrical Conductivity (EC)	Electrode method		Kohlrausch (1879), ASTM D:1125-23
3	Total Dissolve Solids (TDS)	Electrode method		Rhoades (1976)
4	Temperature	Thermometric		EPA (1974)
5	Carbonate (CO_3)	Titration	Glassware	BIS (2023), APHA (2017)
6	Bi-carbonate (HCO_3)	Titration	Glassware	BIS (2023), APHA (2017)
7	Calcium (Ca)	Complexometric method	Glassware	BIS (2009), APHA (2017)
8	Magnesium (mg)	Complexometric method	Glassware	BIS (2009), APHA (2017)
9	Sodium (Na)	Flame Photometer	Model No. CL-378, Elico Company, Telangana, India	BIS (1993), Jackson (1973)
10	Potassium (K)	Flame Photometer		BIS (1993), Jackson (1973)
11	Total Suspended Solids (TSS)	Filtration and Gravity method	Hot Air Oven	BIS (1985)
12	Total Alkalinity (TA)	Derived Parameters		Gran (1952)
13	Sodium Adsorption Ratio (SAR)			Richards (1954)
14	Potassium Adsorption Ratio (PAR)			Richards (1954)
15	Magnesium Adsorption Ratio (MAR)			Szabolcs and Darab (1964)
16	Residual Sodium Content (RSC)			Eaton (1950)
17	Total Hardness (TH)			Clark (1865)
18	Soluble Sodium Percentage (SSP)			Wilcox (1955)
19	Exchangeable Sodium Percentage (ESP)			Richards (1954)
20	Percent Sodium (SP)			Wilcox (1995)
21	Permeability Index (PI)			Doneen (1962), Domenico and Schwartz (1990)
22	Kelly's Ratio (KR) or ESR			Kelly (1963)

Analysis ofPhysiochemical Parameters

On-site measurement

Primary water quality parameters such as Electrical conductivity (EC) (accuracy ±2%F.S.), Total Dissolve Solid (TDS) (accuracy ±2%F.S.), Temperature (accuracy ±0.5°), and pH (accuracy ±0.05pH) were measured during the samples collection using Digital Multifunctional Water Quality Tester with model no. Yinmik BLE-9908, manufactured by Gaby Instruments, Pvt. Ltd. Coimbatore, Tamil Nadu, India.

Laboratory analysis

The laboratory work of field collected water samples was performed in P.G. Research Laboratory at

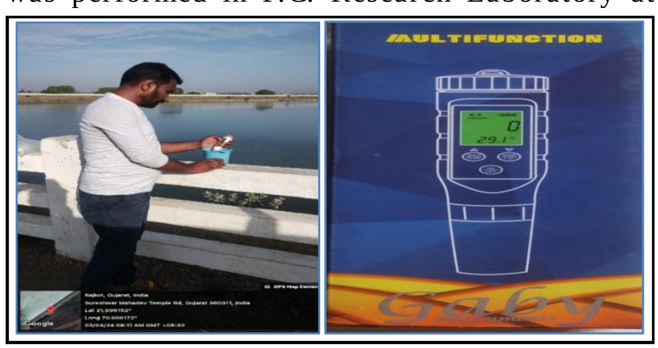

Fig. 3: On-site measurement of primary quality paramters.

Table 3: The assigned unit weight of each parameter, and Pre and Post monsoon WQI value.

Para-meters	s_i	$1/s_i$	$W_i=k/s_i$	Sub-Index Value	
				Pre-monsoon WQI	Post monsoon WQI
EC	3000	0.0003	0.000143	0.0020	0.0036
TDS	2000	0.0005	0.000215	0.0023	0.0041
Na	200	0.0050	0.002148	0.0334	0.0577
K	12	0.0833	0.035794	0.2685	1.0440
CO3	400	0.0025	0.001074	0.0063	0.0048
HCO3	600	0.0017	0.000716	0.0266	0.0241
Ca	200	0.0050	0.002148	0.0373	0.0665
Mg	100	0.0100	0.004295	0.0748	0.1618
TA	600	0.0017	0.000716	0.0294	0.0262
TH	600	0.0017	0.000716	0.0062	0.0119
SAR	30	0.0333	0.014318	0.2906	0.3615
RSC	200	0.0050	0.002148	0.2089	0.1293
% Na	100	0.0100	0.004295	0.1617	0.1539
SSP	50	0.0200	0.008591	0.6359	0.5903
ESP	100	0.0100	0.004295	0.1574	0.1442
PAR	1	1.0000	0.429526	7.3910	21.5617
MAR	100	0.0100	0.004295	0.0015	0.0016
(PI)	100	0.0100	0.004295	0.2373	0.1887
KR	1	1.0000	0.429526	25.6185	23.0599
pH	8.5	0.1176	0.050532	3.1152	2.3471
TSS	2000	0.0005	0.000215	-	0.0007
$\Sigma 1/s_i$		2.3281	ΣW_i=1.00	WQI (ΣSl_i) =38.31	WQI (ΣSl_i) =49.94
K = $1/\Sigma(1/s_i)$		0.4295	*All parameters value in mg/L except pH and EC*		

