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Pollution Potential in the Catchment Area and the Distribution of Groundwater Quality

Sangeeta Saxsena[1], Prashant Pandey[2]
Assistant Professor[1], Student[2]
Department of Civil Engineering
Global Engineering College
Corresponding Author's Email: *prashantpandey322@gmail.com*

Abstract

Pollutants in groundwater can occur naturally or be introduced by various anthropogenic pollution sources. Pollution from both point and non-point sources has an impact on the quality of both surface and ground water. Solvent concentrations are normally low when water infiltrates. However, after penetration, their spatial extent follows a regional pattern that must be thoroughly investigated. As a result, the spatial pattern of important ground water quality parameters obtained from secondary observation well data in the Betwa river catchment is presented in this paper. An overview of various sources of pollution from agriculture, industries, and cities, as well as their potential impacts, is also provided.

Keywords: *Groundwater data network, spatial interpolation, solute concentration level, pollution potential, domestic pollution, agricultural pollution*

INTRODUCTION

Pollution from both point and non-point sources has an impact on groundwater quality. Water contamination from home and industrial usage is a substantial source of pollution that is contributed at a single place. Non-point or dispersed pollution is caused by water movement in the catchment region. Soil, organic matter, plant residues, nutritional elements, organic compounds, toxic elements, and bacteria are among the pollutants emitted by topsoil losses. Pollutants can be retained, modified, decomposed, or

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absorbed by soil. Because partly treated or untreated sewage is used for irrigation in the watershed, a well-managed and balanced soil system does not pose a serious danger to water quality. It is an excellent provider of nutrients in the soil, particularly nitrogen. Gardens, streets, and storm-water drains that carry sewage, sludge, and other solid waste created by residential, commercial, and industrial operations all contribute to it. However, because pollutant-soil interaction is so complicated, it is impossible to measure the actual amount of such contamination. Soils with a high clay and organic matter content, in general, have a high retention capability for many contaminants. Erosion is the principal carrying vector for contaminants due to its limited permeability. Sandy soils, on the other hand, have a low erosion potential but a relatively poor ability to absorb contaminants, allowing pollutants to penetrate the topsoil and reach groundwater aquifers. Agriculture-related water contamination is mainly caused by the use of a considerable amount of commercial fertiliser and pesticides. The use of fertiliser increases the quantity of contaminants that might possibly be lost in agriculture. Fertilizer and residue movement from agricultural fields to rivers happens mostly during the wet season. The quantity of their contribution to river pollution is directly connected to the number of suspended particles in runoff water and the intensity with which these chemicals are applied. That is why it is difficult to correctly quantify. It is estimated that 10-15% of the nutrients given to the soil via fertilisers end up in the surface water system [1].

Because numerous criteria are involved in evaluating groundwater quality, genetic algorithms have been developed to handle the multi-objective groundwater monitoring issue [2]. Similarly, non-linear and mixed-integer programmes have made the standard linear programming approach for selecting the best network design solution more realistic [3]. Even the smallest aspects, such as measurement scale and network sampling size, are being addressed in groundwater networks [4]. With the use of remote sensing data, studies in India have gained relevance in the last decade in terms of water quality evaluations of both surface and ground water. A systematic method for the examination of the Ken Graben area has been developed by merging remote sensing data with hydrologic data in order to explore the underlying geological and geomorphological aspects and to illustrate the aquifer geometry and ground water

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quality in the region. The hydrogeological state of ground water has been inferred through the integration of structural, lithological, and vegetational information, as well as a DEM of the subsurface topography derived using depth to bedrock contours. It allowed for the identification of brackish groundwater pockets that are consistent with the field investigation [5]. In light of many studies on groundwater quality, the current research presents a single objective study on the spatial pattern of critical parameters at the catchment level during a particular time period. In addition, an indirect assessment of potential pollution sources that might impair groundwater quality has been made.

STUDY AREA

The Betwa River, which is characterised by different geological conditions and undulating terrain spanning from alluvial plains in the north to the Vindhyan plateau in the south, was chosen for studying the catchment and watershed-wise distribution of groundwater contaminants. In southern Uttar Pradesh and northern Madhya Pradesh, the catchment region spans 22°20' to 26°0' N. latitudes and 77°10' to 80°20' E. longitudes (Figure 1).

