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Full Length Research Article

Assessment of Water Quality of Handpumps in Kathua Tehsil of the Union Territory of Jammu and Kashmir

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ABSTRACT

Water is one of the most valuable resources. It covers over 75% of the earth's surface, although just 2.5 percent of all water is fresh in nature. Most of this fresh water resource is in the form of ice and snow, which is inaccessible to mankind, therefore, groundwater becomes increasingly important due to its accessibility. Over the years groundwater has got contaminated due to rapid industrialization, urbanization, high population, and advanced techniques in agriculture. Around 37.7 million people in India are affected by water-borne diseases, which kill 1.5 million people each year. Groundwater quality is being analyzed all around the world to understand its distribution and level of contamination. Chemical, biological, and physical properties of water are used to assess the quality of water in a specific area. In our study weighted arithmetic water quality index method has been used for overall water quality analysis in a more easy and reasonable manner. Values in weighted arithmetic water quality index method ranges from 0 to more than 100. The output value near 0 represents excellent water quality and the values approaching 100 represents very poor water quality. In our study water samples from the Kandi area showed a low water quality index ranging from 10.87 to 43.81 with an average of 28.85 while the water quality index values of Outer plains range from 43.13 to 94.47 having an average of 57.77. Thus, the hand pumps are good in water quality and therefore suitable for drinking purposes in the Kandi area. On the other hand, the water quality of handpumps in the Outer Plains varies from good to very poor water quality category and hence the water from most handpumps in the Outer Plains is unfit for drinking purpose. The study provided an insight about the status of water quality of handpumps which can be used for proper planning and management of water for sustainable water development.

Key words: Groundwater, Water quality index, Water contamination, Handpump, Sustainable

Water is one of the most valuable resources and the plenteous compound that is available on the earth surface [1-3]. As 75 percent of the earth surface is covered with water but only 2.5 percent of total water is fresh in nature. Out of this freshwater, 68.9 percent is in the form of snow and ice and 29.9 percent is present as groundwater [4-6]. Water available in the form of ice and snow is not easily accessible for human beings therefore groundwater becomes very crucial as it is easily accessible for human use. Around 80 percent of the total water need is fulfilled by the groundwater in the rural area and as far as urban area is concerned it constitutes 50 percent of total urban water needs [7-9]. Nearby 1.5 billion people use groundwater directly or indirectly. With an estimation of 250 billion m^3 per year, India ranks first in groundwater usage. In our country around 85 percent of drinking water and 60 percent of irrigated agriculture is carried out with the help of groundwater [10-13]. Water is a universal solvent. Because of this property of water, it is very rare in pure form. It gets contaminated very easily [14-17]. The groundwater also gets contaminated due to industrialization, urbanization, advanced techniques in agriculture, high population growth, high rate of evaporation and low rainfall in some area etc. Therefore, the water quality of groundwater around the world is being studied and its distribution and knowledge of the level of contamination become crucial [18-20]. In our country, it is estimated that out of industrial waste or domestic waste, domestic waste contributes more to the contamination of water. According to UNICEF, around 663 million people in the world is using contaminated water. In India, around 37.7 million people suffer from water-borne diseases, which results in the death of 1.5 million people annually [21-24.

The quality of water of a particular area can be measured by using Chemical, Biological and Physical parameters of water. If the value of these variables crosses the defined limits, they become detrimental to us [25]. To check the water quality of any water resource whether it is surface water or groundwater, Water Quality Index (WQI) is widely used. In WQI, quality of water is represented in term of index number which is used in the analysis of overall quality of water [26]. It takes bulk of information about the concentration of various

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water quality parameters and reduces this information into a single number which represents the overall water quality in a more easy and reasonable manner [27]. In our study, weighted arithmetic water quality index method is used which gives different values from 0 to more than 100. The output value near 0 represents excellent water quality and the output value approaching 100 represents very poor water quality. It is not only used to assess the temporal changes in any water resource but can be applied to differentiate the water quality of various water sources [28-30]. In order to monitor the groundwater status in India Central Groundwater Board (CGWB) has established number of monitoring wells in whole country. As far as J&K is concerned there are around 261 active groundwater monitoring wells which are in different parts of the Union Territory. As the UT J&K is very large in area, the number of active water monitoring wells is insufficient.

