Abstract

India has experienced rapid industrial growth since the enactment of the economic liberalization policies in 1991. Nowadays Industrialization has become an important factor to the development of a country’s economy, through the establishment of plants and factories. A consequence of India’s higher economic growth is increased consumption of the natural resources and increased waste generation that contributes to ecological degradation.

Water is the essence of life. Without water, human beings cannot live for more than few days. The earth’s surface is 71% water, but out of this only 3% is fresh water, of which only 1% is available for people to use. Water is only substance that exists naturally on Earth in all three physical states of matter i.e. gas, liquid and solid. Groundwater is a precious and the most widely distributed resource of the earth and unlike any other mineral resources, it gets its annual replenishment for the meteoric precipitation. Quality of groundwater is important as it controls its usability. Conceptually, water quality refers to the characteristics of a water supply that will influence its suitability for a specific use. The quality of water is a vital factor for mankind as it is directly linked with human health. Pollution of surface water and groundwater from agro-chemicals (Fertilizers and Pesticides) and from industry poses a major environmental health hazard with potentially significant costs to the country.

The quality of groundwater is very important in evaluating its utility for agricultural, domestic and industrial purposes. Hence protection and management of groundwater quality is emerging as a great concern around the world and especially in India.

The human activities such as rapid urbanization, ever increasing population and deforestation have interrupted the natural hydrological cycle. The chemical composition of surface and groundwater is controlled by many factors that include composition of precipitation, mineralogy of the watershed and aquifers, climate and topography. The industrial effluent contains appreciable amounts of inorganic and organic chemicals and their by-products. Most of the industries in the small scale
sector do not have any sewer lines. Even today most of them don’t have proper wastewater treatment plants and they discharge industrial effluents in unlined channels and streams. As a result, the highly colored and toxic chemical effluents join the River system, a natural water course polluting the surface water and groundwater. During the last century a huge amount of industrial wastewater or effluents was discharged into rivers, lakes and coastal areas. This resulted in serious sediment pollution problems in the water environment and caused negative effects to the ecosystem and human’s life.

Among the industries the major contributors in the deterioration of groundwater, soil and sediment are that of the pulp and paper, textiles, tannery, sugar, petrochemical, dairy, electroplating, distillery, hydrogenated vegetable, oil and soap, oil and surfactants. The effluents from the fertilizer plants, synthetic rubber industries and chemical industries such as pesticides and insecticides are some of the other industries. The metal-working industries discharge Chromium, Nickel, Zinc, Cadmium, Lead, Iron and Titanium compounds among them the electroplating industries is an important pollution distributor.

Life on earth depends directly on soil and aquatic ecosystem of river. Soil is mixture of various inorganic and organic chemical compounds. Inorganic constituents are Ca, Mg, Fe, Si, K and Na. Small amounts of compounds of Mn, Cu, Zn, Co, B, I and F, etc are present in the soil. The soil solution contains complex mixture of minerals as carbonates, sulphate, chlorides, and nitrates, also organic salts of Ca, Mg, K and Na etc. The chief organic component of soil is humus. It is reported that more than 70 million of organic chemicals are synthesized every year in the world and have multiplied ten times since 1950. Industrial wastes mainly consist of organic compounds along with inorganic complexes and non-biodegradable material. These harmful compounds adversely affect the bio-chemical properties of soil. About 0.5 million people die annually because of these toxic chemicals.

Sediment consists of soil and mineral particles washed from land by natural and manmade activities. River sediments as basic component of our environment
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provide food stuff to living organism. They also serve as a sink and reservoir for a variety of environmental contaminants.