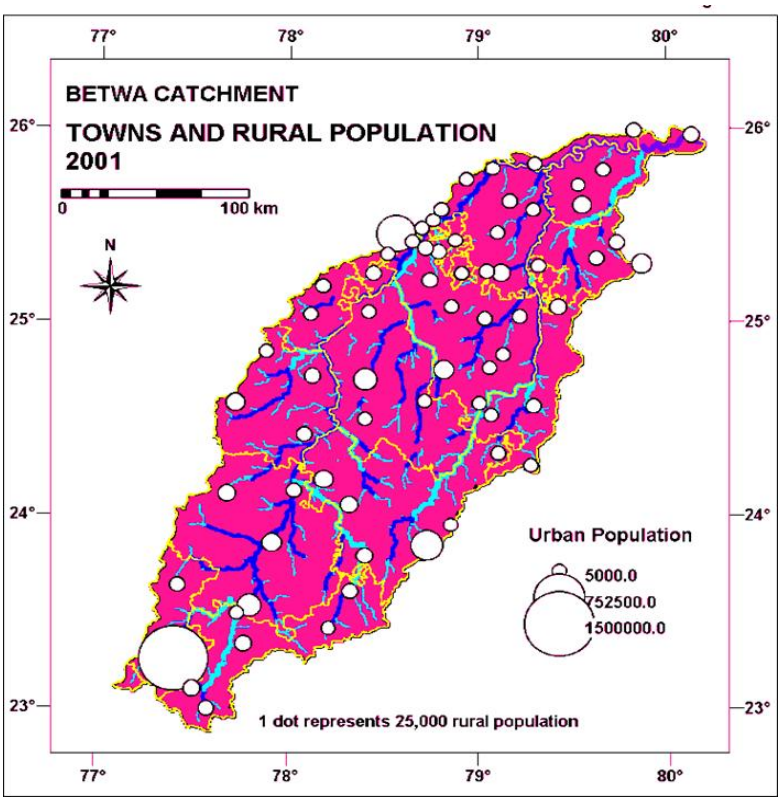

Fig.1: Study Area.

(Source: Author using ILWIS based on data from Census of India (2001) Final Population Tables CD)

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The River Betwa is referred to as Vetrawati in a number of Hindu mythical Granthas and Puranas. However, the whole Betwa basin, from its headwaters to its confluence with the Yamuna and its tributaries, is now susceptible to human activities that directly or indirectly impair water quality. The River Betwa is the lifeline of the region through which it runs, and it plays a significant part in the region's overall growth and development. It provides drinking water to a large population in the region, particularly in Raisen, Vidisha, Basoda, and Kurwai (Figure 1). It is the primary source of irrigation for the region, which is noted for producing high-quality wheat, gramme, and soy beans in the country.

METHODOLOGY

The study is based on information gathered from secondary sources. Ground water quality data for one season (May 2001) from Central Ground Water Board hydrograph stations were gathered from the website www.IndiaAgristat.com [6]. For rural and urban population increase, data from Census of India reports and CDs was used. Fertilizer usage statistics for all 14 districts in the Betwa watershed were collected once more from the website www.IndiaAgristat.com [7].

Data on land usage and irrigation were gathered from the Indian Agricultural Statistics volumes and the Ministry of Water Resources website, respectively [8]. The Survey of India toposheets, District Planning Map Series, and Watershed Atlas of India were used to create the region's base map. Field visits were also conducted at some of the sites to ascertain the level of water quality.

First and foremost, hydrograph stations were installed in each sub-catchment of the Betwa River watershed. The groundwater quality data from observation wells was then processed in MS-EXCEL and loaded into the GIS programme ILWIS for attribute mapping. The moving average interpolation approach was used to generate pixel-wise values of essential water quality metrics. Following that, the resulting maps were compared to population statistics and fertiliser usage in each region to determine the contamination potential.

RESULTS AND DISCUSSIONS

Network of Water Quality Monitoring Stations in Betwa Catchment

The watershed still has a shortage of surface and groundwater quality monitoring stations. They have only been developed on major rivers and a few lakes.

