# 10

# Assessment of Groundwater Quality in Industrial Areas of Delhi, India by Indexing Method

Papiya Mandal[1]* and Sunil Kumar[2]
[1]National Environmental Engineering Research Institute (NEERI), Delhi Zonal Laboratory, New Delhi,
[2]NEERI, Kolkata Zonal Laboratory, Kolkata, India

## 1. Introduction

The GW contamination has become a grave problem due to rapid growth of population, expansion of irrigation activities, industrialization and high rate of urbanization in India. Over the last few decades, the land and water use patterns have changed drastically in India. GW is an important resource for drinking purpose which contains over 90% of the fresh water resources (Sabahi et al. 2009). The untreated industrial effluents discharged into the surface water sources cause severe GW pollution in the industrial belt (Mondal et al. 2005). People are becoming more aware of the complexity of the nature and the delicate balance that exist with the global ecosystem (Ahmet et al. 2006). The National Capital Territory (NCT) of Delhi, India is a water scare state with a deficit in the drinking water supply to its resident (Shekhar et al. 2009). The Yamuna flood plain is only potential fresh GW resources in Delhi. The exploration, exploitation and unscientific management of GW resources in the NCT of Delhi, India have posed a serious threat of reduction in quantity and deterioration of quality (Adhikary et al. 2009). In Delhi, GW level has gone down approximately 8 m per year in the last 10 years which is at the rate of about 0.8 m per year (CGWB 2006). Annual replenishable GW sources of NCT Delhi are about 297 million cubic meter while the GW draft is about 480 million cubic meter (Chatterjee et al. 2009). Thus out of nine districts, seven districts of NCT Delhi have been categorized as overexploited with regards to the dynamic GW resources (CGWB 2006).The city is forced to meet 50 % of its water requirement from GW (Kumar et al. 2006). Solid and liquid waste emanating from the industry are inevitability the by products of manufacturing process which contains toxic chemicals and trace metals. The open unlined drains and availability of dumping of toxic industrial waste in nearby recharge of GW areas, act as the source of GW pollution (Dutta et al. 1997).

The application of statistical approaches *viz.,* Pearson correlation coefficient, linear regression analysis and water quality index (WQI) offer a better understanding about the GW quality. WQI is a mathematical instrument used to transform large quantities of water

*Corresponding Author

quality data into a single number, which represents the water quality level (Saeedi et al. 2010). It is useful to identify the suitable location of GW resources in a particular region.WQI is generally calculated from the point of view of the suitability of GW for human consumption (Sikdar et al. 2007). It provides information to the citizens and policy makers. Moreover, GW quality assessment is important because of spreading water borne diseases. Several epidemiological studies advocated that about 80% of the diseases in the world are due to poor quality of drinking water. The present paper deals with the assessment of GW contamination, identification of suitable locations of GW resources and mitigation measures suggested for its sustainable management.

## 2. Materials and methods

### 2.1 Study area

Naraina industrial area (NIA) in Delhi covers approximately 2000 industries in two phases, out of which, phase I has approximately 700 industries. The total area covered by phase I is 114.5 acres. It has a latitude and longitude of 28 $^{0}$38´´3.1´and 77$^{0}$ 8´´0.1´, respectively. In Phase I, 400 industries are classified as green category and 300 industries are classified as orange category by Central Pollution Control Board (CPCB), Delhi according to pollution potential. The green industry includes garment, footwear, packaging, printing etc. The orange industry includes dye, pan masala, electroplating, service station etc. Piped water supply of Delhi Jal Board (DJB) at NIA Phase I is not enough, so people are to some extent dependent on GW. The wastewater collection system comprises of sewer and open brick masonry drain. Wastewater from both the phases I & II are discharged into the trunk sewer near Samta Ashram. The sampling locations of GW were identified through GIS map as depicted in (Fig. 1).

### 2.2 Sampling

The characterization of GW quality at every location is not always feasible in view of time and cost involvement for sample collection. So selectively ten numbers of GW samples were collected in clean polyethylene bottles from manually operated tube wells in the month of April 2009, covering entire NIA phase I. The bottles were washed thoroughly with dilute nitric acid and then rinsed with distilled water. Prior to sampling, sampling bottles were rinsed thoroughly with GW to be analyzed. For heavy metals analysis, separate glass bottles were used for sampling. Water samples were acidified with 1.5 ml nitric acid. Collected samples were protected from direct sunlight during transportation, refrigerated at 4 $^{0}$C and analysed within 2 to 3 days. Glassware's used for analyses were rinsed thoroughly with nitric acid followed by double distilled water before use.