Sediment acts as carrier and possible source of pollution because they do not permanently fix heavy metals. These sediments release metal into water by the changes in the environmental condition. The process of sedimentation is a comprehensive natural geomorphological process, which operates through the chain of erosion of soils and deposition of these eroded materials in different paths of water bodies. The rivers are the most dynamic on the earth’s ecosystem, their major function being transportation of water. Urbanization and growth of newer industries is causing huge amount of waste water production affects soil, sediment and groundwater. With increased industrialization these heavy meals are released through the waste effluent into the restricted environment. Heavy metals are of considerable environmental concern due to their toxicity and accumulation behaviour. Rapid progress of the industrialization, population and modern methods in agriculture generate many types of hazardous contaminants. These toxic wastes are released in to the environment and thus pose a threat to living biota (Patil 2012).

Aurangabad is one of the developed cities in Maharashtra in respect of industry, agriculture and infrastructure. There are more than hundred Small Scale Industries registered in Chikalthana and Shendra industrial area. Due to liberalized policies of state and central government to encourage investors, many industries are coming up in Aurangabad. The accelerated growth of industries and the discharge of the industrial waste water around the Chikalthana and Shendra industrial area causing heavy damage to the soil, sediment and groundwater quality.

Aurangabad is one of the critically polluted industrial clusters identified by Central Pollution Control Board. In such scenario, groundwater contamination due to industrial effluents is quite common as seen in parts of Chikalthana and Shendra industrial area of Aurangabad. The Chikalthana industrial area developed by Maharashtra Industrial Development Corporation has a total area of 719.68 hectares with renowned companies including Wockhardt, Maharashtra Distilleries Ltd., Lupin,
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Indo German Tool Room, Greeves, Cosmo Films, Concept Pharmaceuticals Ltd., Hindustan Lever Ltd., HMT, Dagerfost and NRB which have based their manufacturing units. These industries produce medicines, beverages, cold drinks, chemicals, etc. Shendra industrial area developed by Maharashtra Industrial Development Corporation in the 1990’s has total area of 902 hectares, with renowned companies including Audi India, Skoda Auto, Volkswagen, Etchon, Perkins Engines, J B Forge I Pvt. Ltd., Rucha Engineering Pvt. Ltd., Gas Power and Infrastructure Pvt. Ltd., Monoginis and Siemens. These industries produce medicines, beverages, chemicals, optic fiber, cold drinks, electric multiple unit and metro coaches etc. The enormous quantity of waste water generated by these industries has led to the problems of soil, sediment and groundwater in and around Chikalthana and Shendra industrial Area of Aurangabad.

In Chikalthana and Shendra industrial area most of the industries discharge their effluents without proper treatment into nearby open pits or pass them through unlined channels, which move towards the low lying depressions on land, resulting in the soil, sediment and groundwater contamination. In view of this, it is proposed to take up a detailed geochemical study of soil, sediment and groundwater in watersheds around the industrial areas of Aurangabad.

Considering this serious aspect the present study assesses the quality of soil, sediment and groundwater in Chikalthana and Shendra industrial area of Aurangabad.

The objectives of the study were

1) Inventory of industries (location, effluent discharge with respect to quality and quantity) to create a database on the environmental status.
2) Understanding the hydrogeological condition in and around the industries.
3) Know the quality of soil with respect to physico-chemical parameter and preparation of soil map of the study area.
4) Geochemical analysis of large number of Groundwater and sediments samples for various physico-chemical parameters including heavy metal to know the quality.
5) Suitable abatement measure to contain pollution due to industries.

The study is presented in six chapters. The first chapter gives the general introduction of the area covering physiographic elements such as location, population, communication systems, physiography and drainage and soil. Aurangabad is Head Quarter district of Marathwada division. The location co-ordinates for Aurangabad are N 19° 53' 47" - E 75° 23' 54"", falling on Survey of India Toposheet No. 47M/5. The population of the Aurangabad city area is 11,71,330 (Census 2011).

