GROUND WATER QUALITY AND ITS IMPACT ON HUMAN HEALTH IN DUNGARPUR DISTRICT OF RAJASTHAN, INDIA

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ABSTRACT:

Dungarpur, one of the most backward districts of India, is a predominantly tribal region of Rajasthan state. Ground water is the major source of drinking water in the region. High concentrations of Fluoride (F) and Iron (Fe) have been reported in the region which poses high risk of rampant water-borne diseases. This study evaluates the ground water quality for drinking purpose in terms of 10 hydro-geochemical and two biological parameters in context of causative factors like land use and geology of the region. The occurrence of water borne diseases in resident population has been examined in association with quality of drinking water and priority areas for policy intervention have been identified. Water samples have been collected from 173 drinking water sources and 346 households consuming water from the selected sources have been surveyed for prevalence of water borne diseases. Water quality surfaces have been mapped in terms of F, Total Dissolved Solids (TDS), Hardness, Fe, alkalinity, Faecal Coliform (FC), E. Coli, and Water Quality Index (WQI) computed on the basis of 10 geochemical parameters, using Inverse Distance Weighted (IDW) method. Results reveal that the north-eastern part comprising Aspur, Sabla and part of Sagwara tehsils predominantly has 'very poor' to 'unsuitable' water quality. The western part has excessive faecal contamination. Entire district has high levels of TDS and hardness, while excessive Fe and F occur in specific regions. Disease incidence closely corresponds to the geochemical and microbial composition of water. Higher values of WQI correspond with occurrence of Phyllites and Mica Schists.

1. INTRODUCTION

In the last few years, the problem of safe drinking water has increased rapidly due to indiscriminate development activities in some states of India like West Bengal, Jharkhand, Odisha, Western Uttar Pradesh, Andhra Pradesh, Rajasthan and Punjab (Tiwari and Singh, 2014). Rajasthan is India's largest state by area, and has a significant groundwater reliant population due to a general lack of surface water accessibility (Coyte et al., 2019). Water scarcity in Rajasthan is found naturally due to very low rainfall, very few rainy days and high aridity (Gantait et al., 2022).

Ground water has proved to be a reliable source for meeting rural water demand. It is considered a 'safe source' of drinking water because it is abstracted with low microbial load with little need for treatment before drinking. However ground water resources are commonly vulnerable to pollution, which may degrade their quality (Palamuleni and Akoth, 2015). Once groundwater is contaminated, it's quality cannot be restored.

Water quality refers to the chemical, physical, biological, radiological and aesthetic characteristics of water (BIS, 2012; WHO, 2017). Good water quality is essential to a healthy life and whole ecosystem (Adimalla, 2018). According to World Health Organization (WHO) about 80 percent of all the diseases in human beings are caused by water. Water Quality Index (WQI) is considered to be the most effective method of measuring water quality (Vishwakarma et al., 2018). It is an indicator of how suitable the water is for human consumption (Alobaidy et al., 2010).

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The groundwater quality is largely affected by intense usage of fertilizers in agricultural area (Malki et al., 2017). The geochemical composition of water is also significantly controlled by local geological parameters, hydrological regime and anthropogenic activities. Coyte et al. (2019) have observed that both human made pollutants and naturally occurring toxic minerals are affecting ground water quality adversely in Rajasthan at a distressing and alarming rate. High concentration of fluoride in groundwater has been reported from many parts of India (Dar et al., 2010; Vikas et al., 2018). In Rajasthan, groundwater used for drinking is the main source for chronic flouride intoxication in both humans and domestic animals (Choubisa, 2018). Dental and skeletal fluorosis can be related to the usage of high fluoride groundwater for drinking (Vikas et al., 2018).

Dungarpur district is a predominantly tribal region of Rajasthan state in India. With approximately 71 percent Scheduled Tribe (ST) and 93 percent rural population (Census, 2011), it figures among the country's 250 most backward districts. Major part of the district is dependent on ground water for drinking and domestic purposes. As per the reports of the Central Ground Water Board (2013) the ground water in the region is affected by high concentrations of Fluoride (F) and Iron (Fe) which poses high risk of rampant water-borne diseases. For effective water management in the region, precise quantification of intensity of the problem and identification of priority areas for policy intervention is required.

This study analyses the spatial patterns of ground water quality of Dungarpur district of Rajasthan for drinking purpose in terms of 10 hydro-geochemical and two biological parameters in context of causative factors like land use land cover (LULC) and geology of the region. The occurrence of water borne diseases in resident population has been examined in association

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with quality of drinking water. Priority regions which are more vulnerable to water borne diseases have been identified.

2. STUDY AREA

Dungarpur is situated in the southern part of Rajasthan State in India extending across a geographical area of 3770 sq km. between 23° 19’ 42.87” to 24° 0' 42.68” north latitude and 73° 20’ 59.23" to 74° 23’ 42.87” east longitude. The district has an uneven topography and forms part of Mahi or Chappan Basin and Mewar Rocky region of southern Aravali hills. The northern and western part of the district is hilly and dissected. Larger part has pediplained topography with small isolated hills and mounds. The eastern part is predominantly plain area. The study area occupies a prominent place in the Humid Southern Plain agro-climatic zone. Average rainfall is approximately 76 cm.