In the study area, people use the water of handpump for drinking and domestic purposes, especially in the Outer Plains. Even though they have PHE water supply as an alternative, still they heavily rely on handpump water as there is low availability of PHE water compared to handpump water which is easily accessible. The water of the handpumps is prone to contamination because water is drawn from the low depth. Improper disposal of domestic waste and sewage, excessive use of pesticides and fertilizers in agriculture also increases the vulnerability of handpump water to contamination. It is usually not treated before use therefore, the study of water quality of hand pumps in the Kathua Tehsil becomes crucial as this study will intensively highlight the quality of hand pump water and will suggest the measures to improve the degrading water quality of hand pumps.

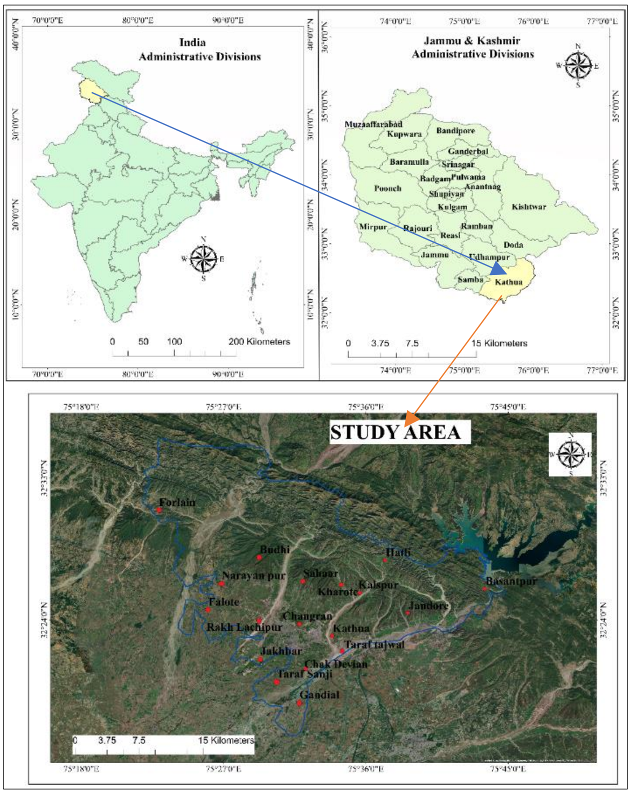


Fig 1 Location map of the study area

MATERIALS AND METHODS

Kathua Tehsil is one of the 11 Tehsils of Kathua District, which is situated in the Southern part of Union Territory of J&K. To be precise it lies towards the S-W direction in the Kathua District. This region has a population of around 115154 and culturally it is very diverse in nature. Out of the total of 512 villages in Kathua District 155 villages lies in Kathua Tehsil [31].

The total average annual rainfall of Kathua tehsil is 1400mm. Most of the rainfall in the study area is received through the south-west monsoon from the month of July to September whereas in the winter season rainfall occurs due to the western disturbance from the month of November to February. The annual temperature of the study area ranges between 5°C to 43°C [32].