### 2.3 Methodology

Each samples were analyzed for 13 physico-chemical parameters, such as pH, turbidity, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), sodium ($Na^+$), potassium ($K^+$), calcium ($Ca^{++}$), magnesium ($Mg^{++}$), chloride ($Cl^-$), fluoride ($F^-$), nitrate ($NO_3^-$) and sulphate ($SO4^{--}$). pH, turbidity, EC were measured by pH meter, turbidity meter and conductivity meter respectively. TDS was determined as the residue left after evaporation of filtered samples. The Whatman filter paper no.42 was used for filter the samples. TH, $Ca^{++}$ and $Mg^{++}$ were determined by EDTA titration method. $Na^+$ and $K^+$ were determined by flame photometric method. The amount of $Cl^-$ present in GW was measured by silver nitrate method. The $F^-$ concentration was measured by SPANDS spectrophotometric method. The phenol disulfonic acid method was employed for estimation of $NO_3$. $SO_4$ amount was derived from turbidimetric method. Trace elements namely iron (Fe), copper (Cu), lead (Pb), chromium (Cr) and cadmium (Cd) were analyzed using atomic absorption spectrophotometer (AAS). Analyses were carried out as per standard methods of APHA (20th edition, 1998). All units except pH, turbidity and EC were measured in $mgl^{-1}$. Turbidity was measured in NTU and EC in was measured µmohs/cm.