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The network of groundwater quality monitoring stations in the Betwa watershed consists of around 50 observation wells out of a total of 136 hydrograph stations. The gaps might be addressed by monitoring several metrics at possible pollution sources. There is just one CPCB station for monitoring surface water quality in the Betwa River watershed, located near Hamirpur. The state pollution control board is in charge of the other stations. Mandideep, Bhojpur, two in Vidisha, one at Raisen in the upper reaches of the Betwa, Rahatgarh on the Bina, and one station each on the Jamni and Dhasan rivers comprise the upper Betwa sub-catchment. With the current increase in urban population and more area being brought under irrigated agriculture, it is advised that a minimum of 5-8 more stations be present in the Betwa watershed.

Pollution Potential in Betwa Catchment

Pollution potential in the catchment area is due to both point and non-point pollution sources, as evidenced by pollutant concentrations at selected monitoring sites.

Point Sources of Pollution

Urban areas are major sources of home pollution. Over the decades, the share of the urban population has continuously risen, reaching more than 3 million in 2001. (Table 1). The greatest rise occurred during the 1971–1981 decade. Because of the rising demand for water to fulfil residential needs and the impact of the resulting effluent, discharge into receiving waterways has the cumulative effect of degrading the quality. The amount of wastewater added from 70 metropolitan centres in the Betwa catchment area has expanded dramatically. Although there are only one million people in the Betwa watershed, Bhopal contributes tremendously to pollution. Jhansi and Sagar, which are located on the catchment border, are the other major cities. Because Sagar is located far from the main Betwa and its tributary, Dhasan, in that region, its impact on water quality in the Betwa basin may be ignored. Jhansi, on the other hand, derives its water supply from the major middle Betwa and has a significant influence on water quality due to its untreated sewage. The majority of the other towns are similarly located near rivers.

Despite the fact that various companies have been developed in the watershed region, a precise estimate of their contribution to river pollution could not be obtained due to the vast range in their discharges. As a result, an examination of census data on the most prominent

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industries, as well as the number of industrial employees in each district, indicates indirectly the kind and amount of industrial pollution. The majority of polluting industrial operations are located in the upper Betwa area, near Bhopal. Mandideep, being the fastest developing industrial centre, is now experiencing the worst levels of crucial parameters. A field investigation in this town yielded frightening results not just for humans but also for animals. Because Ashoknagar is located away from the major river or tributary, the polluting industrial cluster producing plastic bags is especially damaging to groundwater quality. Another probable source of pollution is the central industrial belt around Jhansi and Tikamgarh. Although food processing and bidi (forest-based household product) enterprises prevail in the remainder of the towns, the chemicals used in processing that are left untreated can become a major cause of groundwater contamination in the near future. As a result, establishing independent regular monitoring sites will help to improve the tight and stringent application of standards at these locations.

The situation is exacerbated further by the lack of treatment facilities in these tiny communities. The BOD load generation from smaller towns, calculated for several classes of towns based on CPCB categorization per capita load, exceeds the overall load from a few large cities. Domestic pollution from rural residents is not extremely detrimental, but a greater proportion of rural residents (approximately 90%) in the Betwa watershed may constitute a substantial hazard, particularly to groundwater quality. As a result, in vast irrigated rural areas, at least seasonal monitoring stations are necessary.

Table 1: Watershed-wise Total Population (2001) and Fertilizer Consumption in Betwa Catchment.

S. No.	Watershed	Total Urban* Population	Total Rural Population	Weighted Average Fertilizer Consumption (Tonnes)
1	Kaliasote	1,498,275	751,883	12,234
2	Upper Dhasan	298,715	3,279,558	19,011
3	Lower Dhasan	244,360	2,934,181	20,544
4	Lower middle Betwa	240,841	3,628,332	18,699
5	Upper Betwa	167,939	1,562,171	20,639

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6	Bina	156,450	1,941,892	21,897
7	Narain nadi	----	1,502,573	19, 619
8	Jamni	129,279	2,492,838	15,.223
9	Newan nadi	---	862,445	25,294
10	Upper middle Betwa	98,214	2,760,108	21,036
11	Birma	88,802	1,150,399	10,095
12	Orr nadi	68,052	555,507	19,124
13	Kevtan nadi	---	1,275,109	23, 159
14	Naren nadi	---	862,445	25, 294
15	Kethan nadi	42,179	1,257,535	22, 588
16	Halali	----	1,562,171	14, 995
17	Baen nadi	24,302	1,149,507	17, 225
18	Sagar nadi	----	862,445	25,294
19	Uppermost Betwa	19,938	699,726	20, 222
20	Lowermost Betwa	14,941	502,386	15, 221

