GROUNDWATER POLLUTION MONITORING USING GIS FOR PIMPRI CHINCHWAD MUNICIPAL CORPORATION, WESTERN INDIA

N.J.Pawar[1], Shubhrangini Chauhan[1] and Vishwas Kale[2]

Department of Geology [1]/ Geography[2]

University of Pune,

PUNE - 411 007 (India)

1. INTRODUCTION

Water is a very valuable and scarce resource without which sustainable development is not possible. In India, groundwater is especially very important resource as it is utilized by more than 80% population for drinking purpose and agriculture is largely dependent on groundwater during the long dry, non-monsoon season. In the recent past, population clustering in cities, coupled with the industrial development and excessive use of chemical fertilizers and pesticides, with poor waste disposal practices have started causing serious deterioration of the groundwater resource. Such kind of contamination of wells has been studied by many workers namely, Ham (1971), Berk and Yare (1977), Pawar and Shaikh (1995), Pawar et al. (1998), Mohan et al (2000), Ballukraya (2000), Umar et al. (2001) and Subba Rao et al.(2002). These studies have highlighted the intensity of local problem on the basis of purely geochemical approach. However, with the advent of GIS approach recent papers by Soam and Singh (1994); Cheng et al. (1998), Rao et al (2000); Amarsaikhan et al. (2000) have underscored the immense utility of this technique in this field of pollution studies. Therefore, in this article the groundwater pollution problem of Pimpri - Chinchwad Municipal Corporation area has been studied by adopting a GIS based approach.

2. THE STUDY AREA

The Pimpri - Chinchwad Municipal Corporation (PCMC) is one of the most urbanised and industrilised megacity located close to Pune city on Mumbai-Pune National Highway in western India. It is situated in the interfluves between three rivers – the Indrayani, Mula and Pauna (Fig. 1). Most of the industrial and urban development of PCMC is localized on the Indrayani - Pauna interfluve. The elevation of the area is generally between 560 and 620 m ASL. The interfluve area between Pauna and Mula is almost feature-less and rocky.

Geologically, the area is characterised by Deccan Trap basalts. The thick basaltic flows are generally covered with thin veneer of soil and regolith mostly in the interfluve areas. Only along the main rivers, thick alluvium is seen. Small tributaries may have thin deposits, but generally the channels are cut into basalt. The valleys of the main rivers are very narrow because of the incised nature of the river channels. Most tributaries of

Indrayani, Pauna, and Mula are short, lower order streams with limited catchment areas. Largely, streams rising in the PCMC area are 2^{nd} to 4^{th} order streams. Because of the limited catchment area, the rocky nature of the area, and the semi-arid conditions, all the streams are ephemeral or highly seasonal in nature. The three main rivers are also not truly perennial, but they contain water for some months after the end of the monsoon season. In the source regions of the rivers large dams have been built to supply water to the city.

Phenomenal growth of population during the last 2-3 decades, coeval with industrialization and urbanization has affected the environmental status of the city. The population of the city between 1971 and 2001 increased by 2 orders of magnitude. This extraordinary growth of population has enormously increased the pressure on already limited land, water and soil resources. The problem of water pollution is particularly serious, mainly due to release of industrial and domestic effluents into the adjoining watercourses. In addition to this, in certain areas use of wastewater for crops has caused severe soil degradation. Infiltration of rainwater through such polluted soils has deteriorated the groundwater quality. Apart from this the landfill sites used for disposal of solid wastes have a great potential to develop leachates of polluted water in the downstream areas.

The main objective of the present paper is to study the spatio-temporal aspects of groundwater pollution and relate them to topography, drainage and land use.

