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Physico-Chemical Analysis of Water of River Chambal at Keshoraipatan U/S near Shri Raj Rajeshwar Mahadev Temple, District Bundi and their Statistical Interpretation

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Abstract
Bundi, the blue city of eastern Rajasthan, is considered as a perfect travel destination attracted by tourists from all over the world. Though famous for its tourist attraction, still this cultural city is facing current trends of urbanization, over-exploitation of resources and exorbitantly increasing population. Shri Raj Rajeshwar Mahadev Temple, a shrine of Bundi is located at the town Keshoraipatan around 20 km from the Education City, Kota. Water, the elixir of life, is a priceless commodity and accessibility of clean water is a right of each and every person. Therefore, study of physico-chemical parameters of water is considered as an important aspect of pollution studies in the environment. This study is designed to assess the water quality standards of physico-chemical parameters and their statistical interpretation of water of River Chambal at Keshoraipatan U/S near Shri Raj Rajeshwar Mahadev Temple, District Bundi of Hadoti Division. In this study, we found that Turbidity and Fecal Coliform level are comparatively more than that of permissible limit in months of Monsoon Season. Different statistical analyses also explain the suitability of water for agriculture and domestic purposes.
Keywords: *Water quality, Keshoraipatan, Shri Raj Rajeshwar Mahadev Temple, Bundi, Physico-chemical parameters, statistical analysis*

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Abbreviations

SAR	Sodium Absorption Ratio
CAI	Chloro Alkaline Indices
% Na	Sodium Percentage
APHA	American Public Health Association
WHO	World Health Organization
NWMP	National Water Monitoring Programme
ICMR	Indian Council of Medical Research

I. Introduction

Water, the most vital component, is necessary for the continuity and proliferation of life. All metabolic reactions occur in the water. The collective volume of water under, on and over the surface of planet earth is considered as hydrosphere. India has diversified forms of lands in which Rajasthan is situated in the north-west region as a dry state. The south-eastern part of Rajasthan especially Hadoti Divison shows the characteristic climatic conditions such as long and intensely hot summer, low rainfall and short mid-winter. The Hadoti Divison is made up of Kota, Bundi, Baran and Jhalawar, with Kota in the centre, Bundi in the west, Jhalawar in the southeast and Baran in the east.

Temperatures typically vary between 7^{o}C in January and 48^{o}C in May. The average annual precipitation in the area is approx 700 mm. The lithological units that constitute the Hadoti division are mainly those of upper Vidhyan system. In parts of the southern sector, the upper Bhander sands stone covers the huge area to the north, mantled by the Deccan trap flows. The eastern part of the central belt is occupied by the Suket Shales, while on the west there are rocks of Kaimur sandstone.

The water quality is affected by geological formations, anthropogenic activities, current trends of urbanization, over-exploitation of resources and exorbitantly increasing population [24]. In other words, the quality of water is deteriorated by excessive use of fertilizers and industrial discharge [7] [22].

The only perennial river 'Chambal' originating from the hills of Western Madhya Pradesh passes through this area. Owing to human activities, the water in some areas is being unfit for drinking and irrigation purposes.

From Hadoti division, the selected site for the present study is the water of River Chambal at Keshoraipatan U/S near Shri Raj Rajeshwar Mahadev Temple, District Bundi. Bundi is just like a small oasis situated in a narrow valley of the south-eastern region within Aravali Hills. The silhouette of this Charming city is represented by mansions, forts, paintings, Step-wells and palaces. Bundi is also known as the 'city of step-wells' where Raniji ki Baori and Dabhai Kund are very famous to visit. The town Keshoraipatan has located around 20 km from the Education City, Kota where Shri Raj Rajeshwar Temple present. The king of Bundi built Shri Raj Rajeshwar Temple of Lord Shiva which was earlier named as Kunwar Suwalaal ka Bagh. The coordinates for Shri Raj Rajeshwar temple are 25°17'15''N and 75°55'44''E.

There is no denying that water is inextricably connected to sustainable growth. A number of studies on groundwater and surface water quality with respect to drinking and irrigation purposes have been carried out in different parts of India and around the world with reference to major ions chemistry, trace element chemistry and through multivariate statistical techniques

II. Materials and Methods

In this study, the water quality standards of different Physico-chemical parameters such as pH, Temperature, Conductivity, Turbidity, Fecal coliform, Total dissolved solids, BOD, COD, TA, TH, Calcium, Potassium, Sodium, Magnesium, Nitrate, Sulphate, Phosphate, Chloride, Fluoride, and Boron dissolved and their statistical interpretation for domestic and agriculture purpose were evaluated for the water of River Chambal at Keshoraipatan U/S Near Shri Raj Rajeshwar Mahadev Temple, District Bundi of Hadoti Division

Twelve sample readings were considered for the water of River Chambal at Keshoraipatan U/S near Shri Raj Rajeshwar Mahadev Temple, District Bundi collected from Rajasthan Pollution Control Board, Jaipur's Web-Site. Water sample readings were analyzed throughout the year for various Physico-chemical parameters using standard methods recommended by the American Public Health Association [1]. There are various methods to determine different physical and chemical parameters.