Source: Computed from Fig. 1 & 2 based on data from Census of India (2001). Town Directory; Final Population Tables. Fertilizer Association of India (2002) (*Towns lying on catchment boundary are excluded)

Non-Point Sources of Pollution

Non-point or dispersed pollution is caused by water movement in the catchment region. High pollution loadings in an unbalanced system are related to excessive fertiliser applications, disturbed and unprotected soils, and exceptional weather circumstances, particularly in the ravinous irrigated belt of Betwa and Dhasan. The surplus comes from livestock feedlot runoff and leachates from overly fertilised and manured fields. Agriculture and in-stream water usage are significant sources of dispersed pollution in the Betwa River watershed. A considerable volume of commercial fertiliser contributes to water contamination caused by agriculture. The weighted average annual fertiliser usage, estimated pro-rata from district data, was found to be greater in watersheds located in the upper Betwa sub-catchments (Table 1). Fertilizer use patterns vary significantly throughout space (Figure 2). The average quantity in the lower reaches, which have more irrigated area, is less than half that in the upper reaches. It might be because there are fewer agricultural tracts available in the plateau region, so higher levels of fertiliser application increase productivity.

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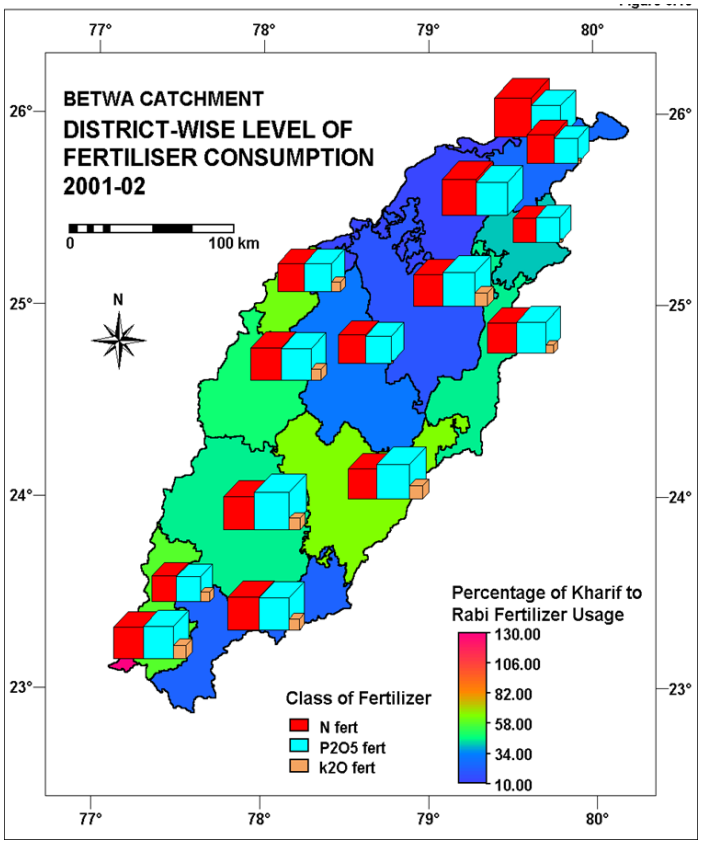

Fig.2: Pattern of Fertlised Agriculture.

(Source: Author using ILWIS based on data (2002) from Government of India, Fertilizer Association of India)

Spatial Variation in Groundwater Quality Parameters

Common groundwater solutes, usually present in concentrations above 1mg/l, include calcium (Ca2+), sodium (Na+), magnesium (Mg2+), potassium (K+), bicarbonate (HCO -), sulphate (SO 2-), chloride (Cl-) and silica (SiO2). Secondary ions include iron (Fe2+), nitrate (NO -) and fluoride (F+). A hydro- geochemical analysis based on observation wells data for May, 2001 revealed spatial variations in groundwater quality. From the detailed location-wise well data and their GIS based map interpolation (Figures 3a to l), a brief discussion on status of 13 parameters is presented as follows:

pH

The pH of groundwater in the Betwa watershed is in the usual range. Its value of greater than 7 in the majority of cases suggests the slightly alkaline nature of groundwater. Only one observation well near Vidisha had a pH value of 8. This range has a little difference on the western side (Figure 3a).

