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Impact of opencast limestone mining on groundwater in Katni river watershed, Madhya Pradesh, India – A geoinformatics approach

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Abstract. Katni river watershed covering an area of 1480.4 km^2, extends between 23° 34' 53" N to 24° 06' 07 " N latitudes and from 80° 10' 29" E to 80° 41' 38" E longitudes. The limestone rocks in the northern part of Katni watershed pertains to Vindhyan super group. The limestone is of high grade, rich in calcium content and good for extraction of lime. Several small opencast mining activities have developed in this area in past few years. These mines are located in the pediplains situated at the foothills of linear ridges along the northern boundary of the watershed. The underlying rocks are soft and permeable therefore the rainwater filled in these opencast mine pits percolates and degrade the ground water quality by increasing the calcium content and total hardness. The analysis of water samples of few villages for the year 1995 is compared with water sample analysis for the year 2006 shows a significant rise in calcium concentration and total hardness. The concentration is directly related to lithology, geomorphology, slope and drainage pattern of the area.

Keywords: Opencast mining, Limestone, Ground water, Calcium concentration, Total hardness

1. Introduction

Rapid population growth coupled with industrialization over the past many years has increased a tremendous pressure on our natural resources resulting in rapid exploitation of our mineral resources. Deep opencast mines for limestone of Upper Cretaceous age in the northernmost state of Germany, Schleswig-Holstcin, greatly impact the local environment *(Alexander, 2006)*. The scenario is not very different in India. Water pollution is a serious problem as almost 70% of India's surface water resources and a growing number of its groundwater reserves have been contaminated by biological, organic and inorganic pollutants. (*Khurshid et al., 1997; Das et al., 1998; Garode et al., 1998; Kapley et al., 1998; Naidu et al., 1998; Jain et al., 2000a, b, c, 2003a, b, c, 2004; Sohani et al., 2001; Jain 2002, 2004a, b, c; Meenakumari and Hosmani, 2003; Dhindsa et al., 2004; Ramasubramanian et al., 2004; Rao and Mamatha, 2004).* Opencast mining leave a great impact on our environment. It not only deteriorates water quality but also degrades other resources such as forest, agriculture etc. The rainwater fills these opencast mine pits dissolving the minerals such as calcium and magnesium which percolate downwards through fractures and joints. This leads to pollution of ground water by increasing the calcium, magnesium content and total hardness. There are broad evidences, that water quality deterioration is threatening health, economic development and leading to long term drinking water scarcity. Calcium and magnesium, along with their carbonates, sulfates, and chlorides make the water hard (*Jain et al., 2010*). Waters with high total dissolved solids are of inferior palatability and may induce an unfavorable physiological reaction in the transient consumer and gastro-intestinal irritation (*Singh and Kumar, 2004; Cumar and Nagaraja, 2011*). Rural scenario with respect to availability of water for drinking and agricultural purposes is further bleak. The national water policy in India gives domestic use or drinking water, the first priority of groundwater use *(Limaye, 2003).* Therefore, it is of utmost important to monitor the quality of groundwater and to take preventive measures.

Remote sensing and Geographical Information System (GIS) offer technologically, an appropriate method of studying depletion of ground water quality with respect to other terrain information like topographical and geological variations. To substantiate the above stated concept an attempt was made to analyze the spatial distribution of calcium concentration and total hardness of ground water correlating with slope, drainage, lithology and geomorphology of Katni river watershed, Katni district, Madhya Pradesh, India, which is a rapidly growing area in terms of population, industrialization and mining activities.

2. Study area

Madhya Pradesh, the geographic heart of India, extended between latitude 21° 04' and 26° 52' N and 74° 01' and 82° 48' E. Katni district is situated in the east central portion of Madhya Pradesh, surrounded by Jabalpur, Damoh, Panna, Satna and Umaria districts. Katni river is the main river passing through the district, gave the name to the district (Fig. 1). Katni river watershed extends from 23° 34' 53" N to 24° 06' 07" N latitudes and from 80° 10' 29"E to 80° 41' 38" E longitudes covering an area of 1480.4 km^2. Climate of the study area is sub tropical and sub humid. The mean annual temperature is 37.8° C with a mean maximum temperature 41.3° C and a mean minimum temperature 12.5°C. The study area enjoys good monsoon rains with an average annual precipitation of 1368 mm.