Department of Agricultural Chemistry and Soil Science, Junagadh Agricultural University, Junagadh, Gujarat. The physio-chemical analysis was performed using following standard methods or guidelines reported by distinct scientist and agencies:

Water quality index (WQI)

In the present study, all the quality parameters (except trace or heavy metal) were selected to calculate the water quality index. The WQI has been determined using the standards permissible limit of drinking water quality recommended by Bureau of Indian Standard (BIS, 2012), World Health Organization (WHO 1992) and Indian Council for Medical Research (ICMR1975). The weighted arithmetic index method (Brown *et al.*, 1972) has been implemented for the analysis of WQI of the water. The following steps are involved in WQI determination.

Weightage factor (W_i)

Firstly, there is need to assigned weight (w_i) of the individual parameter in according to its significance in the drinking water quality (Table 4). This weightage is completely based on the standard value of individual parameter reported by distinct agencies such as BIS (2012), WHO (1992), ICMR (1975) etc. The weightage factor is calculated by following formula:

Table 4: Description of acceptance degree of water.

Classes	Range of WQI	Acceptance degree of Water
Class – 1	0-25	Excellent
Class – 2	26-50	Good
Class – 3	51-70	Poor
Class – 4	71-90	Very poor
Class - 5	>100	Not consumable
		Brown *et. al.* (1972)

$$W_i = {w_i}/{\sum_{i=1}^{n} w_i} \text{ or } {k}/{s_i} \quad (1)$$

$$w_i = \frac{k}{s_i} \quad (2)$$

Where,

W_i= Relative weight,

w_i= Weight of each parameter and

n = Number of parameters

s_i= Permissible or standard value of individuals parameter,

k = $1/\Sigma s_i$.

Calculation of quality rating / sub index (q_n)

Quality rating is calculated by the following equation:

$$(Sub\ Index)q_n = \frac{Measured\ value\ (m_i) - Ideal\ value\ (v_i)}{Standard\ value\ (s_i) - Ideal\ value\ (v_i)} \times 100 \quad (3)$$

(Let there be n water quality parameters and quality rating or sub index (q_n) corresponding to n^{th} parameter is

Fig. 4: Laboratory work at PG Research Lab., Dept. of Agril. Chem. & Soil Sc., JAU, Junagadh, Gujarat.

Table 5: Statistical analysis of physio-chemical parameters.

Parameters	Mean ± St. Dev.	Max.	Min.	CV (%)
EC	599.5 ± 217.30	891.5	408	36.24
TDS	299.5 ± 108.54	445.5	204	36.24
pH	8 ± 0	8.71	7.77	4
CO_3	20 ± 10.95	40	10	54.77
HCO_3	212.5 ± 18.90	240	185	8.89
Ca	49.66 ± 20.15	78.05	26.05	40.57
Mg	27.34 ± 13.65	48.60	8.51	49.94
Na	42.6 ± 17.19	70	21.9	40.0
K	2 ± 1	4.15	0.5	70
TSS	61.67 ± 4.73	67	58	7.66
TA	232.5 ± 21.85	260	205	9.39
TH	76.99 ± 29.92	113.29	48.7161	38.86
RSC	155.50 ±45.97	210.85	96.71	29.57
%Na	36.59 ± 4.4	42.63	31.31	12.00
SAR	6.8 ± 1.69	9.46	4.42	25
PAR	0.33 ± 0.19	0.56	0.10	60.47
MAR	35.54 ± 11.84	46.99	14.52	33.31
SSP	35.56 ± 4.57	42.29	30.83	12.84
ESP	35.00 ± 4.59	42.04	30.50	13.14
PI	49.36 ± 7.02	59.46	41.29	14.23
KR or ESR	0.56 ± 0.12	0.73	0.46	20.59

a number in the polluted water with respect to its standard permissible value).

Where,

q_n = Quality rating for the n^{th} Water quality parameter.

v_i= All the parameter has zero '0' ideal value except pH = 7 and Dissolve Oxygen 14.6 mg/L (Dhanush *et al.*, 2024).

WQI calculation

For measuring the WQI, sub-index is first calculated for each parameter using the following equation:

$$Sl_i = q_n \times W_i \quad (4)$$

Where,

SI_i =Sub-index of i^{th} parameter,

q_n=Sub rating based on concentration of i^{th} and

n = Number of parameters.

