Groundwater assessment and its health impacts for Rajghat dam reservoir, Sagar district, Madhya Pradesh, India

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Abstract

Water quality assessment and management of Rajghat Dam reservoir is the biggest problem facing in Sagar city and their surrounding areas. Rajghat dam reservoir is mainly used for drinking water supply by the municipal co-operation. Some important parameters like pH, Temperature, Turbidity, Conductivity, Total Alkalinity, Chloride, Nitrate, Sulphate, Total hardness, Calcium, Magnesium, Total Dissolved Solid (TDS), Iron, Sulphate, Fluoride, Copper, Manganese and Chromium are analyzed. Seven samples have been collected from Rajghat dam catchment in pre and post monsoon seasons during year 2015 and 16. Different parameters of water have been analyzed and evaluated to find out its suitability of drinking water for human consumption, public hygiene scenario and health impacts. These parameters are observed by the prescribed limits of ISO: 10500 (2012) for drinking water. The present study is aimed at assessing the water quality aspects of Rajghat dam reservoir situated in Sagar District of Madhya Pradesh, India.

The study area falls in Survey of India (1:50,000) topo-sheets No. 55I/9, 55I/10, 55I/11, 55I/12, 55I/13 and 55I/14. The Rajghat dam is rock and earth-fill type of dam. The catchment area of Bewas river at the dam site is 472 sq. kms is located between 23° 22' 0" N to 23° 48' 0" N latitude and 78° 28' 0" E to 78° 50' 0" E longitude. The normal annual rainfall of the study area is 1371.6 mm about 90% of the annual rainfall takes place during the southwest monsoon period i.e. June to September only 5.5% of annual rainfall takes place during winter and about 4.5% of rainfall occurs during the summer months. Last of December to January end is the coldest months with the temperature falling as low as 4.60 C and max. up to 24.50 C, and in the month of May, the temperature goes up to 48.70 C. The present scenario of Rajghat catchment is mainly shown by the physico-chemical condition to find out the suitability of the groundwater through the water quality assessment.

Keywords: Rajghat catchment, Pre- monsoon, Post- monsoon, water quality assessment

1. Introduction:

The availability of water supply adequate in terms of both quantity and quality is essential to human existence. The demand for water has increased over the years and this has led to water scarcity in many parts of the world. The situation is aggravated by the problem of water pollution or contamination. India is heading towards a freshwater crisis mainly due to improper management of water resources and environmental degradation. This leads to lack of access to safe potable water supply to millions of people. This freshwater crisis is already evident in many parts of India, varying in scale and intensity depending mainly on the time of the year. (K. Sundara Kumar et.al 2010).

Groundwater is controlled by factors such as precipitation, evapotranspiration, mineralogy, type of aquifers, climate, topography and also pumping rates. The combinations of these factors create diverse water types that change groundwater composition spatially and temporally (Chenini and Khemiri, 2009; Gholami et al., 2009; Praveena et al., 2011). Therefore, quality of groundwater varies from place to place, with depth of water table and from season to season (CPCB, 2008).

Groundwater is an important source of water supply throughout the world. The quantity and the suitability of groundwater for human consumption and for irrigation are determined by its physical, chemical and bacteriological properties. Its development and management plays a vital role in agriculture production, for poverty reduction, environmental sustenance and sustainable economic development. In some areas of the world, people face serious water shortage because groundwater is used faster than it is naturally replenished. Human development and population growth exert many and diverse pressures on the quality and the quantity of water resources and on the access to them. Water quality monitoring and assessment is the foundation of water quality management; thus, there has been an increasing demand for monitoring water quality of many rivers and ground water by regular measurements of various water quality variables. (Mangukiya Rupal et. al. 2012).

2. Study area:

The Rajghat dam is rock and earth fill type of dam. This dam is 1680.0 m long with 400.0 m masonry spillway, and which get water from Bewas River, Parkul River, and Jamunia River junction at Hinota village. Bewas River is 53.03 kms, Parkul River is 33.93 kms, and Jamunia River is 18.05 kms long at the dam site. The catchment area of Bewas river at the dam site is 472 sq. kms is located between 23° 22' 0" N to 23° 48' 0" N latitude and 78° 28' 0" E to 78° 50' 0" E longitude. The total water capacity of dam is 96.0 million cubic meter with 80.0 live storage, and 16.0 dead storage. Bed level of river is 495.0, minimum sill level is 509.0 m, maximum water level is 518.0 m, and maximum bed level is 520.0 m at dam site. The Bewas River originates from the northeast part of Raisen district located at about 720 meter near the Pipalia Katan. The study area falls in Survey of India (1:50,000) top sheets No. 55I/9, 55I/10, 55I/11, 55I/13 and 55I/14 (Fig.1). The normal annual rainfall of the study area is 1371.6 mm about 90% of the annual rainfall takes place during the southwest monsoon period i.e. June to September only 5.5% of annual rainfall takes place during winter and about 4.5% of rainfall occurs during the summer months. Last of December to January end is the coldest months with the temperature falling as low as 4.60 C and max. up to 24.50 C, and in the month of May, the temperature goes up to 48.70 C. (Chourasia A. et.al 2015 & Rawat R.K. et. al 2013)