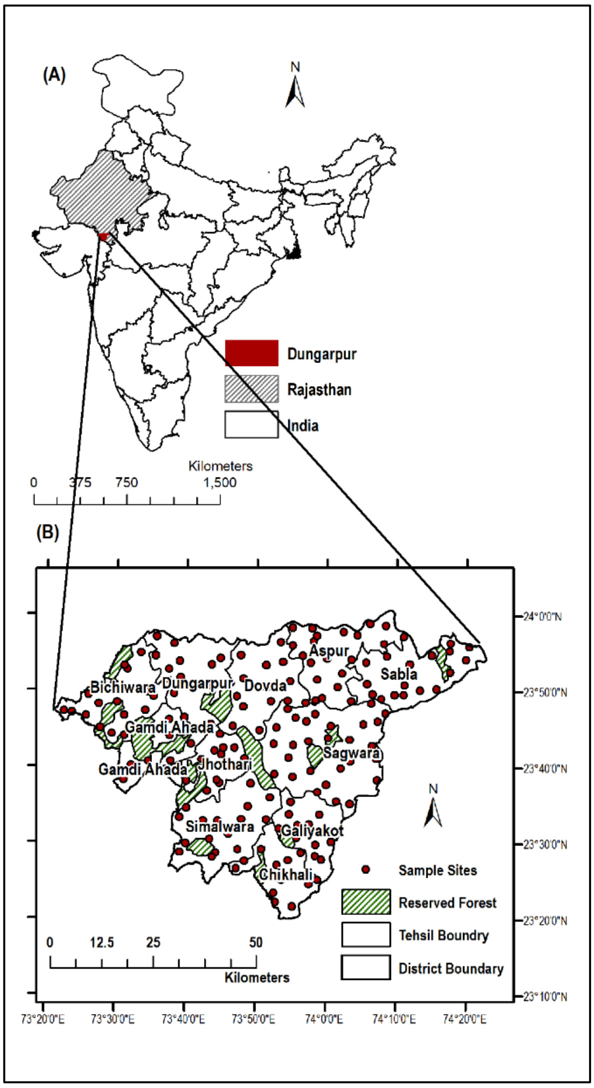

Figure 1. Location map of the study area (A) Location of Dungarpur in Rajasthan state and India, and (B) Administrative units of Dungarpur and location of sample sites

As per Census (2011) the total population of the district was 13.8 lakhs which is estimated to have increased to 16.10 lakhs in 2023 (www.indiacensus.net). Administratively the district comprises of 11 tehsils (2023) and 976 villages (2011). There are 04 towns – Dungarpur and Sagwara municipalities, and Galiakot and Simalwara Census towns – Dungarpur being the largest with 4.95 lakhs population in 2011. The district is inhabited predominantly by Scheduled Tribes having very poor and miserable socio-economic status earning it the status among the most backward districts of the country. The economy is predominantly agricultural with 64.2 percent workers either cultivators or agricultural laborers. The Work Participation Rate of the district was recorded as 46.2 percent in 2011. The literacy rate of the district was 59.46 percent placing it 27th among the districts of Rajasthan (Census, 2011).

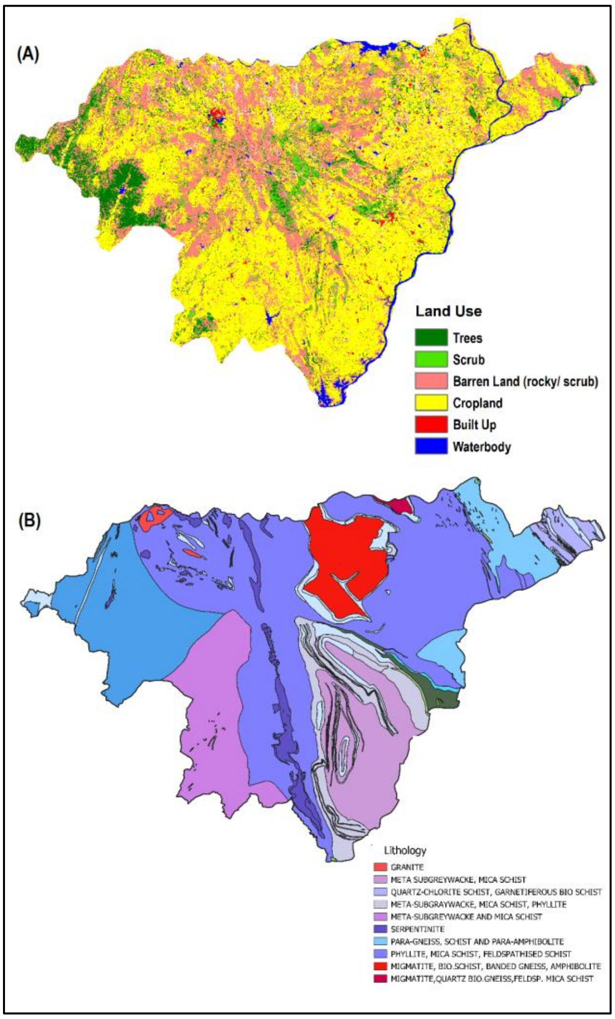

Figure 2. (A) Landuse, and (B) Geology of the study area.

Agriculture land dominates the land use in the district with 48.70 percent area under cropped and fallow land mainly in the northern and eastern region. Various types of forests occupy approximately 23 percent area mainly in western part of the district. Barren, unculturable and waste lands occur in approximately 23 percent area scattered mainly in northern and central region. The major water reservoir is Som Kamla Amba Dam built on Som river in Aspur tehsil in the north. Mahi and Som are major rivers. Water bodies and built up occupy 0.43 percent and 0.01 percent of the total area respectively (Bhuvan, NRSC, 2015-16). Except the command area of the Dam, remaining part of the district is dependent on ground water for drinking use. Canals, wells and tube wells are major sources of irrigation.