The overall water quality-index (WQI) was figured by adding together each sub-index value of each groundwater sample as follows (Pandey *et al.*, 2020):

$$WQI = \sum Sl_i \quad (5)$$

Computed WQI values were classified into 5 categories mentioned in given below Table 3.

Results and Discussion

Quality Parameters ofDam Water

Electrical conductivity (EC)

EC defines the available concentration of salt in water. It measures a water sample's ability to carries electricity, reflecting the concentration volume of dissolved ions such as sodium, calcium, and chloride. It is a critical indicator, with WHO guidelines suggesting permissible EC levels below 1500 µS/cm safe for drinking purposes.

Table 6: Correlation matrix analysis between Veri dam water quality parameters.

	EC	TDS	pH	Na	K	CO3	HCO3	Ca	Mg	TSS	TA	TH	SAR	RSC	% Na	SSP	ESP	PAR	MAR	PI
EC	1.00																			
TDS	1.00	1.00																		
pH	-0.38	-0.38	1.00																	
Na	0.93	0.93	-0.57	1.00																
K	0.81	0.81	-0.33	0.81	1.00															
CO3	-0.28	-0.28	-0.44	-0.21	-0.42	1.00														
HCO3	-0.31	-0.31	-0.27	-0.24	-0.47	0.00	1.00													
Ca	0.83	0.83	0.04	0.79	0.80	-0.65	-0.48	1.00												
Mg	0.91	0.91	-0.56	0.80	0.73	-0.03	-0.15	0.55	1.00											
TSS	0.43	0.43	-0.99	0.69	0.99	0.67	0.79	-0.28	0.84	1.00										
TA	-0.41	-0.41	-0.45	-0.32	-0.62	0.50	0.87	-0.74	-0.15	0.94	1.00									
TH	0.98	0.98	-0.23	0.90	0.87	-0.45	-0.39	0.92	0.83	0.28	-0.57	1.00								
SAR	0.74	0.74	-0.72	0.92	0.62	0.05	-0.17	0.57	0.62	0.79	-0.12	0.67	1.00							
RSC	-0.83	-0.83	-0.06	-0.74	-0.86	0.53	0.67	-0.95	-0.61	0.73	0.84	-0.92	-0.49	1.00						
% Na	-0.02	-0.02	-0.60	0.30	-0.06	0.51	0.01	-0.11	-0.09	0.95	0.27	-0.11	0.65	0.20	1.00					
SSP	-0.07	-0.07	-0.58	0.24	-0.16	0.55	0.09	-0.18	-0.13	0.91	0.35	-0.18	0.60	0.28	0.99	1.00				
ESP	-0.10	-0.10	-0.56	0.20	-0.21	0.57	0.12	-0.22	-0.15	0.88	0.39	-0.22	0.56	0.33	0.98	1.00	1.00			
PAR	0.69	0.69	-0.27	0.71	0.98	-0.44	-0.51	0.75	0.60	0.82	-0.66	0.78	0.54	-0.82	-0.06	-0.17	-0.23	1.00		
MAR	0.17	0.17	-0.47	0.02	-0.09	0.60	0.24	-0.37	0.53	1.00	0.51	-0.01	-0.02	0.25	-0.13	-0.09	-0.06	-0.20	1.00	
PI	-0.74	-0.74	-0.19	-0.53	-0.80	0.62	0.52	-0.82	-0.62	0.99	0.77	-0.84	-0.19	0.91	0.57	0.64	0.67	-0.76	0.08	1.00

Increases EC can indicate salinity or contamination from industrial effluents, agricultural runoff, or sewage, impacting human health, aquatic ecosystems, and irrigation. The observed data in Fig. 5(a) defines highest value (891.5 mg/L) was observed in October, 2024 (post-monsoon) while lover concentration (408 mg/L) was found in the month of May, 2024 (pre-monsoon). The trend line analysis represents a linear increment in the EC value with $R^2 = 0.75$. There is a slight decline was observed in the month of May, 2024, possibly due to monsoon rains diluting salinity. The standard deviation (SD in ±) and co-efficient of variation (CV in %) and mean values were calculated 217.3, 36.25% and 599.5 respectively. High EC denotes potential contamination risks, highlighting the necessity of regular monitoring, pollution control, and sustainable water management to ensure the quality of water resources.