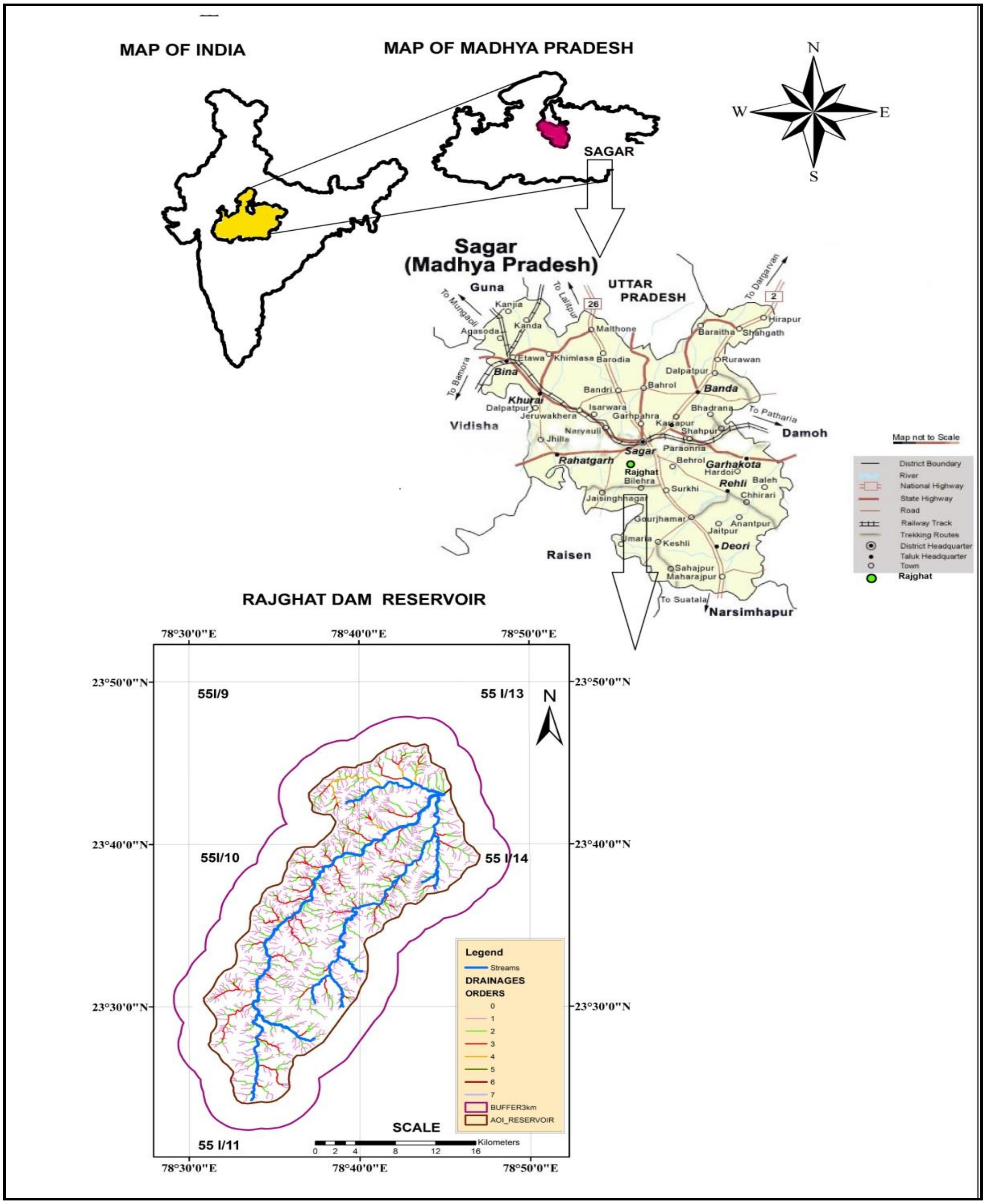

Figure 1 Location map of study area

3. Materials and Methods

Remote sensing has become an important tool applicable to developing and understanding the global, physical process affecting the earth. Recent development in the use of satellite data is to take advantage of increasing amount of geographical data available in conjunction with GIS to assist in interpretation. GIS is an integrated system of computer hardware and software capable of capturing, storing, retrieving, manipulating, analyzing and displaying geographically referenced (spatial) information for the purpose of aiding development oriented management and decision making processes.

The present investigation was based on field observations as well as laboratory analysis. There are seven samples are collected from the reservoir catchment area (Figure 2). The location of sample collection points is given table 1. These samples are collected for physic-chemical analysis during pre- monsoon and post monsoon season in year 2015. Temperature, pH, Turbidity and Conductivity were measured on-site using digital meter kit. The others parameters like Total Alkalinity, Chloride, Nitrate, Sulphate, Total hardness, Calcium, Magnesium, Total Dissolved Solid (TDS), Iron, Sulphate, Fluoride, Copper, Manganese and Chromium were analyzed in the laboratory by collected samples in sample containers.