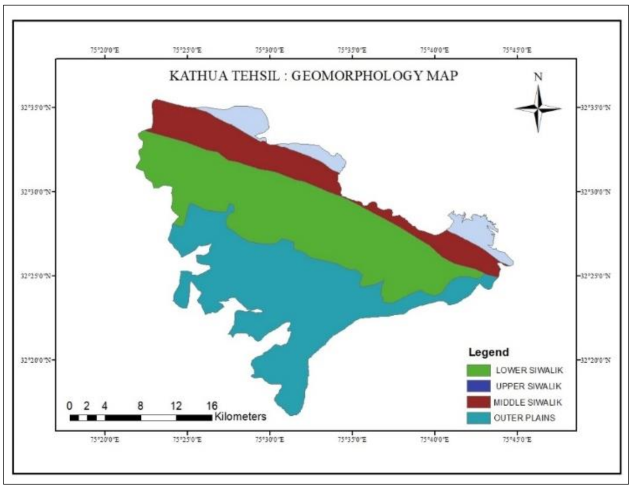


Fig 2 Geomorphology map of Tehsil Kathua

Geomorphologically the study area is classified into Siwaliks and Outer plains. Siwaliks are further divided into Upper, Middle and Lower Siwaliks (Kandi belt). Water samples of different handpumps were collected only from the Kandi area (Lower Siwaliks) and Outer plains because Middle and Upper Siwalik being located at higher altitude do not have handpumps [33].

Both primary and secondary data has been used in our study. For the primary data water sample of handpumps were collected from various sites and after that, all those samples got tested in P.H.E Lab Kathua to obtain the desired results. Secondary data related to water quality standards were taken from BIS standards [34] while data related to water quality index was retrieved from published research work. Satellite imagery of LISS III was collected from the Bhuvan portal to prepare the land use landcover map of the study area through supervised classification in Arc GIS, whereas geology map has been retrieved from the Bhukush portal of the Geological Survey of India.

There were two types of handpumps found in the study area namely India Mark II and PHC 6. In the Kandi area, India Mark II type of handpumps was found while PHC 6 type of handpumps were found in Outer plains. India Mark II type of handpumps are used to draw water up to 100 feet deep which is suitable for the Kandi area. While PHC 6 types of handpumps are widely used to draw water in the area having high water table which is suitable for Outer Plains. About 18 water samples of handpumps were taken from the study area, out of which 9 water samples were from outer plains while 9 were from the Kandi area These water samples were tested in P.H.E lab Kathua for nine water quality parameters that include Calcium, Flouride, Chloride, Hardness, Iron, Magnesium, Nitrate, Turbidity and pH as per BIS guidelines.

Line graphs were prepared for the representation of each water quality parameter. The average concentration of each water quality parameter of all the water samples of Kandi and outer plains was calculated for their comparative analysis. For the analysis of the overall water quality of the study area water quality index has been calculated. Water Quality Index (WQI) is a useful method for assessing the quality of water for any intended use. It represents the quality of water in term of an index number, from which the overall quality of water can be analyzed. It takes information from various sources and reduces this bulk of information into a single number to represent the overall status of water in a more simplified and logical way. With the help of WQI, information regarding the quality of water can be easily provided to the general public and policymakers for efficient management of water.

For assessing the water quality of Handpumps in the study area Weighted Arithmetic Method was used [35]. To calculate Water Quality Index nine parameters (Calcium, Chloride, Fluoride, Hardness, Iron, Magnesium, Nitrate, pH, and Turbidity) were used. Bureau of Indian Standards has been used for the acceptable limit of water quality parameters.

The formula used for calculating Water Quality Index is as follows:

$$WQI = \frac{\Sigma QiWi}{\Sigma Wi}$$

Where;

Qi refers to the quality rating for i^{th} water quality parameter and W_i shows the value of unit weight of i^{th} water quality parameter.

Quality rating Qi has been calculated using the following formula:

$$Q_i = 100 \left[\frac{(Vi-V0)}{(Si-V0)} \right]$$

Where V_i is the estimated value of i^{th} water quality of parameter

V_0 is the ideal value of the i^{th} water quality parameter

$V_0 = 0$ (except pH = 7.0 and DO = 14.6 mg/l)

S_i is the acceptable value of i^{th} water quality parameter as per BIS.

For the calculation of unit weight for each water quality parameter following formula was used:

$$W_i = k/S_i$$

Where,

W_i is unit weight fo i^{th} water quality parameter

Si is the standard acceptable limit for i^{th} water quality parameter

K is proportionality constant which is calculated using the following formula:

$$K = \frac{1}{\Sigma\left(\frac{1}{Si}\right)}$$

Here S_i stands for the standard acceptable limit for ith water quality parameter.

After the calculation of WQI, the computed values have been classified into 4 categories as shown in the following (Table 1).