The Aurangabad situated in Dundhna Valley between Jathwada (Lakenvara) range on the north and the Satara hills on the south. Aurangabad is well connected with Mumbai, the capital of Maharashtra by air, rail and road, with Delhi by air and rail. An excellent road network connects Aurangabad with rest of states. It has moderate rains and the climate is dry throughout the year. The drainage pattern of the study area is dendritic. The slope of the hill is steep due to which dendritic drainage pattern developed. The soil in study area has coarse texture and is suitable for growing crops such as Jawar, Bajra, Wheat, Pulses and Sugarcane (CDP, AMC, 2006).

In the second chapter general geology of the area is described. The stratigraphic succession includes Deccan basalt and alluvium. The entire Aurangabad district is covered by the Deccan Trap lava flows belonging to Upper Cretaceous to Eocene age. The traps are overlain by thin alluvial deposits along the major rivers. The basaltic lava flow units belonging to the Deccan Trap is the only major geological formation occurring in the district. The lava flows are horizontal and each flow has distinct two units. The upper layers consist of vesicular and amygdaloidal basalt while the bottom layer consists of massive basalt. The flow thickness ranges between 15-20 meters. In all 10 flows have been demarcated which are lying between 510-740 m MSL. The flows are generally separated by a red clay bed commonly called as ‘Red bole’ and thickness of the ‘Red bole’ is ranges from 0.1 to 0.65m. The thickness of alluvium ranges between 10-15 meters. The extension of alluvial belt is confined to 0.5-1 km across the rivers.
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The study area made up of Deccan Trap comprising a thick pile of basaltic flows, horizontally disposed and apparently more or less uniform in composition. This chapter also deals with the hydrogeology of the area. Groundwater occurs in fissured formations (different units of basaltic lavas flow) and porous formations (isolated patches of alluvial). The occurrence and movement of groundwater is controlled by variation in water bearing properties of these formations (CGWB2010).

The third chapter deals with the methodology adopted for the study including collection of data and analytical methods used in determination of physiochemical parameters of soil, sediment and groundwater samples. The present study is based on the detailed field work and collection of soil, sediment and groundwater samples for three years.

Soil and sediment samples were collected in the month of May consecutively (2009 to 2011) for three years. This comprises 50 soil and 25 sediment samples. Water samples from 18 bore wells and 82 dug wells were collected for three years in pre-monsoon and post-monsoon seasons during 2009 to 2011.

The physico chemical parameters determined for soil samples include pH, Conductivity (EC), Bicarbonate (HCO₃), Exchangeable Calcium and Magnesium, Sodium (Na), Potassium (K), Sulphate (SO₄), Total Phosphorous (PO₄), Chloride (Cl) and Trace elements like Lead (Pb), Zinc (Zn), Iron (Fe), Copper (Cu), Chromium (Cr), Manganese (Mn) and Nickel (Ni) were determined.

Sediment were analysed for only trace elements like Lead (Pb), Zinc (Zn), Iron (Fe), Copper (Cu), Chromium (Cr), Manganese (Mn), and Nickel (Ni).

The physico chemical parameters of groundwater determined include pH, Conductivity (EC), Total dissolved solid (TDS), Calcium (Ca), Magnesium (Mg), Total Hardness (TH), Sodium (Na), Potassium (K), Sulphate (SO₄), Chloride (Cl), Carbonate (CO₃) and Bicarbonate (HCO₃) and Trace elements like Lead (Pb), Zinc (Zn), Iron (Fe), Copper (Cu), Chromium (Cr), Manganese (Mn), and Nickel (Ni).
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In fourth chapter geochemical behaviours of different element are discussed for soil, sediment and groundwater samples. Groundwater is generally used for domestic (drinking) and irrigation purposes. Therefore, the quality of groundwater has been assessed in terms of its suitability for drinking and irrigation purposes only.