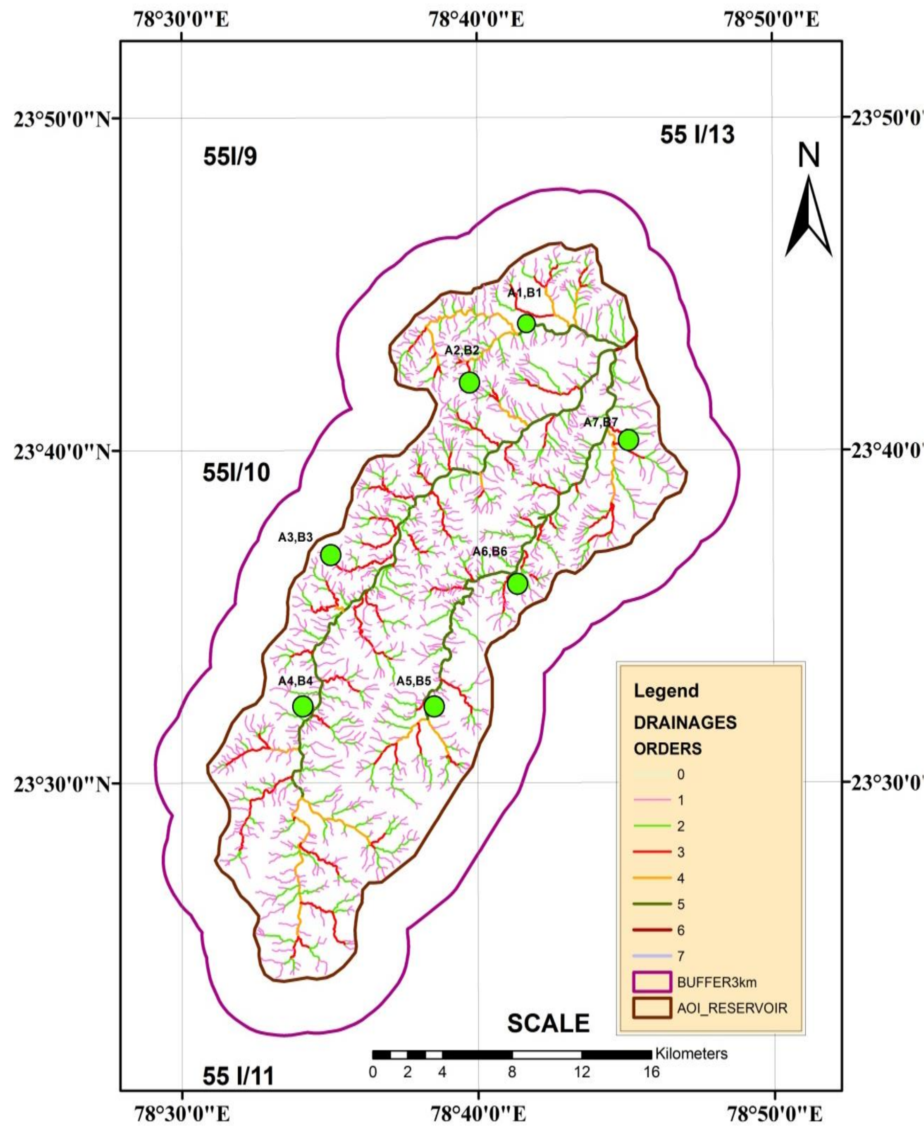

Figure 2 Location of Sample Collection in the catchment area

Table 1
Location of sample in study area

Sample No.	Location	Longitude	Latitude	Altitude (m)
A1, B1	PARKUL RIVER	E78^{0}45'14.1"	N23^{0}43'37.7"	1720
A2, B2	BILEHRA FIELD SITE RIVER	E78^{0}44'17.3"	N23^{0}43'26.3"	1718
A3, B3	JAISINAGAR RD. BRIDGE 3	E78^{0}42'37.6"	N23^{0}43'30.4"	1748
A4, B4	BILEHRA VILLAGE	E78^{0}43'03.3"	N23^{0}36'53.1"	1724
A5, B5	BILEHRA VILLAGE	E78^{0}44'18.6"	N23^{0}40'37.3"	1712
A6, B6	JAISINAGAR RD. BRIDGE 2	E78^{0}42'53.9"	N23^{0}43'55.0"	1760
A7, B7	JAISINAGAR BILEHRA RD.	E78^{0}40'07.4"	N23^{0}39'42.4"	1789

Water Quality Index (WQI) is calculated from the point of view of suitability of groundwater for human consumption. The standards for drinking purposes as recommended by BIS 10500 (2012) have been considered for the calculation of WQI. For computing WQI three steps are followed: (Vasanthavigaret al., 2010).

