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Original Research Paper

Water Quality Assessment of Kishanpura Dam, Baran, Rajasthan, 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 Kishanpura 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.

INTRODUCTION

India is rich in water resources being endowed with a criss-cross 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). Ganesan et al. (2004) 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, has been studied by Mathivanan et al. (2005) who reported high pollution load attributed to dense urbanization of the area. Karibasappa et al. (2009) have studied eutrophication in Hosur town lakes and reported its high level due to contamination with sewage and agriculture runoff. Singh et al. (2005) studied the water quality of six reservoirs of Damodar river basin. Water quality of Pench reservoir was studied by Pokale et al. (2010) 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 Kishanpura dam for agricultural activities.

THE STUDY AREA

Fern leaf shape River Parbati, a principal tributary of River Chambal, is situated at east longitudes of 75°22’ to 77°12’ and north latitudes of 24°19’ to 25°51’. It occupies a total catchment area of 15,861 km^2 and originates in the Vindhyachal ranges at an elevation of 609 m near Astha town in Sehore district of Madhya Pradesh. The river enters Rajasthan near Khurai village in Baran district and joins River Chambal near Pali village of Kota district, after travelling 159 km. The river is joined by a number of tributaries in Rajasthan, the more important of which are Uperni, Dubraj, Andheri, Beram, Kosam, Ahelil and Sukni.

The Kishanpura dam is constructed across River Parbati just downstream of the joining point of River Andheri near Atru town of Baran district. The dam was constructed in 1882. Catchment area of the dam is 10443 km^2 with an average annual rainfall of 848.50 mm. The technical data are not available but the data, engraved on a stone fixed on dam, read as: constructed in S.B.T. 1941, length 1310 ft, width 13 ft, canal length 36 miles, cill 6 ft below anicut, area commanded 30,000 bighas average. The dam is also called pick-up weir. The dam height was raised by 0.73 m in 1960 and again 0.30 m in 2004. Channels of 0.45 m were also fitted in 2004 by which temporarily fencing is done in monsoon period with the help of iron shutters. The dam is broad crested vertical drop weir constructed in stone masonry with lime mortar with wing walls and earthen flanks on both sides, without any protection works in upstream and down stream.

By construction of the dam, the river water is stored in river channel which is diverted to canals by sluice gates. Canal system presently nourishes 12500 acres land of 58 villages by 58 km long main canal, 17 km Rajwah branch and 88 km minor and distributaries in Atru, Baran and Mangrol tehsils. No Kharif irrigation was done earlier than 1960 and canal used to be opened for Rabi crops in October. After 1960 the water was also provided for Kharif which is possible by increased height of dam.

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 Kishanpura dam in Baran district of Rajasthan. 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).

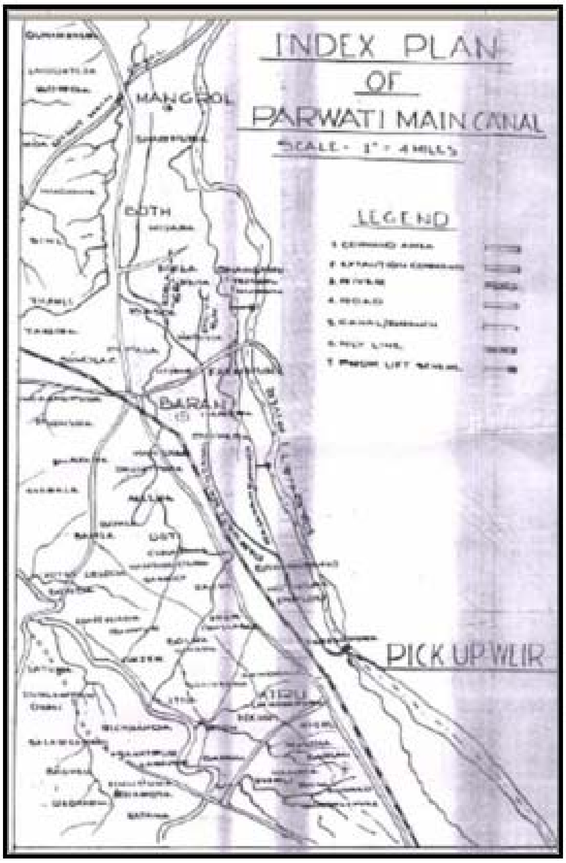

Fig. 1: Kishanpura dam (pick up weir) on Parbati river.

MATERIALS AND METHODS

Water samples were collected for three years (January 2008 to September 2010) in the three seasons i.e., winter, premonsoon and postmonsoon. 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 precleaned polypropylene screw capped bottles of one litre 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 analyse other physico-chemical parameters using standard methods (APHA 1995).

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).

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

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

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

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).

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

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).

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

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

Table 1: Calculated indices and water quality data of Kishanpura dam.

Parameters	2008			2009			2010		
	Winter	Pre-monsoon	Post-monsoon	Winter	Pre-monsoon	Post-monsoon	Winter	Pre-monsoon	Post-monsoon
Physico-chemical Parameters									
pH	7.70	7.95	7.80	7.95	8.25	8.05	8.10	8.20	8.05
EC, µS/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

ters. RSC is calculated by the formula given below (Richards 1954).

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

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 Kishanpura dam and calculated indices are given in Table 1.

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). In the present study values of TDS ranged from 164 mg/L to 241 mg/L. The minimum value was observed in postmonsoon 2009, and maximum in premonsoon 2008.

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 µS/cm is considered good and greater than 3000 µS/cm is unsuitable for irrigation (Westcott & Ayers 1984). In present investigation EC ranged from 260 µS/cm to 382 µS/cm. The minimum value was observed in postmonsoon 2009, and maximum in premonsoon 2008.

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 Kishanpura 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). 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 Kishanpura 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 Kishanpura 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). In the present study, the minimum value of PI is 354.59, hence, the water quality of Kishanpura 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 Kishanpura dam is good with respect to irrigational use.

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