Total dissolve solids

TDS represents the concentration of diluted inorganic and organic substances in water, often representing overall water salinity. Fig. 5(b) showcases a steady increase from March 2024 (229 mg/L) to October 2024 (445.5 mg/L), followed by a slight decline in November (422 mg/L). This trend ratiocinates evaporation during the dry period and dilution from monsoon rains; while TDS below 500 mg/L is acceptable for drinking higher levels *i.e.,* 2000 mg/L (Table 4) (as per BIS, 2012), may affect taste and long-term usability for domestic and agricultural purposes. An increasing nature of trendline were identified in the graph with $R^2=0.75$, which defines on raising the months, the concentration of TDS also enhancing. The outcome shows the TDS values of every month was under the permissible limit of the BIS Standard. The value of mean, SD and CV were determined 299.5, 108.54, and 36.24% respectively.

The pH of an aqueous solution is the measure of acidic or basic capacity. The pH of a solution can be determined by using the concentration of hydrogen ion concentration. pH measures the acidity or alkalinity of water, crucial for determining its usability and environmental health. The mean value calculated as 8; and CV was found 4%. There is no deviation found in the parameter outcomes with $R^2=0.0008$. Fig. 5(c) represent the observed pH levels which were varied from 8.22 to 8.71 in both monsoon periods, indicating slightly alkaline conditions, except for October 2024 (7.76), where it approaches neutral. Generally, the ideal value of water considered as 7 that defines the neutral condition. pH levels outside the recommended range of 6.5 to 8.5 (BIS, 2012 and WHO, 2024) can harm aquatic life and reduce water suitability for drinking and irrigation. During the post-monsoon period in the month of November 2024, the value of pH was found beyond the permissible limit (Table 4). Regular monitoring is necessary to ensure pH remains within a safe range for maintaining ecological balance and usability.

Carbonate (CO_3)

CO_3 concentration reflects the buffering capacity of water, which helps maintain pH stability. Fig. 5(d) shows the graphical representation, depicts a decline signature of parameter concentration in dam water during trend analysis. The value of coefficient of determination (R^2) was found 0.47. The highest concentration of CO_3 was calculated 40 mg/L in the month of March, 2024 during pre-monsoon season while the lowered concentration measured in the month of November, 2024 during post-monsoon season. The mean, SD and CV values were determined 20, 11 & 54.8% respectively.

Bicarbonate (HCO_3)

HCO_3 is a chief component of alkalinity, regulating pH and buffering against acidity. The observed data shows in Fig. 5(e) fluctuating levels, a lowest and highest values were observed during the month of October, 2024 (post-monsoon) and April, 2024 (pre-monsoon) respectively. CV and SD were calculated 8.9% and 18.9 resp. The mean value was estimated as 213 which reflects the availability of concertation under permissible limit as reported by BIS and WHO. Trendline analysis present a slight inclination signature with $R^2=0.17$ that defines reducing concentration of the parameter in the dam.

Calcium hardness (Ca)

Ca is available in divalent cations (Pandey *et al.,* 2020). Due to presence of higher concentration, the water causes abdominal ailment and encrustation (Kumar *et al.,* 2014). Ca is a crucial component of water hardness, influencing its usability for domestic, agricultural, and industrial purposes. In the current study the Ca concentration ranges from 26.05 to 78.05 mg/L (Fig. 5f) which are under the permissible limit of 200 mg/L (Table 4).

Magnesium hardness (Mg)

Mg an essential mineral, contributes to water hardness and is immense role for aquatic ecosystems. Mg hardness was measured from the difference between the total hardness and the calcium hardness which is expressed in mg/l or ppm. In the current study the hardness of Mg ranges from 8.51 mg/L (May, 2024) to 48.61mg/L (October, 2024) which are under the permissible limit of 100 mg/L. Trendline in the Fig. 5(g) is showing increasing nature of concentration (R^2=0.44) on increasing the month duration.

Sodium (Na)

Na significantly influences water salinity and its suitability for drinking and irrigation. Fig. 5(h) shows a graphical representation of measured concentration of Na of both monsoon periods from which it is inferences that the higher concentration was in the month of October, 2024 (21.9 mg/L) while lower concentration in the month of April, 2024 (70 mg/L). The outcome result showcases Na concentration are under permissible limit of 12 mg/L (Table 4).

Potassium (K)