The overall geology of the area is highly complex. The rocks exposed in the area are quite old in geological age and belong to Bhilwara Supergroup of Archean age and Aravali Supergroup of Pale Proterozoinc age. Rocks of Aravali Supergroup cover the major part of the district. These rocks are represented by phyllites, schists, quartzite, dolomite and slates and are exposed in the central and eastern part of the study area. The rocks of Bilwara supergroup are mainly represented by migmatite, gneiss and mica-schists occupying a small portion in the northern part of the area. The fluorides in groundwater apparently originate from the rock formations. Figure 1 illustrates the geographical location, administrative composition and sample sites of the study area. Land use and geology of the study area has been illustrated in Figure 2.

3. METHODOLOGY

Village map of the study area has been generated in vector format using the administrative boundary maps of the Administrative Atlas of Rajasthan (2011), an official publication of the Office of the Registrar General & Census Commissioner, India. The demographic statistics has been derived from District Census Handbook of Dungarpur district for the year 2011.

A grid of 5x5 km has been overlaid on the village map of the district and 173 sample sites have been identified for field survey, taking one inhabited village from each cell. Water samples have been collected from drinking water sources at these sites including open wells, tube wells and hand pumps. These samples have been analysed in water testing laboratory for 12 selected hydro-geochemical and biological parameters – pH, Total Dissolved Solids (TDS), Hardness, Alkalinity, Turbidity, F, Chloride, Nitrate (NO_3), Sulphate and Fe, Faecal Coliform (FC), and E. Coli (EC). Point file has been generated using the coordinate locations of the sample sites and the measurements of the 12 parameters were joined as attributes with the respective sites. The occurrence of various water quality parameters has been examined in two ways – (1) examining the number of sites having level exceeding the standards prescribed by the Bureau of Indian Standards (BIS 2012), and (2) analysing the descriptive statistics and the histogram for each parameter. Table 1 shows the BIS standards, weights and descriptive statistics of the water quality parameters.

Overall water quality for drinking purpose has been quantified in terms of WQI for all sample sites. WQI is a weighted arithmetical index used to evaluate the suitability of ground water based on ground water chemistry and physical parameters. WQI has been computed using the formula suggested by Vishvakarma et al. (2018), on the basis of the 10 geochemical parameters. The physico-chemical parameters were assigned weights on a scale of 1 to 4 in increasing order of significance depending on their importance in causing water borne diseases observed in the study area.

After assigning weights (AW_i) to the each parameter WQI has been computed in four steps as under :

1. Calculation of relative weight (RW_i) for each parameter as per Equation (1).

$$RW_i = \frac{AW_i}{\sum_i^n AW_i} \quad (1)$$

where RW_i = Relative weight of i^{th} parameter
AW_i = Assigned weight of i^{th} parameter
n = number of parameters

2. Computation of quality rating scale (Q_i) for each parameter by dividing its concentration in each water sample by its respective BIS standard, and multiplying the result by 100 as per Equation (2).

$$Q_i = \left(\frac{C_i}{S_i}\right) x\ 100 \quad (2)$$

where Q_i = Quality rating of i^{th} parameter
C_i = measured concentration of i^{th} parameter at the sample site
S_i = BIS standard of i^{th} parameter

3. Estimation of sub-indices (SI_i) as per Equation (3).

$$SI_i = RW_i\ x\ Q_i \quad (3)$$

4. Computation of WQI at each sample site as per Equation (4).

$$WQI = \sum SI_i \quad (4)$$

The WQI values have been classified into five categories of suitability of water for drinking purpose (Table 2) as per the scheme adopted by Gantait et al. (2022).

Parameter	BIS	Sites	W_i	Min.	Max.	SD	Median	S
1	2	3	4	5	6	7	8	9
pH	6.5-8.5	Nil	4	6.58	8.33	0.32	7.14	0.82
Turbidity (NTU)	1	37	2	0.3	22.0	3.15	0.4	4.07
TDS (mg/L)	500	**122**	4	232	2818	456.2	615	1.97
Hardness (mg/L)	200	**156**	3	96	1380	242.5	368	1.62
Alkalinity (mg/L)	200	**119**	4	64	890	166.5	256	1.4
Chloride (mg/L)	250	35	2	13	750	157.9	120	1.81
Fluoride (mg/L)	1	26	4	.04	10.5	1.18	0.2	4.9
Sulphate (mg/L)	250	5	2	6	303	63.9	40.9	1.73
Nitrate (mg/L)	45	1	3	0.5	58.4	7.6	7.9	2.32
Irom (mg/L)	0.3	17	1	0.02	1.64	0.21	.07	3.9
FC *	0	**173**	-	<1	37000	-	-	-
EC *	0	**173**	-	<1	2700	-	-	-

Note: Column 2 – Acceptable limits as per BIS standard; Column 3 – No. of samples exceeding maximum acceptable limit; Min. – Minimum; Max. – Maximum ; SD – Standard deviation ; M – Median ; S – Skewness ; * Counts/ 100 ml

Table 1. BIS standards for drinking water quality and summary statistics of selected hydro-geochemical parameters in ground water samples.