Table 2
Drinking Water quality standards by BIS 10500; 2012

Sl No.	Characteristics	Unit	As Per BIS-10500:2012 For Drinking Water	
			Desirable Limit	Permissible Limit
1.	Temperature	^{0}C	-----------	-----------
2.	*p*H	*p*H scale	6.5 to 8.5	6.5 to 8.5
3.	Turbidity	NTU	1.0	5.0
4.	Conductivity at 25^{0}C	μΩ/cm	-----------	-----------
5.	Total Alkalinity as $CaCO_3$	mg/l	200	600
6.	Chloride as Cl	mg/l	250	1000
7.	Nitrate as NO_3	mg/l	45.0	45.0
8.	Total Hardness as $CaCO_3$	mg/l	300	600
9.	Calcium as Ca^{++}	mg/l	75	200
10.	Magnesium as Mg^{++}	mg/l	30	70
11.	Total Dissolved Solids	mg/l	500	2000
12.	Iron	mg/l	0.3	1.0
13.	Sulphate as SO_4	mg/l	200	400
14.	Fluoride as F	mg/l	1.0	1.5
15.	Copper as Cu	mg/l	0.05	1.5
16.	Manganese as Mn	mg/l	0.1	0.3
17.	Chromium as Cr^{6+}	mg/l	0.05	0.05

In the first step, each of the 17 parameters (Temp., Turbidity, pH, Conductivity, Total Alkalinity, Cl^-, NO_3^-, Total Hardness, Ca^{++}, Mg^{++}, TDS, Fe_2^+, SO_4^{--}, F^-, Cu, Mn, Cr_6^+) has been assigned a weight (*wi*) according to its relative importance in the overall quality of water for drinking purposes. In the second step, the relative weight (*Wi*) is computed from the following equation:

$$Wi = wi / \sum_{i-1}^{n} wi \tag{1}$$

Where,
Wi is the relative weight
wi is the weight of each parameter
n is the number of parameters

In the third step, a quality rating scale *(qi)* for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS 10500 (2012) and the result is multiplied by 100:

$$qi = (Ci/Si) \times 100$$

Where,
qi is the quality rating
Ci is the concentration of each chemical parameter in each water sample in milligrams per liter
Si is the Indian drinking water standard for each chemical parameter in milligrams per liter according to the guidelines of the BIS 10500 (2012).

For computing the WQI, the SI (Sub-Index) is first determined for each chemical parameter, which is then used to determine the WQI as per the following equation:

$$SIi = Wi \times qi$$

Then, $WQI = \sum SIi$

Where
SI*i* is the sub-index of *i*th parameter
qi is the rating based on concentration of *i*th parameter
n is the number of parameters

According to Ramakrishnaiah et al. (2009), Vasanthavigar et al.(2010) and Yidana and Yidana (2010); Computed WQI values are classified into five categories as follows (Table 3):

Salinity based classification of water, as given by Davis and DeWiest, 1967, is also adapted for present study (Kumar et al., 2006) (Table 4):

Table 3
Classification of water based on WQI values

WQI values	Water Quality
<50	Excellent
50-100	Good
100-200	Poor
200-300	Very Poor
>300	Unsuitable for drinking

Table 4
Classification of water based on TDS values

TDS (mg/l)	Types of Water
0-1000	Fresh
1000-10,000	Brackish
10,000-100,000	Salty
>100,000	Brine

4. Results and Discussions:

The concentration of various Chemical parameters and WQI in ground water samples collected during Pre-Monsoon and Post-Monsoon periods are shown in table 5 and table 6 respectively:

Table 5
Concentration of chemical parameters and WQI values of pre- monsoon water samples

Characteristics	**Unit**	**Result**						
		A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**
Temperature	^{0}C	33.0	33.0	33.0	33.0	32.0	33.0	33.0
*p*H	*p*H	7.7	7.4	7.5	7.6	7.4	7.5	7.6
Turbidity	NTU	16.0	10.0	18.0	12.0	10.0	18.0	12.0
Conductivity at 25^{0}C	μΩ/cm	390	340	1250	640	460	1250	640
Total Alkalinity as $CaCO_3$	mg/l	140	160	114	240	164	114	240
Chloride as Cl	mg/l	25.0	22.0	430	70.0	40.0	430	70.0
Nitrate as NO_3	mg/l	nil	14.2	48.2	58.0	59.0	48.2	58.0
Total Hardness as $CaCO_3$	mg/l	121	127	450	198	180	450	198
Calcium as Ca^{++}	mg/l	31.2	36	104	31.2	31.2	104	31.2
Magnesium as Mg^{++}	mg/l	10.3	8.9	45.6	28.8	24.4	45.6	28.8
Total Dissolved Solids	mg/l	234	204	750	384	276	750	384
Iron	mg/l	3.2	0.8	1.5	1.2	2.8	1.5	1.2
Sulphate as SO_4	mg/l	32.0	44.8	64.0	19.2	26.8	64.0	19.2
Fluoride as F	mg/l	0.14	0.13	0.14	0.45	0.35	0.14	0.45
Copper as Cu	mg/l	0.137	0.173	0.112	0.094	0.104	0.112	0.094
Manganese as Mn	mg/l	0.123	0.231	0.233	0.171	0.106	0.233	0.171
Chromium as Cr^{6+}	mg/l	0.196	0.169	0.227	0.102	0.111	0.227	0.102
WQI values		**24.91**	**19.78**	**31.26**	**23.62**	**21.52**	**31.26**	**23.62**