Kis a minor but essential nutrient for plants, influencing

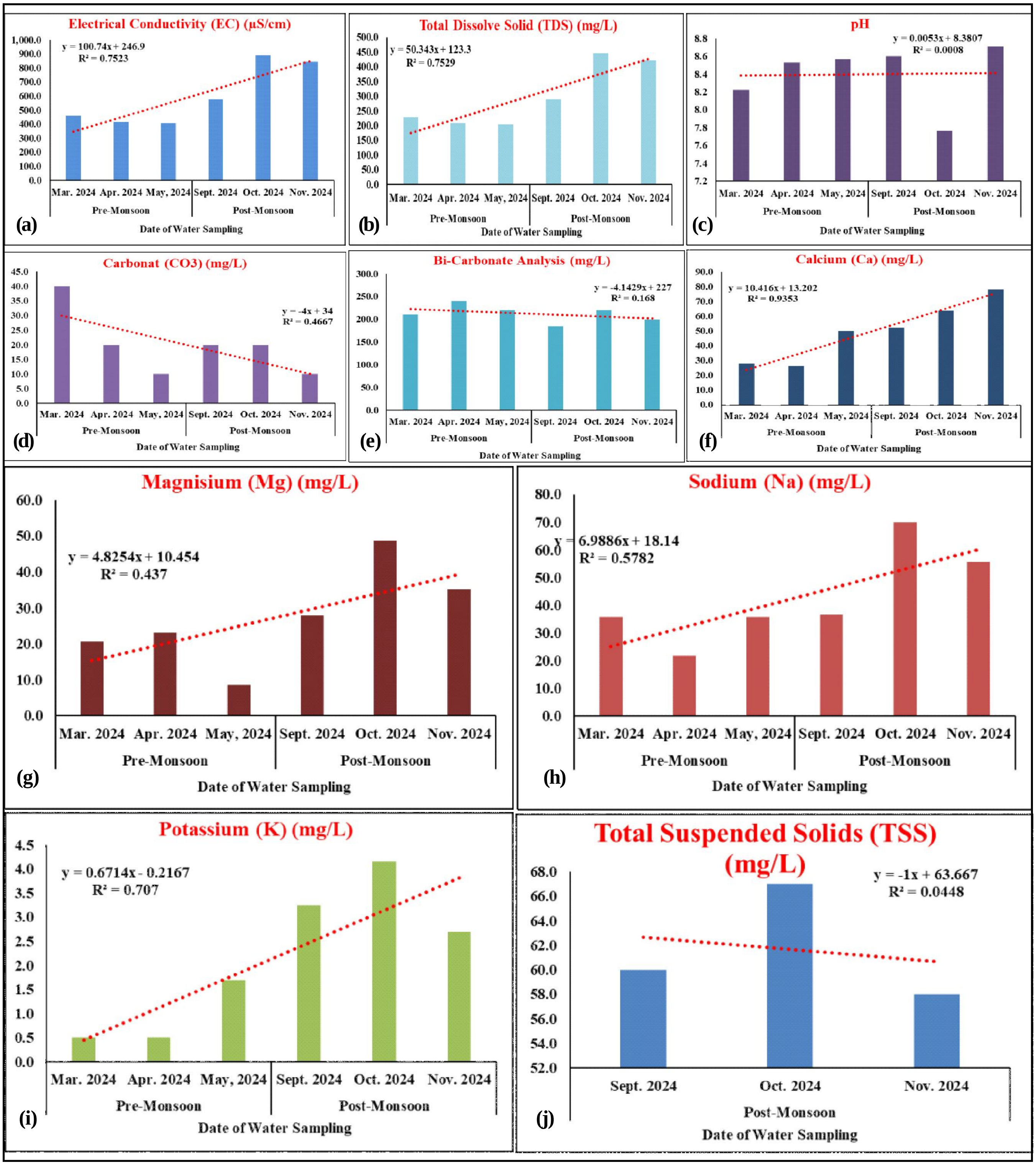

Fig. 5 (a to j): Graphical presentation of different observed parameter concentration **[General parameters].**

water quality and crop health. The observed data in Fig. 5(i) shows k levels rising from 0.5 mg/L (March, 2024) to 4.2 mg/L in October, followed by a decline to 2.7 mg/L in November, 2024; are under BIS maximum allowable concentration of 12 mg/L (Table 4). This increasing signature may result from agricultural runoff or leaching from potassium-rich soils.

Total suspended solids (TSS)

TSS measures the concentration of dissolved solids in water, including salts, minerals, and organic matter, impacting water clarity, quality, and suitability for various uses. High TSS levels can reduce light penetration in water bodies, affecting aquatic plant growth and disrupting ecosystems. For drinking water, TSS levels above 500 ppm are undesirable. In the Veri dam samples, TSS in the Fig. 5(j) showed fluctuations, with a peak of 67 mg/L October, 2024, which may reflect seasonal changes or anthropogenic influences. Elevated TSS levels can also indicate pollution or erosion in the catchment area, suggesting a need for water quality management to protect aquatic life and maintain water usability.

Total alkalinity (TA)

The buffering capacity of a water body is known as alkalinity. Its determinates the ability of water bodies to neutralize acids and bases thereby maintaining a moderately stable pH. During the study, the high and low concentration of TA were observed 260 mg/L (April, 2024) & 205 mg/L (September, 2024) resp. Fig. 5(k) reflects the trendline analysis that defines a slight decline concentration in the dam. Concentration of TA was observed under permissible limit of 600 mg/L.

