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Water quality and sedimentary analyses of Siddheshwar dam (India) for assessing irrigational suitability

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Abstract

The physico-chemical properties of water and sediments therein were analyzed for assessing the suitability of Siddheshwar dam (India) waters for irrigation purpose. The physical parameters include total dissolved solids and electrical conductivity. The chemical parameters studied include pH, free carbon dioxide, total hardness, calcium hardness, magnesium hardness, phenolphthalein alkalinity, total alkalinity, biochemical oxygen demand and salinity. The present research was undertaken to monitor the irrigational suitability of this water body over the period of June 2009 to May 2010 by Sodium Absorption Ration (SAR), Magnesium Ratio (MR), Residual Sodium Carbonate (RSC), Soluble Sodium Percentage (SSP), Residual Sodium Bicarbonate (RSBC), Kelly's Ratio (KR) and Permeability Index (PI) parameters. The UV-Spectrophotometer determined the concentrations of heavy metals such as iron, zinc, chromium and manganese. The sediments' physico-chemical characteristics like temperature, conductivity, pH, % carbon, organic matter and phosphate have been detected using standard methods. It is observed that the sediments are in a complex milieu with the overlying water in the aquatic ecosystem and they affect water chemistry and get affected by it. The water quality is found to be good and it is therefore safe for irrigation.

Keywords: Siddheshwar dam (India); irrigation water quality; permissible limit; sediment, UV – spectrophotometer.

Introduction

Water is the most precious resource for supporting all known forms of life on the earth. Though water covers 71% of the planet's surface, fresh water is rapidly becoming a scarce commodity. Water is the basic necessity on which society's quality of life depends. The most common usages of water include drinking, irrigation, health, energy, recreation, etc. Water is an environmentally benign chemical but is prone to pollution. Water quality is a term used to express the suitability of water to sustain various uses or processes as there are certain

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requirements and standards for the physical, chemical, biological or micro-biological characteristics, including the health hazards of water. It is advisable to monitor toxic inorganic and organic pollutants in aquatic environments as there are almost uniform policies and legislations on water quality placed worldwide (UN Agenda 21; Format: A/RES/67/290; IWA http://www.iwa-network.org/which-water-for-which-use; FAO Irrigation and Drainage Paper 1994, WHO 2004); Bureau of Indian Standards 1987 [1-6]. Though no such standards exist for sediment quality and load, more attention is being given to water quality analysis by extending it to sediment monitoring. There is a widespread interest in fluvial geomorphology i.e. the study of the land and water interactions [7]. In recent years, the sedimentation of surface waters has been a topic of concern because sediments are the largest single nonpoint source pollutants and the primary factors in the deterioration of water quality [8]. The sedimentary material types and composition in streams are usually based on geology, topography, precipitation rates and all the forces of erosion these materials succumb to from water, wind and pressures caused by expanding and contracting forces [9]. For example, soil erosion or land disturbing activities such as road construction, timber harvesting, agriculture, residential and industrial development, sewage disposal, landfills, abandoned or active mines, oil drilling, etc. contribute to this issue. Excess aquatic sedimentation makes the stream bottom muddy and thereby smothers oxygen producing plants, insects, trout eggs, etc. An increased turbidity due to suspended sediments enhances water temperatures and reduces visibility for prey capturing by fishes. This interferes with breathing, and thereby kills fishes from abrasive gill clogging effects of sediments [10]. In order to assess the water quality and also to understand natural processes, including sediment transport, accumulation, biodiversity and biogeochemical reactions within sediments, it is essential to analyze and characterize sediments. Many consider this as contamination evaluation because the sediments are said to (i) act as a sink for varied substances having potential to cause toxicity and (ii) to alter biodiversity and human health. Sediments of aquatic body act as a major source of metals and other contaminants [11]. Methods for determining the chemical composition of aquatic sediments to detect and control the sources of pollution are active fields of research [12]. Nowadays sediment is considered as an integral part of aquatic ecosystems and there are complex reactions taking place within aquatic sediments and between soil and water [13]. The biological availability of heavy metals in sediment is due to various factors like precipitation, adsorption onto the organic and inorganic sediment fractions. It is considered necessary to study the mechanism of heavy metal adsorption and adsorption capacity of the sediment [14].

We report herein the physical and chemical parameters to monitor the irrigational suitability of Siddheshwar dam by Sodium Absorption Ratio (SAR), Magnesium Ratio (MR), Residual Sodium Carbonate (RSC), Soluble Sodium Percentage (SSP), Residual Sodium Bicorbonate (RSBC), Kelly's Ratio (KR) and Permeability Index (PI). The concentrations of heavy metals within sediments were determined by UV-Spectrophotometer.

Materials and methods

Study area

Quality of water is investigated by taking a number of samples for laboratory analyses from the Siddheshwar dam (India). This dam (Figure 1) has been constructed on Purna River in northern part of Marathwada region at village Siddheshwar of Aundha taluka in Hingoli district of Maharashtra state in (the Republic of) India. The location of dam is at $19^0$35'-$19^0$40' N latitude $76^0$5'-77^0 E longitudes. The Purna River (a tributary of the Godavari River) originates in the Ajanta Range in hills of Aurangabad district and after a winding course of about 250 miles meets the Godavari near Purna city. The regions of Hingoli, Parbhani and Nanded districts get benefits from Siddheshwar dam. Average rainfall of this region is 900 mm. A substantial number of papers have been published by us in the past on this site but no such attempts were made to analyze water quality along with sediments in view of a fluvial geomorphological project. An assured water supply through irrigation channels, river, rainfall runoff, dug or deep wells, etc. and pond draining bottom at a level higher than that which the maximum water table reaches during the harvesting periods in a normal year are the most important factors considered when deciding on the suitability of this site.

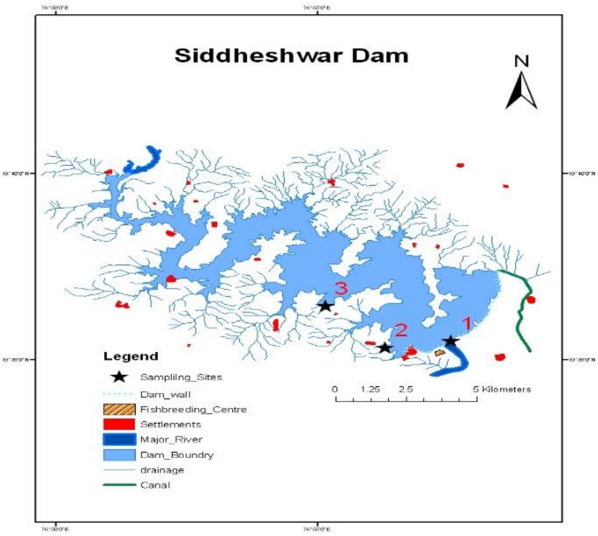

Figure 1. Geographic map of the Siddheshwar dam and the location of the sampling sites in the study area

Measurement of physico-chemical parameters of water samples

The water samples were collected from three sampling sites named S_1, S_2 and S_3 from the Siddheshwar dam and taken in pre-cleaned polyethylene bottle. S_1 is the sampling site located near the dam's gate, S_2 is the sampling site in the middle of the dam and S_3 is near the pump house. Water test procedures followed and all the water quality parameters were estimated by the standard methods given by APHA [15] and were also discussed in accordance with the relevant Standard Classifications from the World Health Organization (WHO, 2004) [4].

Measurement of physico-chemical parameters of sediment sample

Sediment samples were collected from Siddheshwar dam in polythene bags and transported to laboratory immediately as there are some parameters needed to be determined immediately upon sampling [16].