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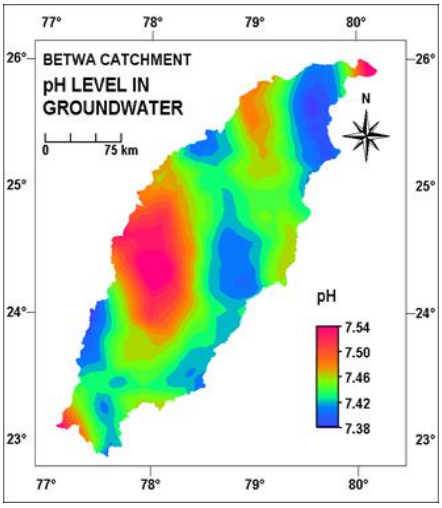

Fig.3a

Electrical Conductivity (EC)

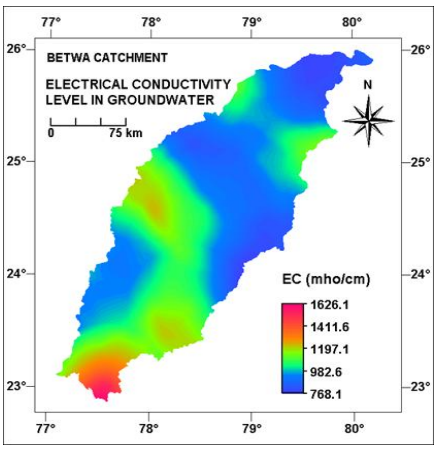

Fig. 3b

EC values vary from 769 □ siemens in northern plains to 1621 □ siemens towards southeast. It shows close correspondence with geological structure. Higher values of EC are found in exposed area of Vindhyan scraps. In the undulating Vindhyan sandstone and alluvium zone, moderate to low values prevail (Figure 3b).

Chlorine (Cl)

The chlorine content is far below the desired level in the majority of the catchment. Local maxima can be found in the topmost Betwa, the middle reaches of Dhasan, and locations dominated by the Bijawar series (Figure 3c). The chloride level was more than 150 mg/l in roughly 12 wells. In these critical areas, diligent and ongoing monitoring is essential to ensure that the excess limit is not exceeded.

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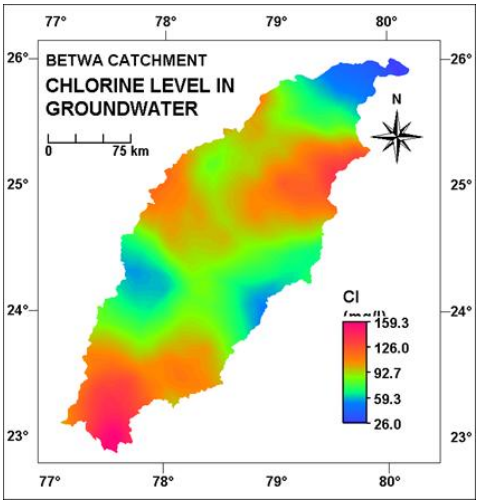

Fig.3c

Fluorine (F)

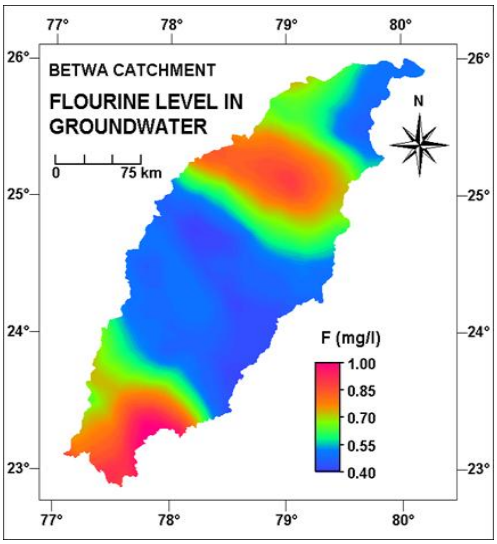

Fig. 3d

Most of the time, the level of fluorine in groundwater is within acceptable limits. Two zones of considerably higher concentration have emerged in the catchment's south-eastern perimeter and in the north central uplands (Figure 3d).