Total hardness (TH)

TH hardness is a very critical parameter representing the total diluted concentration of calcium and magnesium ions in water. In general, hard waters create in realm where the top soil is thick and limestone formations are dominant (Arumugam 2010). In the present study hardness varied between 113.29 to 48.7161 mg/l (as shown in Fig. 5(l)) which are within the permissible limits (600 mg/l) (Table 4).

Residual sodium carbonate (RSC)

RSC measures water quality by juxtapositioning carbonate and bicarbonate levels against calcium and magnesium levels. High RSC can lead to soilsodicity, which harms soil structure and limits plant growth by decreasing soil permeability. The safe RSC range is typically below 1.25 meq/L for irrigation (Ayers and Westcot, 1985). The high value of RSC was found during the month of April, 2024 (210.86 mg/L) in pre-monsoon period demonstrates a significant spike while lowest was in the month of October 2024 (96.71 mg/L) in post monsoon period. A decline signature of trendline was seen in the Fig. 5(m). The RSC concentrations were seen under permissible limit (table 4). The high value of RSC indicates a potential risk of soil alkalinity issues if this water is release for irrigation.

Percent sodium (%Na)

In the present study, concentration of %Na was calculated 42.63% (March, 2024) to 31.31% (April, 2024). The both level of parameter concentration were identified in the pre-monsoon season. Fig. 5(n) shows the decreasing order of trendline in the both monsoon seasons that demonstrate the value are retains in permissible limit (Table 4).

Sodium adsorption ratio (SAR) or Sodicityindex

Sodicity is an important indicator of water's suitability for irrigation, representing the ratio of sodium ions to calcium and magnesium ions in water. For irrigation purpose, suitability of surface water has been checked introducing the SAR analysis. Fig. 5(o) demonstrates the SAR measured value which inferences maximum and minimum concentration occurred in the month of October (9.46) and April, 2024 (4.42) respectively. High SAR levels can reduce soil permeability and structure, leading to restricted water and air movement within soil, which affects plant growth (Richards, 1954). The acceptable SAR range for irrigation water is below 10, though ideal levels vary based on soil type. In the Veri Dam water samples are under limit scenario.

Potassium adsorption ratio (PAR)

The graphical presentation of PAR observed data shown in Fig. 5(p) that demonstrates a linier increment with R^2=0.61 except in the month of November, 2024. The greatest and lowest value were found between 0.56 to 0.10 respectively.

Magnesium adsorption ratio (MAR)

Surface water having MR values <50 is suitable, while MR values >50 are unsuitable for irrigation (Devi and Sharma, 2020). Fig. 5(q) demonstrates the value of 46.99% in April, 2024 retains maximum value whereas 14.59% in May, 2024 contains minimum value. MR Values were observed under limit scenario (Table 4).

Soluble sodium percentage (SSP)

The term of SSP was first time introduced by Wilcox in 1955 and proposed a classification scheme for rating Surface or irrigation water on the basis of its sodium solubility in aqueous solution (Sachin *et al.,* 2021). The values of SSP <50 indicate good quality of water while higher values (SSP >50) indicate that the water is unsafe for irrigation (Richards 1954). Fig. 5(r) reflects the peak value in the month of March, 2024 (42.29 mg/L) and fallen value in the month of April, 2024 (30.83 mg/L). The parameter outcome defines suitability of dam water for the irrigation purposes.

Exchangeable sodium percent (ESP)

Fig. 5(s) show the Minimum and maximum concentration of ESP having 30.50% (September, 2024) in post-monsoon period and 42.04% (March, 2024) during pre-monsoon period. Trendline shows a minimum variation between the all pre- and post-monsoon water samples with $R^2 = 0.14$.

Permeability index (PI)

The PI values greater than 75 indicate best quality of water for irrigation. When the values of PI fall between 25 and 75, they remark good irrigation water quality. Although, if the PI values are below the 25, shows non-suitable nature of water for irrigation practices and drinking purposes (Sachin *et al.*, 2021). The PI values varied between 41.29 and 59.46%. On behalf of these PI values, Veri dam water samples were fallen under good quality