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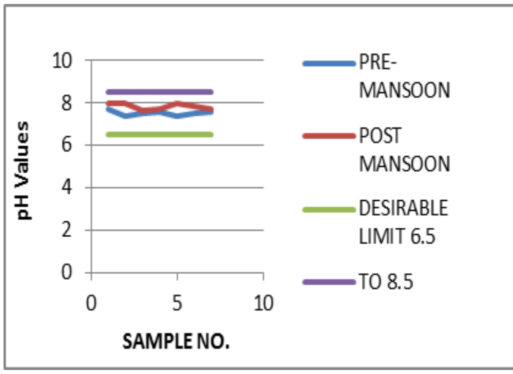
Table 6
Concentration of chemical parameters and WQI values of post- monsoon water samples

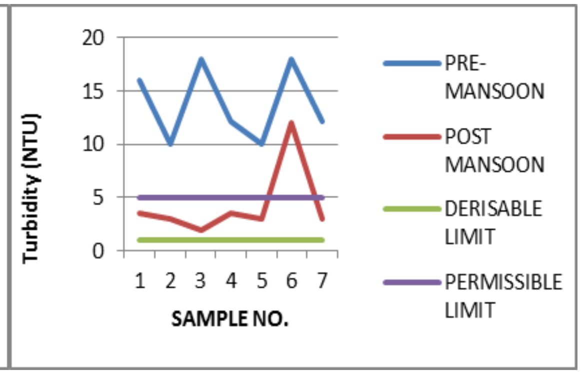
Characteristics	**Unit**	**Results**						
		B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**
Temperature	^{0}C	26	26	26	26	26	26	26
*p*H	*p*H scale	7.96	7.94	7.94	7.72	7.94	7.84	7.72
Turbidity	NTU	3.5	3.0	2.0	3.5	3.0	12.0	3.0
Conductivity at 25^{0}C	µΩ/cm	265	334	572	399	334	334	409
Total Alkalinity as $CaCO_3$	mg/l	138	174	220	212	174	240	224
Chloride as Cl	mg/l	15	13	105	30	13	55	25
Nitrate as NO_3	mg/l	17.7	41.1	31.4	38.8	41.1	27.7	19.9
Total Hardness as $CaCO_3$	mg/l	130	162	280	200	162	210	200
Calcium as Ca^{++}	mg/l	88	110	164	124	110	160	116
Magnesium as Mg^{++}	mg/l	42	52	116	76	52	50	84
Total Dissolved Solids	mg/l	136	172	297	206	172	172	211
Iron	mg/l	0.05	0.06	0.1	0.04	0.06	0.05	0.08
Sulphate as SO_4	mg/l	6.4	12.8	9.6	22.4	12.8	5.4	3.2
Fluoride as F	mg/l	1.0	0.8	0.7	0.9	0.8	0.6	0.7
Copper as Cu	mg/l	0.075	0.104	0.173	0.094	0.104	0.137	0.112
Manganese as Mn	mg/l	0.097	0.106	0.231	0.171	0.106	0.123	0.233
Chromium as Cr^{6+}	mg/l	0.101	0.111	0.169	0.102	0.111	0.196	0.227
WQI values		**13.99**	**14.72**	**16.71**	**16.03**	**14.72**	**22.58**	**15.63**

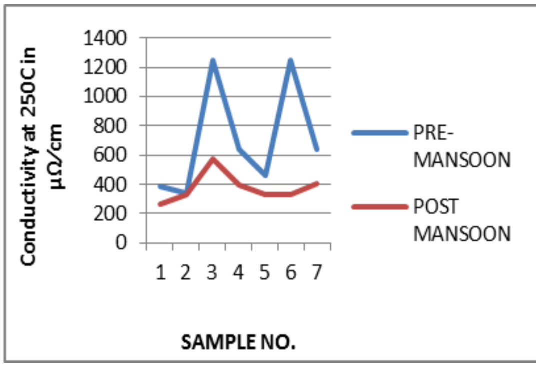
Table 6
Safe limits in PPM (as per BIS, WHO, ICMR, APHA) & Minimum Acceptable & Maximum Acceptable limits for drinking purpose use of Ground Water & Adverse effect on wring Bodies. (After Jinwal et.al 2009 & Kataria et.al. 2011)

