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Water quality assessment of Ghunghuta Dam, Surguja (CG), India

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Abstract

Considering the impacts of agricultural runoff, domestic and industrial effluents on the quality of many dams and rivers as cited in literature, a physico-chemical study regarding water quality assessment of Ghunghuta dam has been carried out to indicate the irrigation suitability of water. In the present study, physico-chemical parameters like pH, EC, TDS, TH, Ca, Mg, Na, K, carbonate and bicarbonate were estimated to evaluate sodium percentage (% Na), Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Exchangeable Sodium Percentage (ESP) and Permeability Index (PI). The data show that water is suitable for irrigation and classified as fit for irrigation purpose.

Keywords: Water quality, % Na, SAR, ESP, RSC, permeability index, Ghunghuta dam

Introductions

India is rich in water resources being endowed with a crisscross network of rivers that can meet a variety of water requirements of the country. Due to need for meeting the increasing demands by urbanization, industrialization and modern agricultural activities, the available water resources are getting depleted and the water quality has deteriorated. The Indian rivers are polluted due to discharge of untreated sewage, industrial effluents and agricultural runoff. In the country maximum precipitation occurs in four months of monsoon period and rivers also have maximum flow in this period. In lean seasons rivers have very little or no flow. To meet the water demand for drinking, domestic, agriculture and industry in lean periods, several types of water storage devices like anicuts, check dams, small and large dams, etc. have been constructed across the country on main course of river streams. The water quality of these storage structures depends upon physiography, geology, geomorphology, hydrogeology, demography, land use pattern and human settlement of the area concern.

Several workers have studied water quality of storage structures all over the world. Water quality studies of dams worldwide in last fifty years have been reviewed by Biswas & Tortajada (2001) ^[1]. Ganesan *et al.* (2004) ^[2] studied seasonal variation in the water quality of Pilavakkal reservoir in Western Ghats in India with respect to biological and chemical properties. Water quality of inflow and outflow of Mettur dam, constructed over River Cauvery, and has been studied by Mathivanan *et al.* (2005) ^[3] who reported high pollution load attributed to dense urbanization of the area. Karibasappa *et al.* (2009) ^[4] have studied eutrophication in Hosur town lakes and reported its high level due to contamination with sewage and agriculture runoff. Singh *et al.* (2005) ^[5] studied the water quality of six reservoirs of Damodar river basin. Water quality of Pench reservoir was studied by Pokale *et al.* (2010) ^[6] for drinking and agricultural activities. Considering the impacts of agricultural runoff, and domestic and industrial effluents on water quality of rivers and dams, the present study was undertaken to investigate water quality of Ghunghuta dam for agricultural activities.

Study area

The Ghunghutta reservoir is located in Surguja district (22°94N latitude & 83°164E Longitude) of northern Chhattisgarh in India. Ghunghutta is a medium irrigation project which was constructed in 2002 across the river Ghunghutta which is a tributary of Rehar Sub basin Sone in the Ganga basin. The Dam is 14 km. from the district head quarter Ambikapur. The Dam is 242.20 meter long and 31.50 meter high. The live storage capacity of the reservoir is 62.05 MCM. Mainly reservoir water is used for irrigation but it is also utilized for pisciculture practices.

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The Dam has typical rural environment which is enriched with the growth of variety of flora and fauna. The impact of anthropogenic pressure on the reservoir seems quite high and hence a constant monitoring of this water body is highly essential. A number of limnological studies were carried out on manmade reservoirs in India but there is a lack of baseline data on immunological characteristics of Ghunghutta reservoir Surguja which is used for irrigation and pisciculture activities. Therefore the present study was undertaken.

Irrigated agriculture is dependent on an adequate water supply of usable quality. In irrigation water evaluation, emphasis is placed mainly on the chemical and physical

characteristics of the water. Here attempt has been made to assess the irrigation water quality of Ghunghutta dam in Surguja district of Chhattisgarh. Since, for more than a century, water of the dam is being used for irrigation, it is worthwhile to assess suitability for its intended use. The quality characteristics studied in the present investigations were pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), calcium, magnesium, potassium, sodium, carbonate and bicarbonate. The calculated indices were sodium percentage (SP), sodium adsorption ratio (SAR), residual sodium carbonate (RSC), exchangeable sodium percentage (ESP) and permeability index (PI).

