SUMMARY AND CONCLUSIONS

Increased industrialization, urbanization and agricultural activities during the last few decades have deteriorated the groundwater quality. Groundwater constitutes one of the principal sources of fresh water. Hence it assumes enormous importance in domestic as well as industrial activities. In view of the groundwater being used for potable purpose, its quality remains one of the issues of concern. The leaching of heavy metal contaminants into the groundwaters is a realistic and significant environmental hazard because of their ecotoxicological potential, non-biodegradable and accumulative nature, pollute the local ecosystems and affect much larger systems. Within industrial estates, vastly accelerated emission of heavy metal pollutants inevitably renders the local ecosystems susceptible to irreversible degradation and contamination. The Aurangabad urban agglomeration during the last three decades has emerged as a major industrial hub, and one of the fastest developed industrial sectors in India. The heavy industrialization and the increasing urbanization are responsible for the rapidly increasing stress on the groundwater of the area. The enormous quantity of wastewater generated from domestic, commercial, industrial, and other sources, has led to the problems of groundwater in and around Chikalthana area of Aurangabad. Therefore considering this serious aspect the studies carried out on groundwater quality to evaluate the impact of industrialization, urbanization and agricultural activities on environment. Both spatial and temporal variation of groundwater has been studied.

Environmental Setting

Aurangabad city, located in the heart of the drought-prone interior of Maharashtra state, is one of the major urban centers of the Deccan sub-region. It is an important example of a progressive fast-growing Indian city.

Aurangabad city is a head quarter of district and Marathwada region and situated at the latitude of 19°53’50’’ north and longitude of 75°22’ 46’’ east covering an area of approximately 138.5 sq. km and fall in Survey of India Toposheet No. 46 M/5. Aurangabad sits in a strategic position on the Deccan Plateau. It stands in the Dudhana valley between Lakenwara range on north and Satara hills on south. Along the base of higher range soil is shallow and rocky, while towards the center it deepens
and becomes rich and fertile. The area is mostly highly dissected or moderately
dissected plateaus with insignificant valley fills.
The study area covering approximately 30 sq.km lies to the Eastern part of
Aurangabad city and spread between latitude 19° 50’ and 19° 53’ N and longitude
75°24’ and 75°25’E and houses more than 200 industries dominated by Chemical,
Pharmaceutical, Pesticides, Fertilizer and allied industries.

The entire study area is covered and surrounded mainly by basaltic lava flows
belonging to the Deccan volcanic province that flooded during Upper Cretaceous to
Lower Eocene age in the Deccan Plateau and is a part of Godavari basin. The
prominent geological units observed in study area are the horizontally disposed
basaltic lava flows and each flow has distinct two units. The upper layers consist of
vesicular and amygdule zeolitic basalt whiles the bottom layer consists of massive
basalt. This basaltic lava flows are the only water bearing formations in the area. The
weathered and fractured mantles of the traps are forming water table aquifers in the
area where ground water occurs under phreatic conditions. A number of lineaments
which are fracture zones have been identified on the satellite imagery due to linear
pattern, exhibited by darker tone and straight drainage course. These lineaments are
favorable for occurrence of groundwater (CGWB 2010).

**Groundwater Quality Studies**
Physicochemical characteristics of groundwater were studied and it is found that
groundwater quality deteriorated day by day.

In general the pH of groundwater varies from 7.3 to 8.6 and 7.8 to 8.8 in pre-
monsoon and 6.9 to 8.5 and 7.1 to 8.7 in post-monsoon season indicating weakly
alkaline to moderately alkaline nature of groundwater.
The EC of groundwater range from 250 to 5600 and 320 to 5810 micromhos/cm in
pre-monsoon and 300 to 5750 and 400 to 5900 micromhos/cm in post-monsoon
season.
The TDS of groundwater range between 162.5 to 3640 and 208 to 3776.5 in pre-
monsoon and 195 to 3737.5 and 260 to 3835 mg/l in post-monsoon season.
The higher values of EC and TDS in post-monsoon season can be related to the
dissolution of minerals during this season. The calcium content of groundwater varies
from 15 to 910 and 18 to 918 mg/l in pre-monsoon and 18 to 920 and 22 to 922 mg/l
in post-monsoon season. The Mg content of groundwater ranges from 70 to 3972 and 76 to 4021 mg/l in pre-monsoon and 68 to 3965 and 69 to 3955 mg/l in post-monsoon season. Total hardness of groundwater varies from 108 to 4440 and 111 to 4430 mg/l in pre-monsoon and 110 to 4450 and 120 to 4500 mg/l in post-monsoon season. Sodium content of groundwater ranges from 18 to 425 and 39 to 430 ppm in pre-monsoon and 45 to 441 and 50 to 450 ppm in post-monsoon season. The potassium is not present in all groundwater samples. The chloride content of groundwater varies from 28 to 2585 and 33 to 2590 mg/l in pre-monsoon and 35 to 2600 and 40 to 2613 mg/l in post-monsoon season. The bicarbonate of groundwater ranges from 10 to 380 and 12 to 390 mg/l in pre-monsoon and 13 to 395 and 15 to 400 mg/l in post-monsoon season. The sulphate content of groundwater varies from 23 to 255 and 25 to 261 ppm in pre-monsoon and 32 to 269 and 40 to 291 ppm in post-monsoon season. The phosphate content of groundwater varies from 94 to 380 and 95 to 395 ppm in pre-monsoon and 102 to 400 and 123 to 420 ppm in post-monsoon season.