In the present research, we conducted the experiments for measurement of physico-chemical parameters of water and sediment samples. The protocols such as Thiocyanate method, Dithiozone method, Diphenylcarbazide method and Persulphate method were used to determine the concentrations of iron, zinc, chromium and manganese using UV-Spectrophotometer respectively. All the reagents used were of (Merck) AR grade. The solutions when required were prepared using double-distilled water. For carbonate and bicarbonate analyses, the reagents such as phenolphthalein indicator, methyl orange indicator, sodium thiosulphate solution, sulphuric acid, etc. were used. In case of calcium and magnesium, the disodium salt of EDTA, ammonium chloride in 143 ml of concentrated ammonium hydroxide, Erichrome black T indicator, NaCl, Sodium Sulfide, murexide indicator, NaOH, and other salts like potassium chloride (for K) and sodium chloride (for Na) were of all AR grade. For manganese, ammonium persulfate was used.

Modern instruments like the UV-VIS Spectrphotometer (Elico India make) and the Digital Flame Photometer (Elico India make) were used for this study.

Statistical analysis

The statistical methods are found helpful in understanding and interpreting the large number of observations and also in summarizing the data to get important hidden information.

$$\textbf{Mean} = \frac{\sum X}{N} \quad (1)$$

$$\textbf{Standard Deviation} = \sqrt{\frac{\sum (X - \bar{X})^2}{N - 1}} \quad (2)$$

$$\textbf{Range} = L - S \quad (3)$$

$$\textbf{Standard Error} = \frac{\sigma}{\sqrt{N}} \quad (4)$$

$$\text{Correlation Coefficient (X,Y)} = \frac{\sum (X - \bar{X})(Y - \bar{Y})}{\sqrt{\sum (X - \bar{X})^2 \sum (Y - \bar{Y})^2}} \quad (5)$$

In this formulae, $\bar{X}$ and $\bar{Y}$ are the values of the mean, N is the sample size = 36, σ is standard deviation, L is largest value, S is smallest value and X and Y are two variables [17].

Correlation matrix for analyzed water parameters was carried out to deduce the relationship among the parameters. Though high correlation does not necessarily mean a theoretically correct relation, correlation with negative sign here represents that the two variables do not have similar trend of variation where as positive value represents similar trend [18].

Results and discussion

The Siddheshwar dam water analysis results obtained over the period of June 2009 - May 2010 are given in Tables 1 to 3.

Average value of different water parameters in monsoon, post-monsoon and pre-monsoon are showed in Table 4. The average electrical conductivity

446.36 ± 75.46 µS/cm is above the permissible limit of 250 µS/cm. Conductivity is decreased during periods of rain, which contain small amounts of dissolved ions. The TDS concentration was detected highest 374.58 mg/L in post-monsoon and lowest 192.75 mg/L in pre-monsoon (Figure 1).

The water hardness of Siddheshwar dam was highest 228.5 mg/L in post-monsoon and lowest 107.3 mg/L in monsoon. The dissolved oxygen from Siddheshwar dam water was highest 4.64 mg/L in monsoon and lowest 4.32 mg/L in pre-monsoon. The highest concentrations of dissolved oxygen occurred at all sampling sites during high-flows when colder water and more mixing of waters allowed oxygen to enter in water column. Dissolved oxygen concentrations decreased during low flows when warmer water temperatures held less oxygen. The lack of flow resulted in a reduction of oxygen replenishment. The carbon dioxide found maximum 0.06 mg/L, 0.05 mg/L and 0.05 mg/L at S_1, S_2 and S_3 respectively and minimum 0.0 mg/L at all sampling sites. The calcium hardness content was highest 150.5 mg/L in post-monsoon and lowest 83.15 mg/L in monsoon season. The magnesium hardness content was highest 77.8 mg/L in post-monsoon and lowest 24.32 mg/L in monsoon season. The water salinity of dam was highest 86.44 mg/L in pre-monsoon and lowest 61.75 mg/L in post-monsoon. The average phenolphthalein alkalinity was 7.8 mg/L in post-monsoon, 16.08 mg/L in pre-monsoon and below detectable limit (BDL) in monsoon. The total alkalinity of dam was highest 94.66 mg/L in pre-monsoon and lowest 34.56 mg/L in post-monsoon. The biochemical oxygen demand (BOD) was highest 2.12 mg/L in monsoon and lowest 0.41 mg/L in post-monsoon season.

Correlation coefficient matrix was calculated and correlations among all the parameters were worked out. The correlation coefficient for analysed parameters of Siddheshwar dam water is presented in Table 6. We tested the significance of the observed correlation coefficients. Significant positive and negative correlations among all the parameters were determined. The 31 negative (inverse) correlations were found. Highly significant correlations between the parameters were not found. The total alkalinity and salinity shows highest correlation coefficient 0.85 among all other parameters.

Yannawar et al. [19] studied physicochemical and irrigational parameters of Nagzari dam, Maharashtra during 2012-2013. Kobingi et al. [20], Toshniwal et al. [21], Dhanalakshmi et al. [22], Ajibade et al. [23] found similar results during study of water quality of aquatic bodies. Different researches have widely studied the sediment of surface waters like Taghinia et al. [24], Nnaji et al. [25], Abdullah and Roxana [26].

Table 3 shows results of sediment analysis of Siddheshwar dam. In the present investigation, iron, chromium and zinc were detected in Siddheshwar dam sediment but manganese was not detected. It is assumed that the sediments in aquatic ecosystem are analogous to soil in the terrestrial ecosystem and its interaction with aquatic body. The nature of sediment under investigation was possibly due to the neutral and slightly alkaline nature of water in the study area. A look at the tables shows that there is a relationship between physico-chemical parameters of water and those of the sediment. In Table 4, season-wise average value of different parameters is shown. Table 5 displays the statistical average value of different parameters.

Table 1. Water quality parameters of Siddheshwar dam during June 2009-May 2010

Months	Sites	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
TDS	S_1	180	200	180	183	182	182	600	392	236	230	210	200
	S_2	350	400	170	175	175	180	900	386	186	175	165	150
	S_3	275	300	175	179	178	181	750	389	211	190	185	175
EC	S_1	470	490	319	362	400	544	556	534	500	495	480	470
	S_2	380	403	270	379	420	473	605	506	470	450	405	400
	S_3	400	447	295	370	410	508	580	478	480	470	450	400
Hard.	S_1	57.1	64	94	98.6	330	75	265	280	110	180	180	160
	S_2	152	161	104	129	310	80	256	230	160	185	185	185
	S_3	104	112	99	113	320	78	260	255	135	182	182	172
DO_2	S_1	5.5	6.3	3.78	3.6	4.2	4.55	4.5	4.14	5.6	4.3	3.8	3.4
	S_2	5.0	6.34	2.84	4.0	3.78	4.56	4.5	4.7	5.4	4.4	3.9	3.5
	S_3	5.2	6.32	3.31	3.6	3.99	4.55	4.5	4.42	5.5	4.5	4.0	3.6
CO_2	S_1	0.04	0.05	0.05	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	S_2	0.03	0.04	0.04	0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	S_3	0.03	0.04	0.04	0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ca. Hard.	S_1	49	44	66	70	250	74	190	100	77	155	155	155
	S_2	120	112	100	104	225	70	195	100	112	150	157	160
	S_3	84.5	78.3	83	87	238	72	192	100	95	152	160	157
Mg. Hard.	S_1	8.19	20	28	28.6	80	1.0	75	180	33	25	25	5.0
	S_2	32.78	48.6	4.0	25	85	10	61.6	130	48	35	25	25
	S_3	20.49	33.6	16	26.6	82	6.0	68	155	40	30	25	15
Sal.	S_1	66.8	70.5	72.2	68.6	55.1	56.9	54.1	72.2	72.2	75.8	86.5	86.7

