Chapter VI

SUMMARY AND CONCLUSIONS

The impact of industrial effluent on Surface water (6 samples), Groundwater (49 Samples) and Soil (10 samples) quality in and around Chincholi Industrial area of Solapur District, Maharashtra has been assessed through physicochemical and trace element analyses. The obtained data have been processed by using GIS and multivariate statistical tools and techniques. The water quality parameters like pH, EC, TDS, TH, Ca, Mg, Na, K, CO₃, HCO₃, Cl, SO₄ and NO₃ were investigated and compared with the Bureau of Indian standards (2012). The Soil samples have been evaluated for pH, EC, and micro and macro nutrients. The groundwater samples have been analyzed to determine their suitability for drinking, irrigation and industrial purposes. Moreover, graphical representation and spatio-temporal variation maps of physicochemical parameters have been illustrated to know the seasonal extent of ions. Groundwater classification based on TDS, TH, EC and Cl contents has been discussed to define the drinking suitability. In addition to that a new Integrated Water Quality Index (IWQI) has been developed and utilized to define the drinking suitability of groundwater samples. The groundwater suitability for irrigation is evaluated based on total ionic content of the water as reflected by EC, SAR, RSC, MAR, KR, SSP and PI etc, and its interpretation and spatio-temporal variation maps have been demonstrated. A precise summary of the present research work and the important conclusions drawn at the end of this research are presented in this chapter.

The pH of all the groundwater samples is seen to be above the desirable value of pH (6.5) in all the seasons and the permissible limit (8.5) in post monsoon season of the year 2014. In the year of 2014 only 22.45% groundwater samples exceeds permissible limit in pre monsoon season; while, 12.24% groundwater samples exceeds the permissible limit of pH in pre and post monsoon seasons of the year 2015. Majority of the groundwater samples exceeds the desirable limit of total hardness and few samples exceed the permissible limit of hardness in both the seasons. It is illustrated that, the concentration of TDS is increased in samples from Pakni site which can be attributed to leaching of salts from agricultural fields, and samples from Chincholi industrial area are influenced by the mixing of industrial effluents in
shallow aquifer during the process of percolation and infiltration which restricts the drinking suitability.

It is observed that, sample numbers 38, 39, 41 and 44 are the most affected samples which exceeds the PL of Ca, Mg, Na, Cl, NO₃, TDS and TH in all the seasons of 2014 and 2015. These samples are mainly located on the periphery of industrial area and pits filled with industrial effluents were discernible around them. Moreover, sample number 26 and 27 are highly enriched with potassium owed to the application of potassium rich fertilizers and sample number 39 is impacted from industrial effluent for the elevated concentration of potassium.

Davies De Weis Classification of TDS suggests that, the elevated concentration of TDS limits the suitability of drinking and majority of the groundwater samples which fall in useful for irrigation and unfit for drinking and irrigation category representing their unsuitability for drinking. In the year 2014, the 25% of groundwater samples are seen to be permissible for drinking. However, in the year 2015 it reduced to nearly 10% which depicts the mixing of contaminants along with surface runoff and discharge of industrial effluents in the study area. Sawyer and McCarty classification based on TH corroborates that; majority of the samples belongs to hard and very hard category. The higher values of Ca, Mg, Cl, and SO₄ increased the hardness of water. Richards classified groundwater samples based on their electrical conductivity values, which depicts that, sample numbers 1 to 8, 11, 14 to 17, 19, 23, 36, 37 and 48 in the year 2014 and sample number 1 to 3, 5 to 8, 15, 17 and 49 in the year 2015 found suitable for drinking; whereas, sample numbers 21 to 22, 25-27, 38-41, 44 and 45 in the year 2014 and sample number 19, 21 to 23, 25, 28, 32, 38 to 41 and 43 to 46 in the year 2015 found unsuitable for drinking due to the enrichment of salts.