The suitability of groundwater for drinking purpose is determined keeping in view the effects of various chemical constituents in water on the biological system of human being. The study revealed that the most of the groundwater samples in the study area are heavily polluted. The majority of parameters exceeding permissible limit given by BIS (1991) and WHO (1993) are total dissolved solids, total hardness, Calcium, Magnesium and Chloride.

The temporal variation indicates that the parameters like conductivity, total dissolved solids, TH, Ca, Cl and SO$_4$ show higher concentration in samples of post-monsoon season as compared with pre-monsoon season. While the parameter likes Mg, Fe and Cu have higher concentration in samples of pre-monsoon season as compared to the samples of post-monsoon season.

The spatial variation in both cationic as well as anionic constituents indicates higher concentration in the south western part of the study area. Spatial distribution of different parameters like conductivity, total dissolved solids, total hardness, sodium, chloride, bicarbonate and in few samples iron indicates that the groundwater quality is more deteriorated in south-western part of the study area towards Sukhana river. This may be due to effluent charged and polluted this river which is recharging these aquifers. Overall 16% of the sample of groundwater from the south western part of the study area is not fit for irrigation purpose, i.e. area affected by salinity hazard zone.
The iron content of groundwater varies from 0.1 to 4.5 and 0.11 to 5.4 ppm in pre-monsoon and 0.08 to 3.4 and 0.12 to 5.21 ppm in post-monsoon season. The copper content of groundwater varies from 0.28 to 0.83 and 0.33 to 0.99 ppm in pre-monsoon and 0.13 to 0.74 and 0.33 to 0.98 ppm in post-monsoon season.

The level of heavy metals in groundwaters for iron, chromium, nickel, manganese, cadmium and lead is above the permissible limit as prescribed by BIS (1991) and WHO (1993). High level of these metals in groundwater can harm ecosystems, plants, and animals and cause health problems in humans. Overall in the study area groundwater samples are heavily contaminated by iron, chromium, lead and nickel throughout the area. Urban runoff as well as municipal sewage and industrial effluents could be the main cause of the groundwater contamination.

Classification scheme for magnesium Hazard (MH) for irrigation water is given by Szabolcs and Darab (1964) with MH values of 50 or more taken as hazardous. Based on this all samples fall in harmful category during both pre and post-monsoon season.

Another important parameter of groundwater is Total hardness, which is the total concentration of calcium and magnesium ions expressed as calcium carbonate in mg/l. The hard water is unsuitable for domestic and industrial applications and irrigation use. The water hardness classification scheme of Twofr (1974) was followed in the present study. It is seen that 71.11% of wells sampled grouped in very hard type during both pre and post-monsoon season for two years. The TH values have increased gradually over the period of two years.

The major element data were plotted on Piper trilinear diagram to evaluate the hydrochemical facies. From the figures 4.15a, b, c & d it seen that 29% groundwater samples of pre-monsoon season and 22 and 25% groundwater samples of post-monsoon season represents Ca + Mg (alkaline earth) hydrochemical facies. While 16% groundwater samples of pre-monsoon season and 19 and 23% groundwater samples of post-monsoon season represents Ca + Mg > Na + K (alkaline earths exceeds alkalies) hydrochemical facies. Similarly, 12 and 15% groundwater samples of pre-monsoon season and 15% groundwater samples of post-monsoon season represent Cl + SO\textsubscript{4} > HCO\textsubscript{3} + CO\textsubscript{3} (strong acid exceeds weak acid) hydrochemical facies. While 30 and 33% groundwater samples of pre-monsoon season and 30% groundwater samples of post-monsoon season belong to Cl + SO\textsubscript{4} (Strong acid) while
1 % groundwater samples of post-monsoon season 2008 represents Na + K > Ca + Mg hydrochemical facies. The slight change on temporal scale in the groundwater type from Ca + Mg in pre-monsoon season to Na + K in post-monsoon indicates cation exchange process. On the other hand no significant change is observed in the anion facies of two seasons.