S.No.	WQI Range	Suitability for Drinking Purpose
1	< 50	Excellent
2	50-100	Good
3	100-200	Poor
4	200-300	Very Poor
5	> 300	Unsuitable

Table 2. Classification for groundwater for drinking purpose based on WQI (After Gantait et al., 2022)

Prevalence of water borne diseases has been investigated through schedule based survey of 346 households of the same villages from which water samples had been collected. The reported diseases have been categorised into 08 broad types based on possible causative bio-geochemical composition of drinking water and impact of water quality on health has been quantified in terms of number of types of diseases prevalent in the village.

Out of the 12, 7 parameters - FC, EC, F, Hardness, TDS, Alkalinity and Fe - were selected for further analysis identified on the basis of exceeding levels and highly prevalent diseases. Water quality surfaces of the 07 parameters and WQI have been mapped using Inverse Distance Weighted (IDW) method.

LULC has been mapped using the European Space Agency (ESA) World Cover 10 m Sentinel product generated through Google Earth Engine. The LULC maps at 1:50000 scale prepared by National Remote Sensing Centre (NRSC) for the year 2015-16 have been used as reference. The geology has been acquired from Bhukosh, the official portal of Geological Survey of India.

Regions more vulnerable to water borne diseases have been identified using zonal statistics operations implemented by overlaying the village map on WQI surface. Geospatial analysis has been implemented in ArcGIS v. 10.3. Statistical analysis has been implemented in SPSS v. 23.0.

4. RESULTS AND DISCUSSION

4.1 Evaluation of Water Quality Parameters

4.1.1 Flouride (F): Fluorine commonly occurs as a negatively charged ion in water, either in trace amounts or as a major ion with high concentrations (Narsimha and Sudarshan, 2017). The acceptable limit of F in drinking water has been prescribed as 1 mg/L by BIS and 1.5 mg/L by WHO. Excessive F intake usually occurs through the consumption of groundwater containing excess F, or use of such water in food preparation or irrigation of crops (WHO, 2023). Excessive exposure causes dental fluorosis or crippling skeletal fluorosis, and bone deformities. Water rock interactions by fluoride bearing mineral are the source of F in groundwater. Fourite (CaF_2) is the sole principal mineral of fluorine, occurring in nature, and is commonly found in granitic gneiss. It is also abundant in apatite, micas, amphiboles and clay minerals (Narsimha and Sudarshan, 2013).

The F concentration in the region ranges from .04 to 10.5 mg/L. However the excessive occurrence is highly localised as the level of F is less than 1 mg/L in 142 (82 percent) samples (Figure 3) and less than 1.5 mg/L in 157 (91 percent) samples. Two samples, both located in eastern part of Aspur tehsil have recorded six to about ten times high F concentration. High F concentrations occur mainly in north eastern part of the district covering almost entire Aspur tehsil, western Sabla and eastern part of Sagwara tehsils. Some small scattered pockets with twice to four times the acceptable limit occur in Simalwara, Jothari, and Bichiwara tehsils too (Figure 4A).

4.1.2 Total Dissolved Solids (TDS) : TDS is a measure of amount of dissolved ions in water. It mainly includes inorganic salts (calcium, magnesium, potassium, sodium, bicarbonates, nitrate, chlorides, and sulphates), metals and some amount of dissolved organic matter. Water being an efficient solvent, easily picks up impurities from natural (mineral springs, carbonate deposits, salt deposits etc.) and anthropogenic (sewage, urban and agricultural runoff, industrial wastewater etc.) sources. The permissible TDS for drinking water is 500 mg/L. Potential health risks associated with TDS depend on the specific ion composition of the measurement. Prolonged consumption of water with elevated TDS may cause kidney stone, nausea, lung irritation, vomiting, dizziness, weakened immunity, nervous system disorders etc.

TDS levels in the study area range between 232 to 2818 mg/L with 122 (70.5 percent) sites having TDS level higher than the standard. The high spatial variability is evident in high standard deviation (SD) (456 mg/L) and positively skewed distribution (Table 1 and Figure 3). North eastern part of the district comprising entire Aspur, southern Sabla and north-eastern part of Sagwara tehsils is the worst affected region having excessive TDS higher than 1000 mg/L (Figure 4B). The TDS levels are above the acceptable standards in the remaining parts too (500 – 1000 mg/L) except some pockets in the western parts of Bichiwara, Gamdi Ahada, Chikhali and eastern Simalwara tehsils.

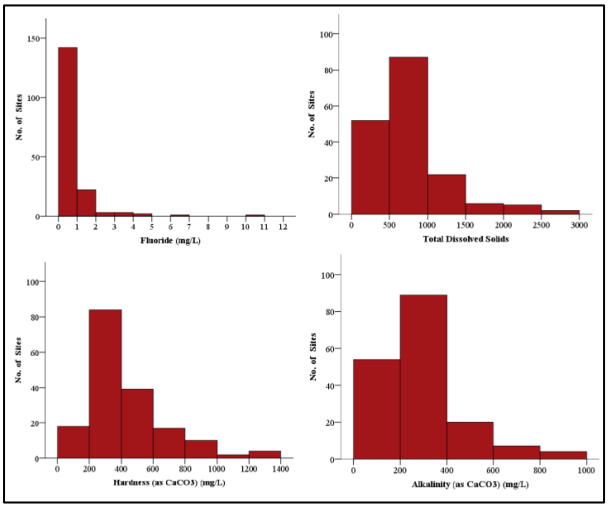

Figure 3. Frequency distribution of sample sites along the scale of concentration of selected hydrogeological parameters.