3. METHODS OF STUDY

On the basis of the study of topographical maps and their correlation with the satellite images, followed by field studies for ground truthing of the landuse and landcover of the area, fifty groundwater monitoring stations were established in the PCMC area. Groundwater samples were collected during the June - July 2000 (rainy), November-December, 2000 (winter) and March-April, 2001 (summer) seasons. Chemical and microbial assessment of 150 groundwater samples was done. The major anionic constituents were determined by using the volumetric procedures. The SO_4 determination made use of the colorimetric method. Amongst the major cationic constituents the Ca was determined by titration method and the Na and K were estimated by flame photometric technique. The Mg was calculated as per the formula Mg = 0.244 (Total hardness as $CaCO_3$ – Ca hardness as $CaCO_3$). The remaining parameters i.e. PO_4, SiO_2, Fe, Mn, NO_3 were analyzed by employing the spectrophotometric methods (APHA et al, 1989). In addition, microbial analysis of the samples was also performed.
In order to relate the variations in the chemical and microbial parameters to land use in the PCMC area, the classification of land use classes from the IRS satellite data of December 17,1993 and December 20, 2000 was undertaken. The nature and extent of changes in the land use and land cover during the seven year period were interpreted and analyzed by using GIS. The extracted data were then related to the sources of groundwater pollution. Zones of pollution were demarcated by overlay analysis.

4. RESULTS AND DISCUSSION

Remote sensing along with GIS can provide valuable information about land use and landcover characteristics. Both land use and land cover characteristics are very important factors that influence the quality parameters of groundwater. Therefore, remote sensing and GIS analysis of PCMC area was undertaken.

4.1 Remote sensing analysis

The landuse and landcover of the study area was determined by using IRS-1B and IRS-1D geocoded (FCC) satellite data. Visual image interpretation was undertaken using well established remote sensing elements of interpretation. The elements were adopted to provide land use and land cover maps for 1993 and 2000 on 1:50,000 scale. About eight classes of land use and land cover were recognized and mapped following National Remote Sensing Agency's (NRSA) classification scheme. The interpreted land use and landcover categories were transferred on to the base map.

4.2 GIS Analysis

To evaluate the changes in the landuse between 1993 and 2000 as well as to understand the nature of relationship between the elevation above sea level, the drainage network and road network was used. In addition to this, land use / land cover types were also utilised. The Windows-based IDRISI geographic information software was used for the analysis. A scoring system was adopted for each of the thematic map.

The information about five thematic layers was used to prepare rasterized thematic maps and define thematic layers. The layers include absolute relief layer, drainage network layer, transport network layer and land use layers (1993 and 2000). To rasterize the thematic maps the entire area was first covered with a grid mesh, with each cell roughly representing 900 x 900 m on the ground. In all about 277 grids covered the entire study area. The scores for different layers, for each grid were noted and stored in a data file. Using these data and IDRISI GIS package, all the five thematic layers were combined by using the ‘overlay’ procedure.

The analysis reveals that, as expected, all the land use and land cover categories have registered some degree of change. However, there is no noteworthy change in the area under cultivation between December, 1993 and 2000. On the other hand, the area under vegetation cover and barren land shows a significant decrease and a corresponding increase in the urban and built-up area. The numerous patches of vegetation cover within the PCMC area that were observed in 1993 have either become smaller or have completely disappeared. A point to remember here, however, is that the year 2000 was marked by poor monsoon rainfall, as compared to the 1993 monsoon. Therefore, the apparent shrinking of the area under vegetation cover can also be attributed to early reduction in moisture conditions in 2000.

It is very clear from the remote sensing analysis, that the built-up and urban area has registered a significant increase during the seven years period. Although, the good part of this change is that the recent growth has mostly been confined to barren and wasteland area between the Indrayani and Pauna Rivers. But the undesirable part is that this area forms the highest part of the terrain. Consequently, all the waste generated by urban and industrial areas are likely to be transported to the low-lying areas and ultimately to the streams and rivers. As a result, not only the surface water but also the groundwater is likely to be severely affected by this situation.

4.3 Delineation of zones of groundwater pollution

In order to identify zones of pollution, the water quality data (chemical + microbiological) derived for all the three seasons and 50 samples, the elevation data and the land use data were considered. Using these data a seven-digit code was developed. The first digit represents EC, the second hardness, the third is chloride, fourth is Na, fifth is total microbial count, sixth is elevation of the area, and seventh digit represents land use. The value of each digit varies from 1 to 6 as per Table 1.