The fifth chapter gives the discussion of result of the present study. It is observed that average values for three years in soil for parameters like pH ranges from 7.26 to 8.66, conductivity ranges from 425.33 to 4326.67 micromhos/cm, chloride ranges from 11.59 to 95.40 mg/100g, bicarbonate ranges from 43.80 to 1161.97 mg/100g, exchangeable calcium ranges from 59.29 to 647.94 mg/100g, exchangeable magnesium ranges from 16.57 to 340.94 mg/100g, sodium ranges from 35.50 to 276.93 mg/100g, potassium ranges from 30 to 130.90 mg/100g, sulphate ranges from 2.13 to 58.73 mg/100g and total phosphorous ranges from 40.84 to 160.78 mg/100g. Trace element parameter like Fe ranges from 3.93 to 83.22 mg/Kg, Cu 0.29 to 1.79 mg/Kg, Zn 0.34 to 1.51 mg/Kg, Cr 0.08 to 1.33 mg/Kg, Ni 0.07 to 0.99 mg/Kg, Mn 2.77 to 13.77 mg/Kg and Pb 0.01 to 2.29 mg/Kg.

From the study, it was concluded that the study area has black cotton soil, which is rich in calcium and magnesium. From the result of the work, it can be concluded that the pH of the soil samples was slightly alkaline. The soil sample contains iron above the permissible limit.

In sediment quality analysis, it is observed that average values for three years for parameters such as Fe ranges from 49.60 to 90.27 mg/Kg, Cu 0.44 to 2.15 mg/Kg, Zn 0.35 to 1.93 mg/Kg, Cr 0.23 to 0.96 mg/Kg, Ni 0.29 to 1.06 mg/Kg, Mn 9.94 to 33.02 mg/Kg and Pb 0.24 to 1.06 mg/Kg.

The order of abundance of these metals in sediments is as follows Fe>Mn>Cu>Zn>Cr>Ni>Pb. These metal profiles can be correlated to levels of human and industrial activity and as such represent a record of pollution in the region.

In groundwater quality analysis, it is observed that the average values of six season for the parameter like TDS (24.16%), Total Hardness (55.16%), Calcium
(32%), Magnesium (39.33%), Bicarbonate (25.66%) and Chloride (16.66%) of the wells exceeding maximum permissible limit in the groundwater, while the trace element average values of six season for the parameter like Fe (44.16%), Cr (41.83%), Ni (41.16%), Mn (45.66%) and Pb (42.83%) of the wells exceeding maximum permissible limit in the groundwater of the study area for three years as per BIS standards.

The groundwater in the study area also classified adopting the U.S. Salinity Laboratory procedure for classification of irrigation water. As per U.S. Salinity classification 3.33%, 33%, 56.33%, and 7.33% of the wells fall in C5, C4, C3 and C2 respectively for pre-monsoon season during 2009 to 2011. The post-monsoon samples show that 5%, 37.66%, 52.33% and 5% samples fall in C5, C4, C3 and C2 respectively. Overall 35 % from both the season samples falls in C4 type indicate very high salinity with the water being not suitable for irrigation under ordinary conditions and overall 4.10% from both the seasons samples falls in C5 indicates excessive salinity water not suitable for irrigation.

The U.S. Salinity classification of groundwater for irrigation purpose based on EC and Sodium Adsorption Ratio helps in planning agricultural land use. The plots of groundwater chemistry of study areas in the USSL diagram showed that 7.33%, 49.66 %, 29.66 %, 1.33%, 5.33%, 3%, 2%, 1.33% and 0.33% grouped in C2S1, C3S1, C4S1, C5S1, C3S2, C4S2, C5S2, C3S3 and C4S3 type respectively for pre-monsoon season during 2009 to 2011, also in post-monsoon groundwater chemistry of the study area showed that 5%,45.66 %, 32.33%, 1.66%, 5%, 5%, 3.33%, 1.66% and 0.33% grouped in C2S1, C3S1, C4S1, C5S1, C3S2, C4S2, C5S2, C3S3 and C4S3 type respectively during 2009 to 2011. Samples grouped within C2S1, C3S1, and C4S1 type showed that the irrigation quality of the water was good in the study area. Samples grouped in C3S2 and C4S2 showed that the water was moderately suitable where as samples grouped in C5S1, C5S2, C3S3 and C4S3 are not suitable for irrigation.
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Based on the Wilcoxon diagram (1948), average value 25.66% and 27.33% of the samples were unsuitable for irrigation purposes during pre and post-monsoon season respectively.