4.1.3 Hardness: Hardness or Total Hardness (TH), commonly expressed as milligrams of $CaCO_3$ equivalent per litre, is caused by dissolved metallic ions, predominantly calcium and magnesium cations, along with others like aluminium, barium, iron, manganese, zinc and strontium (WHO, 2010). The principal natural sources of Hardness in water are dissolved ions from sedimentary rocks (limestone and chalk being sources of calcium and magnesium) seepage and runoff from soils. BIS standard of permissible limit for hardness (as $CaCO_3$) in drinking water is 200 mg/L. Maximum permissible limit in absence of alternative source is 600 mg/L. Diarrhoea, itching and eczema are some health effects reported due to prolonged consumption of hard water.

TH ranges between 96 and 1380 mg/L in the study area with 156 (90.17 percent) sites having TH higher than 200 mg/L (Figure 3). The distribution of TH is positively skewed with SD at 242.5 indicating high spatial variability (Table 1). However only 33 sites have TH exceeding 600 mg/L. TH exceeds the acceptable limit of 200 mg/L in entire study area.

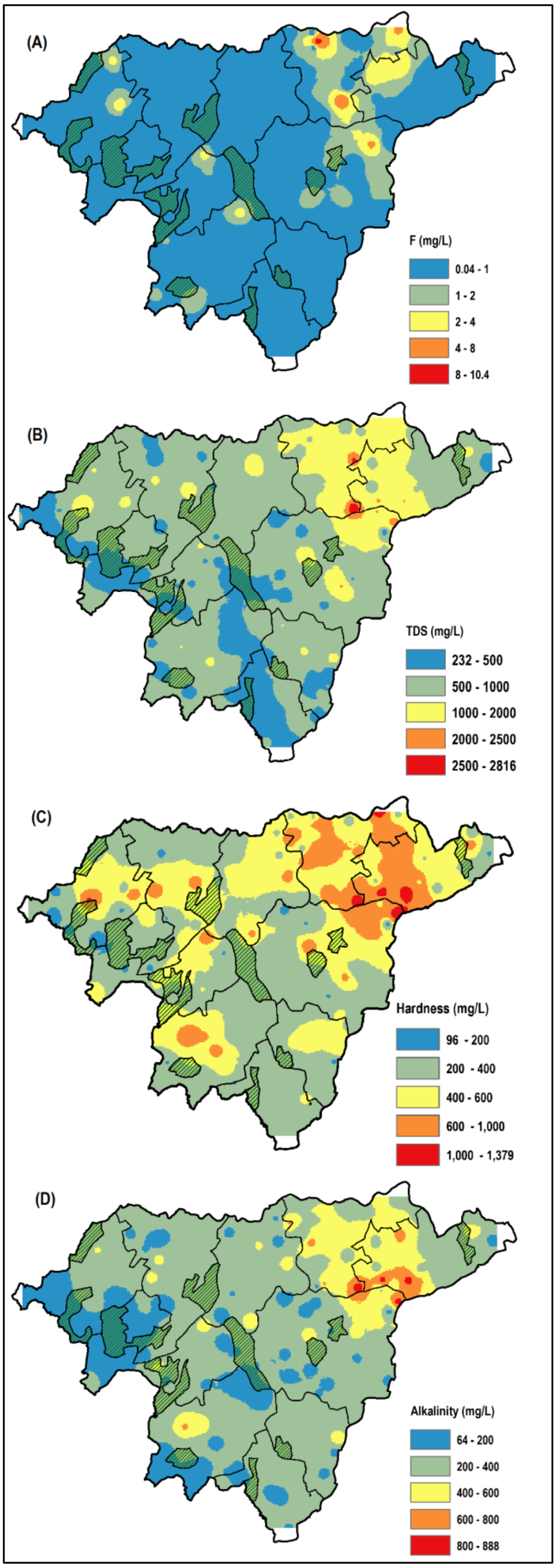

Figure 4. Spatial distribution of hydrogeochemical parameters in drinking water in Dungarpur district (A) Flouride, (B) TDS, (C) Hardness, and (D) Alkalinity

Considering the permissible standard of 600 mg/L, excess concentrations primarily occur in Aspur, Sabla and north-eastern Sagwara tehsils. The region along the boundary of the 03 tehsils has the maximum TH levels exceeding 1000 mg/L (Figure 4C).

4.1.4 Alkalinity: Alkalinity in natural waters refers to the presence of carbonates (CO_3^-), bicarbonate (HCO_3^-) and hydroxyl (OH^-) anions. Borates, phosphates, silicates, and other bases also contribute to it (Wilson, 2019). It is reported as equivalents of calcium carbonate ($CaCO_3$). Geology of an area, particularly limestone formations, is a primary source of alkalinity in groundwater. The acceptable and maximum permissible limits for total alkalinity (as $CaCO_3$, mg/L) prescribed by BIS are 200 and 600 respectively. Consumption of alkaline water is beneficial for human health. However, excessively alkaline water (pH > 10) causes skin, eye, and mucus membrane irritation in humans. It may also cause gastrointestinal irritation in sensitive people.