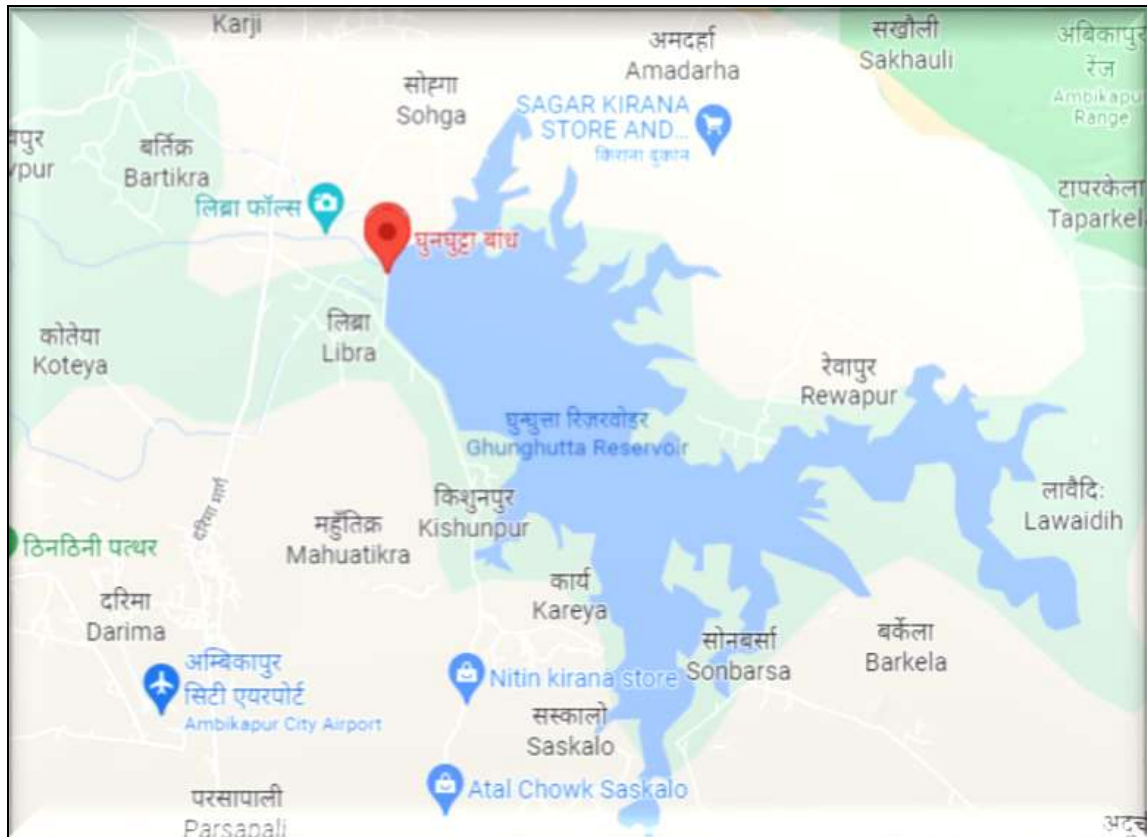


Fig 1: Map depicting different sampling locations in Ghunghutta dam

Material and Methods

Water samples were collected for three years (January 2019 to September 2021) in the three seasons *i.e.*, winter, premonsoon and post monsoon. In order to get truly representative sample integrated sampling was done. Samples were drawn from six different identified locations and then mixed together. Samples were collected in pre-cleaned polypropylene screw capped bottles of one liter capacity. The standard methods and procedures were used for quantitative estimation of water quality parameters. Determination of pH was carried out at site. Samples were brought to the laboratory to analyses other physico-chemical parameters using standard methods (APHA, 1995) [7].

From the water quality data, the irrigational indices *i.e.*, sodium percentage (%Na), sodium adsorption ratio (SAR), residual sodium carbonate (RSC), exchangeable sodium percentage (ESP) and permeability index (PI) were calculated from the following equations. For calculation of these indices, concentrations are taken in meq/L.