Table 1 Categories of water quality index [36]

Water quality index level	Water quality status
0-25	Excellent water quality
25-50	Good water quality
50-75	Poor water quality
75-100	Very Poor Quality
>100	Unsuitable for drinking

IDW interpolation technique in Arc GIS was used to prepare the water quality map of handpumps of the study area.

RESULTS AND DISCUSSION

Statistical analysis of water quality parameters

Statistical analysis of the water quality parameters from the water samples of the Kandi area and outer plains was done by calculating the range and mean of each water quality parameter and comparing it with the standard values as per BIS standards.

Table 2 Statistical analysis of water quality parameters of outer plains

Water quality parameter	Jhakhbarh	Falote	Changran	Rakh Lachipur	Gandial	Chak Devian	Taraf Sanjhi	Taraf Tajwal	Kathua	Standard values	Mean	Max	Minimum
Calcium	40	50	100	60	60	55	50	55	100	75	63.33	100	40
Chloride	240	240	150	200	210	200	200	210	150	250	200	250	150
Fluoride	0.35	0.38	0.4	0.4	0.5	0.4	0.35	0.38	0.4	1	0.4	1	0.35
Hardness	180	185	200	180	180	175	180	180	200	200	184.4	200	150
Iron	0.016	0.03	0.014	0.015	0.06	0.05	0.05	0.05	0.014	0.3	0.03	0.3	0.016
Magnesium	28	20	20	26	24	25	26	28	20	30	24.11	30	20
Nitrate	15	15	15	15	15	15	15	15.12	15	45	15.01	45	15
Turbidity	4.6	1.69	1.69	1.69	3.2	0.8	3.95	1.69	0.8	1	2.23	4.6	0.8
pH	7.21	7.64	7.47	7.3	6.97	7.15	7.95	7.49	7.47	7.5	7.41	7.95	6.07

Table 3 Statistical analysis of water quality parameters of the Kandi area

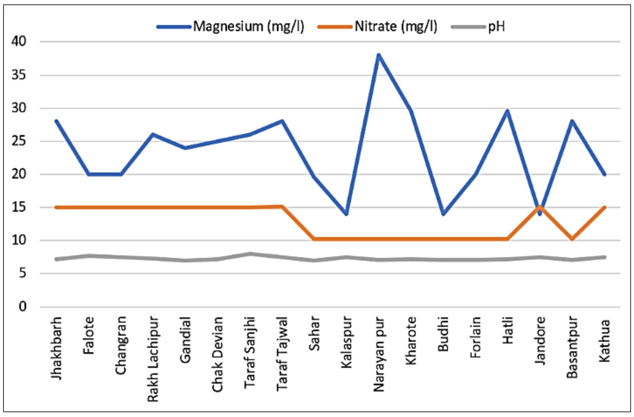
Water quality parameter	Jhakhbarh	Falote	Changran	Rakh Lachipur	Gandial	Chak Devian	Taraf Sanjhi	Taraf Tajwal	Kathua	Standard values	Mean	Max	Minimum
Calcium	40	50	100	60	60	55	50	55	100	75	63.33	100	40
Chloride	240	240	150	200	210	200	200	210	150	250	200	250	150
Fluoride	0.35	0.38	0.4	0.4	0.5	0.4	0.35	0.38	0.4	1	0.4	1	0.35
Hardness	180	185	200	180	180	175	180	180	200	200	184.4	200	150
Iron	0.016	0.03	0.014	0.015	0.06	0.05	0.05	0.05	0.014	0.3	0.03	0.3	0.016
Magnesium	28	20	20	26	24	25	26	28	20	30	24.11	30	20
Nitrate	15	15	15	15	15	15	15	15.12	15	45	15.01	45	15
Turbidity	4.6	1.69	1.69	1.69	3.2	0.8	3.95	1.69	0.8	1	2.23	4.6	0.8
pH	7.21	7.64	7.47	7.3	6.97	7.15	7.95	7.49	7.47	7.5	7.41	7.95	6.07