The increased concentration of EC, Ca, Mg, Na, Cl, NO₃, SO₄ and TH is observed in the Central and North-West region of the study area; where, industrial inputs influences the groundwater quality. The high values owed to the discharge of untreated or partially treated industrial effluents into simple pits and natural drainage which ultimately enters into the aquifer systems through percolation and leaching. In South-Western region on the bank of Sina River few samples show the elevated values due to the accumulation of salts through long prevailing intense agricultural activities. Particularly in this site the potassium is elevated 8 to 10 folds than the rest of the samples.
The Water Quality Index (WQI) results have been classified into five different categories i.e. Excellent to Unsuitable. Throughout study area, majority of the groundwater samples fall in good category; considerable number of groundwater samples belong to marginal category and very few groundwater samples are poor and unsuitable for drinking purpose. In post monsoon seasons of the year 2015, unsuitable type of water category numbers of groundwater samples are increased to 6.12% (Sample numbers 39, 41 and 44) from 2.04% in post monsoon season of the year 2014. Conclusively, groundwater quality is mainly influenced by storm water runoff from agricultural and industrial area as well as domestic runoff. The groundwater sample number 39, 41 and 44 are mainly influenced by the leaching of industrial effluents. Groundwater sample numbers 26 and 27 are affected by the leaching of agrochemicals, mainly potassium, nitrate and chloride. Due to the elevated concentration of these parameters the overall quality is deteriorated. The groundwater samples located in the upper reaches (sample numbers 35, 36, 37 and 38) of the study area are suitable for drinking; hence, does not affected from industrial activities as well samples from lower reaches have good quality (sample numbers 28 to 32, 42, 43 and 46 to 49); but the samples located in Central region and on the periphery of industrial area (sample number 38, 39, 40, 41, 44 and 45) are severely contaminated due to industrial wastewater and represents their unsuitability for drinking. In addition to that, few groundwater samples in South and South-West direction also show their unsuitability for drinking. The Eastern side of the study area has good quality of water for drinking while the southern part is with moderate type of water quality in all the seasons.