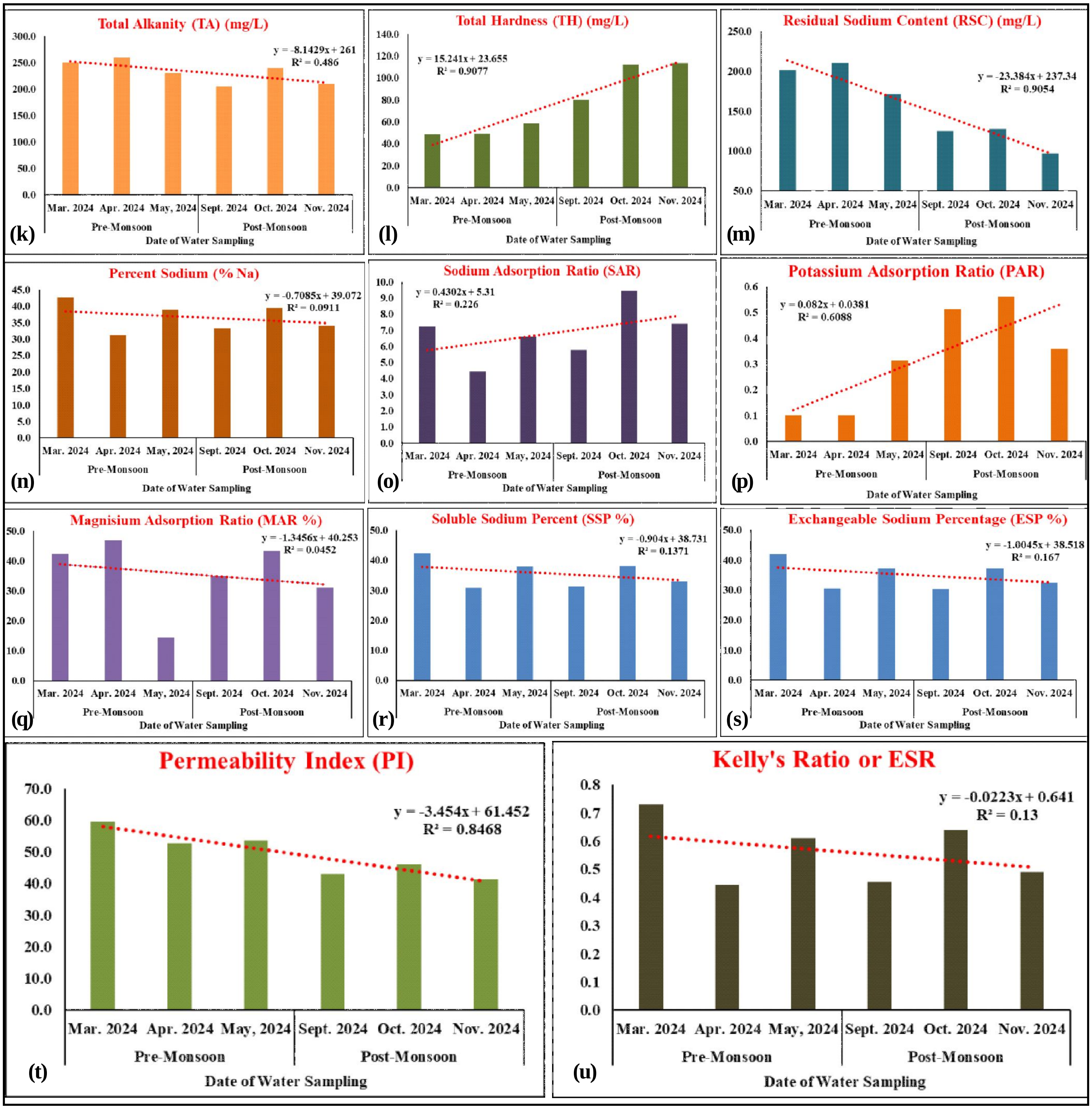

Fig. 5 (k to u): Graphical presentation of different observed parameter concentration. [**Derived parameters**] of water for irrigation purposes.

Kelly's ratio (KR)

Kelly's ratio was pioneered by Kelly in 1963 and stated that if the value of KR is < 1, defines good quality of water for irrigation, whereas KR > 1 refers its unsuitability of irrigation water for the purpose of agricultural due to alkali hazards (Karanth, 1987). In the current study, all pre- and post-monsoon seasons samples are found < 1, Fig. 5(u), *i.e*. showcases suitability of water for irrigation purpose.

Water Quality Index (WQI)

The analysis of WQI was done using the Weighted Arithmetic Method suggested by Brown *et al.,* 1972. The WQI analysis was performed to check the pre and post monsoon water quality status of Veri dam. The study findings revealed that WQI value of 38.31 & 49.94 (mentioned in Table 3) defines dam or reservoir water was under the good condition scenarios during the pre and post monsoon period (Table 4).