Concentration of various water quality parametre

Magnesium: Magnesium is an important water quality parameter as it directly affects the concentration of water hardness. Magnesium concentration in water mainly depends on the type of rock and is a significant element for human health in limited quantity [37]. As per the Bureau of Indian standard, the acceptable limit of magnesium in drinking water lies below 30 mg/l [34]. As far as our study is concerned the concentration of magnesium lies between 14 mg/l to 40 mg/l. The average concentration of magnesium is 23.4 mg/l in Kandi and 24.11 mg/l in the plain area. Out of total 9 water samples in the Kandi area, only one water sample from Narayanpur lies above the desirable limit. As far as the plain area is concerned all the water samples comes under the desirable limit.

Nitrate is a major groundwater contaminant in rural area due to excessive use of fertilizers and storage of manure. It is hazardous in nature as a high concentration of nitrate leads to Blue baby syndrome, hemorrhage of the spleen, gastric cancer, goitre and hypertension [38]. The concentration of nitrate lies between 10.18 mg/l to 15.45 mg/l with an average of 13.85 mg/l. All the sampled water showed a concentration of nitrate below the acceptable limit of 45 mg/l.

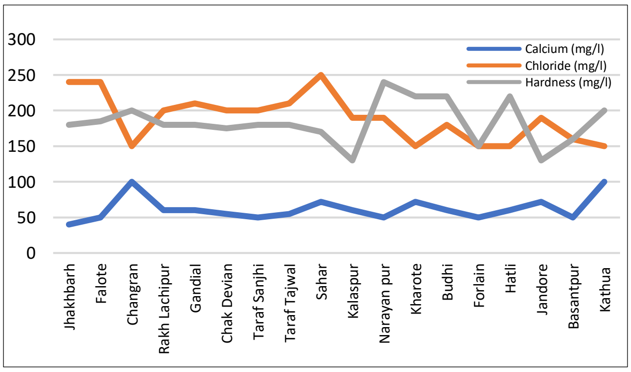
pH value: pH value is an indicator of the acidic or basic nature of water. As per the Bureau of Indian Standard acceptable limit of pH is 6.5-8.5 for drinking water [34]. In our study region, the pH value of all water samples ranges between 7.0 to 7.95, with an average of 7.23 and 7.41 in Kandi and plain area respectively. The result reveals that water of handpumps from all sampled water is slightly alkaline in nature as there is only one water sample that is from Sahar which is neutral in nature.



Concentration of magnesium, nitrate and pH

Calcium: Concentration of calcium along with magnesium affects the hardness of water and is mainly found in the form of carbonates [35] Concentration of calcium in all the collected water samples ranges between 40 mg/l to 100 mg/l, with an average of 59.25 mg/l in the Kandi area and 63.33 mg/l in the outer plains. Two water samples which are from Kathua and Changran showed a higher concentration of calcium than the acceptable limit of 75 mg/l.

Chloride: In humans, the toxicity of chloride has not been observed except in some cases of impaired sodium chloride metabolism which results in heart failure [39]. As far as our study is concerned concentration of chloride ranges between 150 mg/l to 250 mg/l, with an average of 170 mg/l in the Kandi area and 200 mg/l in Plain areas. The acceptable limit of chloride is 250 mg/l. There is not even a single water sample in our study which crosses this limit.



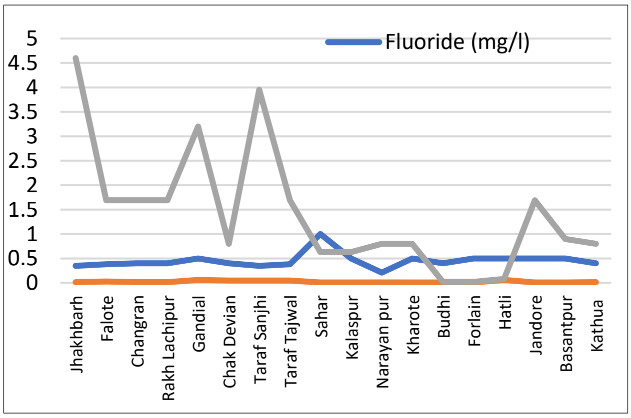
Concentration of calcium, chloride and hardness

Hardness: Hardness in water refers to the amount of dissolved magnesium and calcium ions. Sometimes the other ions like aluminum, barium, iron, manganese, strontium and zinc also result in the hardness of the water [40-41]. The concentration of hardness ranges between 130 mg/l to 240 mg/l with, a mean value of 184.4 mg/l in the Kandi area and 179.4 mg/l in outer plains. One water sample which is collected from Narayanpur showed a hardness value above the acceptable limit of 200mg/l.