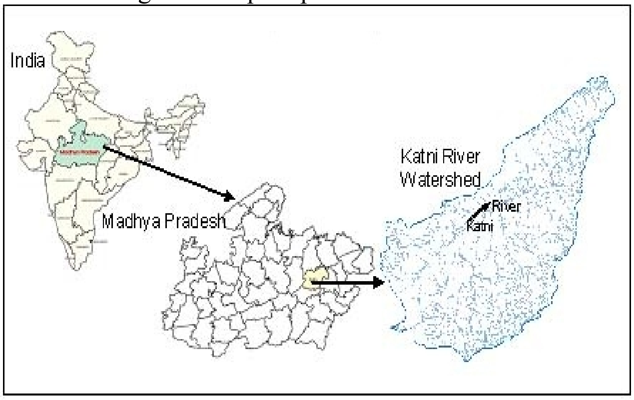

Figure 1: Location map of the study area map Map

3. Data used

The Survey of India Topographical maps on 1:50,000 scale with nos. 64A/1, 2, 5, 6, 9, 10 & 63D/12 along with Indian Remote Sensing Satellite (IRS) image of LISS III sensor dated 11 October 2005, scene path-row no. 100-55 were used in the present study. Periodical ground water sample analysis is being carried out by two agencies viz. Central Ground Water Board (CGWB), Government of India and Public Health Engineering Department (PHED), Government of Madhya Pradesh. PHED is the Govt. agency which ensures the drinking water supply in various parts of the state. The village wise water quality analysis data for 72 observation wells were collected for the post monsoon season i.e. October – November for the year 1995 and 2006 from CGWB and PHED. There are about 60 open cast mining sites in the study area out of which most are limestone quarries and few are laterite quarries. Information about these mining sites is collected from Directorate of Geology and Mining, Katni. Slope is an important aspect of the study. Slope map is prepared from the Digital Elevation Model (DEM) generated by Shuttle Radar Topography Mission (SRTM) data.

4. Methodology

Satellite image of LISS III camera of IRS-1C satellite (Fig. 2) was interpreted to generate lithology and geomorphology. Drainage map was prepared with the help of topographical maps. This map was overlaid on satellite image and updated. SRTM data was used to generate the DEM which was further interpolated and slope map was prepared. Village wise ground water samples of drinking water source used by the residents were analyzed and compared with sample analysis data of previous years. To visualize the spatial pattern of calcium concentration and total hardness the current ground water sample analysis data of 72 samples (Fig. 3) have been interpolated and maps are prepared using density slicing. These maps were overlaid to correlate the areas having high concentration of calcium and total hardness with lithology, location of mines, geomorphology, drainage and slope. The methodology is briefly represented as a flow diagram (Fig. 4).

5. Results and discussion

5.1. Lithology and geomorphology

Northern and Eastern portions of the Katni watershed are underlain by the rocks of Vindhyan super group of mesoproterozoic to neoproterozoic age (Fig. 5). It comprises Shales, Sandstone, Porcellinite and Limestone. Hard porcellinite and shaly sandstones form the linear ridges along the northern and north eastern boundaries of the area (Fig. 6). Lime stone being the softer rocks forms the pediplain along with Clay with Caliche Concretions of quaternary period covering the central portion of the area. In between the pediplain, Laterites being harder are forming the plateau of level 2. Southern part of Katni watershed is covered by Phyllites and Dolomites of Mahakoshal group. These rocks belong to paleo-proterzoic age. These rocks form the part of pediplain along with denudational hills and linear ridges on the southern boundary.