Considering the acceptable BIS standard (200mg/L) 68.8 percent (119) of the sample sites have recorded higher alkalinity. It ranges from 200 to 600 mg/L (within maximum permissible limits) at 109 sites (63 percent) with larger number of sites having measurement less than 400 mg/L (Figure 3). The north eastern part of the district, having highest levels of hardness, also records highest alkalinity comprising a small pocket along the border of Aspur, Sabla and Sagwara tehsils (Figure 4D).

4.1.5 Iron (Fe): Fe is a basic requirement of human body for biological processes like transporting oxygen in the blood. However, excessive Fe intake may damage the internal organs - the heart, pancreas and liver – causing a host of problems including iron poisoning. Iron poisoning commonly causes ailments like fatigue, weakness, joint pain, and abdominal pain. Overexposure to Fe could cause extremely serious conditions like heart or liver failure.

The maximum permissible limit of Fe in drinking water is 0.3 mg/L. Almost entire study area is Fe content within the safe limit. Only 11 percent (22) of the sites have higher Fe levels, out of which 03 sites have excessive concentration higher than 0.9 mg//L (Figure 5B). Groundwater having excessive Fe concentration is highly localised occuring in small areas in and around Sendwai and Vagdari village in Dungarpur tehsil ; and Ojariya, Palsau and Punawara villages in Chikhali tehsil ; and Khora Kachwara village in Dovda tehsil. Areas around Sendwai and Ojariya are worst affected (Figure 5A).

4.1.6 Faecal Coliform (FC) and E. Coli (EC): Water contaminated with pathogenic microorganisms is unsafe for human consumption causing serious diseases including diarrhea, cholera, typhoid fever, dysentery etc. These pathogens are usually found in human and animal faeces. Monitoring the microbiological quality of drinking water for presence of faecal contamination relies largely on examination of indicator bacteria such as Coliforms. Escherichia Coli (E. Coli) is a member of the faecal coliform group and is considered the best bacterial indicator of faecal contamination in drinking water, more specific than faecal coliforms (Odonkar and Ampofo, 2013). However, it does not survive well outside the intestinal tract, and its presence in environmental samples, food, or water usually indicates recent faecal contamination. FCs can survive in water for longer periods than EC, thus the sources that are contaminated with FC and not with EC might not be contaminated recently (Mahmud et al., 2019).

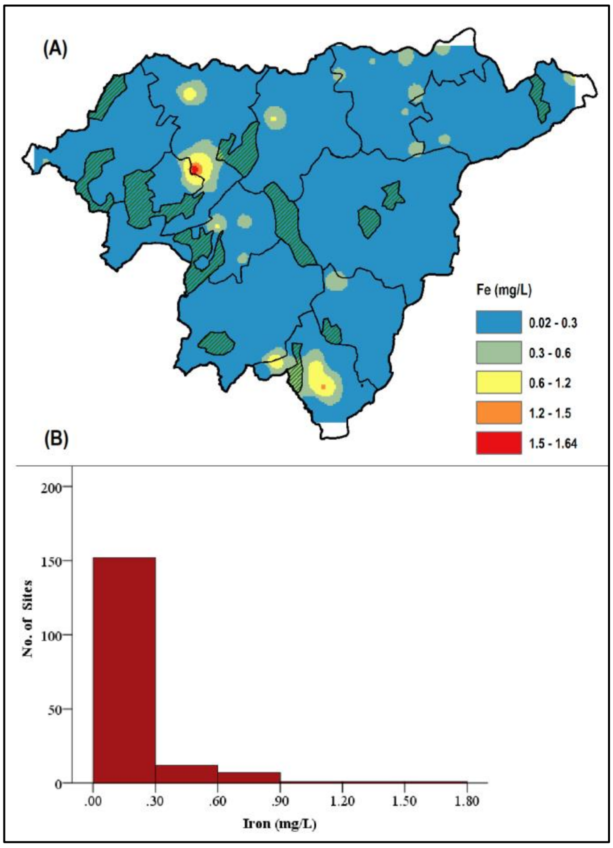

Figure 5. (A) Spatial distribution of Fe in drinking water in Dungarpur district, and (B) Distribution of sample sites along the scale of concentration of Fe in drinking water.

The prescribed BIS standards for bacteriological quality of ‘all water intended for drinking’ is ‘shall not be detectable in any 100 ml sample’ (BIS, 2012).

The region has an extremely worrisome scenario in terms of the bacteriological quality of water. All the samples are contaminated with FC and EC with the FC counts ranging from less than 1/100 ml to 37000 counts/ml, and EC counts from less than 1 to as high as 2700 counts/ ml (Table 1). The spatial distribution pattern of both FC and EC contamination shows excessively high concentration in a continuous extended region comprising Bichiwara, Gamdi Ahada and Jhothari tehsils, northern Simalwara and southeastern part of Galiyakot tehsil having contamination more than 1000 counts/ml (Figure 6). The eastern and central part of the district has relatively lesser contamination; nevertheless none of the samples are safe for drinking.

4.2 Spatial Pattern of WQI and Identification of Priority Areas

The quality of drinking water in the region in terms of WQI computed on the basis of 10 geochemical parameters shows that the problem is most severe in the eastern part of the district. The quality of drinking water has been recorded as ‘excellent’ or ‘good’ at approximately 64 percent of the sites (110 sites). Of the remaining about one-third of the sites have ‘poor’ drinking water quality. Only 01 site in Aspur has recorded WQI higher than 300 placing it in ‘unsuitable’ category. The western part of the district has relatively better water quality (lower WQI) than the eastern part (Figure 7A).