Magnesium content: Magnesium content of water is considered as one of the most important qualitative criteria in determining quality of water for irrigation. Magnesium hazard ratio is calculated by the following formula (Pitchaiah, 1995) [15].

$$\text{Mg content} = \left[\frac{\text{Mg}^{2+}}{\text{Mg}^{2+} + \text{Ca}^{2+}} \right] 100$$

Sodium percentage (%Na): Suitability of water for irrigation is evaluated by sodium percentage. % sodium is calculated by following equation (Chopra & Kanwar, 1999) [8].

$$\text{Na\%} = \left[\frac{\text{Na}^+}{\text{Ca}^{2+} + \text{Mg}^{2+} + \text{Na}^+ + \text{K}^+} \right] 100$$

Sodium adsorption ratio (SAR): Sodium adsorption ratio is an important parameter to determine the suitability of irrigation water and is calculated by the following formula (Wilcox, 1955) [9].

$$SAR = Na^+ / [(Ca^{2+} + Mg^{2+})/2]^{1/2}$$

Exchangeable sodium percentage (ESP): It is a degree of saturation of the soil exchange complex with sodium. It is calculated by the following relationship (Dwivedi & Pathak 2007) [10].

$$ESP = \frac{100 (-0.0126 + 0.01475 SAR)}{1 + (-0.0126 + 0.01475 SAR)}$$

Residual sodium carbonate (RSC): The residual sodium carbonate (RSC) is used for evaluating high carbonate

waters. RSC is calculated by the formula given below (Richards, 1954) [11].

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

Permeability index (PI): Permeability index is calculated by the method given by Domenico & Schwartz (1990). PI is used to evaluate the sodium hazards of irrigation water.

$$PI = [(Na^+ + HCO_3^-) / (Ca^{2+} + Mg^{2+} + Na^+)] 100$$

Results and Discussion

The results obtained from analysis of water samples of Ghunghuta dam and calculated indices are given in Table 1.

Table 1: Calculated indices and water quality data of Ghunghuta dam

Parameters	2019			2020			2021		
	Winter	Pre-monsoon	Post-monsoon	Winter	Pre-monsoon	Post-monsoon	Winter	Pre-monsoon	Post-monsoon
Physicochemical parameters									
pH	7.70	7.95	7.80	7.95	8.25	8.05	8.10	8.20	8.05
EC, μ S/cm	360	382	282	348	378	260	334	370	284
TDS, mg/L	227	241	178	219	238	164	210	233	179
CO ₃ ²⁻ , mg/L as CaCO ₃	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HCO ₃ ⁻ , mg/L as CaCO ₃	122	139	106	128	148	114	118	126	112
TH, mg/L as CaCO ₃	122	135	92	118	132	96	114	128	104
Ca ²⁺ , mg/L	26.8	30.0	18.8	23.2	28.8	20.4	25.6	27.2	19.6
Mg ²⁺ , mg/L	13.2	14.4	10.8	14.4	14.4	10.8	12.0	14.4	13.2
Na, mg/L	14.2	17.6	12.8	13.9	18.7	11.9	15.2	19.4	10.7
K, mg/L	2.1	2.7	1.8	2.3	3.2	1.9	2.1	2.7	1.6
Calculated Indices									
%Na	19.84	21.65	22.78	19.99	23.00	20.81	22.07	24.29	17.99
SAR	0.56	0.66	0.58	0.56	0.71	0.53	0.62	0.75	0.46
ESP	-0.44	-0.29	-0.41	-0.44	-0.22	-0.48	-0.35	-0.16	-0.59
RSC	0.00	0.08	0.28	0.20	0.32	0.36	0.08	-0.04	0.16
PI	381.46	362.32	452.83	402.05	375.86	459.28	391.84	354.59	434.08

Total dissolved salts (TDS): Water used for irrigation can vary greatly in quality depending upon type and quantity of dissolved salts. In dam water salts are present in relatively small but in significant amounts. The salts originate from dissolution or weathering of the rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals. The dissolved salts remain behind in soil as water is used up by crops or evaporates. Salinity problems exist if salt accumulates in root zone to a concentration that causes a significant loss in yield. This occurs when salts accumulate in root zone to such an extent that the crop is no longer able to extract sufficient water from the salty soil solution, resulting in a water stress for a significant period of time. If water uptake is appreciably reduced, the plant growth rate is also reduced. Water with TDS less than 450 mg/L is considered good, and that with greater than 2000 mg/L is unsuitable for irrigation (Westcott & Ayers 1984) [12]. In the present study values of TDS ranged from 164 mg/L to 241 mg/L. The minimum value was observed in post monsoon 2020, and maximum in premonsoon 2019.