Classification scheme for Magnesium Hazard (MH) for irrigation water is given by Szabo and Darab (1964) with MH values of 50 or more taken as hazardous. Based on this 60.66% and 63% average of three years samples fall in harmful category pre and post-monsoon season respectively.

Another important parameter of water 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 Twort (1974) was followed in the present study. It is seen that 80.66% and 88.66% average of three years sampled grouped in very hard type during both pre and post-monsoon season respectively. The TH values have increased gradually over the period of three years.

Kelly’s Ratio gives the sodium hazard given by the formula Na/(Ca+Mg). The KR values for the groundwater samples of the study area shows 15% and 13.13% average of three years for pre and post-monsoon seasons respectively are greater than one indicates the unsuitable quality for irrigation purpose.

The classification of groundwater samples from the study areas with respect to Sodium Adsorption Ratio were showed that during both pre and post-monsoon seasons, the Sodium Adsorption Ratio values of the samples collected from study area were found less than 10, and were classified as excellent for irrigation.

Sodium in irrigation water is usually denoted as percent sodium (%Na). The classification of groundwater samples with respect to percent sodium shows that 8.17%, 58.65%, 25%, 7.64% and 0.5% average of three years samples fall in excellent, good, permissible, doubtful and unsuitable category respectively.

The groundwater of the study areas was also classified on the basis of RSC. It was found that 10.66% and 9.66% samples shows more than 2.5 RSC average values
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for three years during pre and post-monsoon season respectively indicates that groundwater is unsuitable for irrigation.

The Piper Trilinear diagram is used to understand hydrogeochemical facies. The diamond shape fields of the diagram denotes that the overall chemical character of groundwater. The study shows that average value of three years for different hydrogeochemical facies as follows, 85% samples fall in “alkaline earths (Ca+Mg) exceeds alkalies (Na+K)” facies, 15% samples fall in “alkalies exceeds alkaline earths” facies, 44% samples fall in “weak acid (CO$_3$+HCO$_3$) exceeds strong acids (SO$_4$+Cl)” facies, 56% samples fall in “strong acids exceeds weak acids facies”, 31.33% samples fall in “carbonate hardness (secondary alkalinity) exceeds 50%” facies, 13.67% samples fall in “non-carbonate hardness (secondary salinity) exceeds 50%” facies, 2.33% samples fall in “non-carbonate alkali (primary salinity) exceeds 50%” facies, 12.67% samples fall in “carbonate alkali (primary alkalinity) exceeds 50%” facies and 40% samples fall in “none of the cation and anion pairs exceeds 50%” facies for pre-monsoon season.

Similarly for post-monsoon season 86.67% samples fall in “alkaline earths (Ca+Mg) exceeds alkalies (Na+K)” facies, 13.33% samples fall in “alkalies exceeds alkaline earths” facies, 44.67% samples fall in “weak acid (CO$_3$+HCO$_3$) exceeds strong acids (SO$_4$+Cl)” facies, 55.33% samples fall in “strong acids exceeds weak acids facies”, 34.33% samples fall in “carbonate hardness (secondary alkalinity) exceeds 50%” facies, 11.67% samples fall in “non-carbonate hardness (secondary salinity) exceeds 50%” facies, 2.67% samples fall in “non-carbonate alkali (primary salinity) exceeds 50%” facies, 10.67% samples fall in “carbonate alkali (primary alkalinity) exceeds 50%” facies and 40.67% samples fall in “none of the cation and anion pairs exceeds 50%” facies.