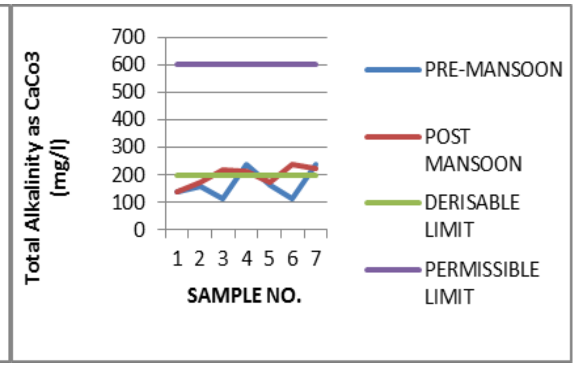
Parameters	**Groundwater (Mg/l)**		**Effect on lifting**
	Max.	**Min.**	
Fluoride	1.5	1.0	Fluoride is essential for human beings as a trace element. Its higher concentration causes toxic effects. Fluoride concentration between 0.6-1.0 mg/l in potable water protects tooth decay and enhances bone development.
Sulphate	400	200	The presence of Sulphate has less effect on the taste of water compared to the presence of chloride. Its high concentration may induce diarrhea and intestinal disorders. Excess amount of Sulphate in water has cathartic effect on human health.
Iron	1.0	0.3	Promote Iron Bacteria in water, bad Taste, In trace is nutritional. Excess causes reduced metabolism of iron to form Hemoglobin.
Copper	0.05		Astringent taste but essential elements for metabolism, deficiency results is anemia in infants, excess may results in liver damage.
Manganese	0.1		Produces bad taste, essential as cofactor in enzyme system & metabolism process. Excess causes reduced metabolism of iron to form Hemoglobin.

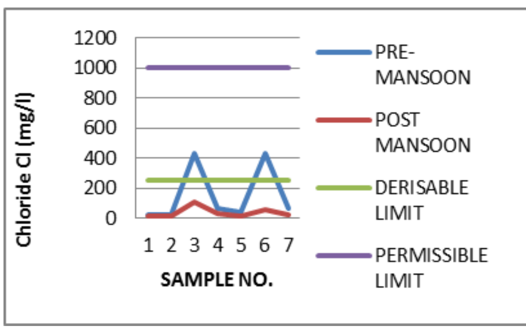
Chromium	0.05		Carcinogenic acuity (cancer), can produce coetaneous and nasal mucous membrane ulcer & Dermatitis, Hexavalent Cr causes lung tumors

