Physico-Chemical Analysis of Water of U/S of Bhim Sagar Dam on River Ujad, Jhalawar District and their Statistical Interpretation

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Abstract

Water, the elixir of life, is a priceless commodity and should be available to each and every person. With the increase in population, the requirement of water increases constantly, 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 U/S Bhim sagar Dam on River Ujad, Jhalawar District 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, BhimSagar Dam on River Ujad, Jhalawar, Physico-chemical parameters, statistical analysis.*

1.0 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 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}C in 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 of Kaimur sand stone.

1.1 Area of Study

Out of the four, Jhalawar is a city famous for its rich natural wealth of vibrant flora and fauna of cultural state Rajasthan of India which is situated in south-eastern location of the state at the edge of the Malwa

Plateau. Jhalawar is surrounded on the northwest by Kota district, on the northeast by Baran district, on the east, west, and south by Guna, Ratlam and Rajgarh of Madhya Pradesh respectively. It covered an area of 6928 km^2 and population 66,919 according to 2011 census of India[32].

Historically the name Jhalawar is derived from princely state of Jhalawar which literally means the abode of the Jhalas i.e. a Rajput Clan. The founder of Jhalawar was a Rajput Jhala Zalim Singh.(1791 A.D.) [22]. In 1838 A.D. English ruler separated Jhalawar state from Kota state and gave it to Jhala Madan Singh, the grandson of Jhala Zaalim Singh. After that many rulers did the remarkable work for the development of Jhalawar state. Earlier the other name for Jhalawar was Brijnagar.

Jhalawar is located at coordinates[32] 24.6^0N and 76.16^0E[15]. It has an average elevation of 1023 feet. Temperature range of Jhalawar in summer is from 40^0C to 45^0C but in winter, minimum temperature can reach 1^0C. Highest rainfall is found in this district of Rajasthan. It receives the maximum annual rainfall i.e. 95 cm.

Kalisindh thermal Power Station and BGR Energy System Ltd. are different thermal power stations in Jhalawar. This area is surrounded by lush greenery with flora around and serves as a popular place for picnic. Sun-temple at Jhalarapatan, Shri1008 Shantinath Digambar jain temple including Jhalawar Fort, Bhawani Natyashala, Government Museum, Jhalarapatan, the city of bells, Gagron Fort, Chandarbhaga Temples, Buddist cave and stupas, Manohar Thana Fort etc are different places for tourism. Different local festivals like Gangaur and Kaleshwar Mahadev fair at Kyasara, Ananth Chaturthi and Rang panchami at Jhalarapatan are also celebrated to extend cultural patronage.

Rivers of Jhalawar: The general flow of rivers is from south to north and divided into two the groups –the eastern group and the western group.

- The eastern rivers-Parwan, Andheri, Ghar, Newaj and Ujad including artificial lakes Kadila and Mansarovar
- The western group- Piplaj, Ahu, kyasri, Kantali, Rawa, Kalisindh and Chandrabhaga

Different irrigation projects such as Bhimsagar dam, Chappi dam, KaliSindh dam etc.are present on different rivers. At a distance of 24 km from Jhalawar, The Bhimsagar Dam[3] has been built on the Ujad River near the old capital of khichi Chauhans Rulers. It represents a glimpse of the architecture of Rajput and Mughals in the form of ruins of palaces and temple.

The water quality is affected by geological formations, anthropogenic activities, current trends of urbanization, over-exploitation of resources and exorbitantly increasing population[27]. In other words, quality of water is deteriorated by excessive use of fertilizers and industrial discharge [8,25]. 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 U/S Bhim sagar Dam on River Ujad, Jhalawar District of Hadoti Division.

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

2.0 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 purposes were evaluated for water of U/S Bhim Sagar Dam on River Ujad, Jhalawar District of Hadoti Division. Twelve sample readings were considered for water of U/S Bhim Sagar Dam on River Ujad, Jhalawar District of Hadoti Division 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 Ujad at Jhalawar district U/S with station Code-2946. 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 of U/S Bhim sagar Dam on River Ujad, Jhalawar District of Hadoti Division.for two consecutive years 2018 and 2019