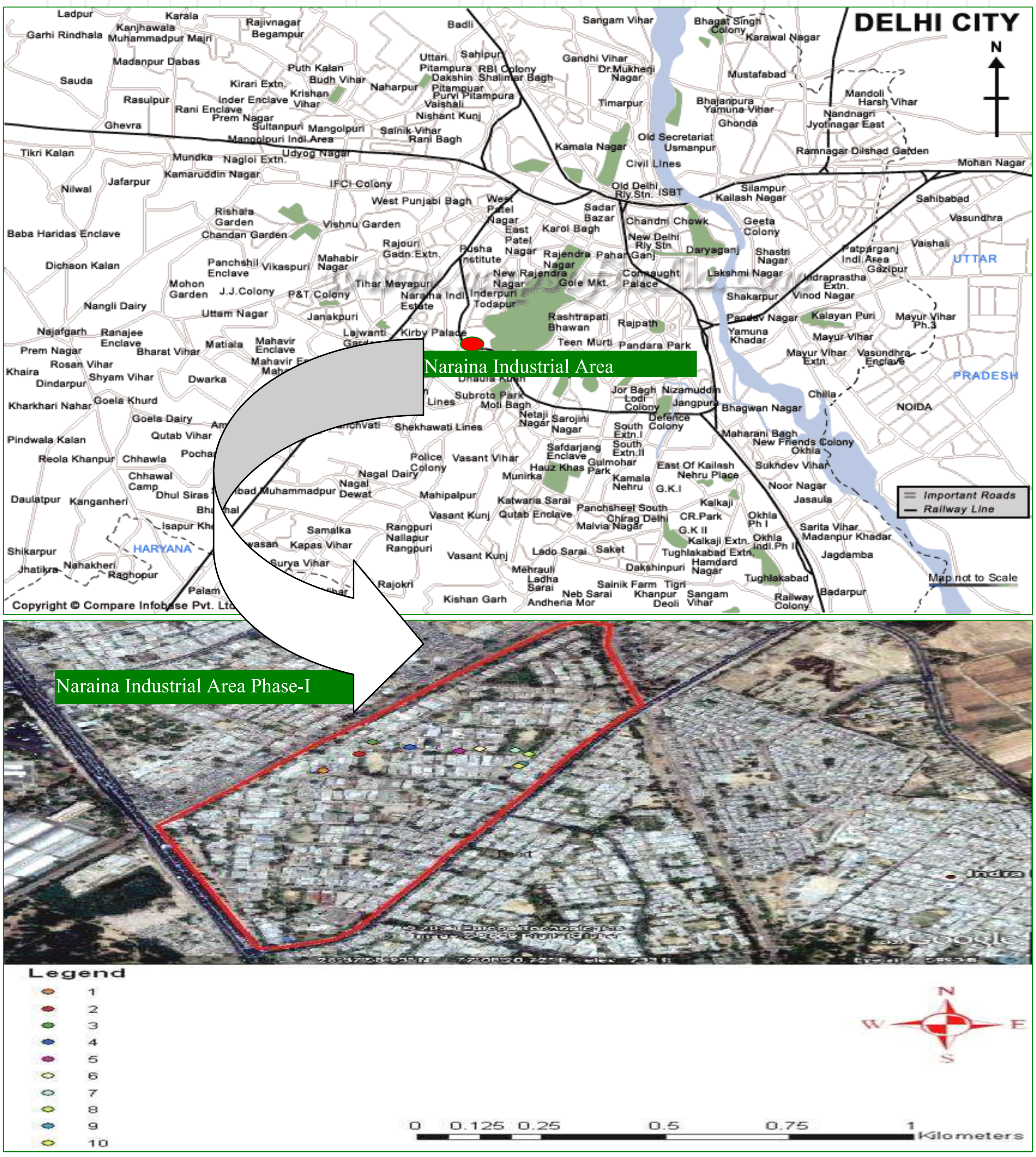



Fig. 1. Locations of GW Sampling

### 2.4 Statistical analysis

The Pearson's correlation coefficient and linear regression were performed between EC and chemical constituents. The significant correlation coefficient (r ≥ 0.7) and linear regression with EC is summarized in Table 1.

| Parameter | Parameters | Correlation Coefficient ( r ) | Regression | Regression Coefficient ($R^2$) |
|---|---|---|---|---|
| EC | TDS | 0.995 | 0.5501 EC + 22.72 | 0.99 |
| | TH | 0.969 | 0.3537 EC -37.29 | 0.94 |
| | $Ca^{2+}$ | 0.851 | 0.0679 EC + 25.82 | 0.72 |
| | $Mg^{2+}$ | 0.868 | 0.0449 EC - 24.84 | 0.76 |
| | $Na^{+}$ | 0.840 | 0.0589 EC + 12.68 | 0.71 |
| | $K^{+}$ | 0.822 | 0.0027 EC -1.03 | 0.69 |
| | $Cl^{-}$ | 0.928 | 0.2228 EC -125.01 | 0.86 |
| | $NO_3^{-}$ | 0.882 | 0.0049 EC -1.74 | 0.91 |
| | $SO_4^{--}$ | 0.80 | 0.0818 EC -33.26 | 0.64 |

Table 1. Significant correlations coefficient (r ≥ 0.7) and linear regressions with EC

### 2.5 Characterization of GW Quality

The average concentration of physico-chemical parameters of GW samples and its percentage compliance with drinking water quality standard BIS (10500, 1991) are delineated in Table 2.

| Parameters | Range | | Average | Indian standard (desirable Limit) | Percent compliance |
|---|---|---|---|---|---|
| | Minimum | Maximum | | | |
| pH | 7.7 | 8.2 | 7.7 ± 0.4 | 6.5-8.5 | 0 |
| Turbidity | 0.25 | 1.47 | 0.65 ± 0.4 | 5 | 100 |
| EC | 998 | 2180 | 1442 ± 402 | – | – |
| TDS | 560 | 1225 | 816 ± 222 | 500 | |
| TH | 290 | 730 | 473 ± 147 | 300 | 10 |
| $Na^{+}$ | 47 | 140 | 98 ± 28 | – | – |
| $K^{+}$ | 1.2 | 5.1 | 2.9 ± 1.3 | – | – |
| $Ca^{++}$ | 75 | 160 | 124 ± 32 | 75 | 10 |
| $Mg^{++}$ | 24 | 82 | 40 ± 21 | 30 | 50 |
| $Cl^{-}$ | 68 | 370 | 196 ± 96 | 250 | 70 |
| $F^{-}$ | 0.37 | 1.42 | 0.94 ± 0.5 | 1 | 50 |
| $NO_3^{-}$ | 3 | 9 | 5 ± 2 | 45 | 100 |
| $SO_4^{--}$ | 32 | 160 | 85 ± 41 | 200 | 100 |
| Fe | 0.01 | 0.09 | 0.04 ± 0.03 | 0.3 | 100 |
| Cu | 0.01 | 0.08 | 0.04 ± 0.02 | 0.05 | 70 |
| Pb | 0.01 | 0.08 | 0.03 ± 0.03 | 0.05 | 80 |
| Cr | 0.01 | 0.09 | 0.04 ± 0.03 | 0.05 | 80 |
| Cd | 0.01 | 0.07 | 0.04 ± 0.02 | 0.01 | 20 |