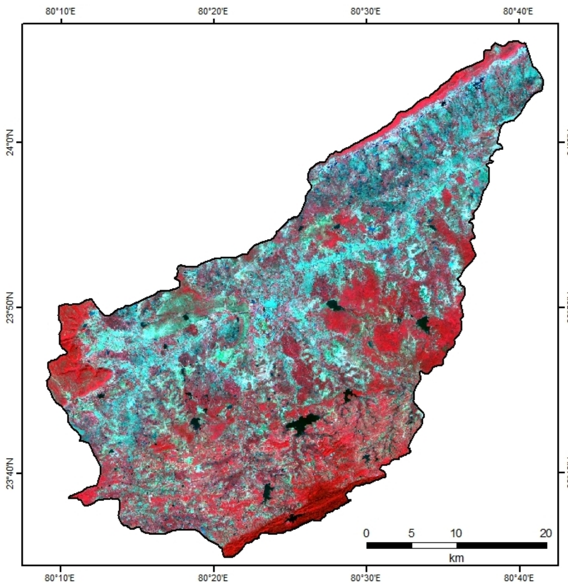

Figure 2: LISS III FCC of study area

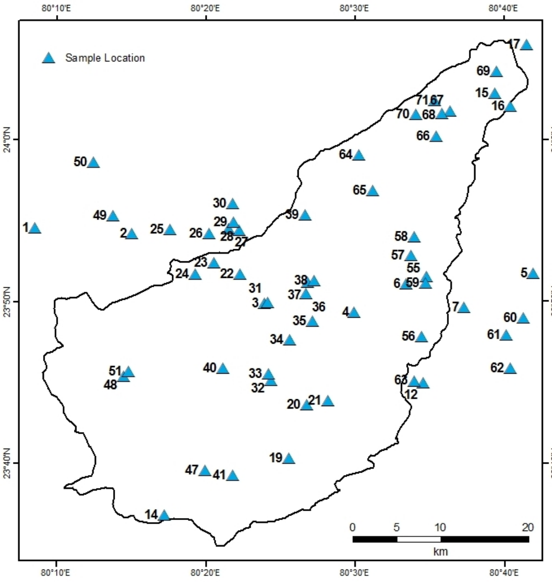

Figure3: Water quality sample points

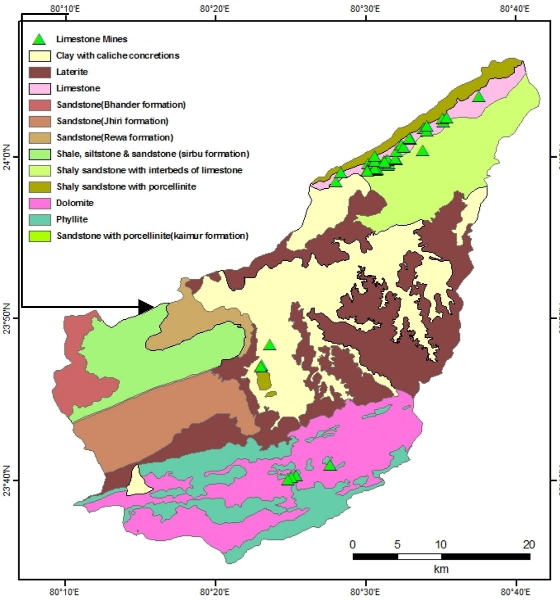

Figure 5: Lithology map

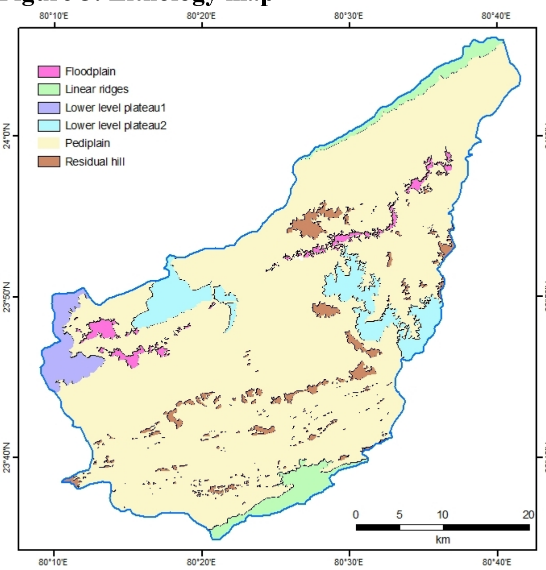

Figure 6: Geomorphology map

This area is well known for its limestone which is of very high grade. Most of the limestone quarries are situated in northern part of the study area which is higher in elevation in comparison to the other parts of the watershed. Therefore, during the rainy season the water filled up in these open mining pits percolates downwards an also increases the turbidity of streams originating from these high elevation areas.