National Water Monitoring Programme (NWMP) of Rajasthan State Pollution Control Board, Jaipur produces an environmental report of different physicochemical parameters for different stations of Rajasthan State. All Sample readings for different Physico-chemical parameters were taken at Regional Laboratory, Kota.

In this analysis, 12 sample readings were considered in 2018 and 2019 for two subsequent years. i.e. six sample readings for each year with even months for the water of River Chambal at Keshoraipatan U/S Near Shri Raj Rajeshwar Mahadev Temple, District Bundi with station Code-10029. In some cases, there was an increase or decrease shown in readings which were due to change in weather.

Table- 1 Physico-chemical analysis of water of River Chambal at Keshoraipatan U/S Near Shri Raj Rajeshwar Mahadev Temple, District Bundi for two consecutive years 2018 and 2019

Physico-chemical Parameters	2018						2019					
	Feb	April	June	Aug.	Oct.	Dec.	Feb	April	June	Aug.	Oct.	Dec
	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12
pH	8.26	8.35	8.4	7.55	7.76	8.23	8.33	8.45	8.5	8.11	7.97	8.43
Tempt.	23	28	31	30	30	19	23	28	33	25	27	19
Turbidity	2.4	3.1	3.6	8.5	3.1	4	4	4.2	4.2	25.4	1.5	2.5
TDS	512	594	624	238	264	386	422	538	596	212	254	388
EC	700	780	840	310	360	610	620	690	810	270	340	610
T A	160	188	196	128	140	140	156	164	172	44	56	68
T H	160	168	188	128	136	148	164	180	120	68	92	108
BOD	2.1	1.42	2.35	1.4	4.8	2.52	1.6	2.37	3.33	1.38	1.3	1.8
COD	12.75	33.77	28.36	8.64	43.2	20.8	28	39.2	21.83	7.43	11.2	14.62
Fecal Coliform	14	75	11	20	20	20	23	23	39	20	150	150
Ca^{2+}	36.8	43.2	40	27.2	28.8	38.4	38.4	38.4	38.4	20.8	20.8	24
Mg^{2+}	16.59	14.64	21.47	14.64	15.62	12.69	16.59	20.49	5.86	3.9	9.76	11.71
Na^{+}	82	88	174	45	53	64	64	59	71	36	39	59
K^{+}	1.6	1.5	1.7	1.1	1.5	1.7	1.7	3.2	4.2	2.6	1.9	3.1
Cl^{-}	204	172	228	84	84	136	156	80	116	44	48	84
SO_4^{2-}	142.5	150	135	38	50	88	84	35.5	76	41	55	86
NO_3^{-}	2.68	2.68	2.28	2.28	2.28	2.2	2.36	1.84	2.2	1.84	2.1	2.36
PO_4^{3-}	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.4	0.7
F^{-}	0.82	0.82	0.92	0.84	0.84	0.84	0.86	0.9	0.98	0.84	0.84	0.9
Boron	0.25	0.33	0.38	0.3	0.27	0.33	0.33	0.23	0.3	0.21	0.25	0.21

Note: All ionic concentration are expressed in mg/lit. except EC(μmho/cm), Tempt.(^oC) Turbidity(NTU) and Fecal Coliform (MPN/100 ml)

III. Result and Discussion:

3.1 Water Quality Parameters

Different Physico-chemical parameters were reported in Table-1. 12 samples i.e. 6 samples for the 2018 year and 6 samples for the 2019 year and were analyzed for the following parameters:

TDS, EC, TA, TH, BOD, COD, Fecal Coliform, pH, temperature, turbidity Ca^{2+}, Mg^{2+},Na^+, K^+, Cl^-, SO_4^{2-}, NO_3^-, PO_4^{3-}, $F^-$and boron dissolved.

Following water quality parameters were studied in the water and compared with standard permissible limits.