	S_2	59.6	64.1	65.0	59.6	66.1	59.6	57.8	79.4	79.4	83.1	102	108
	S_3	63.2	67.2	68.6	64.1	60.6	58.2	56.0	65.0	75.8	75.8	94.5	97.5
P.A.	S_1	0.0	0.0	0.0	0.0	8.0	10	6.6	6.1	08	10	12	16
	S_2	0.0	0.0	0.0	0.0	10	10	6.0	6.0	18	20	22	24
	S_3	0.0	0.0	0.0	0.0	9.0	10	6.0	6.0	10	15	18	20
T.A.	S_1	58	50	45	41	37	32	33.2	32	60	80	93	140
	S_2	48	45	41	40	40	34	36.0	32	60	80	92	154
	S_3	52	48	42	40	39	33	34.6	32	60	80	90	147
BOD	S_1	1.2	1.32	2.74	3.0	0.70	0.52	0.41	0.36	1.1	2.0	2.7	3.3
	S_2	1.4	1.64	2.74	3.0	0.29	0.27	0.42	0.42	0.20	1.0	1.5	3.2
	S_3	1.3	1.48	2.74	2.9	0.49	0.29	0.38	0.39	0.65	1.4	2.0	3.1

Table 2. Irrigational water parameters of Siddheshwar dam

Months	**Sites**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
SAR	S_1	1.21	0.98	0.82	0.83	0.51	1.03	0.56	0.53	0.90	0.72	0.73	0.76
	S_2	0.753	0.62	0.87	0.76	0.48	0.91	0.49	0.51	0.75	0.69	0.67	0.66
	S_3	0.922	0.82	0.88	0.79	1.01	1.01	0.53	0.73	0.83	0.71	0.70	0.70
RSC	S_1	-0.19	-0.46	-1.14	-1.3	-5.7	-0.8	-4.5	-4.9	-0.9	-1.9	-1.6	-0.37
	S_2	-2.26	-2.49	-1.41	-1.9	-5.2	-0.7	-4.3	-3.9	-1.6	-1.7	-1.4	-0.37
	S_3	-1.22	-1.09	-1.29	-1.6	-0.6	-0.6	-4.4	-1.9	-1.3	-1.8	-1.5	-0.36
SSP	S_1	50.8	44.0	36.9	34.9	14.8	41.2	17.7	16.7	34.7	25	25.2	27.0
	S_2	27.5	24	34.5	29.5	14.8	39.0	16.4	17.9	26.7	23.9	23.6	23.2
	S_3	36.0	35.1	35.7	31.9	41.8	41.6	17.0	28.8	30.6	24.6	24.4	25.1
MR	S_1	14.38	31.2	29.7	28.9	24.4	11.9	28.5	65.0	30.3	13.8	13.8	3.12

	S_2	21.31	30.6	48.1	19.3	27.6	12.5	23.9	56.8	30.2	19.1	15.1	13.5
	S_3	18.75	17.0	16.6	23.0	107	7.09	26.2	25.0	29.8	16.4	12.0	8.72
RSBC	S_1	-0.031	-0.06	-0.58	-0.7	-4.6	-1.2	-3.4	-1.6	-0.8	-2.1	-1.9	-1.3
	S_2	-1.614	-1.50	-1.33	-1.4	-8.8	-1.1	-3.5	-1.6	-1.8	-2.3	-2.3	-1.4
	S_3	-0.838	-0.77	-0.97	-1.0	-4.4	-1.2	-3.4	-1.6	-1.2	-2.2	-2.3	-1.3
	S_1	0.83	0.61	0.46	0.42	0.14	0.56	0.17	0.15	0.42	0.26	0.27	0.30
KR	S_2	0.30	0.24	0.42	0.33	0.13	0.51	0.15	0.17	0.29	0.25	0.24	0.24
	S_3	0.45	0.42	0.44	0.37	0.57	0.57	0.16	0.31	0.35	0.26	0.26	0.27
	S_1	91.8	81.8	62.9	58.8	20.0	52.9	23.8	22.4	56.9	42.9	44.5	55.0
PI	S_2	45.6	41.1	57.3	48.2	20.0	53.6	24.1	25.0	37.8	37.6	39.0	48.0
	S_3	61.6	62.9	59.7	53.1	60.4	55.1	24.1	40.3	46.0	40.5	41.1	51.4

Table 3. Analysis of sediment of Siddheshwar dam. Please note that in this table, the parameters with Sr. No. 7 to 10 are ions Cr(VI), Fe(III), Zn(II), Mn(II).

Sr. No.	Sediment Parameters	Average
1	Temperature	26.2°C
2	Conductivity	2.79 Ms/cm
3	pH	8.57
4	% Carbon	14.13%
5	Organic Matter	24.36%
6	Phosphate (PO_4^{2-})	0.55 mg/kg
7	Chromium (Cr)	5.3 mg/kg
8	Iron (Fe)	39.2 mg/kg
9	Zinc (Zn)	1 mg/kg
10	Manganese (Mn)	0.0

Table 4. Season-wise average value of different parameters

Sr. No.	Seasons	Monsoon	Pre-Monsoon	Post-Monsoon
1	TDS	230.58	192.75	374.58
2	EC	382.08	455.83	501.16
3	Hard.	107.30	168	228.5
4	DO_2	4.64	4.32	4.36
5	CO_2	0.043	---	---
6	Ca. Hard.	83.15	140.41	150.5
7	Mg. Hard.	24.32	27.58	77.8
8	Salinity	65.79	86.44	61.75
9	P. A.	---	16.08	7.80
10	T. A.	45.83	94.66	34.56
11	BOD	2.12	1.84	0.41
12	SAR	0.85	0.735	0.691
13	MR	14.90	17.15	34.65
14	SSP	35.06	26.16	25.64
15	KR	0.44	0.28	0.29
16	PI	60.4	44.9	35.1

Table 5. Statistical average value of different parameters

Parameters	Mean	Standard Error	Standard Deviation	Variance	Min.	Max.	Range	Permissible limit
TDS	265.97	28.17	169.04	28435.23	150	900	750	500 mgL^{-1}
EC	446.36	12.57	75.46	5695.09	270	605	335	250 uS/cm
Hard.	167.85	12.72	76.35	5830.55	57.1	330	272.9	500 mgL^{-1}
DO_2	4.446	0.144	0.868	0.7536	2.84	6.34	3.5	>4 mgL^{-1}
CO_2	0.014	0.003	0.021	0.00045	0.0	0.06	0.06	----

Ca. Hard.	124.6	8.968	53.81	2896.3	49	250	201	----
Mg. Hard.	43.23	6.883	41.30	1706.0	4.0	180	176	----
Salinity	71.32	2.275	13.65	186.36	54.1	108	53.9	----
P. A.	7.96	1.221	7.33	53.81	0.00	24	24	----
T. A.	58.35	5.456	32.74	1072.0	32	154	122	200 mgL^{-1}
BOD	1.45	0.17	1.05	1.11	0.20	3.3	3.1	30 mgL^{-1}
SAR	0.760	0.028	0.172	0.0297	0.48	1.21	0.73	<10
MR	25.57	3.156	18.93	358.63	3.12	107	104.1	>50
SSP	28.95	1.5154	9.0926	82.67	14.8	50.8	36.0	<15
KR	0.341	0.0264	0.1585	0.0251	0.13	0.83	0.70	<1
PI	46.86	2.736	16.42	269.75	20	91.8	71.8	>25

Table 6. Correlation matrix for different water variables

Variables	TDS	EC	Hard.	DO	CO_2	Ca. Hard.	Mg. Hard.	Sal.	P.A.	T.A.	BOD
TDS	1										
EC	0.591	1									
Hard.	0.418	0.275	1								
DO	0.202	0.394	-0.222	1							
CO_2	-0.181	-0.59	-0.568	0.102	1						
Ca. Hard.	0.264	0.146	0.853	-0.34	-0.562	1					
Mg. Hard.	0.429	0.319	0.735	0.036	-0.317	0.275	1				
Sal.	-0.376	-0.14	-0.022	-0.25	-0.265	0.086	-0.15	1			
P. A.	-0.215	0.230	0.284	-0.26	-0.757	0.452	-0.06	0.72	1		
T. A.	-0.324	-0.10	-0.043	-0.26	-0.277	0.220	-0.36	0.85	0.704	1	
BOD	-0.399	-0.63	-0.37	-0.48	0.497	-0.146	-0.51	0.44	-0.02	0.56	1