In this study, Integrated Water Quality Index (IWQI) has been developed and applied to assess the groundwater suitability for drinking. The result reveals that, none of the groundwater sample fall in excellent type of water quality in all the seasons except post monsoon season of the year 2014. However, few groundwater samples found to be good for drinking and majority of the groundwater samples marginally suitable for drinking in pre and post monsoon seasons of the year 2014 and 2015. The marginal category samples can be used for drinking after some primary treatments. However, due to the lack of centralized drinking water treatment and supply facilities, people consume such water without any treatment; which may lead to ill effects on human health. The poor category of water i.e. (4 to 8%) suggests that, water quality is deteriorated from natural or anthropogenic activities, which restricted for drinking.
These samples were mainly affected due to the excessive contents of Na, Cl and SO$_4$ from domestic activities, which are due to the dearth of concrete sewerage line, poor sanitary seals and incompetent casing. The groundwater sample number 36 is affected due to high content of Ca, Mg, Na, Cl, SO$_4$, and NO$_3$; while, groundwater sample number 40 and 45 are impacted from Ca, Mg, Na, SO$_4$, NO$_3$ and TDS which is mainly because they are located on the periphery of industrial area representing the influence of industrial activities. The groundwater sample numbers 26, 27, 39, 41 and 44 have IWQI value more than 5 in all the seasons owed to elevated concentration of Ca, Mg, K, Cl, NO$_3$ and TDS. The concentration of all these parameters in groundwater is far above the modified permissible limits, while Na and SO$_4$ found to be less than desirable concentration. It seems that, ion exchange processes are dominant as cations like Ca - Mg replaced by Na and anions viz. Cl and NO$_3$ by SO$_4$. It is observed that sample numbers 26 and 27 are mainly enriched with K content due to the agricultural runoff and all the natural drainages from the study area confluences with Sina River at this region. Moreover, sample numbers 39, 41 and 44 are located in Chincholi industrial area represent the highest IWQI value owed to the release of untreated or partially treated industrial effluents in simple pits, in natural drains and on open land. The excessive Cl and NO$_3$ content represent the leaching of industrial and agricultural waste and inputs from the domestic drainage and open defecation. In sample number 20, 21 and 22 depicts the elevated concentration of NO$_3$ and TDS which may be owed to the leaching of contaminants from surface water tank (Surface water sample number 3) located in the upper reaches of these groundwater samples. The North and South West regions are mainly dominated by poor and unsuitable type of water quality. The North region is highly affected due to the anthropogenic inputs mainly contributed by industrial effluents. The small pits with untreated effluents are discernible at many places, through such pits the effluent leached to aquifer systems. Dug wells like 39, 41 and 44 located in the vicinity of industrial area are highly polluted due to this process. This index is very flexible to use and interested variables can be added to the calculation if a change in that indicator is of interest. Thus, the integrated water quality index will represent the optimal water quality for human health as per the standard guidelines. It will help to identify the drinking suitability at its best as per the standards. Prior to industrialization the water from these wells were used for drinking; but presently used only for domestic and irrigation activities. The effluent is discharged along with rain water in natural drainages during rainy season,
which pose vulnerability to groundwater resources in the study area. The South West region is mostly affected from the agricultural runoff due to the prevailed agriculture. This region is under good irrigation and irrigated through Ujani canal water, Sina river water and groundwater, the application of fertilizers and improper sealing of dug wells and bore wells lead to the mixing of wastes into the aquifer system. The pollution spread is limited to sample number 46; but considering with the present pace, in the nearby time sample numbers 32, 38, 42, 43, 47, 48 and 49 will be affected. Hence, there is need to control the discharge of industrial effluent from different industries affecting the groundwater quality to a considerable extent and also to manage the agricultural waste leaching through proper sealing of water resources. Groundwater based on many indices such as Sodium Adsorption Ratio (SAR), Magnesium Hazard (MH), Residual Sodium Carbonate (RSC), % Sodium (% Na), Soluble Sodium Percent (SSP), Permeability Index (PI), and Kelleys Ratio (KR) were used to determine irrigation suitability. It is observed that with respect to SAR, all the groundwater samples from pre and post-monsoon seasons of the year 2014 and 2015 fall in excellent category; except, one groundwater sample (Sample number 17) in post monsoon season of the year 2015 have SAR value more than 10 which belong to good category. The spatial distribution maps of SAR illustrates that, Western and Central Zones are affected and rest of the area remains safe in pre and post monsoon seasons of the year 2014. However, in the year 2015 Northeast and Western region shows elevated SAR value and few patches in southern region. MH values suggests that, 40.82%, 87.76% 87.76% and 48.98% groundwater samples fall in suitable category during pre and post monsoon seasons of the year 2014 and 2015 respectively. The Spatio-temporal distribution maps depict that, samples from industrial area and downstream of industrial area shows high MH value; in addition, few samples from Eastern portion also shows elevated values of MH in the year 2014. Moreover in the year 2015, samples located along the surface water runoff shows increased MH value. As concerned with RSC content, in post monsoon season of the year 2014, 89.80% groundwater samples are good, 4.08% are marginally suitable and 6.12% are unsuitable for irrigation; whereas, in post monsoon season of the year 2015, 91.84% are good, 6.12% are marginally suitable and 2.04% groundwater samples are unsuitable for irrigation. Spatial distribution map demonstrated that, throughout the seasons the lowest RSC values are recorded in groundwater samples which are at the periphery of industrial area and few samples located on the bank of
Sina River in South-West region of the study area. The lowest %Na values have been observed at groundwater sample numbers 29, 30, 32, 42, 38 and 40 which are located on the natural drainage flow line in pre and post monsoon seasons of the year 2014 and 2015. In addition, sample numbers 37, 44 and 45 also show lower values in all the seasons. The highest values are observed in North and East region of the study area. SSP classification shows that, 91.84%, 87.76%, 85.71% and 81.63% groundwater samples fall in suitable category in pre and post monsoon seasons of the year 2014 and 2015 respectively. The spatial distribution maps illustrates that, highest values of SSP were recorded in both the seasons at sample numbers 17, 26, 31, 36, 46, 47 and 48 while lowest SSP measured at sample numbers 1, 2, 11, 24, 29, 30, 32, 37, 39, 42, 44 and 45 in both the seasons of the year 2014 and 2015. According to permeability indices, 4.08% groundwater samples excellent, 71.43 and 73.47% samples represent good and 24.49 and 22.45% samples are unsuitable in pre and post monsoon seasons of the year 2014. In 2015, 6.12% and 2.04% samples are excellent, 69.39 and 79.59% fall in good category and 24.49 and 18.37% groundwater samples belongs to unsuitable category pre and post monsoon seasons respectively. The Spatio-temporal distribution maps of PI depicts that, maximum number of samples from Eastern region shows lower values and Western region in the periphery of industrial has more samples with higher PI values except few samples in southern region in both the seasons of the year 2014 and 2015. The Kelsey’s ratio suggests that, 18.37% groundwater samples are unsuitable for irrigation in both the seasons of the year 2014; whereas, 24.49% and 26.53% groundwater samples in post monsoon season of the year 2015 are unsuitable for irrigation. The spatial distribution map suggests that, sample numbers 17, 18, 26, 31, 36, 46 and 47 are found as hot spots having KR value more than one which is not suitable for irrigation in pre and post monsoon seasons of the year 2014. conversely, in the year 2015, pre monsoon season 9 groundwater sample shows high values and in post monsoon season samples get reduced 6 groundwater samples only. The USSL classification represent, 17.24%; 20.41%; 16.33% and 16.33% groundwater samples belongs to C₄S₂ category in pre and post monsoon seasons of the year 2014 and 2015 respectively. It suggests that, these samples are suitable for growing only a few salt-tolerant and semi-tolerant varieties crops. Generally, this type of water is undesirable for irrigation and it should not be used for low permeability soil. However, such water can be used for high salt-tolerant crops, i.e., sugarcane, cotton barley. The C₄S₃ field having very high salinity hazard
and high sodium hazard contains 2.04% samples in pre monsoon season of the year 2014, post monsoon season of the year 2014 and pre monsoon season of the year 2015 seasons whereas 2.04% groundwater samples from study area falls in very high salinity hazard and very high sodium hazard which is not suitable for any type of crops.