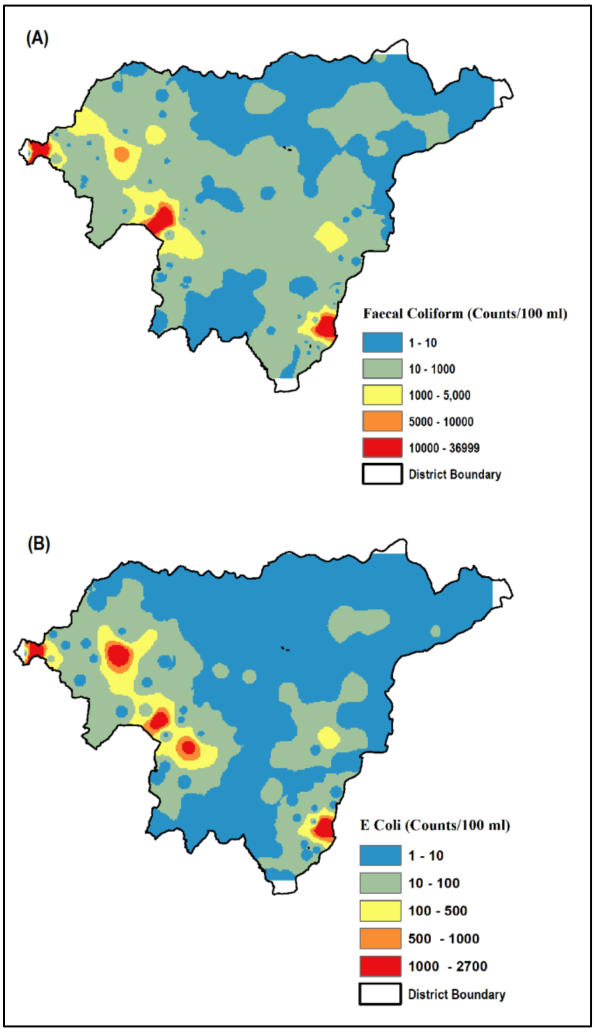

Figure 6. Spatial pattern of pathogenic contamination in drinking water in Dungarpur district (A) Faecal Coliform, and (B) E-Coli.

The southern part of the district has relatively better water quality than the northern part. Worst quality of water (WQI > 300) has been recorded in Indaura village in Aspur tehsil. In the south, Ojariya village in Chikhali has the highest WQI (218).

A continuous region comprising Dhani Khajur, Khumanpur, Usmaniya, and Bhewri villages of Aspur; Karada Kawara, Gara Vasan, Vamasa and Bhachriya villages of Sagwara tehsil; Vijaypur and Borigama Chhota villages of Sabla tehsil have the poorest water quality with highest zonal mean WQI, thereby indicating the pressing need for supply of treated water in these villages. However the zonal mean WQI falls in ‘poor’ to ‘very poor’ category in all the villages of Aspur , majority of the villages in Sabla (mainly west) and eastern half of Sagwara tehsils. Villages located in northern part of Dovda tehsil adjoining Aspur, central and western part of Dungarpur, part of Bichiwara tehsil, an extended region comprising villages of eastern Jhothari, central and north-eastern Simalwara and central and western part of Chikhli tehsil have zonal mean falling in ‘poor’ category (Figure 7B).

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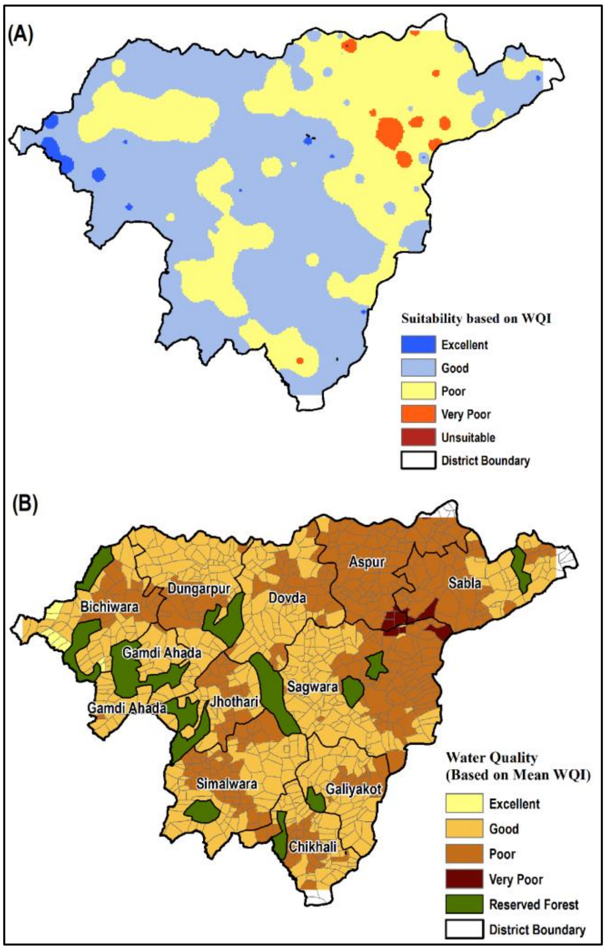

Figure 7. (A) WQI distribution in Dungarpur district, and (B) Suitability of drinking water based on village wise mean WQI .