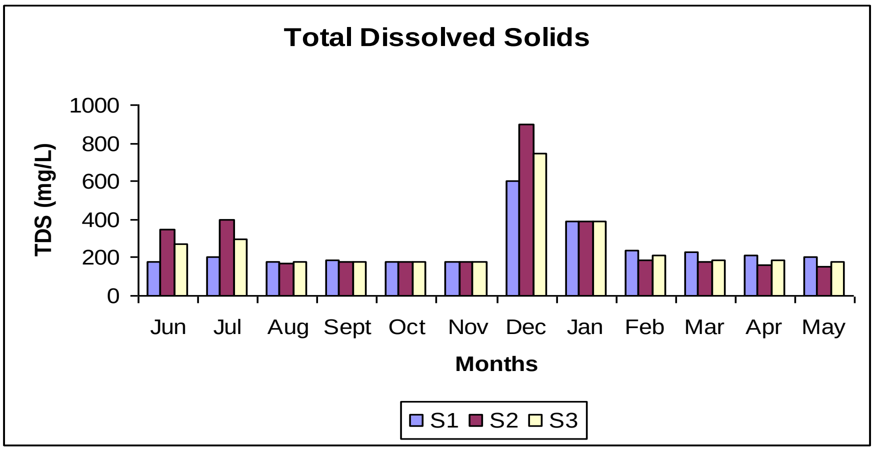

Figure 1. Monthly values of Total Dissolved Solids of Siddheshwar dam water

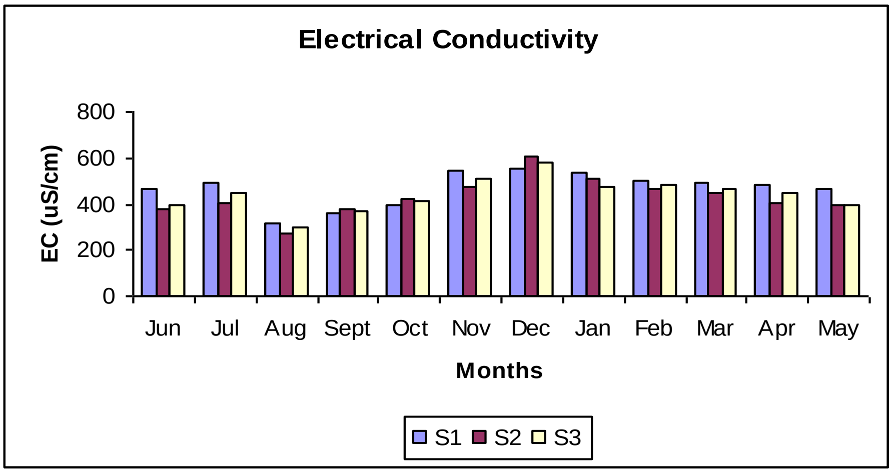

Figure 2. Monthly values of Electrical Conductivity of Siddheshwar dam water

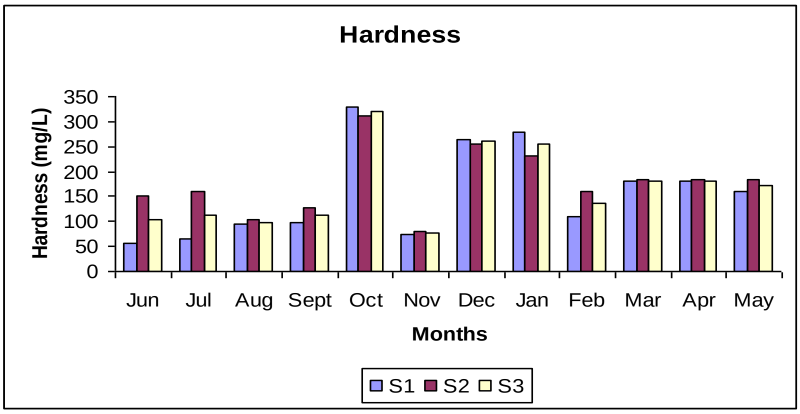

Figure 3. Monthly values of Hardness of Siddheshwar dam water

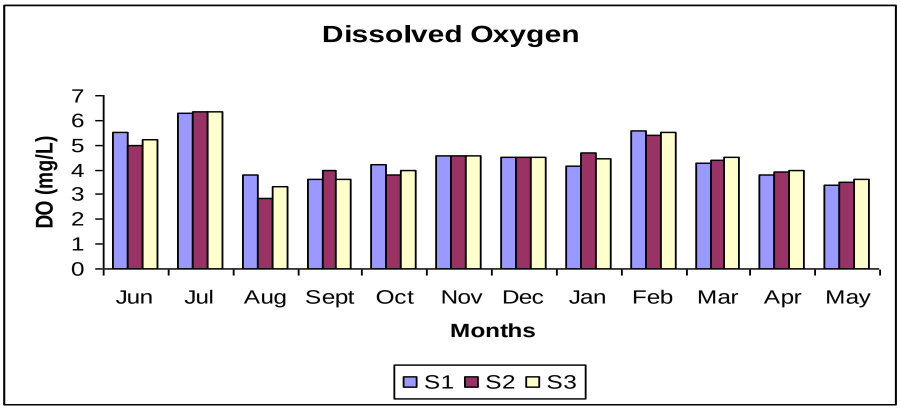

Figure 4. Monthly values of Dissolved Oxygen of Siddheshwar dam water

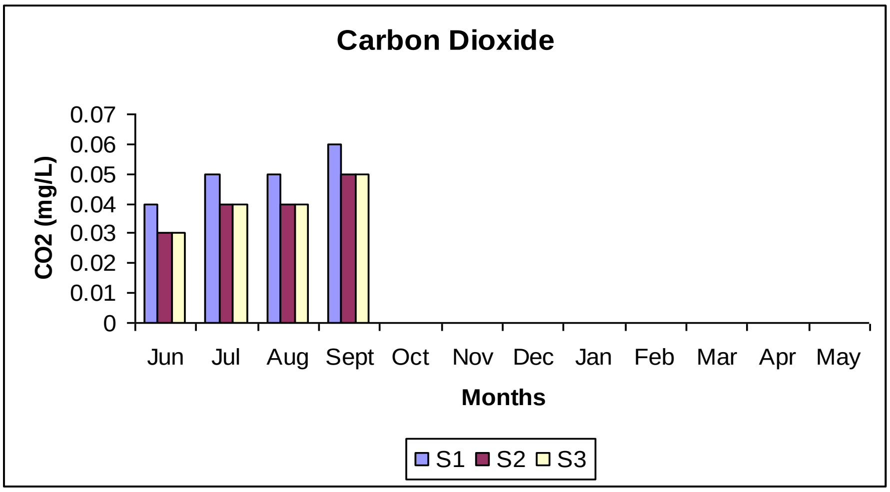

Figure 5. Monthly values of Carbon Dioxide of Siddheshwar dam water

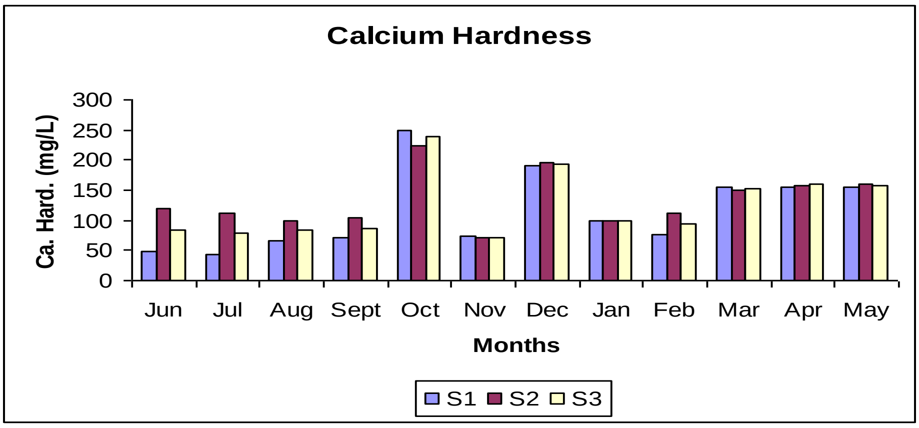

Figure 6. Monthly values of calcium hardness of Siddheshwar dam water

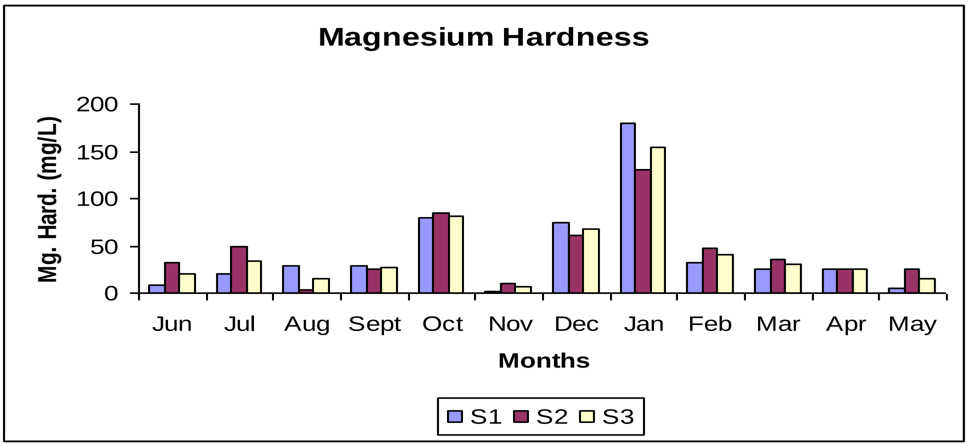

Figure 7. Monthly values of magnesium hardness of Siddheshwar dam water

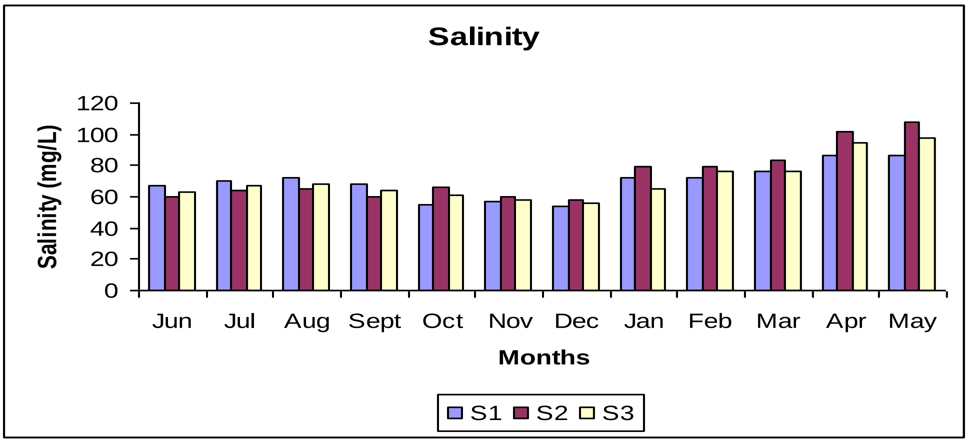

Figure 8. Monthly values of salinity of Siddheshwar dam waammonter