3.1.1 pH – A significant parameter that reflects the acidic and alkaline nature of water. It is vital for varied biochemical reactions [23][16]. The permissible limit for pH in water is 6.5 – 8.5 [1]. Less pH causes tuberculation and corrosion while higher pH causes Incrustation and sediment deposit [14].

3.1.2 Temperature- A vital parameter which not only influences the chemistry of water but also governs biological activity and growth of living organisms. It also influences the different kinds of organisms that can live in water bodies.

3.1.3 Turbidity -Turbidity represents cloudiness of the liquid which is formed by the accumulating individual particles which are not visible by the naked eyes like smoke in the air. The permissible limit for turbidity is 5-10 NTU

3.1.4 Total Dissolved Solids (TDS) - TDS measures the total number of charged ions absorbed in a sample of water, including minerals, salts, or metals. In mg/lit, it is represented. TDS originates from natural sources, sewage, urban runoff, chemicals used in water treatment processes, industrial wastewater and nature of hardware used in water transport. [28]. Permissible limit is 1500 mg/lit. [4].

3.1.5 Electrical conductance -The measure of water's capacity to pass electric flow [27]. Electrical conductance is represented in the ionized form of dissolved salts and other inorganic chemicals present in the water. This concentration of ionized form contributes to conductance. Permissible limit is 200-1000 μmho/cm.

3.1.6 Total Alkalinity- The measure of the buffering capacity of water or the capacity of bases to neutralize acids. It basically regulates the pH of a water body and also maintains the metal content. It refers to the power of water to resist change in pH.

The general level of freshwater for the alkalinity level is 20-200 mg/lit.

3.1.7 Total Hardness -A significant measure of polyvalent cations in water is a vital factor. Polyvalent cations mainly include the concentration of calcium and magnesium including other cations like aluminium, barium, manganese and iron etc also contribute to it. 300 mg/lit is permissible to limit of total hardness of water by ICMR. The higher hardness content is due to unnecessary lime usage by the manufacturing and chemical effluent. [18].

3.1.8 Biochemical Oxygen Demand (BOD) -BOD measures the oxygen utilized for the biochemical degradation of organic material (carbonaceous demand) and oxidation of inorganic material such as sulphides and ferrous ions during a specified incubation period. The permissible limit for BOD is 3-5 ppm which represents a moderately clean level.

3.1.9 Chemical Oxygen Demand (COD) -The measure of the capacity of water to consume oxygen during the process of decomposition of organic matter and oxidation of inorganic compounds like Ammonia, nitrite. It also means the oxygen mass absorbed in the solution volume. It is expressed in mg/lit. Ideally COD should be zero.

3.1.10 Fecal Coliform -A group of total coliforms that are present in animal intestines and faeces. Faecal coliform bacteria may occur in ambient water as a sign of overflow of domestic sewage. At the same time, it may cause some waterborne diseases such as typhoid fever, viral and bacterial gastroenteritis. The optimal amount of coliform in 100 ml must not be measurable.

3.1.11 Calcium- The optimal amount of coliform in 100 ml must not be measurable. The main source is an erosion of rocks such as limestone and minerals like calcite. The permissible limit for Calcium is 75-200 mg/lit. Excess amount of calcium concentration causes less absorption of essential minerals in the human body.

3.1.12 Magnesium- The greater concentration in water makes unpleasant taste. The main source of magnesium in water is by the erosion of rocks and minerals like dolomite or magnetite. The permissible limit of Magnesium is 30-150 mg/lit.

3.1.13 Sodium- Permissible limit for sodium in drinking water must be in the range of 30 to 60 mg/lit. Higher concentrations are caused by hypertension, renal and heart-related diseases.

3.1.14 Potassium – As well as for humans, the lower potassium concentration is advantageous for vegetation. Hypertension, diabetes, adrenal insufficiency, kidney and heart-related diseases are caused by a higher concentration of potassium.

3.1.15 Chloride- Chlorides are present in almost all natural water resources. As we all know, the concentration of chloride content varied widely and it is maximum in ocean water. The maximum permissible limit of Chloride ion by WHO 1991 is 200 ppm and the maximum allowable limit is 600 ppm.[26] It is considered an essential water quality parameter by affecting its usability and aesthetic property with taste and make it unfit for drinking purpose. The main source of Chloride concentration is the formation of rocks and soil with sewage wastes.
3.1.16 Sulphate –Sulphate is present in almost all drinking natural water sources [27]. The sources for sulphate concentration are rocks and geological formation. The excess amount of sulphate content causes a laxative effect. The permissible limit for sulphate is 200-400 mg/lit.
3.1.17 Nitrate–Maximum permissible limit of nitrate is 50 mg/lit.[4]. The higher concentration of nitrate causes blue-baby disease or methemoglobinemia.
3.1.18 Phosphate-The admissible phosphate level is 0.005 to 0.05 mg/lit. The main source of phosphate is sewage and industrial waste disposal in freshwater. Basically, it promotes the growth of micro-organism. [8]
3.1.19 Fluoride- The controlled addition of fluoride in water supplies to maintain public health is known as water fluoridation. This fluoridated water is used to prevent cavities by maintaining the concentration of fluoride in water. Required level is 1.0-1.5mg/lit. Excess concentration causes fluorosis and deformation in joints
3.1.20 Boron Dissolved- Permissible concentration of boron in the surface water is 1-5 mg/lit for a day. It is an essential nutrient present in plants.