Physico-chemical Parameters	2018						2019					
	Feb.	Apr.	Jun.	Aug	Oct.	Dec.	Feb	Apr.	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	7.88	8.18	8.33	7.56	7.89	7.78	7.98	8.09	8.42	7.67	7.93	8.11
Tempt.	22	29	29	28	29 2	20	21	28	30	24	26	26
Turbidity	2.3	2.5	2.9	6.3	2.4	2.9	2.7	2.8	3.6	17.5	1.6	1.9
TDS	224	332	280	192	174	178	184	246	232	184	198	212
EC	320	450	400	260	240	290	310	320	310	230	270	320
T A	108	124	140	76	108	100	108	88	80	60	64	68
T H	104	124	132	80	96	100	120	128	136	72	84	76
BOD	1.28	1.18	1.34	1.20	3.50	0.50	1.41	2.06	1.05	1.23	0.90	2.10
COD	5.71	10.43	15.43	8.64	29.6	4.99	18.4	32.56	8.14	15.16	13.2	28.84

Fecal Coliform	9	7	14	14	11	7	9	11	9	11	14	23
Ca^{2+}	22.4	28.8	28.8	22.4	27.2	22.4	27.2	28.8	27.2	19.2	20.8	17.6
Mg^{2+}	11.71	12.69	14.64	5.85	6.83	10.74	12.69	13.67	16.59	5.86	7.81	7.81
Na^{+}	30	46	47	28	19	21	25.5	25	21	18.5	22	25.5
K^{+}	1.1	1.4	1.9	1.8	1.2	1	1.1	1.9	1.6	1.3	1.7	1.9
Cl^{-}	124	144	132	88	72	68	80	36	40	28	32	40
SO_4^{2-}	27	49	28.5	30.5	23.5	26	35.5	23	19.5	24.5	28.5	22
NO_3^{-}	2.68	1.54	2.68	2.8	2.36	2.46	1.84	1.54	1.66	1.7	1.84	1.7
PO_4^{3-}	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
F^{-}	0.82	0.92	0.86	0.84	0.82	0.8	0.8	0.9	0.84	0.8	0.8	0.86
Boron	0.3	0.3	0.35	0.31	0.23	0.23	0.3	0.25	[N/A]	[N/A]	0.23	0.19

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

3.0 Result and Discussion:

3.1 Water Quality Parameters

Different physico-chemical parameters were reported in Table-1, Twelve samples i.e. six samples for 2018 year and six samples for 2019 year 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 [26,18]. 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 [16].

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 accumulating individual 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[31] originates from natural sources, sewage, urban runoff, chemicals used in water treatment processes, industrial waste water and nature of hardware used in water transport. Permissible limit is 1500mg/lit [5].

3.1.5 Electrical conductance-The measure of water's capacity to pass electric flow. Electrical conductance[27] 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[20].

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 World health Organization (WHO) 1991 is 200 ppm and maximum allowable limit is 600 ppm[29]. 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[27] is present in almost all drinking natural water sources. 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[4] is 50 mg/lit. 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[9]..

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 determines the suitability of water for irrigation[2]. 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[21] is a vital parameter given by Richard in 1954. The basic concept behind the sodium absorption is to find out the soil alkalinity of water used for irrigation purposes [13].

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

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[23]. 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 conductivity given 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[10].

Kelly's ratio was calculated by using the following expression

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

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 [14].

- 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 concentrations 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 $P = (\log_{10}[TDS] - 1)/10$

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

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

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

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 -2 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	Apr	Jun	Aug	Oct	Dec.	Feb	Apr	Jun	Aug	Oct	Dec
SAR	7.26	10.09	10.08	7.44	6.79	5.16	5.71	5.42	4.16	5.22	5.82	7.15
CAI	0.75	0.67	0.63	0.66	0.72	0.68	0.67	0.25	0.43	0.29	0.26	0.31

%Na	0.48	0.53	0.53	0.51	0.37	0.39	0.40	0.39	0.34	0.44	0.45	0.52
KR	0.88	1.11	1.08	0.99	0.55	0.63	0.64	0.59	0.48	0.74	0.77	1.00
LSI	-0.05	0.50	0.74	-0.52	-0.26	-0.23	0.00	0.27	0.63	-0.64	-0.4	-0.08

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

Table-3 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	4 2 `	All
ChloroAlkanine Indices(CAI)	Base Exchange Reaction Cation Exchange Reaction	Negative Value Positive Value	NIL All	NIL All
Sodium Percentage(%Na)	Excellent Good Permissible Doubtful Unsuitable	0-20 20-40 40-60 60-80 >80	All	All
Kelly Ratio(KR)	Suitable Marginal Suitable Unsuitable	<1 1-2 >2	4 2	5 1

Table 4: 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

4.0 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 except only one sample of August month of 2019 in case of turbidity which was due to rainy season.
- On the basis of statistical analysis, that most of the 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.
- 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 U/S Bhim Sagar Dam on River Ujad, Jhalawar District of Hadoti Division, Rajasthan.

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