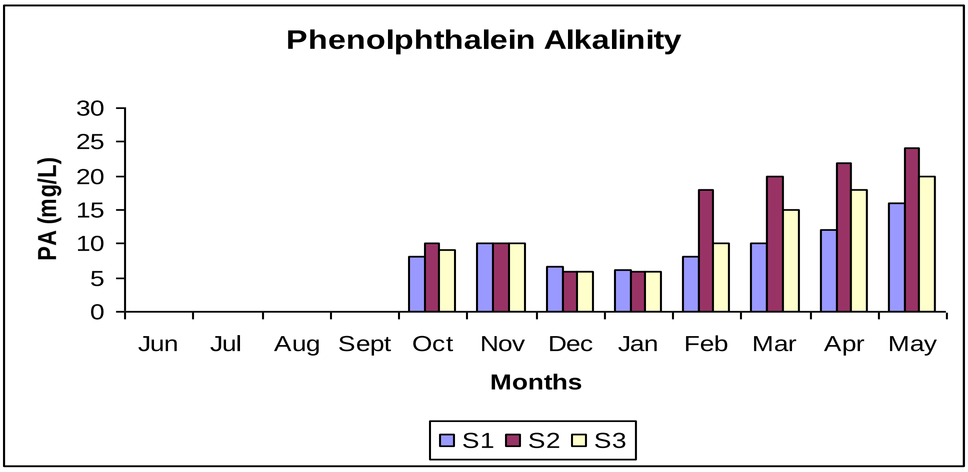

Figure 9. Monthly values of phenolphthaalein alkalinity of Siddheshwar dam water

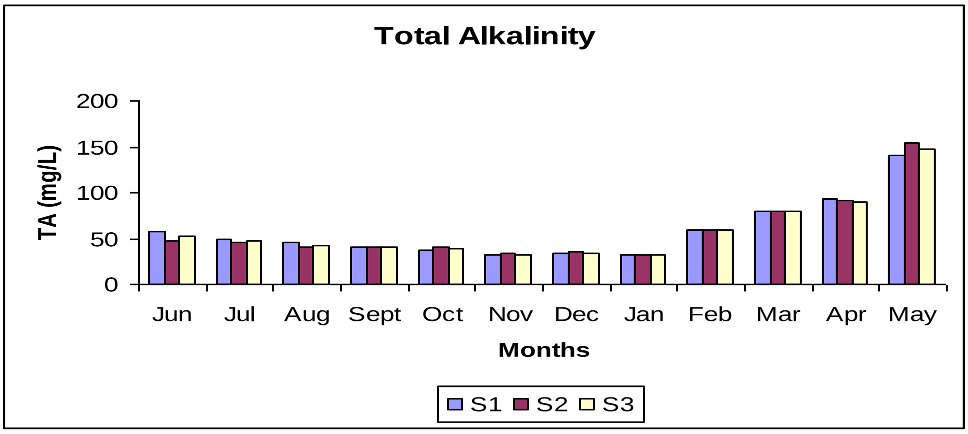

Figure 10. Monthly values of total alkalinity of Siddheshwar dam water

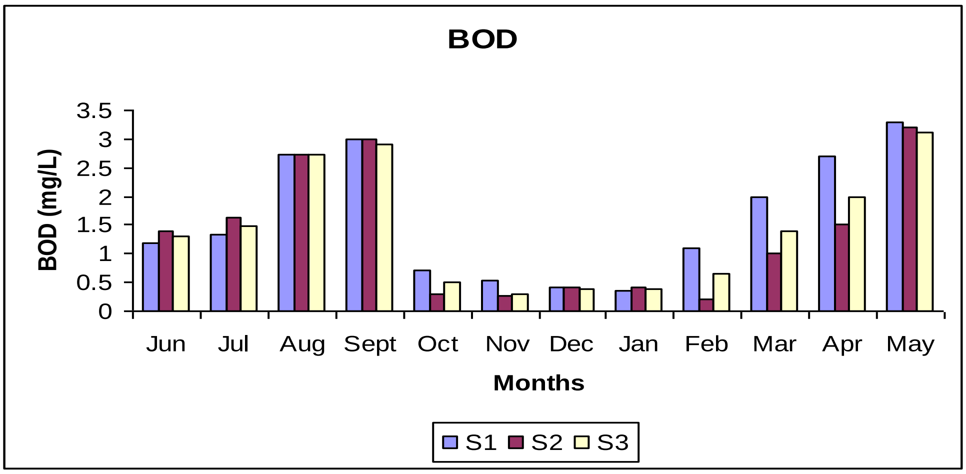

Figure 11. Values of biochemical oxygen demand of Siddheshwar dam water

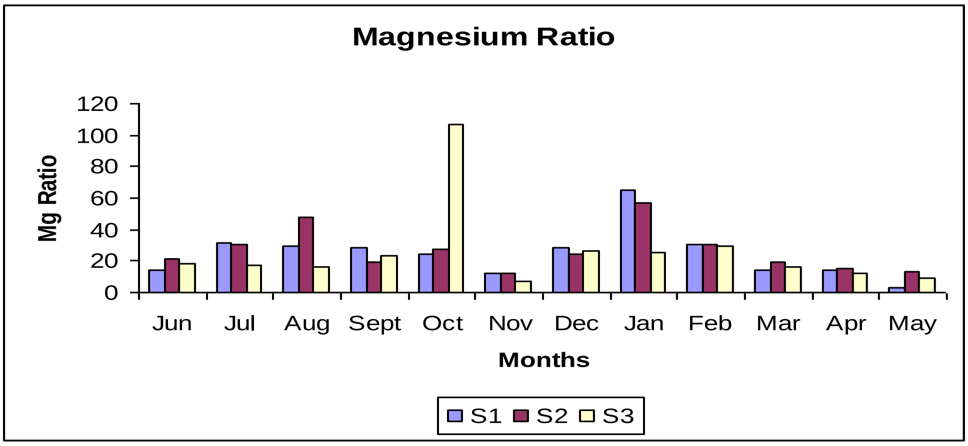

Figure 12. Monthly values of magnesium ratio of Siddheshwar dam water

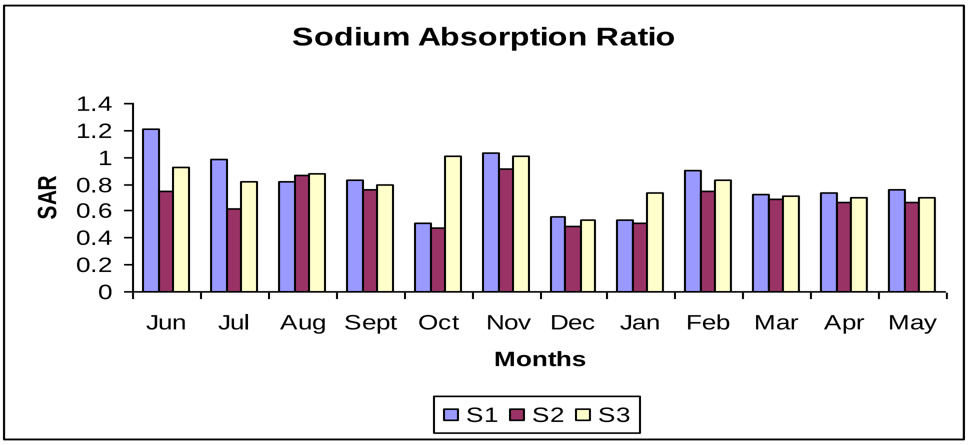

Figure 13. Monthly values of sodium absorption ratio of Siddheshwar dam water

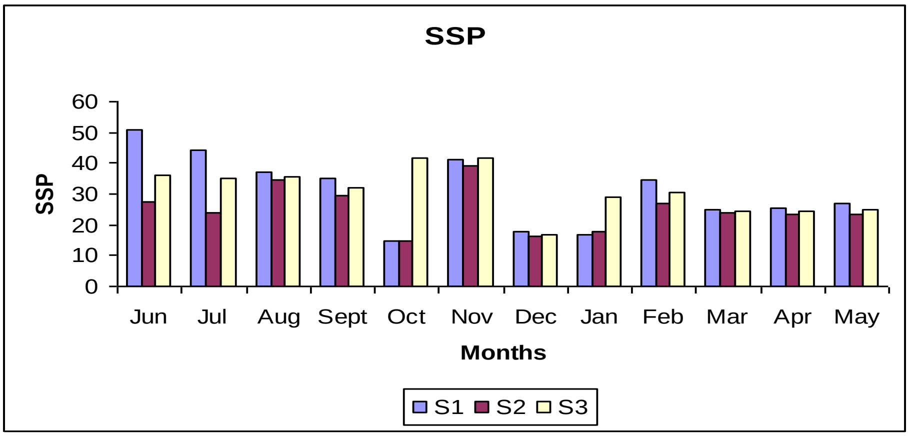

Figure 14. Monthly values of Soluble Sodium Percentage of Siddheshwar dam water

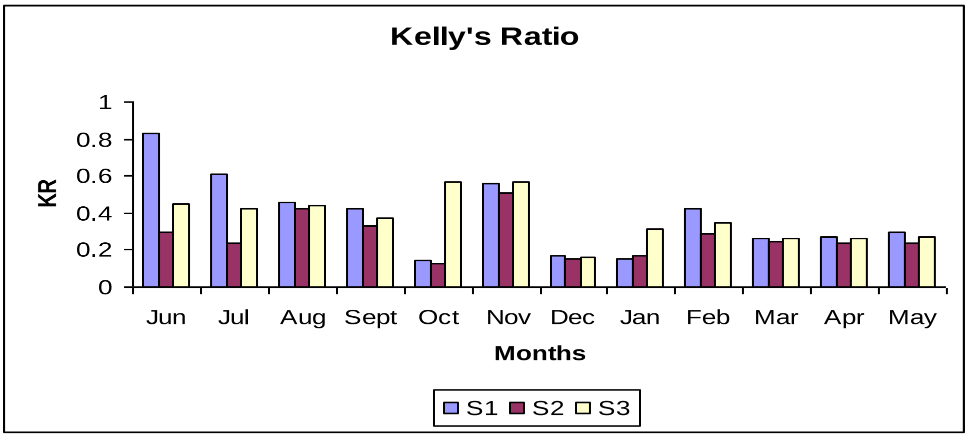

Figure 15. Monthly values of Kelly’s Ratio of Siddheshwar dam water

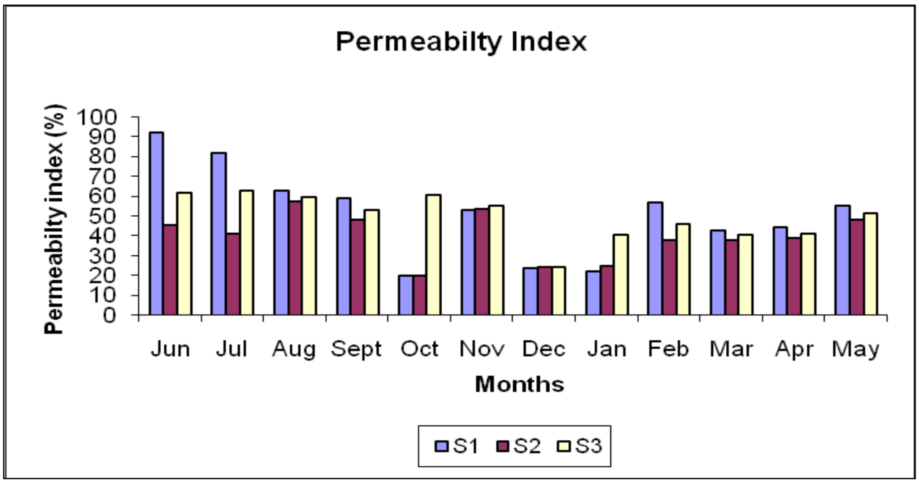