Correlation Analysis (r)

A correlation analysis (given by *Karl Pearson in* 1896) performed to check the parameters interaction between each other. The basin reason behind the analysis to identifying the influencing parameter by which the quality of water deterioration is taking place. The finding explained that electrical conductivity was directly proportional (r = 1) to the total dissolved solids, which is commonly reported in water quality studies (Taylor *et al.,* 2018, Thirumalini and Joseph 2009). Sodium concentration strongly influences electrical conductivity, likely due to its ionic nature. Indicates that calcium significantly contributes to total hardness, aligning with the role of Ca and Mg in water hardness. Highlights that higher pH may reduce total suspended solids, possibly due to precipitation reactions at alkaline pH. Residual sodium carbonate decreases with higher calcium, which aligns with carbonate precipitation dynamics (Raj and Arya, 2018).

Engineering Measures to Control Water Quality

Findings of the research work, post-monsoon WQI value shows a shift toward poorer quality compared to the pre-monsoon. To control the deterioration of water quality in the Veri Dam and address the associated environmental issues, a comprehensive approach integrating engineering measures and management practices is essential. One of the most critical steps is catchment area management. Soil erosion and sediment runoff, significant contributors to post-monsoon water quality issues, can be mitigated by implementing contour bunding,terracing, and afforestation in the catchment area (Azimov, 2022). Structures like check dams, gabion walls, and sediment traps upstream can capture sediments and pollutants before they enter the reservoir (Jin, 2023). Additionally, establishingbuffer zones with vegetative cover around the dam can filter runoff and reduce nutrient and sediment inflow. The reservoir itself requires periodic maintenance to ensure long-term sustainability. Regular desilting and dredging operations can prevent sediment accumulation and maintain storage capacity, while aeration systems can be installed to enhance dissolved oxygen levels, vital for aquatic ecosystems (Katusime, and Schutt, (2020). To address nutrient loading and potential eutrophication, constructing wetlands near inflow points can naturally absorb excess nutrients and contaminants. Additionally, real-time water quality monitoring systems with IoT sensors should be deployed to track critical parameters such as pH, TDS, and dissolved oxygen, enabling early intervention when issues arise (Azimov, 2022 and Nguyen *et al.,* 2018). Addressing pollution from anthropogenic sources is another priority. Strict regulations on effluent discharge from industries and urban areas upstream, coupled with mandatory treatment facilities, are necessary to prevent contaminants from reaching the dam (Nguyen *et al.,* 2018). Encouraging sustainable agricultural practices, such as the use of organic fertilizers and precision irrigation, can reduce the nutrient load in runoff (Min, 2023). Education and engagement of local communities are equally important to foster participation in conservation efforts. By integrating these measures with policy frameworks that prioritize sustainable land and water use, the dual goals of protecting water quality and supporting ecosystem health can be achieved (Winton *et al.,* 2019). This multi-pronged approach ensures the dam remains a reliable resource for drinking, irrigation, and ecological balance.

Conclusion

Water is an essential substance that has power to build the greener environment. A good quality of water plays an immense role in the survival of human as well as agricultural growing crops. The presence of CO_3 in water supports alkalinity, excessive levels can lead to scaling in irrigation systems and will lowered the agricultural productivity. The high sub-index value of SAR depicts sodium depositing waters, are largely not appropriate for watering the soils, as developed deposition of sodium may worsen the soil physical characteristics. Therefore, SAR is reflected a superior quantity of sodium threat in irrigation, as SAR of water is directly connected to the adsorption of sodium by topsoil and is a valued measure for decisive the appropriateness of the water for irrigation. The observed data shows a steady increase in calcium levels from 28.1 ppm in March 2024 to 78.1 ppm in November 2024. This trend likely reflects mineral leaching and agricultural runoff, particularly during the dry season. Calcium levels above 75 ppm may cause scaling in water systems and reduce soil permeability, negatively impacting irrigation efficiency. However, calcium is essential for aquatic ecosystems and crop growth at moderate levels. Regular monitoring and balanced water management practices are necessary to maintain optimal calcium levels, ensuring the water remains suitable for various uses. During the pre-monsoon period all the parameters were under the permissible limit of BIS, (2012) and WHO (1997) except pH and RSC. pH and RSC values were slightly higher form the permissible limit in the both month of April and May, 2024; and March and April, 2024 respectively. The SSP value was also found close to the limit range. Similarly, the pH values were observed over the limit in the post-monsoon season. The basic reason behind the increment in pH value is the dilution of various types of contamination in the dam by introducing surface flowing water in the monsoon period. Overall, the water quality study is clearly showed that the water of Veri dam was under the safe condition in the both pre- and post-monsoon season.But the post-monsoon water quality condition is under thinkable concern because it stand towards boundary line of the Good to Poor quality realm. The finding of the study revealed that there is need of taking necessary and prompt action to control the quality of water *i.e.*, disturbing due to mixed up of the upstream running water in the monsoon seasons months.

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