Fluoride: High concentration of Fluoride in water leads to dental and skeletal fluorosis [42-43]. The concentration of Fluoride in the sampled water ranges between 0.21 mg/l to 1mg/l. The mean value of fluoride in collected samples of the outer plain is 0.4 mg/l and while in the Kandi area it is 0.45 mg/l. The acceptable limit of fluoride concentration in water is 1mg/l as per BIS and none of the collected water samples lies above this limit.

Iron: Excessive amount of iron in water leads to an undesirable taste of water and it also imparts undesirable reddish-brown colour to the water. The health problems such as Diabetes, Hemochromatosis, Nausea, and vomiting are caused by the consumption of water rich in iron. It also affects skin cells [44]. The concentration of iron in all the collected water samples ranges between 0.009 mg/l to 0.06 mg/l with an average of 0.01 mg/l and 0.03 in the Kandi area and outer plains respectively. None of the collected samples exceeded the acceptable limit of 0.3 mg/l of iron as per BIS.

Turbidity: It refers to the degree of transparency of water. It also determines the optical clarity of the water. It is mainly used as an indicator of relative total suspended solid concentration in water [45]. In our study region value of turbidity ranges from between 0.02 NTU to 4.6 NTU, with an average of 0.61 and 2.23 in Kandi and plain area respectively. Out of the total collected samples in the Outer plains, 2 water samples from Kathua and Chak Devian comes under the desirable limit whereas 8 water samples from the Kandi area lies under the desirable limit, while the sample from Jandore lies above the desirable limit.



Concentration of fluoride, iron and turbidity

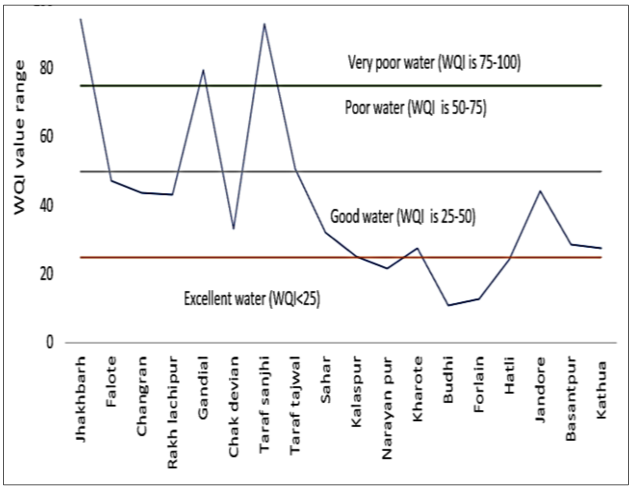
Water quality index of hand pumps in Tehsil Kathua

To assess the overall water quality of water samples of handpumps Weighted Arithmetic Method was used [46]. Nine water quality parameters were used to calculate the water quality index which is calcium, chloride, fluoride, hardness, iron, magnesium, nitrate, pH, and turbidity. After calculating the Water quality index, it was found that Turbidity, Fluoride, and Iron are the dominant factors influencing the water quality index.

Water samples collected from the Kandi area falls under the category of excellent and good water quality while water samples from outer plains lie under the good, poor, and very poor water quality category. In the Kandi area water samples from Narayanpur, Budhi and Forlain lie in the excellent water quality category whereas water samples collected from Kalaspur, Kharote, Hatli, Jandore, Basantpur and Sahaar falls in the good water quality category. In the case of Outer plains Kathua, Chak Devian, Rakh Lachipur, Changran and Falote falls in good water quality while the water sample collected from Taraf Tajwal lies in the poor water quality category. Water samples of Jhakhbar, Gandial and Taraf Sanji from outer plains showed very poor water quality.