Table 1 : Coding of the parameters for classification

Digit	Parameter	Codes
First	EC	1 = low, 2 = medium and 3 = medium II
Second	Hardness	1 = moderately high, 2 = high and 3 = very high
Third	Chloride	1 = unpolluted, 2 = polluted and 3 = highly polluted
Fourth	Sodium (Na)	1 = unpolluted and 2 = polluted
Fifth	Microbial count	1 = low, 2 = moderately high, 3 = high and 4 = very high
Sixth	Elevation	1 = 540 - 560 m ASL 2 = 560 - 600 m ASL and 3 = 600 < m ASL
Seventh	Land use	1 = Barren/open land, 2 = Vegetation, 3 = cultivated land, 4 = rivers, 5 = lakes and 6 = built-up/urban

The above seven-digit coding system was used to classify and map all the 50 sample wells into three categories:

1] Slightly polluted 2] Polluted and 3] Highly polluted

A map was prepared on the basis of the seven-digit code (Fig. 2). It is observed from the figure that slightly polluted areas are almost negligible and found in the form of two small patches, one in the interfluve zone and other one close to the Pauna river. The remaining locations can be classified as polluted to highly polluted in terms of the above parameters. Of these, the polluted zone covers majority of the city area. The highly polluted zone predominantly covers interfluve area between Indrayani and Pauna river. Since, this zone coincides with recharge area, the pollution is likely to spread in the form of a plume in the low lying areas. This is evident from the fact that highly polluted zone is encircled by polluted zone followed by patches of unpolluted zone left in between. A patch of natural development of salinity has been identified in the downstream areas of Indrayani river. This salinity is related to quasi-stagnant conditions in the alluvial aquifer that is thicker in this part. Further, the villages in this area have been recently included in the city. Hence, there is no much urbanization and industrialization in this area. As a result, cause of the salinity is natural and not man-made. Thus, besides these locations, all the remaining locations have been classified as polluted and highly polluted in terms of five parameters.

This exercise highlights the immense potential of GIS analysis in the study of spatial and temporal aspects of groundwater quality. Land use/cover classification on the basis of image processing (supervised) and multi-criteria analysis can provide more information about the pattern of variation in the groundwater quality through space and time. Such information will be more helpful to city planners and health department authorities.

5. REFERENCES

Amarsaikhan, D., M.Ganzorig and M.Saandar (2000) :Urban Change Study Using RS And GIS, Mongolian Academy of Sciences av.Enkhtaivan-54B, Ulaanbaatar-51

APHA, AWWA and WPCF(1989) standard Methods for the examination of water and waste water. American Public Health Assoc, Washington DC.

P.N.Ballukraya,(2000) Overexploitation of Groundwater: A case study from Rasipuram area, Tamil Nadu. Jour.Geol.Soc.India V.56, pp.139 –150

Berk,W. J. & Yare B. S. (1977): An Integrated Approach to delineating contaminated Ground water, Groundwater, Vol.15, No2

Rao B. V. M, Toleti, B. S. Chaudhary, K. E. Mothi Kumar, G. P. Saroha,Manoj Yadav, Ajeet Singh, M. P. Sharma, A. C. Pandey and P. K. Singh (2000) : Integrated Ground Water Resources Mapping in Gurgaon District, (Haryana) India using Remote Sensing and GIS Techniques. Tech. Report, Deptt. of Sci. & Tech., Govt. of Haryana)

Cheng, K-S., Lei, T.C. and Yeh, H.C. (1998) :Reservoir Water Quality Monitoring Using Landsat TM Images and Indicator Kriging 1,Roosevelt Rd. Sec. 4.10617, Taipei, Taiwan,

Ham, H.H. (1971):Water wells & Ground contamination, Bulleton of the Assoc. of Engg and Geologists, Vol.8 No.1

Mohan R..Singh, A.B., Tripathi, J.B. and Choudhary, G.C. (2000) Hydrochemistry and Quality assessment of Groundwater in Naini industrial area, Allahabad Dist., Uttar Pradesh. Jour.Geol.Soc.India V.55, pp. 77-89.

Pawar, N.J. and Shaikh, I.J. (1995) : Nitrate pollution of groundwaters from shallow basaltic aquifers, deccan trap Hydrologic province, India. Environmental geology, V.25, pp 197-204

Pawar N.J. et al. (1998)Groundwater pollution due to sugar-mill effluent, at Sonai, Maharastra, India, Environmental Geology, v.34 (2/3), pp 151-158

Soam, S. K. and J.P. Singh (1994): Spatial modeling approach to water pollution monitoring in the sugar belt of Maharashtra along the Krishna River.