5.2 Slope and drainage

Major part of the study area is having level to gentle slope (Fig. 7) supporting the dendritic drainage pattern. The major stream is Katni river flowing in the central part of the area (Fig. 8). It meets Mahanadi river in north west. In Northern part of the area streams are originating from linear ridges of shaly sandstone, limestone with porcellinite which belongs to Vindhyan supergroup. Most of the limestone mine quarries are situated in this area. These streams originate from high slope area and run almost parallel to each other. These streams pass trough the limestone belt and the mining pits and carry a huge load of silt with them in rainy season.

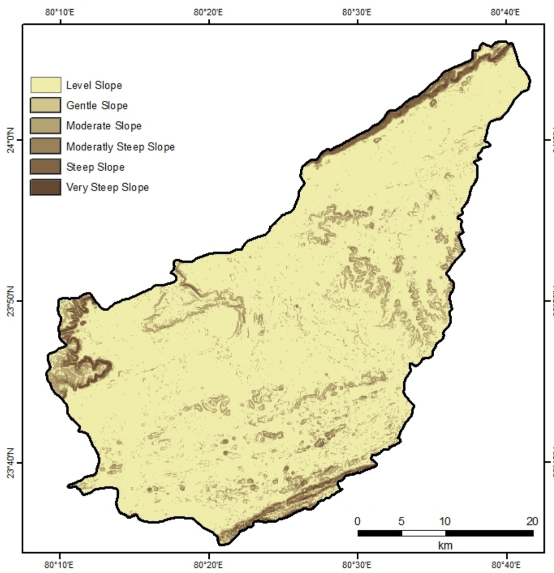

Figure 7: Slope map

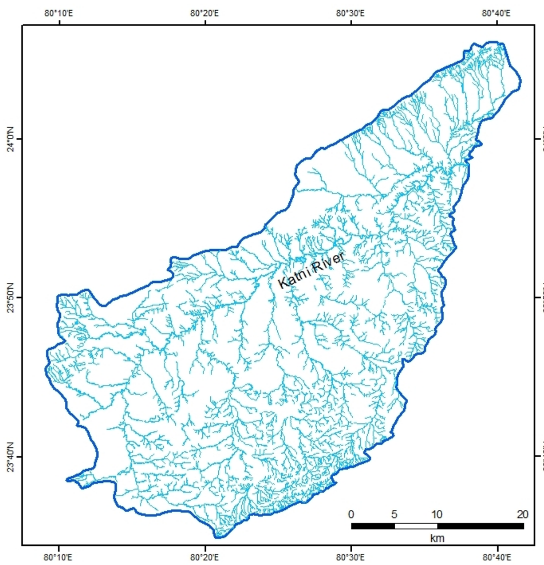

Figure 8: Drainage map

5.3. Water quality

In the study area, the water quality data for 72 observation wells in different villages were collected for the period of October – November 1995 and 2006. Analysis of this data reveals that the calcium concentration in the study area was ranging between 11 to 44 mg/l, in the year 1995. In a period of eleven years i.e. in 2006 calcium concentrations in these observation wells increased to the range of 36 to 114 mg/l (Fig. 9). Similarly the total hardness, which was ranging from 24 to 74 mg/l increased to 115 to 500 mg/l (Fig. 10). As per the water quality standards defined by international agencies such as U.S. Department of Interior and the Water Quality Association the water having total hardness more than 180 mg/l is classified as very hard. As per the Beuro of Indian Standards the desirable limit of Calcium in the drinking water is 75 mg/l and the total hardness is 300 mg/l [BIS 10500 (1991)]. The spatial distribution of calcium concentration indicates that the area near to opencast limestone mines is having higher concentration (Fig. 11). As shown in the map the calcium concentration is above 100 mg/l in most part of the watershed. Similarly the spatial distribution of total hardness also shows that most area is having the total hardness above 200 mg/l ranging up to more than 500 mg/l (Fig. 12). The calcium concentration is above the desired limit in almost entire study area, whereas total hardness is above the desirable limit of Indian standards in almost 30% of the total geographical area.

