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Physico-Chemical Analysis of the Water of River Chambal at Rangpur, Kota District and their Statistical Interpretation

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Abstract: ***Kota district is a fastest developing city of Hadoti Division of Rajasthan. Though famous for its quality education and varied industries like cement, textile, fertilizers, limestone & power plants, still this cultural city is facing current trends of urbanization, over-exploitation of resources and exorbitantly increasing population. Water, the elixir of life, is a priceless commodity and should be available to 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 River Chambal at Rangpur, Kota D/S (2 KM from City) 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 Analysis also explain the suitability of water for agriculture and domestic purposes***

Keywords: Water quality, river Chambal at Rangpur, Kota, Physico-chemical parameters, statistical analysis SAR, CAI, %Na, KR and LSI

Abbreviations

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

1. Introduction

Water, the most vital component, is necessary for the continuity 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 North West region as a dry state. The south eastern part of Rajasthan specially Hadoti Divison show the characteristic climatic conditions such as long and intensely hot summer, low rainfall and short mid winter. Hadoti Divison consists of Kota, Bundi, Baran and Jhalawar in which kota is at central, Bundi on its West, Jhalawar in the South East and Baran in the East.

The temperature normally varies from 7^{o}Cin January to 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. The upper Bhander sands stone covers the wide area on the North in parts of Southern sector are 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 out crops of Kaimur sand stone.

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, 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. Current trends of urbanization, over-exploitation of resources and exorbitantly increasing population Owing to human activities, the water in some areas is being unfit for drinking and irrigation purposes.

From hadoti divison, the selected site for the present study is the water of River Chambal at Rangpur, D/S (2 KM from city) Kota.

There is no doubt that water and sustainable development is inextricably linked. 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

2. 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 water of River Chambal at Rangpur, Kota D/S (2 KM from City) of Hadoti Division

Twelve sample readings were considered for water of River Chambal at Rangpur, D/S (2 KM from city) 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 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 environmental report of different physico- chemical parameters for different stations of Rajasthan State. All Sample readings for different physico-chemical parameters were taken at Regional Laboratory, Kota.

In this study, Twelve sample readings were considered for two consecutive years 2018 and 2019 i.e. six sample readings for each year with even months for water of River Chambal at Rangpur, Kota district D/S (2 KM from city) with station Code-1289. In some cases, there was increase or decrease shown in readings which was due to change in weather.

Table 1: Physico-chemical analysis of water of River Chambal at Rangpur, kota district D/S (2 KM from city) for two consecutive years 2018 and 2019

Physico-chemical Parameters	2018						2019					
	Feb	April	June	August	Oct.	Dec.	Feb	April	June	August	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	8.31	8.38	8.37	7.62	8.04	8.17	8.24	8.38	8.48	8.14	7.93	8.36
Tempt.	22	28	31	29	28	19	22	26	32	24	26	19
Turbidity	2	3.4	3.8	10.8	4.3	3.8	4.1	3.9	4.5	28.3	1.6	2.3
TDS	530	646	598	246	328	382	432	494	576	234	238	352
EC	720	840	810	330	430	600	640	670	780	310	330	550
T A	152	176	168	120	132	132	152	156	168	48	48	60
T H	156	172	176	124	144	144	156	172	140	72	84	96
BOD	1.95	1.85	2.27	1.10	1.70	1.60	1.79	2.47	3.33	1.27	1.10	1.90
COD	10.13	38.37	19.6	18.72	13.6	13.6	20.8	30.86	22.26	5.78	6	15.8
Fecal Coliform	14	28	11	11	14	20	64	20	39	39	150	240
Ca^{2+}	36.8	41.6	38.4	28.8	33.6	35.2	35.2	35.2	40	20.8	19.2	20.8
Mg^{2+}	15.62	16.59	19.52	12.69	14.64	13.67	16.59	20.49	9.76	4.88	8.78	10.74
Na^{+}	80	160	84	39	48	59	63	63	67	38	29	45
K^{+}	1.8	1.7	1.6	1.1	1.5	1.4	1.5	4.5	5.1	3.1	2.1	3.3
Cl^{-}	248	252	256	88	124	132	156	84	108	48	52	76
SO_4^{2-}	122.5	154	152.5	58	67	88	95	35.5	76	49	49	82
NO_3^{-}	2.74	2.06	2.8	2.28	2.1	2.28	2.2	3.04	2.68	1.84	2	2.2
PO_4^{3-}	0.2	0.1	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.3	0.5
F^{-}	0.86	0.82	0.76	0.82	0.82	0.82	0.8	0.92	0.96	0.8	0.84	0.9
Boron	0.27	0.19	0.3	0.31	0.26	0.27	0.26	0.23	0.26	N/A	0.27	0.23

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

3. Result and Discussion

3.1 Water Quality Parameters

Different physico-chemical parameters were reported in Table-1. 12 samples i.e. 6 samples for 2018 year and 6 samples for 2019 year and were analyzed for following parameters: pH, temperature, turbidity, TDS, EC, TA, TH, BOD, COD, Fecal Coliform, 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 – An important parameter which represents acidic and alkaline nature of water. It is vital for varied biochemical reactions [23][16]. 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 influence 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 accumulatingindividual particles which are not visible by the naked eyes like smoke in air. Permissible limit for turbidity is 5-10 NTU

3.1.4 Total Dissolved Solids (TDS)- TDS measures the total amounts of charged ions including minerals, salts or metals dissolved in a given volume of water. It is expressed in mg/lit. TDS originates from natural sources, sewage, urban runoff, chemicals used in water treatment processes, industrial waste water and nature of hardware used in water transport. [28]. Permissible limit is 1500mg/lit. [4].