Subba Rao, N., Rao J.P.,Decdas,D.J. and Rao K.V.S.(2002) Hydrogeochemistry and Groundwater Quality in a developing urban environment of semi-arid region, Guntur, Andhra Pradesh, Jour.Geol.Soc.India V.59, pp. 159-166.

Umar, R.,Umar A., Khurshid, S. and Ahmed, I.(2001):Microbial contamination in the Groundwater of Aligarh City. Jour.Geol.Soc.India,V.58, pp. 157-162.

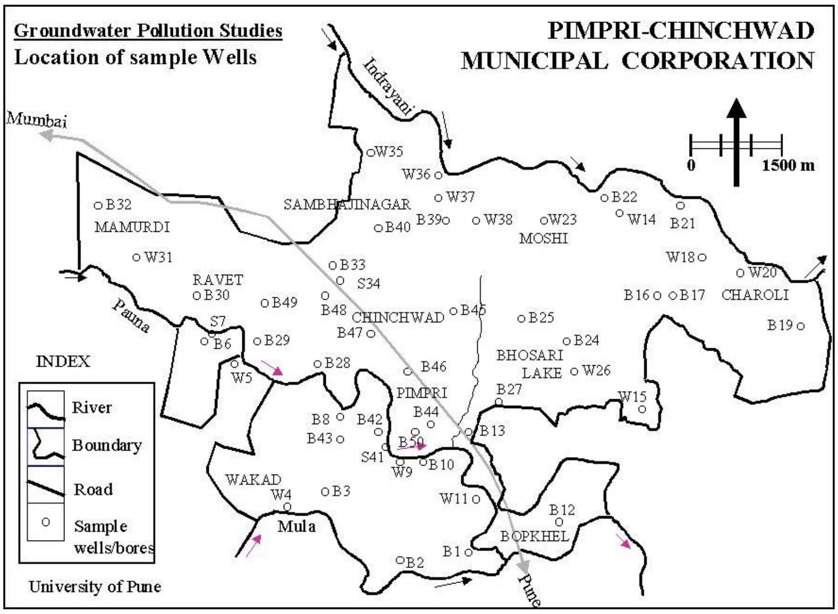

Fig. 1. Map showing the study area and the locations of sample wells

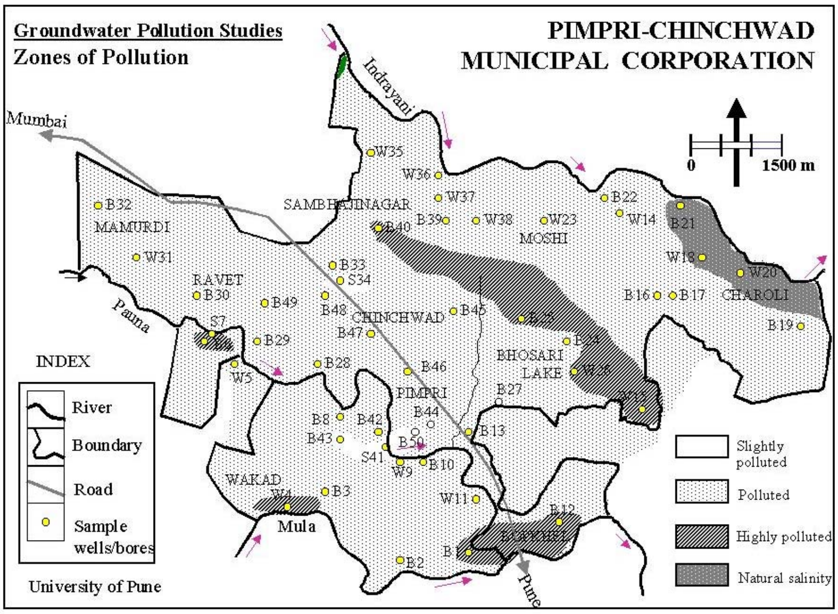

Fig. 2. Map showing the major groundwater pollution zones of the PCMC area.