*All units except pH, Turbidity and EC are in mg/l, *Turbidity in NTU, *EC in µmohs/cm, ± Standard Deviation

Table 2. Comparison of GW quality with Indian Drinking Water Quality Standard (BIS 10500, 1991)

WQI is a useful tool used to obtain a comprehensive picture of GW quality and to identify the suitable location of GW resources in a particular region. For WQI analysis, 14 selected parameters in each sample were assigned a weight ($w_i$) according to its relative importance in the overall water quality for drinking purpose. Four numbers of selected parameters *e.g.*, $NO_3^-$, Pb, Cr and Cd were assigned maximum weight of 5 due to their major importance in water quality assignment. Cu is given minimum weight of 2 as it plays low significant role in the water quality assignment. The weight of other parameters varied from 2 to 5 depending on their significant importance in water quality determination. The relative weight of chemical parameters is shown in Table 3.

| Chemical Parameters | Indian Standard (BIS 10500,1991) | Weight ($w_i$) | Relative Weight $W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$ |
|---|---|---|---|
| TDS | 500–2000 | 4 | 0.0784 |
| pH | 6.5–8.5 | 4 | 0.0784 |
| TH | 300–600 | 2 | 0.0392 |
| $Cl^-$ | 250–1000 | 3 | 0.0588 |
| $SO_4^{--}$ | 200–400 | 4 | 0.0784 |
| $NO_3^-$ | 45–100 | 5 | 0.0980 |
| $F^-$ | 1–1.5 | 4 | 0.0784 |
| $Ca^{++}$ | 75–200 | 2 | 0.0392 |
| $Mg^{++}$ | 30–100 | 2 | 0.0392 |
| Fe | 0.3–1.0 | 4 | 0.0784 |
| Cu | 0.05–1.5 | 2 | 0.0392 |
| Pb | 0.05 | 5 | 0.0980 |
| Cr | 0.05 | 5 | 0.0980 |
| Cd | 0.01 | 5 | 0.0980 |
| | | $\sum w_i = 51$ | $\sum W_i = 1.000$ |

Table 3. Relative weight of chemical parameters

For each parameter, lower value indicates desirable level and higher level indicates permissible limit of BIS 10500, 1991.

In the second step, the relative weight ($W_i$) was calculated using following equation:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad (1)$$

Where $W_i$ =relative weight, $w_i$ =weight of each parameter and n = number of parameters. In the third step, the quality rating scale (qi) was calculated using equation 2:

$$q_i = (C_i / S_i) \times 100 \quad (2)$$

Where, $q_i$ = quality rating, $C_i$ = concentration of selected parameters in mg/L, and $S_i$ = Indian drinking water standard (BIS 10500, 1991) of selected parameter in mg/l

$$SI_i = W_i q_i \quad (3)$$

Where $SI_i$ = Sub index of *i*th parameter.

$$WQI = \sum SI_i \tag{4}$$

Where WQI= Water quality Index.

The WQI is categorized into five types from excellent water to water unsuitable for drinking. Water quality classification based on WQI value as presented in Table 4. The correlation coefficient matrix of chemical constituents is presented in Table 5.

| WQI Value | Water Quality |
|---|---|
| <50 | Excellent |
| 50-100 | Good Water |
| 100-200 | Poor water |
| 200-300 | Very poor water |
| >300 | Water unsuitable for drinking |