As industrial suitability of groundwater, EC values are high (>1500 µS/cm) in 77.55%, 75.51% and 93.88%, 91.84% groundwater samples which corroborate corrosive nature of water in pre and post monsoon seasons of the year 2014 and 2015 respectively. As concern with chloride content, the corrosive nature of groundwater is higher (10.20% and 14.29% samples) in pre monsoon and decreases (8.16 % and 10.20% samples) in post monsoon season of the year 2014 and 2015 due to mixing of recharge water. These samples located in the vicinity of industrial area having high chloride concentration by industrial effluent discharge. The sulphate concentration in groundwater depicts that, in pre and post monsoon seasons of the year 2014, 46.94% samples; while 46.94% and 53.06% groundwater samples are hard incrusting type in pre and post monsoon seasons of the year 2015 respectively. The corrosivity ratio illustrates that, all the groundwater samples are exceeding the threshold limit of 1, hence, not well-suited for industrial operations in all the seasons.

The Langelier saturation Index (LSI) result suggests that all the groundwater samples are scale forming and less corrosive in nature. From the spatial distribution maps it is found that, in pre and post monsoon seasons of the year 2014 very few water samples having corrosive nature in the Western region; whereas, all the groundwater samples are non-corrrosive in nature in pre and post monsoon seasons of 2015. Ryznar classification depicts that, 69.39% and 48.98% groundwater samples from pre-post monsoon seasons of 2014; moreover, 28.75% and 48.98% groundwater samples from pre-post monsoon seasons of 2015 fall in aggressive category means there is no risk of corrosion in all the seasons. However, sample number 17 and 47 represents the water is very aggressive thus unsuitable for transportation through pipes. The spatial distribution maps of Ryznar Stability Index (RSI) infers that, there is no risk of corrosion in industrial and agricultural region located in Central and South-West region; while, few samples from Eastern and Northern region shows little risk of corrosion. Overall, this index suggests that groundwater from the study area is suitable as it is less corrosive in nature. It is observed from Puckorius Scaling Index (PSI) index, 95.95% groundwater sample in pre monsoon and 95.92% groundwater
samples in post monsoon seasons of the year 2014; while, 95.92% and 91.84% groundwater samples from pre and post monsoon seasons of the year 2015 are scale forming and very few samples are corrosive in nature. Spatial distribution map depicts that, sample number 44 located in industrial area shows the corrosive nature in all the season except in pre monsoon 2014. Larson Scold Index (L-S Index) demonstrated that groundwater samples value > 1.2 are higher and L-S index value < 0.8 are lowest in all the seasons except post monsoon season of 2014. The spatial distribution maps L-S index shows that the higher values are observed in industrial area at sample numbers 38, 39, 41 and 44 in all the seasons of the year 2014 and 2015, it suggests that at these locations corrosion can be expected.

In pre and post monsoon seasons of the year 2014, piper plot authenticate that alkaline earth (Ca + Mg) exceeds alkalis (Na + K) in case of 38 groundwater samples i.e. (77.55 %) of the study area. The alkalis content exceeds alkaline earth in 11 groundwater samples (22.44%) of pre and post monsoon season. While 46 groundwater samples (93.87%) and 38 groundwater samples (77.55%) represents strong acid (Cl + SO₄) exceeds weak acid (CO₃ + HCO₃) hydrochemical facies. Conversely, 3 groundwater samples (6.12%) and 11 groundwater samples (22.44%) represents weak acid exceeds strong acid hydrochemical facies in pre and post monsoon seasons respectively. However, in the year of 2015, it is seen that, 35 groundwater samples (71.42%) represent alkaline earth (Ca+Mg) exceed the alkalis (Na+K) hydrochemical facies in both the seasons of the year 2015. While 14 groundwater samples (28.57%) represent alkali exceeds the alkaline earth hydrochemical facies in pre and post monsoon season of the year 2015. On the other hand it is observed that, 46 (93.87%) and 43 (87.75%) groundwater samples represent strong acids (SO₄+Cl) exceed weak acids (CO₃+HCO₃) hydrochemical facies in pre and post monsoon season of the year 2015. While 3 (6.12%) and 6 (12.24%) groundwater samples represent weak acid exceeds strong acid hydrochemical facies in pre and post monsoon seasons of the year 2015. The Schoeller plot clearly indicates the dominance cations is Mg > Ca > Na > K and for anions as Cl > HCO₃ > SO₄ > NO₃ in pre and post monsoon season of 2014 and 2015. Few samples show the dominance potassium due to the application of potassium rich fertilizers. The elevated concentration of chloride is owed to domestic and industrial activities while Ca is owed to the basaltic lithology present in the study area. Durov plot accomplished that, the waters of the study area are classified as mixed type of water such as Ca-Mg-Cl.
and Mg-Na-Cl. Sodium and magnesium ions are high in majority of the samples; while, Cl and CO₃ are dominant anions in the groundwater samples. The Ca+Mg vs. Cl+SO₄ suggests that, majority of the samples in pre and post monsoon samples are clustered due to ion exchange process, it may indicates that, excessive Cl and SO₄ have been contributed from agricultural runoff. The strong positive correlation between them represents the permanent type of hardness. The Ca vs Na plot illustrates that, calcium content is the most dominating cation over the sodium in pre and post monsoon seasons of the year 2014 and 2015.