Figure 16. Monthly values of Permeability Index of Siddheshwar dam water

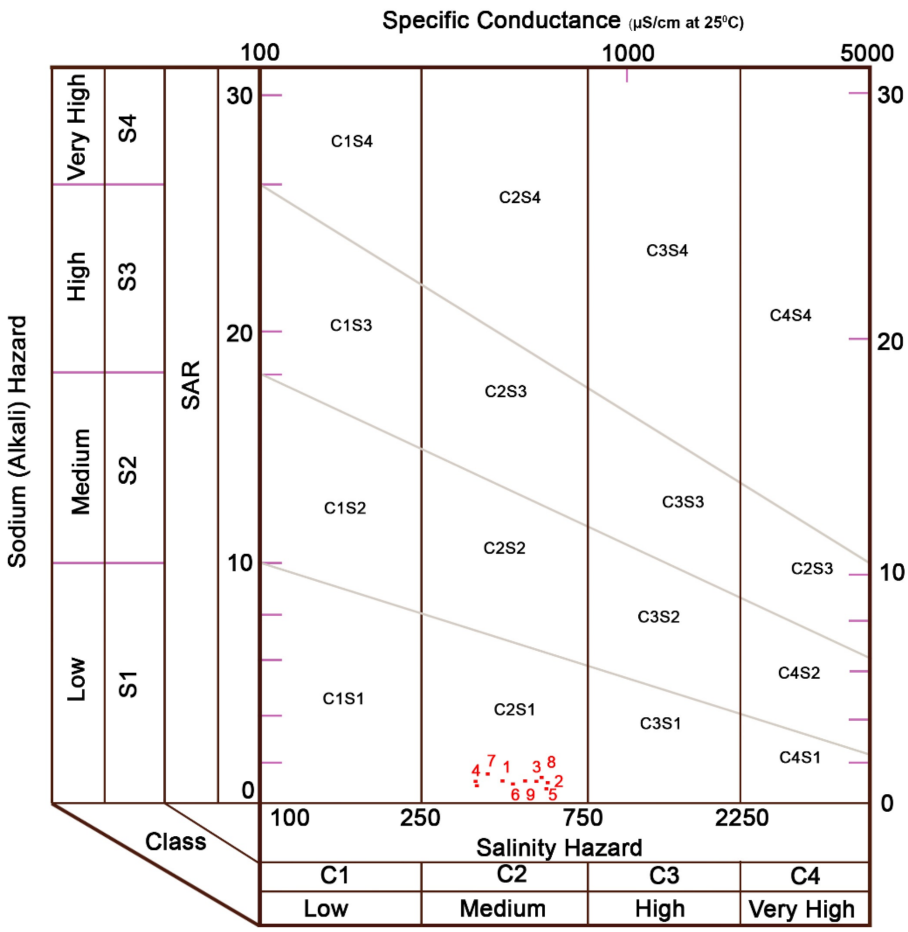

Figure 17. US Salinity diagram for irrigation water quality classification

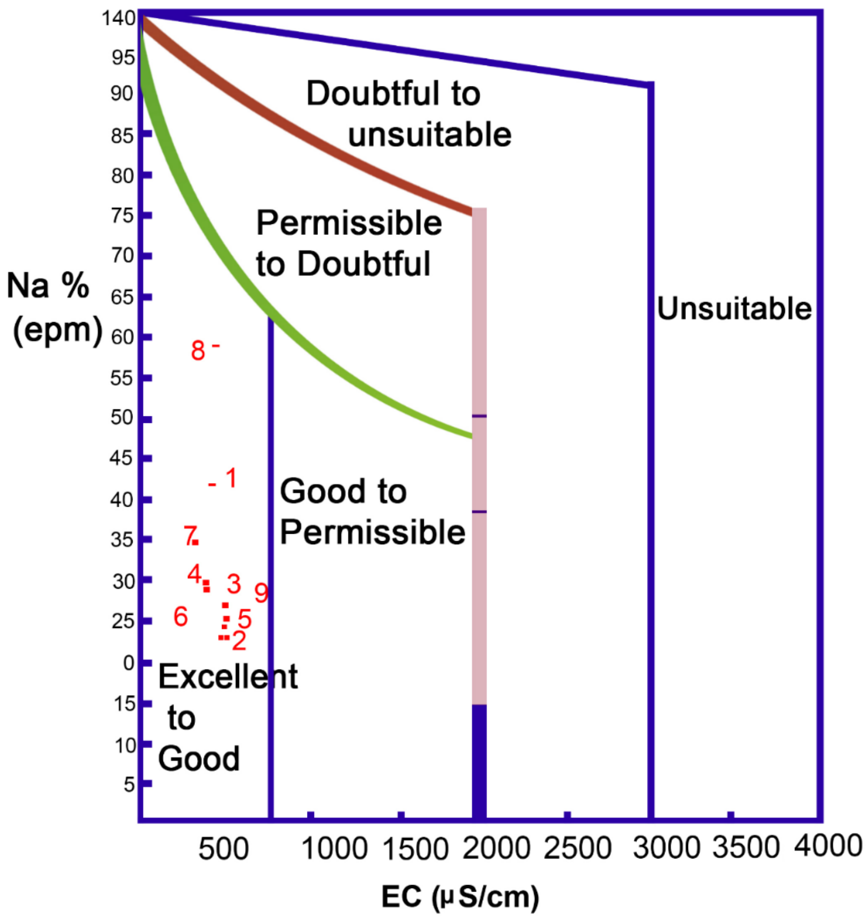

Figure 18. Suitability of water for irrigation in Wilcox diagram

Table 7. Irrigation quality of water based on several classifications [27]

Parameters	Range	Water Class
SSP	<20	Excellent
	20-40	Good
	40-60	Permissible
	60-80	Doubtful
	>80	Unsuitable
Alkalinity hazard (SAR)	< 10	Excellent
	10-18	Good
	18-26	Doubtful

	>26	Unsuitable
RSC	<1.25	Good
	1.25-2.50	Doubtful
	>2.50	Unsuitable
KR	< 1	Good
	> 1	Unsuitable
Total Dissolved Solids (mg/L) (Robinove *et. al.*, 1958)	< 1000	Non saline
	1000 - 3000	Slightly saline
	3000 – 10,000	Moderately saline
	> 10,000	Very saline
PI	75%	Good (Class I)
	25-75%	Good (Class II)
	25%	Unsuitable (Class III)

Irrigation water quality

Siddheshwar dam water is the main source of water for agriculture in this area. The sodium absorption ratio (SAR) of water was minimum 0.48 and maximum 1.21. The SAR of water ranging from 0 to 3 is considered good and water with the SAR greater than 9 is considered unsuitable for irrigation purpose. The magnesium ratio in water was found highest 107 and lowest 3.12. The percent sodium or soluble sodium percentage content was maximum 50.8 % and minimum 14.8 %. The Kelly's ratio ranging from the highest 0.83 to lowest 0.13 were found in water. Kelley's ratio (KR) values for the waters of study area are less than 1 and indicate good quality of water for irrigation purpose. In the present study area, the minimum and maximum permeability index is 20 and 91.8% respectively. Hence, the water quality was suitable for irrigation.