Carbonate and Bicarbonate (HCO3)

The lowest bicarbonate concentrations are found in the middle reaches of the Betwa catchment, in the transition zone of the Vindhyans and Bundelkhand gneisses, where an increasing tendency may be noted both north-eastwards and south-eastwards (Figure 3e). The highest values are once again observed in the upper Betwa watershed. With the exception of Halali, the majority of the wells in the upper Betwa plateau region contain considerably greater concentrations.

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Silicon Dioxide (SiO2)

Silicon dioxide concentrations range from 25 to 49 mg/l, resulting in two zones ofgreater concentration on the eastern side (Figure 3f). A shift in SiO2 levels happens over short distances. Thus, additional observation wells are required for SiO2 coverage in order to provide better spatial estimations.

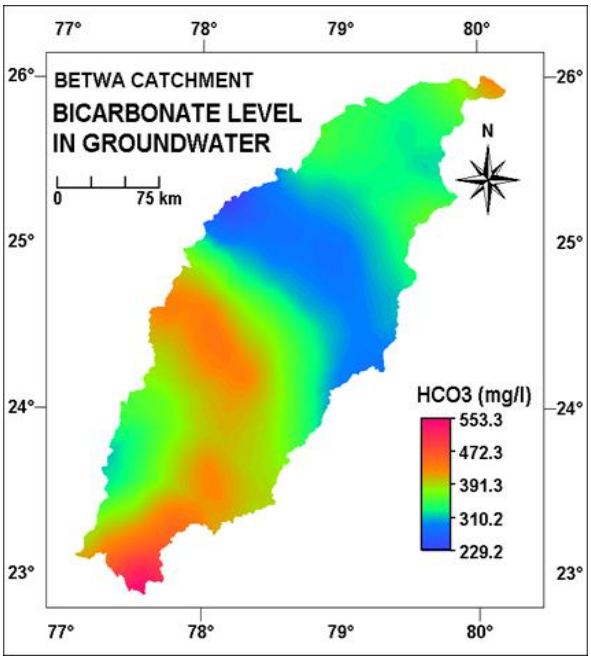

Fig.3e

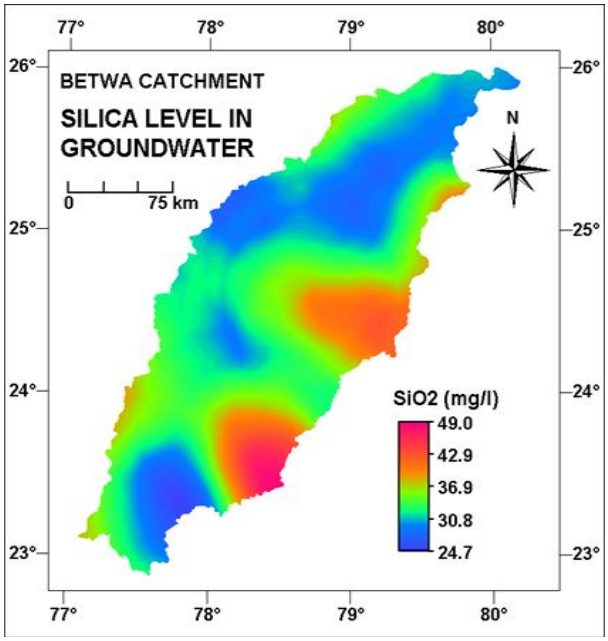

Fig.3f

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Nitrate

In the case of nitrates, the concentration is greater than the desired limit in several areas, particularly along the western edge of the middle plateau region and along the south-eastern border of Bina toward Sagar (Figure 3g).

Sulphate

Except in Garutha, sulphate concentrations are generally below acceptable levels. It might be related to some nearby quarrying activities. Lowest values are seen on the northern plains and in the catchment's middle reaches (Figure 3h).