The plot of Ca/Na vs. HCO₃/Na and Mg/Na showed silicate weathering prevailing in this area while few data points suggest evaporate and carbonate dissolution. The presence of lime kankar supports carbonate weathering. The higher value of Na/Cl ratio in the study area suggests the possible source of Na is silicate weathering and ratio less than 1 indicates the possibility of ion exchanges of Na with for Ca and Mg in clay particles. Scatter plot of Cl vs. Ca + Mg indicate strong correlation in pre and post monsoon seasons of the year 2014 and 2015. The salinity is increased due to increased chloride and Ca + Mg contents in the study area. In pre monsoon season of the year 2014 majority of the samples are Na-HCO₃ type while in post monsoon Na-SO₄ type. The samples from industrial area shows that they have more negative values in both the seasons of the year 2014. In the year 2015, in pre monsoon season few samples are Na-HCO₃ type but in post monsoon season except 4 samples all the sample represent the Na-SO₄ type. In the year 2015, groundwater samples 19 to 29 also depicts the lowered values which may be owed to the agricultural inputs as these samples are located in agriculture area. The meteoric genesis index suggests that very few samples are shallow meteoric percolation type, whereas majority of the samples represent deep meteoric type percolation in both the seasons of 2014 and 2015. The samples from Chincholi industrial area show the lowest values in both the seasons indicates deep meteoric type of water.

The Cl and NO₃ are strongly correlated with EC, Ca, Mg, Na and SO₄; hence, contributing to the salinity of water in all the seasons. The negative correlation of Cl with CO₃ and HCO₃ indicates the anthropogenic origin of chloride. In pre monsoon season, the chloride has strong association with EC, NO₃ and TDS. It supports the dominancy of chloride ions as depicted in piper plot. The strong positive correlation has been found between Cl and NO₃ in pre and post monsoon seasons of the year 2014 and 2015. It signifies the source of origin of chloride and nitrate may be same.
i.e. domestic sewage, agriculture waste and industrial waste water. The elevated nitrate and chloride content corresponds with intensive agriculture and discharge of industrial effluents and application of nitrogen rich fertilizers as additional source. These samples belonging to unpolluted and slightly polluted category are situated in residential or barren land use, where anthropogenic activities are meager. However, samples belonging to moderately and highly polluted category are located in industrial and agricultural area; due to the percolation of industrial effluent and agricultural waste the composition of these samples (sample number 38, 39, 41 and 44) have been altered in recent time. The positive loadings of Cl and NO$_3$ as first factors indicate their anthropogenic origin, possibly derived from industrial effluents and domestic waste. The high loading of TH is controlled by the Mg, Cl and SO$_4$ suggests the permanent type of water hardness which has been demonstrated. Na and Cl concentrations are contributed by anthropogenic activities such as agricultural runoff, industrial effluent and domestic sewage during pre and post monsoon seasons. K is included in PC2 in both seasons as a result of major contributions from the application of potassium rich fertilizers. The high loadings of Mg, Na, Cl and SO$_4$ corroborates that, groundwater is mainly influenced by anthropogenic sources. The high loadings of Na, Cl, SO$_4$ and HCO$_3$ show groundwater quality is controlled by salinity and alkalinity deriving factors.