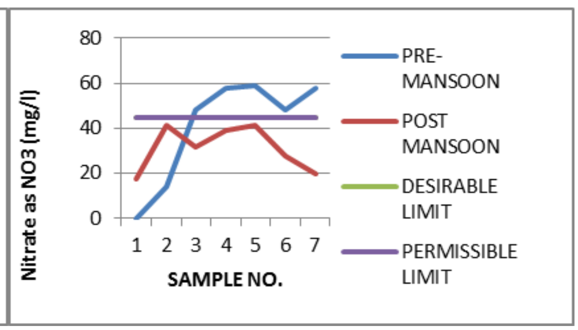


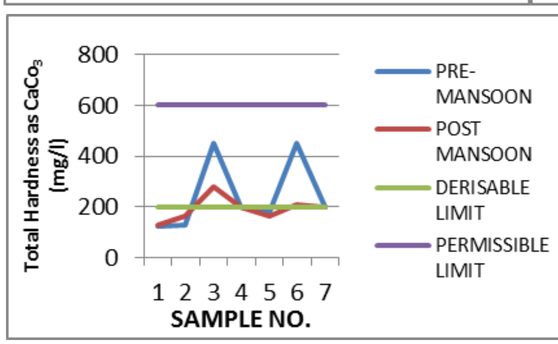


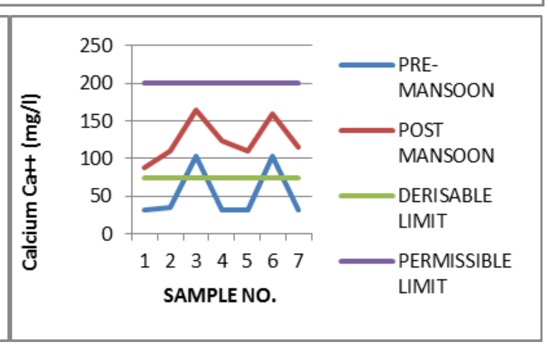












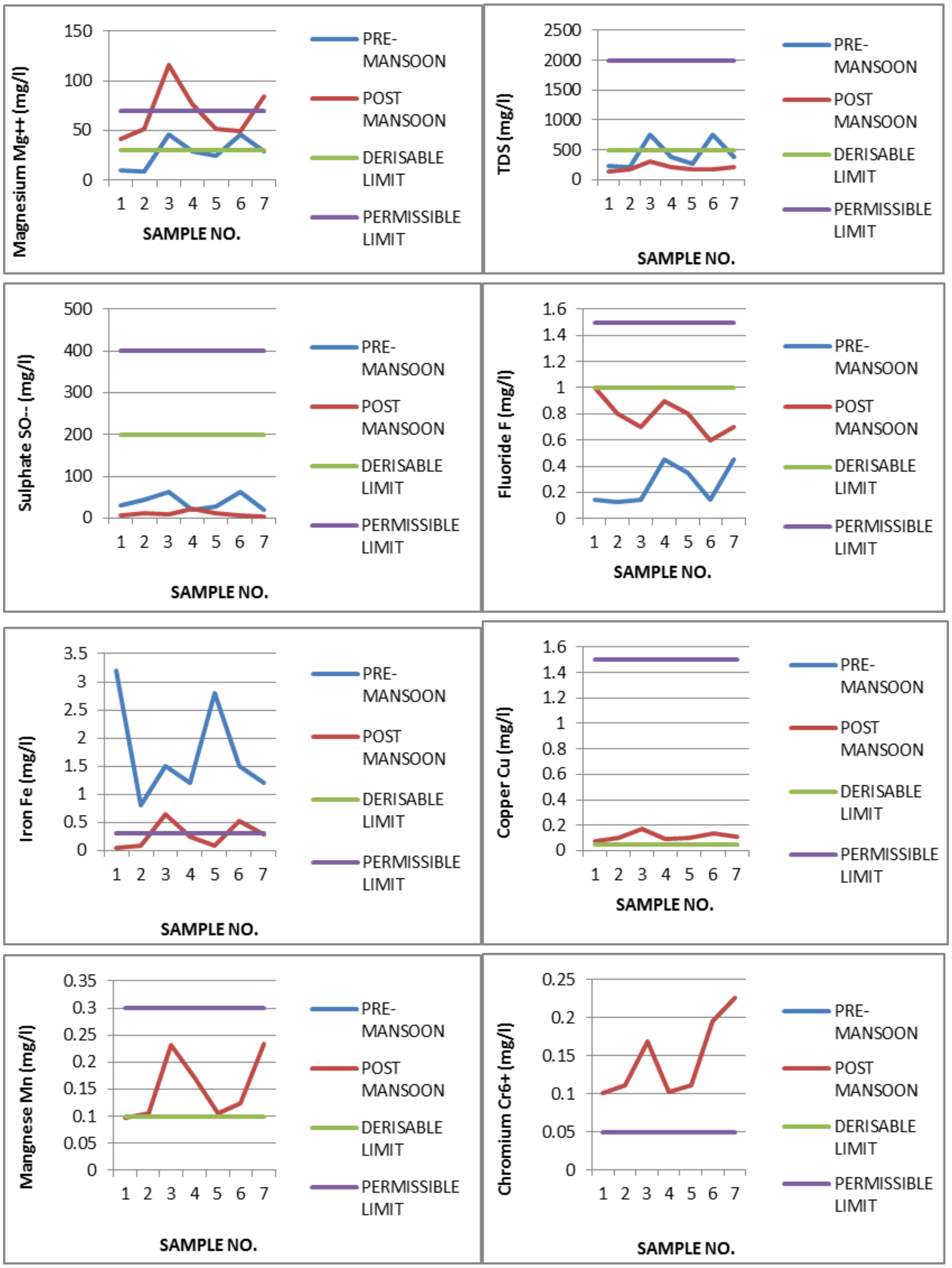


Figure 3 Plots of different parameters representing compliance with BIS standards, a) *pH*, b) Turbidity, c) Conductivity, d) Total Alkalinity, e) Chloride, f) Nitrate, g) Total hardness, h) Calcium, i) Magnesium, j) Total Dissolved Solid (TDS), k) Sulphate, l) Fluoride, m) Iron, n) Copper, o) Manganese and p) Chromium.

4.1 Variation in water quality:

i) *pH*: *pH* was found in the range of 7.4 to 7.96 from all the study sites, which shows that the groundwater in the study area is more alkaline in post- monsoon season than in pre-monsoon.

ii) Turbidity: Turbidity was found in between 2 to 18 NTU where high in pre- monsoon and low in post monsoon season. But the most of pre- samples were range between 10 to 18 NTU which is inappropriate for drinking purpose. Hence special care must be taken while disinfecting the water before supplying to the public.

iii) Chloride: All values for Chloride were within desirable limit while chloride values of sites A3 was above desirable limit. High chloride values in pre-monsoon was reported by (Vasanthavigar et al. 2010) which can be due to leaching from upper soil layers derived from domestic activities and dry climate. Chloride content increases with increase in mineral content. The large variation of chloride concentration indicates recharge and discharge zones of lateral flow regime as local recharge to the unconfined aquifer is more dominant than recharge from lateral flow.

iv) Nitrate: Nitrate is permissible limit of 45 mg/L as per Indian standards. All values for Nitrate were within desirable limit while nitrate values for sites A3, A4, A5 were above desirable limit. Nitrates themselves are relatively nontoxic. Nitrogen essential component of amino acids, and therefore all proteins and nucleic acids, and therefore needed for all cell division and reproduction. Nitrogen is contained in all enzymes essential for all plant functions. However, when swallowed, they are converted to nitrites that can react with hemoglobin in the blood, oxidizing its divalent iron to the trivalent form and creating methanoglobin. Thus, Nitrate compounds can prevent hemoglobin from binding with oxygen at levels above the permissible limit. Thus the drinking water that is contaminated with nitrates can prove fatal especially to infants as it restricts the amount of oxygen that reaches the brain causing the 'blue baby' syndrome.