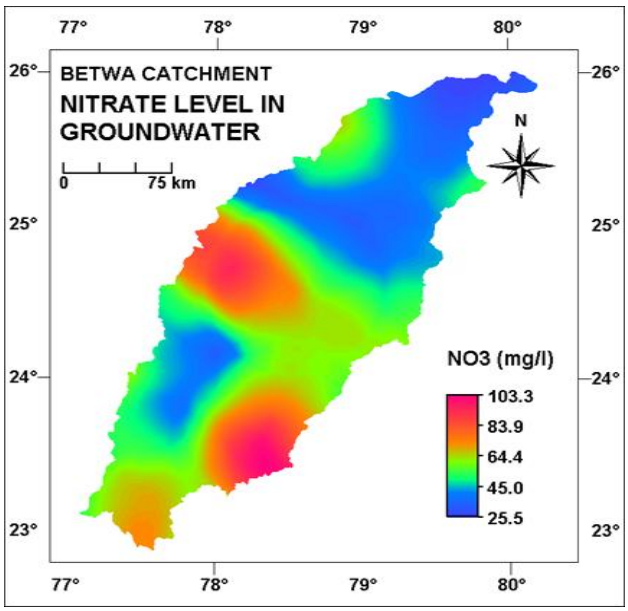

Fig.3g

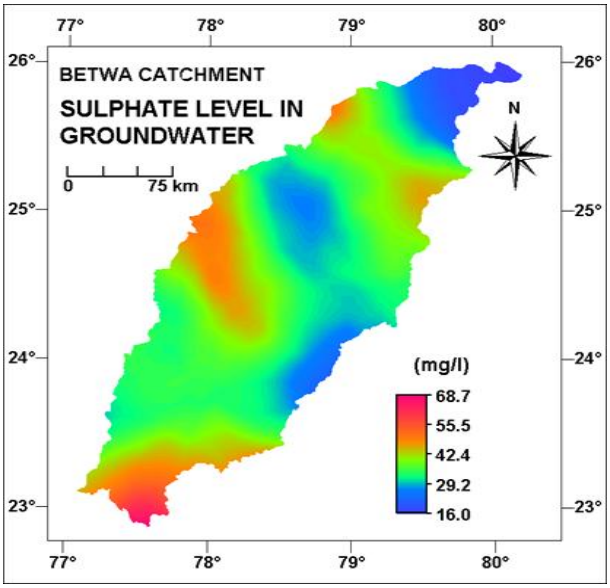

Fig. 3h

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Sodium (Na)

The sodium peak can be seen in the central part of the catchment, from where it declines southwards and northwards with a secondary ridge in the lower Dhasan area of the irrigated belt.