3.2 Water quality criteria for irrigation

The appropriateness of water for agricultural use is determined by its quality for irrigation purpose. The quality of water for irrigation purpose is determined by the concentration and composition of dissolved constituents in water. Quality of water is an important aspect in any appraisal of salinity or alkalinity conditions in an irrigated area. Good soil and water management practices result in good quality of water which can promote maximum yield of the crop.

Total dissolved Solids and the sodium content in relation to the amounts of calcium and magnesium or SAR [2] determines the suitability of water for irrigation. The suitability of groundwater for irrigation use was evaluated in the form of salinity by different statistical calculations such as (Sodium absorption ratio (SAR), soluble sodium percentage (SSP) and Chloro alkaline indices (CAI).

Statistical Representation of Water Parameters

3.2.1 **Sodium Absorption Ratio(SAR)**: SAR is a vital parameter given by Richard in 1954[19]. The basic concept behind the sodium absorption is to find out the soil alkalinity of water used for irrigation purposes [12].

SAR (Sodium Absorption Ratio) = $\frac{Na}{\sqrt{\frac{Ca+Mg}{2}}}$

Note: Ca^{2+}, Mg^{2+} and Na^{+} are reported in mg/l.

3.2.2 **Chloro alkaline indices (CAI)**: Chloro alkaline indices are used to calculate the base exchange proposed by Schoeller[20]. Chloro alkaline indices are used to calculate ion exchange between the water and its surrounded area.

It is measured by the following equation

$$CAI = [Cl^{-} - (Na^{+}+K^{+})/Cl^{-}$$

Note: all ionic concentrations are measured in mg/l.

- CAI >0: No Base Exchange reaction i.e. there is any existence of anion cation exchange type of reactions.
- CAI <0: Exchange between sodium and potassium in water with calcium and magnesium in the rocks by a type of Base Exchange Reactions [17].

3.2.3 **Percentage Sodium (%Na)**: A method used for rating the irrigation waters which is utilized on the basis of percentage and electrical conductivity given by Wilcox [25].

It is calculated by the formula:- %Na = $\frac{(Na+K)}{Na+K+Mg+Ca} \times 100$

Note: All ionic concentrations are expressed in mg/l.

3.2.4 **Kelly's ratio (KR):** Kelly ratio represents the assessment ratio for calculating the suitability of water for agriculture purpose. The suitability and unsuitability of water for agricultural purpose on basis of KR is due to alkali hazards [9].

Kelly's ratio was calculated by using the following expression

Kelly Ratio (KR) $= \frac{Na}{(Ca+Mg)}$

- KR ≤1: Suitable for Irrigation and represent good quality
- KR>1: Unsuitable for irrigation purpose

Note: All ionic concentrations are conveyed in mg/l.

3.3.5 **Calculation of Indices: Langelier Saturation Index (LSI)**

LSI is an equilibrium index which represents the thermodynamic driving force for calcium carbonate scale formation and growth given by Langelier. It is explained with the use of pH [13].

- LSI <0 : No potential scale and water will dissolve $CaCO_3$.
- LSI >0 : Scale can form and $CaCO_3$ precipitation may occur.
- LSI = 0 : Border line scale potential.

To calculate LSI, the value of total alkalinity (as $CaCO_3$), Calcium hardness as $CaCO_3$), total dissolved solids (TDS) and value of pH and temperature of water (°C) required.

Note: All ionic concentrations are expressed in mg/l.

LSI = pH – pHs

pHs in calcite or calcium carbonate is classified as the pH at saturation.

It is calculated by following formula

pHs = (9.3 + P + Q) – (R + S)

where P = ($\log_{10}$ [TDS] –1)/10

Q = –13.12 × $\log_{10}$ (°C + 273) + 34.55

R = $\log_{10}$ [Ca Hardness as $CaCO_3$] –0.4

S = $\log_{10}$ [Total alkalinity as $CaCO_3$]

We can calculate LSI by help of these equations.