High concentration of selected geochemical parameters does not indicate a significant correlation with any specific land use. Notably, excessive bacteriological contamination in the west correlates with agriculture and forest area. This may be attributed to high concentration of tribal population in this region, living in extreme poverty and lack of toilet facilities.

Phyllites and various types of Schists, such as Mica Schists and Chlorite Schists, occupy about 90 percent of the area of the district. Higher values of geochemical parameters (such as TDS, Fe and Alkalinity) correlate with Granites, migmatites and Mica Schists rocks. Higher values of WQI correspond with occurrence of Phyllites and Mica Schists.

4.4 Prevalence of Water Borne Diseases

The household survey of the population consuming water from the selected water sample sites revealed that entire population is suffering from a range of water borne diseases. Major health problems prevalent in the region are diarrhoea, abdominal pain/cramps, dyspepsia, bloating, nausea, vomiting, heaviness in stomach after consuming water, hypersalivation etc.; sweating, anxiety, irritability, headache, general tiredness, laziness and muscle pain, problem in breathing and fastened heartbeat; pain in joints and knee, spinal curvature, weak, yellow and rough teeth, osteoporosis, calculus, dysuria ; blue skin, itching in eyes and skin ; and delayed physical development in children. Occurrence of these diseases indicates the vulnerability of resident population to poor quality of drinking water in terms of selected parameters.

Disease incidence in the study area measured as number of types of diseases occurring at the sample site has been illustrated in Figure 8. Overlaying the disease incidence rate map on distribution maps of WQI and individual parameters clearly establishes the correspondence between bio-geochemical composition of water, overall drinking water quality and vulnerability of resident population to water borne diseases (Figure 6 and 7). Southern part of the study area comprising Chikhli and eastern half of Simalwara tehsils is least affected by water borne diseases. Problems like muscle and joint pain, weakness, headache, irritability have been observed in this area which correlates with occurrence of heavy metals and high TDS. Western half of the district including western part of Simalwara have reported various combinations of three or more water borne diseases co-occurring with higher concentrations of TDS, hardness and alkalinity. Disease incidence rate is higher in eastern half of the study area. Northern part of Dovda, entire Aspur, Sabla, Sagwara, western part of Dungarpur, Bichiwara and Jothari tehsils are worst affected by water borne diseases.

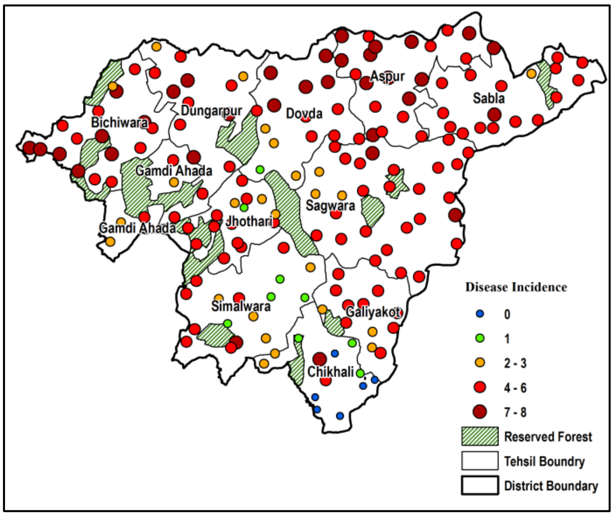

Figure 8. Distribution and intensity of water borne diseases in Dungarpur district.

Extreme vulnerability of the northern and north-eastern part of the district may be attributed to high TDS, hardness, fluoride and alkalinity. The area comprising Aspur, western Sabla and north eastern part of Sagwara is worst affected. In western parts of Bichiwara, Gamdi Ahara, Jothari and south east Galiyakot, pathogenic contamination also adds to the occurrence of diseases.

5. CONCLUSION

Groundwater is the major source of drinking water in Dungarpur district, which is one of the most economically backward tribal dominated region located in southern part of Rajasthan state in India. This study analyses the occurrence of water borne diseases in the district in context of 10 geochemical and 02 microbial parameters. Hydro geochemical composition and pathogenic contamination of drinking water has been analyzed in context of land use and geology of the study area.

Results reveal that the north-eastern part of the district comprising Aspur, Sabla and part of Sagwara tehsils predominantly has 'very poor' to 'unsuitable' water quality. High concentrations of F and Fe occur in specific pockets while excess levels of TDS, Alkalinity and Hardness occur in major part of the district with maximum concentrations primarily in the north central and north eastern part. Pockets of highest concentration with four to five times permissible Iron content occur in two distinct regions – Dungarpur and Gamdi Ahada tehsils in the north, and around Ojariya village in Chikhali tehsil in extreme south. In Aspur, Sabla and Sagwara tehsils, F content is twice to ten times the permissible limit. Western and southern region record hazardous quantities of FC (upto 37000 counts/ 100 ml) and EC (up to 2700 counts/ 100 ml). Vulnerability and intensity of water borne diseases closely corresponds with distribution of individual parameters and overall WQI. Results underline urgent need for drinking water treatment particularly in the northern part of the region.

High concentration of selected geochemical parameters does not indicate a significant correlation with any specific land use. Pathogenic contamination shows positive relationship with forest land cover in the west, economic and cultural practices. Phyllites and various types of Schists, such as Mica Schists and Chlorite Schists, occupy about 90 percent of the area of the district. Higher values of WQI correspond with occurrence of Phyllites and Mica Schists.

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