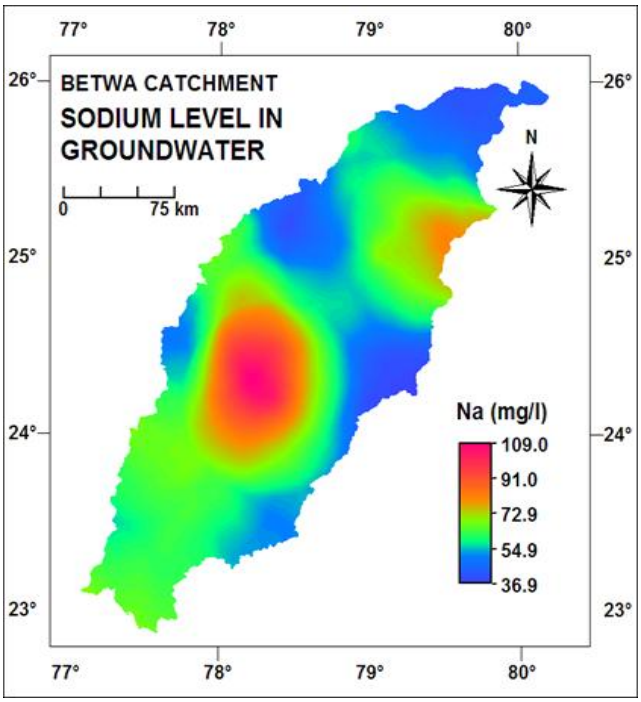

Fig.3i

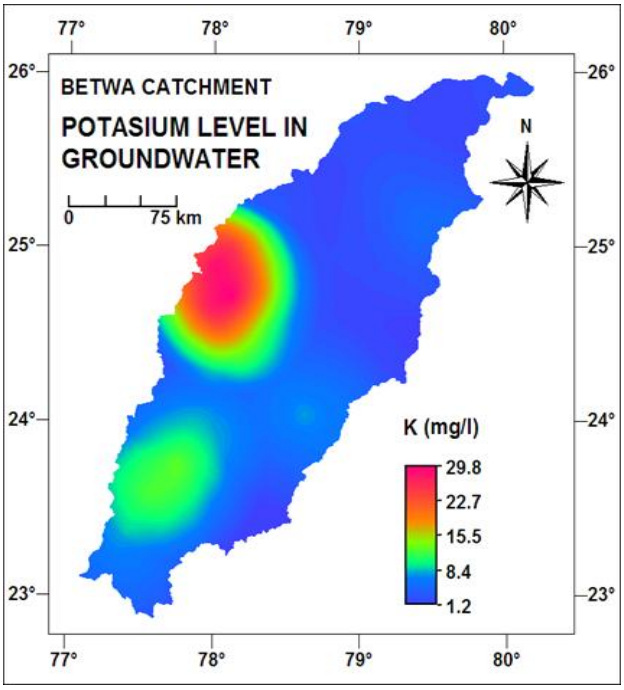

Fig. 3j

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Potassium (K)

A very high potassium concentration was observed at Chanderi compared to much lower levels at other locations, resulting in the highest level of spatial variation among all groundwater quality parameters in the Betwa catchment.

Calcium (Ca)

The calcium content is lower in most valley locations. It is highest in the catchment's southeast corner and in other regions in the eastern and central belts (Figure 3k). It even exceeded the maximum allowable level of 200 mg/l in eight observation wells.

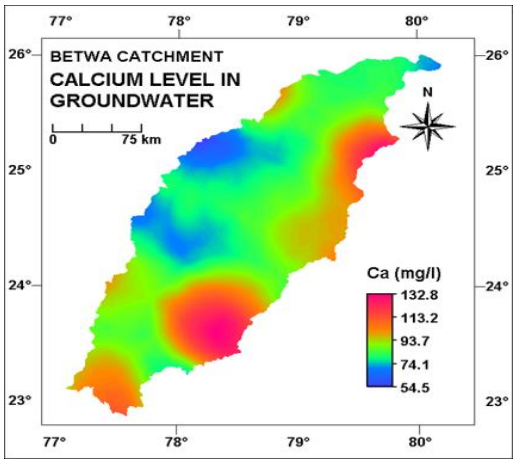

Fig.3k

Magnesium (Mg)

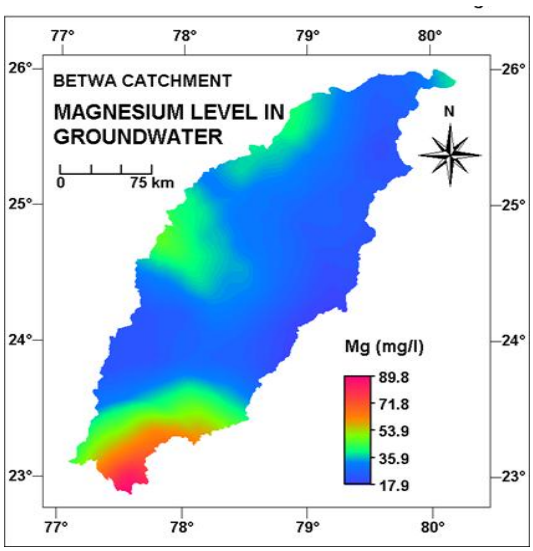

Fig. 3l

Fig. 3: Spatial Concentration of Selected Groundwater Quality Parameters (May, 2001) (Source: By Author using ILWIS based on Well- wise Chemical Analysis of Shallow Ground Water Data of CGWB Groundwater Statistics (2002) from www.IndiaAgristat.com)

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CONCLUDING REMARKS

Thus, subterranean water, like surface water, displays a unique geographical pattern. Individual well data may reveal high concentrations at that place, but the boundaries of its geographical distribution must be investigated within reasonable bounds. If the possible path of their transit is mapped and predicted, it can at least provide solutions to reduce the amount and spread of pollution in the watershed. Furthermore, all municipalities with a population of more than 20,000 and sewage facilities must monitor both surface and groundwater quality criteria.

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