Table 4 Water quality index of the study area

Kandi Area			Outer Plains		
Location	WQI	Average	Location	WQI	Average
Kalaspur	25.23		Jhakhbarh	94.47	
Narayanpur	21.78		Falote	47.26	
Kharote	43.81		Changran	43.75	
Budhi	10.87		Rakh lachipur	43.13	
Forlain	12.72	28.85	Gandial	79.56	57.77
Hatli	25.51		Chak devian	33.33	
Jandore	44.42		Taraf Sanjhi	93.01	
Basantpur	43.01		Taraf Tajwal	57.72	
Sahar	32.27		Kathua	27.67	



Water quality index of ground water samples

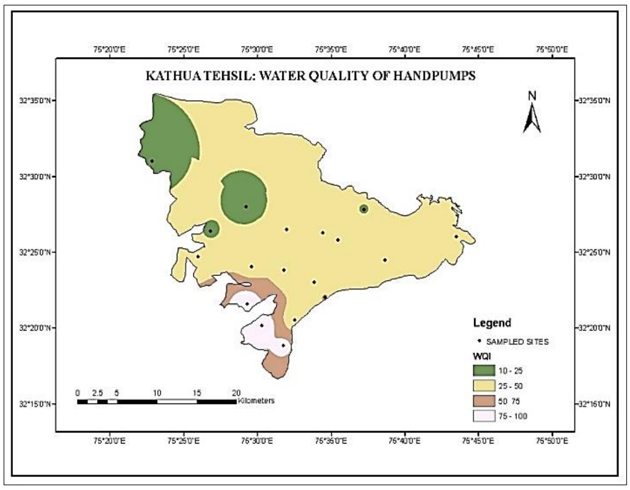


Fig 3 Water quality map of handpumps of Kathua tehsil

In our study water samples from the Kandi, area showed a low water quality index with an average of 28.85 as compared to the Outer plains having an average of 57.77. The water of the Kandi belt is relatively cleaner than the water of the Outer plains because the Kandi area lies at a high altitude due to which the water table is very low and most of the area is non irrigated. Due to the low water table and non-irrigated type of agriculture, the amount of percolation of water is very low which reduces the chances of groundwater contamination from polluted water. In the case of the Outer plains, water is comparatively polluted than the Kandi area because of the high-water table and intensive type of agriculture where the amount of fertilizer and pesticides utilization is comparatively high. Most of the agriculture area is irrigated in the Outer plains due to which the amount of percolation of water contaminated with fertilizer, pesticide and sewage is high which increases the chances of groundwater contamination. Water samples from the vicinity of the river in the outer plains are relatively cleaner than the other samples collected from the outer plains.

With the help of IDW Technique Water quality map of the study area has been prepared as shown in (Fig 3). The map clearly shows that the handpumps lying in the Shiwalik region have shown excellent to good water quality While the region of outer plains showed good, poor, and very poor water quality. This map depicts that there is an increasing trend of water quality index from Shiwaliks to Outer plains.

CONCLUSION

Our study has shown that the hand pumps are good in water quality and therefore suitable for drinking purposes in the Kandi area. The water quality of handpumps in the Outer Plains, on the other hand, varies from good to very poor and hence the water from most handpumps in the Outer Plains is unfit for drinking. Most of the people in the study area have an alternative of handpump water in the form of PHE water supply but still, people use water from handpumps for drinking and other domestic purposes because of their lack of awareness about the quality of water of handpumps and low availability of PHE water. An awareness drive should be conducted in the study area about the water treatment methods and safe disposal of wastewater. People in the Plain area should use water of PHE supply for drinking and cooking purpose instead of using water of handpumps. Government should supply tap water to every household. Proper testing of water of handpumps should be done and the water of handpumps which are not fit for drinking purpose should be labelled as unfit for drinking purposes.

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