Sodium Absorption Ratio (SAR)

Sodium absorption ratio is an important parameter to determine the suitability of water for irrigation and is calculated by the following formula:

$$SAR= Na^{+} /\sqrt{[(Ca^{2+} + Mg^{2+}) /2]} \quad \ldots(Eq^{n}\ 1)$$

(Ion Concentrations are in meq/l)

There are salt problems associated with sodium in water. Excess sodium in waters causes undesirable effects such as reduced soil permeability. The soil becomes compact and impervious if the soil structure is damaged due to sodium replacing adsorbed calcium and magnesium. It is therefore necessary to assess sodium concentration while considering the water suitability for irrigation. The sodium absorption ratio is the degree to which irrigation water tends to enter into cation-exchange reactions in soil. SAR is responsible for the sodium hazard and therefore is an important parameter for the determination of suitability of water for irrigating agricultural farms. There is a classification in place for waters in relation to irrigation based on the ranges of SAR values [28].

Residual Sodium Carbonate (RSC)

The concept of residual sodium carbonate (RSC) is employed for evaluating high carbonate waters and is calculated by the formula given below.

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

…(Eq^n 2)

(Ion Concentrations are in meq/l)

The RSC equals the sum of the calcium and magnesium ion concentrations subtracted from the sum of the bicarbonate and carbonate ion concentrations. A positive RSC reflects that sodium build-up in the soil is possible. The RSC rich irrigation water is harmful for plants because of the increased soil pH and the formation of OH ions via hydrolysis.

Na_2CO_3 ----------> 2 Na^+ + CO_3^{2-}

CO_3^{2-} +HOH ---------> HCO_3^- + OH^-

HCO_3^- +HOH ---------> H_2CO_3 + OH^-

…(Eq^n 3)

It is generally assumed empirically that all Ca^{2+} and Mg^{2+} precipitate as carbonates. The concentrations of bicarbonate and carbonate influence the irrigational suitability of water. Considering this hypothesis, Eaton [29] proposed the concept of residual sodium carbonate (RSC) for the assessment of high carbonate waters. The water with high RSC has high pH and the excess of carbonates causes dissolution of organic matter which in turn leaves black stains on the soil surface after drying. The land irrigated with water excess in sodium bicarbonate and carbonate becomes infertile owing to deposition of sodium carbonate as observed from blackening of the soil.

Percent Sodium (% Na) or Soluble Sodium Percentage (SSP)

The formula used to calculate the soluble sodium percentage is

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

(Ion Concentrations are in meq/l) …(Eq^n 4)

SSP is an important factor to study sodium hazard. It is calculated as the percentage of sodium and potassium against all cationic concentrations. It is also used for evaluating water quality for its use in irrigating agriculture land [30]. Sodium reacts with soil to reduce its permeability [31] and threatens plant growth. Usually SSP > 15% causes serious reduced permeability. The finer the soil texture and the greater the organic matter content, the greater is the impact of sodium on water infiltration and aeration.

Magnesium Ratio (MR)

Magnesium ratio is one of the most important qualitative criteria in determining water quality for irrigation purpose. It is calculated by the following formula:

$$Mg \text{ content} = [Mg^{2+}/ (Mg^{2+} + Ca^{2+})] 100$$

(Ion Concentrations are in meq/l) …(Eq^n 5)

Residual Sodium Bicarbonate (RSBC): The alkalinity hazard should be determined through the index called Residual Sodium Bicarbonate (RSBC). It is calculated as

$$RSBC=HCO_3^- - Ca^{2+}$$

All ions are expressed as meq/ l.

…(Eq^n 6)

This is because carbonate ions do not occur very frequently in appreciable concentrations, and the bicarbonate ions do not precipitate magnesium ions.

Based on RSC/ RSBC ratio, there are 6 alkalinity classes proposed:

Non-alkaline water	(-ve)
Normal water	(0 meq/l)
Low alkalinity water	(2.5 meq/l)
Medium alkalinity water	(2.5-5.0 meq/l)
High alkalinity water	(5.0-10.0 meq/l)
Very high alkalinity water	(> 10.0 meq/l)

Kelly's Ratio (KR)

Sodium measured against Ca^{2+} and Mg^{2+} is used to calculate Kelly's ratio11. The formula used in the estimation of Kelley's ratio is expressed as, Kelly's Ratio (KR) = $Na^{+}/ Ca^{2+} + Mg^{2+}$

…(Eq^n 7)

A Kelly's Ratio (KR) of more than one indicates an excess level of sodium in waters. Hence, waters with a Kelley's Ratio less than one are suitable for irrigation, while those with a ratio more than one are unsuitable for irrigation [32].

Permeability Index (PI)

To identify the suitability of surface water for irrigation, Doneen in 1964 [33] gave a formula for permeability index as PI = $[(Na^{+} + \sqrt{HCO_3^{-}}) / (Ca^{2+} + Mg^{2+} + Na^{+})]$ 100 …(Eq^n 8)

The concentrations are expressed in meq/L.

Doneen (Doneen L.D., 1962) discovered permeability index as a criterion for assessing the suitability of water for irrigation and accordingly, waters are classified as class I, Class II and Class III orders [34]. Class I and Class II waters are categorized as good for irrigation with 75% or more maximum permeability. Class III water are unsuitable with 25% of maximum permeability [35]. PI is used to evaluate the sodium hazard of irrigation waters [36]. Long term use of irrigation water can affect the soil permeability.

Permeability is affected not only by high sodium but also by calcium, magnesium, carbonate and bicarbonate content in the water. The effect on permeability has been evaluated by PI.

A quality diagram [27] given by the U. S. Salinity Laboratory (Richards, 1954) is used for making salinity classification. The diagram gives 16 classes, with reference to SAR as an index of sodium hazard and EC as an index of salinity hazard [37-38]. By plotting the obtained our results in the diagram (Figure 17), it was found that all the 9 mean values of 3 irrigation water samples in monsoon, post-monsoon and pre-monsoon, was categorized into "C_2-S_1" class. Such water is of *medium to good quality* class and can be used safely for irrigation purposes (Richards, 1954) [27]. The water is classified based on the Na % with respect to other cations present in water (cf: Wilcox classification, 1985) [39]. The EC and Na% values plotted on Wilcox diagram. The results illustrate that all water samples in different seasons fall in the field *excellent to good* (Figure 18).

The present investigation was undertaken at the time of serious drought in the (Marathwada) region. Though the study embodied in this manuscript appears to be of local interest, there is a lot to learn from the experiments and results on the water quality and sedimentary analyses for assessing irrigational suitability of the water body. And based on this understanding, others can also make such efforts elsewhere. One way would be comparison of the studies on pollution of water bodies from various parts of the world using the same parameters or indicators [40], rather than waiting till pollution irreversibly damages existing ecosystem [41]. Yet another way would be comparison of the studies on pollution of this water body in different years or at different seasons of a year. The recent rainfall might now be altering water quality or sediments in the fluvial processes and it would therefore be interesting for future studies to identify problems, if any and thereby interpret causes and consequences before actually proposing alternatives for enhancing or restoring irrigational suitability of the dam water. On the ground of the aforementioned consideration, the researchers propose that the local Government authority should adopt a continuous or at least seasonal monitoring of this dam and frame sedimentary quality control measures that identify and estimate slow creeping changes in water for its irrigational suitability.

Conclusion

The pollution might be mainly caused due to the human interference. The physico-chemical parameters of dam water varied according to season. The pollution is anthropogenic or caused due to the interference of human beings. The water quality of Siddheshwar dam is suitable for domestic purposes with few exceptions and concerns. All the irrigational indices show that the water is of good quality and can be used for irrigation without any serious hazard. Metals are also found in sediment samples. It is concluded that though the dam is not that (too much) polluted, the environmentalists and the local Government authority could consider adopting a regular monitoring of aquatic ecosystem and take suitable remedial measures like collection of domestic sewage and setting-up the common treatment plant nearby for controlling further pollution and preventing the depletion of the quality of dam waters. These experiments and results confirmed that though there is no serious pollution observed due to the anthropogenic activities, land or soil erosion, agricultural run-off, etc. near the water reservoir, continuing and permanent assessment as well as mitigation measures in this area are highly desirable.

Acknowledgments

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