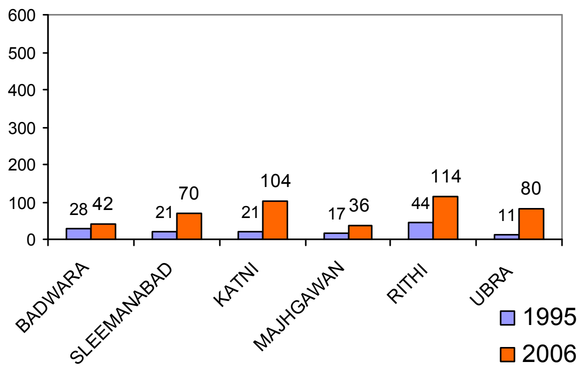

Figure 9: Calcium concentration in 1995 and 2006

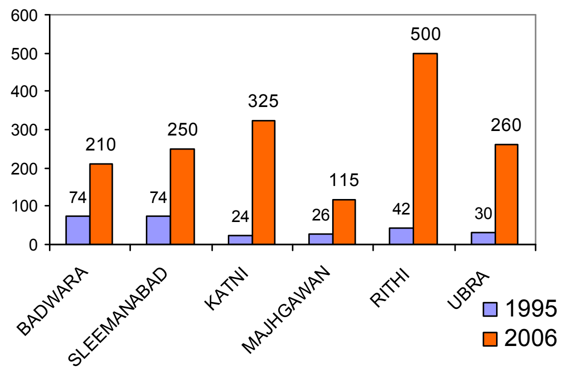

Figure 10: Total hardness in 1995 and 2006

As per the geomorphology of the area the mines are located in pediplains just near the foothills of the linear ridge along the northern boundary of the area. The drainage map clearly shows that several first order streams are starting from these linear ridges and flowing towards south passing through the mine pits. During the rainy season these mining pits are filled with rainwater. These streams and the rainwater filled mining pits dissolve the minerals of underlying soft limestone rocks and overlying debris of these mines. This water percolates through the joints and fractures of these softer rock formations and pollutes the ground water. Few of these mines are presently abandoned therefore the rainwater is filled for almost the entire year and become a major source of pollution of ground water. As shown in the fig 11 & 12 the calcium concentration and total hardness concentration is high in the areas near to the mining locations as well as in the central, South Western & Southern part of the watershed, which lies in the down streams of this limestone mine quarries.