Electrical conductivity (EC): The most significant water quality guideline on crop productivity is the water salinity hazard as measured by electrical conductivity. The primary effect of high EC water on crop productivity is the inability of the plant to compete with ions in soil solution for water. Plants can only transpire water and hence usable plant water in soil solution decreases dramatically as EC increases, even though the soil may appear wet. Water with EC less than

250 μ S/cm is considered good and greater than 3000 μ S/cm is unsuitable for irrigation (Westcott & Ayers 1984) [12]. In present investigation EC ranged from 260 μ S/cm to 382 μ S/cm. The minimum value was observed in post monsoon 2020, and maximum in premonsoon 2019.

Magnesium content (MC): Magnesium content of water is considered as one of the important qualitative criteria in determining the quality of water for irrigation. Generally, calcium and magnesium maintain a state of equilibrium in most waters. More magnesium in water will adversely affect crop yields as the soils become more alkaline. In the present study, the magnesium content of the water of Ghunghuta dam varied from 10.8 mg/L to 14.4 mg/L. The dam water is suitable for irrigation purpose in terms of magnesium content.

Sodium percent (% Na): Sodium percent is another important factor to study sodium hazard. It is calculated as the percentage of sodium and potassium against all cationic concentration. Sodium reacts with soil to reduce its permeability. The use of high percent sodium water for irrigation stunts the plant growth. The most suitable for irrigation is that water having % Na values less than 20%. When % Na is greater than 20%, permeability will be reduced (Wilcox, 1955) [13]. The finer the soil texture with high organic matter content, the greater the impact of sodium on water infiltration and aeration. The calculated sodium percent values of Ghunghuta dam ranged from

17.99 to 24.29. Normally, gypsum is added to soil to reduce the effect of high percentage of sodium in irrigation water.

Sodium adsorption ratio (SAR): Excess sodium in water used for irrigation change soil properties and reduces soil permeability. Hence, the assessment of sodium concentration is necessary while considering the suitability for irrigation. The degree to which irrigation water tends to enter into cation-exchange reactions in soil can be indicated by the sodium adsorption ratio. Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure, which becomes compact and impervious. Water with SAR from 0 to 10 is considered good and with greater than 26 is considered unsuitable for irrigation. In the present study SAR values ranged from 0.46 to 0.75 showing the water of excellent category. It can be used for irrigation on almost all types of soil.

Exchangeable sodium percentage (ESP): It is a degree of saturation of the soil exchange complex with sodium. In study of successive three years, all the calculated values of ESP were in negative showing that the water quality is suitable for irrigation.

Residual sodium carbonate (RSC): Bicarbonate and carbonate concentration of water affects its suitability for irrigation. Water with high concentration of bicarbonate and carbonate has a tendency of calcium and magnesium to precipitate, as the water in soil becomes more concentrated as a result of evaporation and plant transpiration. They get fixed in the soil by the process of Base Exchange, thereby decreasing soil permeability. The calcium and magnesium precipitate as carbonates and residual carbonate and bicarbonates are left in solution as sodium carbonate. The water with high RSC has high pH and land irrigated with such water becomes infertile owing to deposition of sodium carbonate; as known from black colour of the soil. According to U.S. Salinity Laboratory, an RSC value less than 1.25 meq/L is safe for irrigation. A value between 1.25 and 2.5 meq/L is of marginal quality, and value of more than 2.5 meq/L is unsuitable for irrigation. In the present study RSC values are below 1.25 meq/L in all the three years. So water of Ghunghuta dam can be considered safe for irrigation.

Permeability index (PI): The soil permeability is affected by long term use of irrigation water. Sodium, calcium, magnesium and bicarbonate content of the soil influence it. Domenico & Schwartz (1990) evolved a criterion for assessing the suitability of water for irrigation based on the permeability index. Accordingly, waters can be classified as Class I, Class II and Class III orders. Class I and Class II waters are categorized as good for irrigation with 75% or more maximum permeability. Class III waters are unsuitable with 25% of maximum permeability (Joshi *et al.* 2009) [14]. In the present study, the minimum value of PI is 354.59, hence, the water quality of Ghunghuta dam is good for irrigation.

Conclusion

In the present study, EC, TDS, MC, % Na, ESP, RSC, SAR and PI values were found well within the permissible range, hence, the water quality of Ghunghuta dam is good with respect to irrigational use.

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