3.1.5 Electrical conductance-The measure of water's capacity to pass electric flow [27]. Electrical conductance is represented in 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 pH of a water body and also maintains the metal content. It refers to the ability of water to resist change in pH. The general level of fresh water for alkalinity level is 20-200 mg/lit.

3.1.7 Total Hardness-An important parameter which is a measure of polyvalent cations in water. Polyvalent cations mainly include concentration of calcium and magnesium including other cations like aluminium, barium, manganese and iron etc also contribute to it. 300 mg/lit is permissible limit of total hardness of water by ICMR. The higher content of the hardness is due to the industrial and chemical affluent with excessive use of lime [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. Permissible limit for BOD is 3-5 ppm which represents 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 mass of oxygen consumed in Volume of the solution.It is expressed in mg/lit. Ideally COD should be zero.

3.1.10 Fecal Coliform-A group of total coliforms that are found in the gut and faeces of animals. Fecal coliform bacteria may occur in ambient water as a significance of overflow of domestic sewage. At the same time it may cause some waterborne diseases such as typhoid fever, viral and bacterial gastroenteritis. The acceptable level of coliform should be non-detectable in 100 ml

3.1.11 Calcium- Most abundant natural element present in all natural water sources. The main source is erosion of rocks such as limestone and minerals like calcite. Permissible limit for Calcium is 75-200 mg/lit.Excess amount of calcium concentration causes the less absorption of essential minerals in the human body.

3.1.12 Magnesium- Its higher concentration renders undesirable tastes in water. The main source of magnesium in water is by erosion of rocks and minerals like dolomite or magnetite. Permissible limit of Magnesium is 30-150 mg/lit.

3.1.13 Sodium- Permissible limit for sodium in drinking water must be in range of 30 to 60 mg/lit. Hypertension, Kidney and Heart related diseases are caused by higher concentration of sodium.

3.1.14 Potassium– The lower concentration of potassium is beneficial for humans as well as plants. Hypertension, diabetes, adrenal insufficiency, kidney and heart related diseases are caused by 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. Maximum permissible limit of Chloride ion by WHO 1991 is 200 ppm and maximum allowable limit is 600 ppm.[26] It is considered as essential water quality parameter by affecting its usability and aesthetic property with taste and make it unfit for drinking purpose. Main source of Chloride concentration are 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 laxative effect.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 methamoglobinemia.

3.1.18 Phosphate- Permissible range for phosphate is 0.005 to 0.05 mg/lit. Main source of phosphate are sewage and industrial waste disposal in fresh water. Basically it promotes 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. So fluoridated water is used to prevent cavities by maintaining 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 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 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).

Statistical Representation of Water Parameters

3.2.1 Sodium Absorption Ratio(SAR):SAR is an 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 expressed in mg/l.

3.2.2 Chloro alkaline indices (CAI): Chloro alkaline indices is 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 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 conductivitygiven by Wilcox [25].

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

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

3.3.5 Calculation of Indices: Langelier Saturation Index (LSI)

LSI is an equilibrium index which represents 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, 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 concentration are expressed in mg/l.

LSI = pH – pHs

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

It is calculated by following formula

$pHs = (9.3 + P + Q) – (R + S)$

where $P = (\log_{10} [TDS] –1)/10$

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

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

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

We can calculate LSI by help of these equations.

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

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

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	15.62	29.7	15.61	8.57	9.77	13.45	12.4	11.9	13.4	10.60	7.75	11.3
CAI	0.67	0.36	0.66	0.54	0.60	0.33	0.59	0.19	0.332	0.14	0.40	0.36
%Na	0.60	0.73	0.60	0.49	0.51	0.59	0.55	0.55	0.59	0.62	0.52	0.60
KR	1.4	2.7	1.4	0.94	0.99	1.2	1.21	1.13	1.34	1.47	1.03	1.42
LSI	0.67	0.95	0.99	-1.32	0.44	1.01	0.61	0.87	1.015	-0.26	-0.37	0.06

Note: All ionic concentrations are expressed 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	0-10		
	Good	10-18	5	All
	Fair	18-26		
	Poor	>26	1`	
Chloro Alkanine Indices(CAI)	Base Exchange Reaction	Negative Value	NIL	
	Cation Exchange Reaction	Positive Value	All	All
Sodium Percentage (%Na)	Excellent	0-20	All	All
	Good	20-40		
	Permissible	40-60		
	Doubtful	60-80		
	Unsuitable	>80		
Kelly Ratio(KR)	Suitable	<1	2	All
	Marginal Suitable	1-2	4	
	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

4. 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 in Rangpur area of district Kota, Rajasthan.

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