LSI is helpful in forecasting the scaling or corrosive tendencies of the water.

- If water dissolves calcium carbonate, water is corrosive and shows a negative value.
- If the water deposits calcium carbonate; it has a scaling tendency and a positive value.

The suitability of water for agricultural use is determined by its quality for irrigation purpose. The quality of water for irrigation purpose is determined by the concentration and composition of dissolved constituents in water. Quality of water is an important aspect in any appraisal of salinity or alkalinity conditions in an irrigated area. Good soil and water management practices result in good quality of water which can promote maximum yield of crop.

Total dissolved Solids and the sodium content in relation to the amounts of calcium and magnesium or SAR [2] determines the suitability of water for irrigation. The suitability of groundwater for irrigation use was evaluated in the form of salinity by different statistical calculations such as (Sodium absorption ratio (SAR), soluble sodium percentage (SSP) and Chloro alkaline indices (CAI).

Table -3 Statistical Analysis of Various Water Sample Readings

Statistical Parameters	2018						2019					
	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12
	Feb	April	June	Aug	Oct	Dec.	Feb	April	June	Aug	Oct	Dec.
SAR	13.2	10.86	31.4	9.84	11.25	12.67	12.213	10.88	15.106	10.256	7.26	13.98
CAI	0.51	0.51	0.23	0.42	0.35	0.52	0.58	0.22	0.35	0.12	0.14	0.26
%Na	26.8	60.7	74.1	52.5	55.0	57.2	54.4	51.3	62.9	60.9	57.2	63.4
KR	1.53	1.52	2.83	1.07	1.23	1.30	1.16	1.001	1.60	1.457	1.27	1.65
LSI	0.671	0.941	1.107	-0.07	0.204	0.484	0.737	1.026	0.995	-0.335	-0.213	0.232

Note: All ionic concentrations are reported in mg/l.

Table-4 Classification of Water samples on the basis of basis Statistical Analysis

Statistical Analysis Parameters	Categories	Range	No. Of Samples	
			2018	2019
Sodium Absorption Ratio(SAR)	Excellent Good Fair Poor	0-10 10-18 18-26 >26	1 4` 1	1 5
ChloroAlkanine Indices(CAI)	Base Exchange Reaction Cation Exchange Reaction	Negative Value Positive Value	NIL All	NIL All
Sodium Percentage(%Na)	Excellent Good Permissible	0-20 20-40 40-60	 1 3	 3

	Doubtful	60-80	2	3
	Unsuitable	>80		
Kelly Ratio(KR)	Suitable	<1	4	5
	Marginal Suitable	1-2	2	1
	Unsuitable	>2		

Table 5: Interpretation of Langelier Saturated Index (LSI) Test Result

S.No.	LSI Index	Appearance	Water Condition Issues required
1	-4.00	Very severe corrosion	Conditioning required
2	-3.00	severe corrosion	Conditioning usually suggested
3	-2.00	Moderate corrosion	Some conditioning is suggested
4	-1.00	Mild corrosion	Required some conditioning
5	-0.50	Slight corrosion	May need some conditioning
6	0.00	Balanced	Conditioning not suggested
7	0.50	Faint Scale Coating	Conditioning not suggested
8	1.00	Slight Scale Coating	Some visual appearance shown
9	2.00	Mild Scale Coating	Should consider some conditioning
10	3.00	Moderate Scale Coating	Should use some conditioning
11	4.00	Severe Scale Coating	Usually conditioning required

IV. Conclusion

From the observations made in the study, the following conclusions are drawn:

- All the samples readings come near to the permissible range for drinking and irrigation use apart few samples which are exceeding the limit due to anthropogenic activities.
- On the basis of statistical analysis, that all samples are alkaline in nature and are present in permissible range and it shows requirement of mild conditioning agents for drinking and industrial purposes.
- The concentrations of cations and anions are within the allowable limits for drinking water standards except a few samples.
- The suitability of water for irrigation is evaluated based on SAR, CAI, % Na, KR and salinity hazards. Most of the samples fall in the suitable range for irrigation purpose based on SAR, CAI, % Na and KR values, but very few samples that are exceeding the permissible limits. These variations are observed to be in different kind of geological areas and different anthropogenic activities were carried in the study area.

This study will be helpful in sustainable development of water sources of River Chambal at Keshoraipatan U/S Near Shri Raj Rajeshwar Mahadev Temple, District Bundi, Rajasthan with station Code-10029.

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