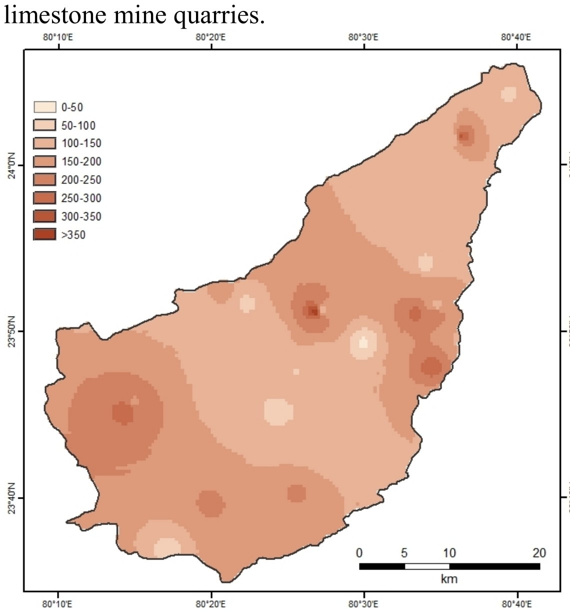

Figure 11: Calcium concentration

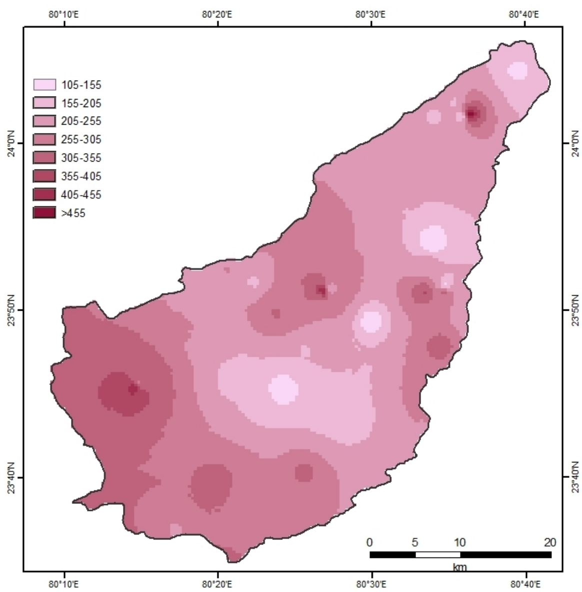

Figure 12: Total hardness map

Conclusion

It is seen that the water quality is degrading very fast in the study area. In a short period of eleven years the calcium content and total hardness of groundwater has reached from the normal limit to a higher side of desirable limit of Indian standards (BIS) and crossed the limits of international standards. The Calcium and total hardness concentration are high in downstream areas of limestone mine quarries. Therefore, it can be concluded that the opencast mining pits of limestone mining are the major source of pollution of ground water, which is the main source of drinking water in this area. Therefore it is necessary to take the preventive measures in the study area to check the pollution in this area.

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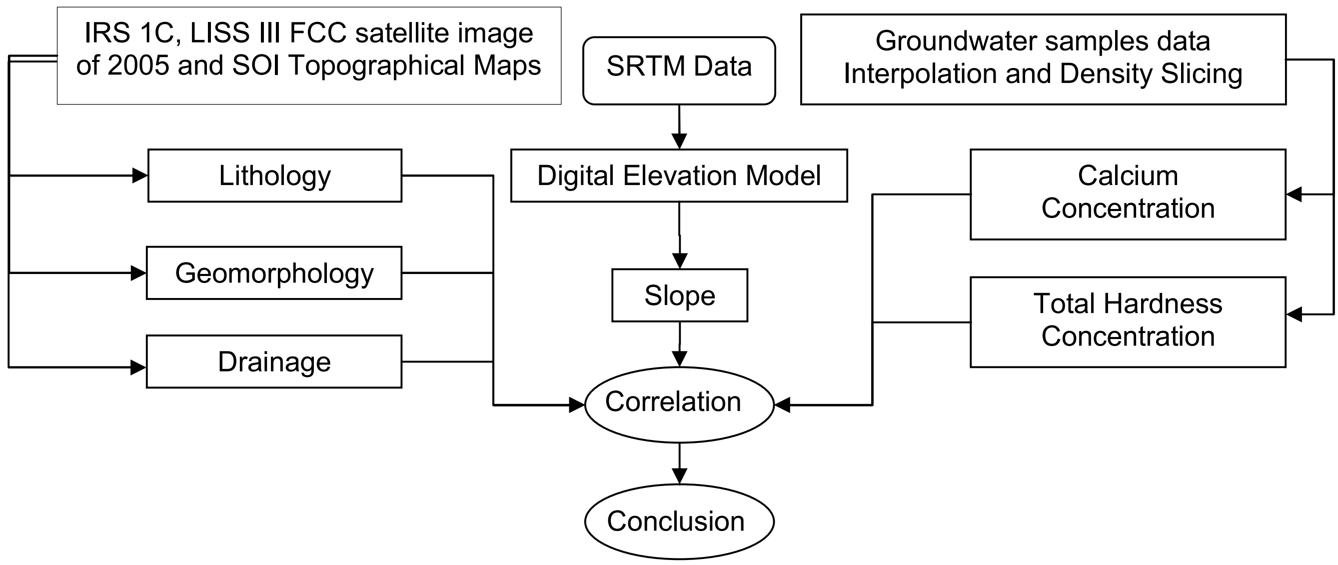

Figure 4: Flow diagram of the methodology adopted