v) Hardness: Total Hardness was found in all sites of catchment area is falls under acceptable limit except site A3 exceed permissible limit. High values of hardness in pre-monsoon were observed due to dissolution of minerals by infiltration of young groundwater into the aquifer system. Six out of seven samples viz. 1, 2, 4, 5, 6 and 7 exceed desirable limit for magnesium.

vi) Magnesium: Mg concentration at site A1, A2 was reported below desirable limit in reservoir area. For site B3, B4, B7 magnesium concentration was reported above permissible limits. High magnesium values in groundwater samples, which might have been derived from dissolution of magnesium calcite, gypsum and dolomite from source rock (Garrels and Christ, 1965).

vii) TDS: Total Dissolved solids refer to any minerals, salts, metals, cations or anions dissolved in water. This includes anything present in water other than the pure water (H_2O) molecule and suspended solids. (Suspended solids are any particles/substances that are neither dissolved nor settled in the water, such as wood pulp.) TDS was found in the range of 136 to 750 mg/L. Groundwater TDS varies considerably in different geological regions owing to difference in solubility of minerals. In the present study, like TDS, EC was found in the range of 265 to 1250 μS/cm appropriate for drinking purpose and in range of 0 to 1000 mg/l. Hence the water is fresh and it falls under desirable limit.

viii) Sulphate: All values for Sulphate were within desirable limit. Sulphate is relatively minor constituents of basalts. It is mainly comes from atmospheric precipitation and magmatic gases. It is also contributed to the groundwater because of breakdown of organic substances in the soil and sulphate rich fertilizers.

ix) Fluoride: Fluoride is the permissible limit of 1 mg/L as per Indian standards. The variation of fluoride is dependent on a variety of factors such as amount of soluble and insoluble fluoride in source rocks, the duration of contact of water with rocks and soil temperature, rainfall, oxidation- reduction process. Easy accessibility of circulating water to the weathered products during irrigation dissolves and leaches the minerals, including fluorine, contributing fluoride to the surface water and groundwater. The health issues body pain, knee pain and back pain were prevalent among people who consumed water containing excess fluoride. The presence of small quantities of fluoride in drinking water may prevent tooth decay. Fluoride is poisonous at high levels, and while dental fluorosis (mottled teeth) is easily recognized, skeletal damage may not be clinically obvious until advanced stages have occurred. Often, ground waters will contain less amount of fluoride to 1 mg/l and in these cases; the water is good for drinking purpose (Mangukiya Rupal et.al 2012).

x) Iron: Iron concentration in the groundwater sample is the permissible limit of 0.3 mg/l as per Indian standards. All sites were shown very high concentration of iron in water. The ground water samples exhibited high Iron contamination which is an indication of the presence ferrous salts that precipitate as insoluble ferric hydroxide and settles out as rusty silt. Iron is an essential element in human nutrition**.** Toxic effects have resulted from the ingestion of large quantities of iron, but there is no evidence to indicate that concentrations of iron commonly present in food or drinking water constitute any hazard to human health. At concentrations above 0.3 mg/l, iron can stain laundry and plumbing fixtures and cause undesirable tastes. Iron may also promote the growth of certain microorganisms, leading to the deposition of a slimy coat in piping.

xi) Copper: Copper concentration in the groundwater sample is the permissible limit of 0.05 mg/l as per Indian standards. All sites were shown very high concentration of Copper in water. It has taste like astringent but essential element for metabolism, deficiency results is anemia in infants. Due to high concentration may cause liver damage.

xii) Manganese: Manganese Mn concentration in the groundwater sample is the permissible limit of 0.1 mg/l as per Indian standards. All sites were shown very high concentration of Manganese in water. It can produce bad taste and essential as cofactor in enzyme system & metabolism process. Excess causes reduced metabolism of iron to form Hemoglobin.

xiii) Chromium: Chromium concentration in the groundwater sample is the permissible limit of 0.05 mg/l as per Indian standards. All sites were shown very high concentration of Chromium in water. Carcinogenic acuity (cancer), can produce coetaneous and nasal mucous membrane ulcer & Dermatitis, Hexavalent Cr causes lung tumors.

5. Conclusions:

According to the calculation of physico-chemical parameters of groundwater, Water Quality Index (WQI) for 7 groundwater samples range varies from 13.99 to 31.26. Therefore, the water quality index (WQI) values for all sites, when arranged in ascending order, are found to be:
In pre- monsoon season, **A2<A5<A7<A4<A1<A3<A6**

In post monsoon season, **B1<B2<B5<B7<B4<B3<B6**

Hence, the overall water quality of groundwater is excellent while in case of analysis of Rajghat catchment area groundwater samples are affected by the studied trace elements. At least 70% of the population is still consuming groundwater. According to the analysis the study area were found Copper, Manganese and Chromium beyond the limit which contaminated water. Chromium enriched refuge should be properly treated and then disposed off. Construction of groundwater structure on dumping sites or its immediate vicinity should be avoided as Cr pollution relates to point sources. In agricultural excessive use of pesticides should be avoided so that it does not leach down to the groundwater and deteriorate its quality. Mass awareness should be generated about the over use of fertilizer, its harmful effects on quality of water and human health.

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