On the basis of U.S. Salinity diagram (1954) Figure (4.16a, b, c and d) the groundwater samples of pre-monsoon season 11.11 to 13.33% of the wells fall in C₄-S₁ class and 15.55 to 17.77 % of the wells fall in C₅-S₁ class. The post-monsoon samples show that 15.55 to 20.00 % of the wells fall in C₄-S₁ class and 15.55 to 17.77 % of the wells fall in C₅-S₁ class. C₄-S₁ type indicates very high salinity with the water being not suitable for irrigation under ordinary conditions and C₅-S₁ indicates excessive salinity water which restricts its suitability for irrigation.

The groundwater in the study area was also classified following the U.S. Salinity Laboratory procedure for classification of irrigation water. Based on the pre-monsoon samples of the area 11.11 to 15.55% of the wells fall in C₄ class and 15.55% of the wells fall in C₅ class. The post-monsoon samples show that 13.33 to 15.55% of the wells fall in C₄ class and 15.55% of the wells fall in C₅ class. Overall 16% of samples from both the season falls in C₄ type indicate very high salinity with the water being not suitable for irrigation under ordinary conditions and C₅ indicates excessive salinity water not fit for irrigation.

Wilcox classified groundwater for irrigation purposes based on percent sodium and EC. On the basis of Wilcox diagram (Fig. 4.17a, b, c & d) about 22.22 % of the sample fall in the field of unsuitable for irrigation purposes during both pre and post-monsoon season for two years.

The Gibbs plot of data from study area (Fig. 4.18a, b, c & d) indicates that the 55.55 to 64.44 % of samples in pre-monsoon seasons fall in the rock dominant category and 35.55 to 44.44 % fall in the evaporation field. While in post-monsoon season 51.11 to 60 % of samples fall in the rock dominant category and 40 to 48.88 % fall in the evaporation field. It is found that majority of the groundwater samples suggest an interaction between rock and the percolating water into the subsurface by means of mineral dissolution (Gibbs 1970). The distribution of the sampling points also suggests that the major ion chemistry of the groundwater seems to be controlled by chemical weathering of rock forming minerals and anthropogenic activities.
The values of sodium absorption ratio (SAR), Kelly’s ratio (KR), soluble sodium percentage (SSP) and residual sodium carbonate (RSC) for both the seasons are within permissible limit which indicates that the quality of groundwater is excellent for irrigation (Table 4.16, 4.17, 4.18 and 4.19).

Study of shallow and deeper aquifer has shown that there is geochemical variation between the two aquifers and the shallow aquifers are more polluted than the deeper aquifer.

The shallow aquifer is more polluted than the deeper aquifer because of percolation of industrial effluents from the river carrying industrial effluents in which they are discharged. The pollution has reached the deepest bore well (85m) which is located near by drain carrying effluent.

Based on the results observed, it is found that most of the sources of groundwater have the concentration of one or other constituent above the safe prescribed limit. The groundwater from most of the places is unsuitable for drinking since it had high concentration of some of the sensitive parameters like total hardness, magnesium and chloride.

**Recommendations**

This study emphasizes the need for regular groundwater quality monitoring to assess pollution activity from time to time for taking appropriate management measures in time to mitigate the intensity of pollution activity.

The remedial measures include,

- Strict implementation of environmental laws;
- Treatment of industrial wastes before their safe disposal;
- Industries should be set up their effluents treatment plants (ETP) independent or jointly as per norms and should remain effectively operational in order to safe guard the ground water for future generation;
- Development of greenery in and around industrial zones;
- Limited withdrawal of groundwater;
- Arrangement of proper drainage system;
- In agricultural excessive use of fertilizers should be avoided so that it does not leach down to ground water and deteriorate its quality;
• Mass awareness should be generated about the over use of pesticide, its harmful effects on quality of water and human health;
• Supply of protected water;
• Drip irrigation should be adopted for more effective irrigation without excessive evaporation and also for preventing weathering and leaching;
• Crop selection should be dependent on water quality, water availability and water needs;
• Rainwater harvesting techniques should be implemented to augment the groundwater resources and reduce salinity, protect soils and increase crop yields;
• Environmental education is needed to create awareness regarding (a) damage on irrigation and health due to inferior quality of groundwater, (b) crop-water requirements, soil characteristics and cropping-patterns, and (c) efficient methods of irrigation to improve agricultural production;
• Farmers should be better educated to increase agrarian income and improve living conditions, and
• The disposal sites for industrial and urban wastes should be away from residential areas.

There is an urgent need to generate public awareness on the sources, causes, extent and prevention of groundwater pollution, and also the consequences of impact of pollution on human health, which would be a key factor for sustainable development of the area. An appropriate management plan is suggested in the study area to have a better groundwater quality for proper maintaining human health for sustainable development.