There is close relationship between the chemical characteristics of groundwater and lithology of the host rock of the aquifer. Gibb’s ratio for the ion (Na+K)/(Na+K+Ca) and Cl/(HCO$_3$+Cl) of groundwater samples were plotted against the respective values of TDS. The result of study indicates that the 31.66% of samples
in pre-monsoon seasons fall in the rock dominant category and 68.44% fall in the evaporation field, while in post-monsoon 26% fall in the rock dominant category and 74% fall in evaporation field. Rock dominance of sample is caused by the interaction between the aquifer rock and groundwater of the study area.

The last sixth chapter deals with summary and conclusion of the study, which has lead to following conclusions,

- In the present study, from analysis of pre and post-monsoon data and the average value obtained. It has inferred that certain parameters like Calcium, Magnesium, Total hardness, TDS, Chloride have increased in concentration. The reason can be attributed to increase in concentration a result of greater leaching. Physico-chemical characteristics of the groundwater indicate that groundwater is polluted by industrial activity.
- The groundwater in the study area is moderately hard (1.5%), hard (13.83%) and very hard (84.66%), fresh (28.84%) to brackish (71.16%).
- Total hardness is generally higher in the groundwater thereby, causing the groundwater in most of the study area to be unsuitable for drinking.
- Based on calcium concentration 20.66% samples exceed the maximum permissible limit.
- On the basis of magnesium 39.33 % of the groundwater exceeds the maximum permissible limit.
- Based on percent sodium 8.17% groundwater samples fall in excellent, 58.65% groundwater samples fall in good, 25% groundwater samples fall in permissible, 7.64% falls in doubtful and 0.50% groundwater samples fall in unsuitable category. The groundwater in unsuitable category is not suitable for human consumption.
- Based on RSC 84% belongs to ‘safe’ category, 6% falls under ‘moderately safe’ and 10% is ‘unsuitable’ for irrigation purpose.
- On the basis of Kelly’s Ratio overall 14.06% groundwater samples of the study are not fit for irrigation.
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➢ Based on Magnesium Hazard overall 60.06% groundwater samples are not suitable for irrigation.
➢ Overall the hydrogeochemical data shows that quality of the groundwater of study areas deteriorated and proper groundwater management strategies are necessary to protect sustainability of this valuable resource

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:

❖ Testing of soil should be done every year to understand and monitor pH, nutrient status of soil, use of organic matter as compost manure should be increased.
❖ The leguminous plants, which have capacity to fix nitrogen in soil, should be encouraged to alternate yearly crop.
❖ Agricultural runoff through fields should be stopped. It minimizes the pollution of the soil. Irrigation by polluted water (sewage water, industrial waste water, hard water) should be avoided since it increases some ions in soil which disturbs the balance of cations and anions of the soil.
❖ Discharged water from industries should meet drinking water standards continuously. No discharge of effluent from any industry to nearby river without treatment.
❖ Polluted region must be separated.
❖ More common effluent treatment plants should be installed within the industrial area. The effluent quality from various units should be monitored regularly.
❖ There should be proper, well channeled system, from industrial unit and Municipal Corporation to common effluent treatment plant or disposal site, should be constructed. It will reduce seepage of effluents into soil.
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- The modern technology like biotechnology, membrane technology should be adopted for water treatment in addition to conventional methods.
- Arrangement of proper drainage system.
- A medical checkup of people who directly use ground water for drinking purpose should be done periodically.
- Environment education by establishing eco-schools, training and awareness programme.
- Regular monitoring of soil and groundwater quality and developing a database for risk evaluation.
- Some awareness programs are needed to educate the society to safe guard the precious river and its surrounding. Some awareness programme should be started for the people about water born diseases associated with them.
- The recycled water should be reused in industry.
- The open well should be constructed with concrete walls to avoid contamination by outside materials.

Moreover, 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 soil and 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.