The comparative assessment of non-industrial (sample number 1 and 2) and industrial surface water samples (sample number 3 to 6) clearly illustrates that the untreated effluent is mixed into the surface water tanks present in industrial area only. The sample number S6 is worst affected may be due to the mixing/recharging from the common effluent treatment plant followed by sample number 5, 4 and 3. The sample number 1 shows TDS concentration higher than the desirable limit but below the permissible limit of the BIS in all the seasons of the year 2014 and 2015. The sodium and chloride content of all the samples fall below the desirable value defined by the BIS in all the seasons of the year 2014 and 2015. The low concentration of nitrate in post monsoon season as compared with pre monsoon season in both the years is owed to the dilution caused by rainwater. In nutshell, the non industrial area samples 1 and 2 are not affected from industrial activities but affected to a lesser extent due to domestic activities. The waster sample from industrial area have average values of pH, EC, TDS, TH, Ca, Mg, Na, K, Cl and NO$_3$ above the permissible limit of the BIS (2012) which clench the water appropriateness for domestic and agriculture. The field
observation reveals that these sites appear as wastewater storage rather than surface water tanks. Such, dejectedly polluted water tanks will act as plausible source of contamination to aquifers tapped below it. The highest value of Zn is observed at sample number 6 located in industrial; while, lowest value is observed at sample number 2. The surface water samples from non-industrial area have concentration below 0.15 ppm and samples from industrial area have more than 0.15 ppm especially sample numbers 4, 5 and 6 have around 0.3 ppm. The highest lead content is observed in sample number 5 (1.568 ppm), followed by 6 (1.41 ppm), and 3 (1.112 ppm). The sample number 1 (0.65 ppm) and 2 (0.52 ppm) have very low concentration. The highest cadmium i.e. more than 0.1 ppm is found at sample number 4 and 5 while lowest cadmium is at sample number 1. Only one sample i.e. sample number 6 have very high Mn content (1.006 ppm) followed by sample number 5 (0.643 ppm) and sample number 1 has very low Mn concentration i.e. 0.126 ppm. The lowest chromium content is found in non industrial area i.e. 0.038 and 0.033 ppm at sample number 1 and 2 respectively whereas in industrial area the highest concentration is observed at sample number 5 which is 0.094 ppm and at sample number 4 is 0.071 ppm. The field observation reveals that these sites appear as wastewater storage tanks rather than natural surface water tanks. Such, miserably polluted water tanks will act as plausible source of contamination to aquifers tapped below it. Therefore, there is heavy need to avoid the mixing of industrial effluents and proper treatment to restore them to natural state.

The lowest concentration of zinc is observed at sample number 33 in pre monsoon season while highest concentration is recorded at sample number 42 in post monsoon season. The nickel concentration ranges from 31.4 to 455 ppb (avg. 276.38 ppb) and 7.0 to 66 ppb (avg. 38 ppb) in pre and post monsoon season respectively. The highest concentration of nickel found at sample number 42 in pre monsoon season and sample number 3 depicts the lowest concentration in post monsoon season. The maximum concentration of lead is observed at sample number 42 in pre monsoon season and sample number 48 shows the minimum concentration in post monsoon season. In pre monsoon season cadmium content swerves from 5.7 to 998 ppb (avg. 31.66 ppb) moreover, 31 to 1956 ppb (avg. 365.5 ppb) in post monsoon. In groundwater samples iron content ranges from 180 to 1847.0 ppb (avg. 733.61 ppb) in pre monsoon and 11 to 158 ppb (avg. 66.5 ppb) in post monsoon season. Pre monsoon has highest manganese concentration whereas post monsoon season shows lowest
concentration. Sample number 42 located in industrial area shows highest Mn value in pre monsoon season while in post monsoon season lowest Mn value of manganese is observed at sample number 4. The maximum concentration of copper is found at sample number 39 in pre monsoon season and minimum concentration is observed at sample number 7 in post monsoon season. The copper was undetectable in post monsoon season at sample numbers 16, 17 and 18 whereas maximum concentration is recorded at sample number 42 in post monsoon season.

Heavy metal Evaluation Index (HEI) corroborates that, in pre monsoon season the HEI values are very high as compared to post monsoon season of the year 2014 which may be attributed to the dilution due to rain water. Classification of groundwater samples based on HEI depicts that, 26.53 % groundwater samples are within the low zone in post monsoon season, 61.22% and 67.35% groundwater samples fall within the medium zone in pre and post monsoon season respectively. However 38.77% groundwater samples in pre monsoon and 6.12% samples from post monsoon season fall within the highly polluted category. Sample numbers 36, 42 and 43 located in industrial area are mostly polluted samples.

The concentration of EC suggests that all the soil samples and two sediment samples are suitable for crop but only one sediment sample from ETP Lake is not suitable for crops. The organic carbon content found very less in 2 soil samples collected from industrial area (sample number IL 1 and IL4) and 2 sediment samples collected from effluent pond and near Sadguru agro, low in 2 soil samples (IL 2 and IL3) and 1 sediment samples (ETP lake). Majority of micronutrients in the soil sample IL1 and all the sediment samples have medium to high content. It is corroborated that, all the soil and sediment samples have high concentration of boron, iron and sulfur. Anthropogenic sources of iron include the iron and steel industry, sewage and dust from iron mining Iron sulphate is also used as a fertilizer and herbicide.

A total three pollution zones and four surface water tanks have been indentified throughout the study area. Out of three different pollution zones two zones have been identified on the western part of the Chincholi MIDC area. These two groundwater pollution zones are separated by the water divide which is inferred on the basis of drainage pattern of the study area. These two groundwater pollution zone reveals the impact of discharge of untreated industrial effluent on the aquifer. Third groundwater pollution zone is located in the South West part on the bank of Sina River. This zone is surrounded by agricultural fields, which suggest that agricultural
activities are influencing the groundwater quality in that area. For the present research work four different surface water tanks were selected to identify the impact of Chincholi MIDC area on the surface water quality. All the surface water tanks are dejectedly polluted and found unsuitable for drinking, irrigation and industrial purposes.

In a nutshell it is corroborated that the discharge of industrial effluent has impacted the groundwater at few locations and surface water quality in the Chincholi industrial area while samples located away from industrial area are in their natural state except few samples from South-Western region are influenced by agricultural activities.

**Recommendations**

There is a need to refine the resolution of groundwater quality observations in areas of suspected agricultural and industrial impacted groundwater.

The monitoring of a polluted dug wells and bore wells for longer duration may be required to validate the results of the risk assessment and to observe the pollution plume behavior.

The waste water from industries should be treated properly (at least primary and secondary treatment) prior to discharge into land/water bodies. For the better management of water quality industries should initiate the zero discharge concepts and people should exercise the proper sanitation systems to diminish contamination problems.

The common drainage in villages are not properly concretized which increases the risk of contamination.

The Immediate sealing of contaminated wells so as to prevent use of water from these wells for drinking as well as irrigation to reduce ill effects on human health.

In agricultural areas the dug wells and bore wells are not protected from agricultural runoff, thus contaminated water enters directly into the aquifer, which signifies the proper measures need to be taken.

To prevent nitrate contamination of groundwater must focus on the major sources of human induced nitrogen (fertilizer and manure) and the agricultural practices that can minimize the losses of nitrogen from these sources. Promote the implementation of the agronomic best management practices (BMPs) for nitrogen
fertilizer and manure, which account for the right nitrogen rate, application timing, source and placements. In addition to that increasing the adoption of cover crops, growing perennial crops such as alfalfa, retiring land from production, conservation easement practices, grazing, alternative cropping varieties that require less nitrogen, and other new technologies will also play crucial role for management of excessive nitrogen.

The success of the above all the suggested recommendations are dependent upon the local participation of farmers, citizens, and local governing bodies.

A contaminant transport model may also support the assessment of groundwater flow and prediction of the extent of negative impacts to down-gradient areas. Conclusions of this study may assist in the extended support to new researchers, local inhabitants and developing strategies for policy makers for the sustainable management of groundwater resources in changing land use patterns.