Table 4. Water quality classification based on WQI value

| Parameters | TDS | TH | Na | K | Ca | Mg | Cl | F | $NO_3$ | $SO_4$ | Fe | Cu | Pb | Cr | Cd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TDS | 1 | | | | | | | | | | | | | | |
| TH | .98** | 1 | | | | | | | | | | | | | |
| Na | .82** | .69* | 1 | | | | | | | | | | | | |
| K | .81** | .78** | .77** | 1 | | | | | | | | | | | |
| Ca | .88** | .88** | .62 | .60 | 1 | | | | | | | | | | |
| Mg | .86** | .89** | .62 | .80** | .58 | 1 | | | | | | | | | |
| Cl | .90** | .87** | .76* | .70* | .76* | .79** | 1 | | | | | | | | |
| F | .07 | .15 | -.20 | .04 | -.10 | .39 | .02 | 1 | | | | | | | |
| $NO_3$ | .85** | .85** | .73* | .73* | .71* | .81** | .85** | .05 | 1 | | | | | | |
| $SO_4$ | .78** | .77** | .65* | .79** | .50 | .86** | .78** | .49 | .76* | 1 | | | | | |
| Fe | .07 | .54 | .15 | -.10 | -.40 | -.57 | -.14 | -.30 | -.43 | -.10 | 1 | | | | |
| Cu | -.43 | .44 | .29 | .50 | .23 | .55 | .16 | .76* | .25 | .62 | -.37 | 1 | | | |
| Pb | .14 | .16 | .21 | .14 | .39 | .14 | -.12 | -.50 | .19 | .10 | -.35 | .38 | 1 | | |
| Cr | .68 | .57 | .66 | .37 | .61 | .41 | .58 | .02 | .24 | .43 | .074 | .23 | .24 | 1 | |
| Cd | -.03 | .07 | -.18 | .02 | .16 | -.04 | -.34 | .06 | -.09 | -.20 | - .80* | .31 | .57 | -.60 | 1 |

* Correlations are significant at the 0.05 level (2 tailed) ** Correlations is significant at the 0.01 level (2 tailed)

Table 5. The correlation coefficient matrix of chemical constituents

### 3. Results and discussion

The average pH of samples was 7.7 ± 0.4 which is within the permissible limit of BIS, recommended as 6.5 to 8.5. Turbidity was much lower than the desirable limit of BIS. EC was observed to vary from 998 to 2180 µmohs/cm which was alarmingly high. EC had strong correlation with TDS, TH, $Cl^-$ and $NO_3^-$ as $R^2 \geq 0.9$. EC had moderate correlation with $Ca^{++}$, $Mg^{++}$, $Na^+$, $K^+$ and $SO_4^{--}$ as $R^2 \geq 0.5$. The average concentrations of TDS and TH were found to fluctuate between 560 to 1225 mg/l and 290 to 730 mg/l, respectively as BIS recommended the safe limit of 500 and 300 mg/l, respectively. Concentration of water by evaporation and contamination of water due to industrial and municipal waste disposals might have caused a huge increase in the dissolved solids (Mondal et al. 2007). Sometimes high TDS is harmful for kidney and heart patient. It may cause laxative or constipation problem. The hardness is generally caused due to Ca and Mg ions present in the water samples. The high degree of hardness in the study area can definitely be attributed to the disposal of untreated/improperly treated sewage and industrial wastes (Shankar et al. 2008). The average concentrations of $Ca^{++}$ and $Mg^{++}$ were recorded 124 ± 32 and 40 ± 21 as BIS recommended 75 and 30 mg/l, respectively. The average $Cl^-$ concentration of samples was 196 ± 96; indicated 70 % of samples were complying with BIS. In general, $Cl^-$ is widely available in various forms in all type of rocks. The $Cl^-$ is also considered to be conservative in GW of Delhi area (Datta et al. 1996). Sometimes soil porosity and permeability also plays a key role in increasing the $Cl^-$ concentration in the GW. The average $F^-$ concentration of samples were recorded 0.94 ± 0.5.In India, 25 million people in 8700 villages are consuming high fluoride water (Handa et al. 1998).The highest fluoride concentration in the present study area was 1.42 mg/litre. The average $NO_3^-$ concentration of samples was 5 ± 2. $NO_3^-$ concentration was very low which indicated that GW was not contaminated due to agricultural runoff. The average $SO_4^{--}$ concentration of samples was 85 ± 41 which was found within the safe limit as prescribed by BIS. The average concentrations of anion and cation of GW sample are presented in Figs. 2 and 3.

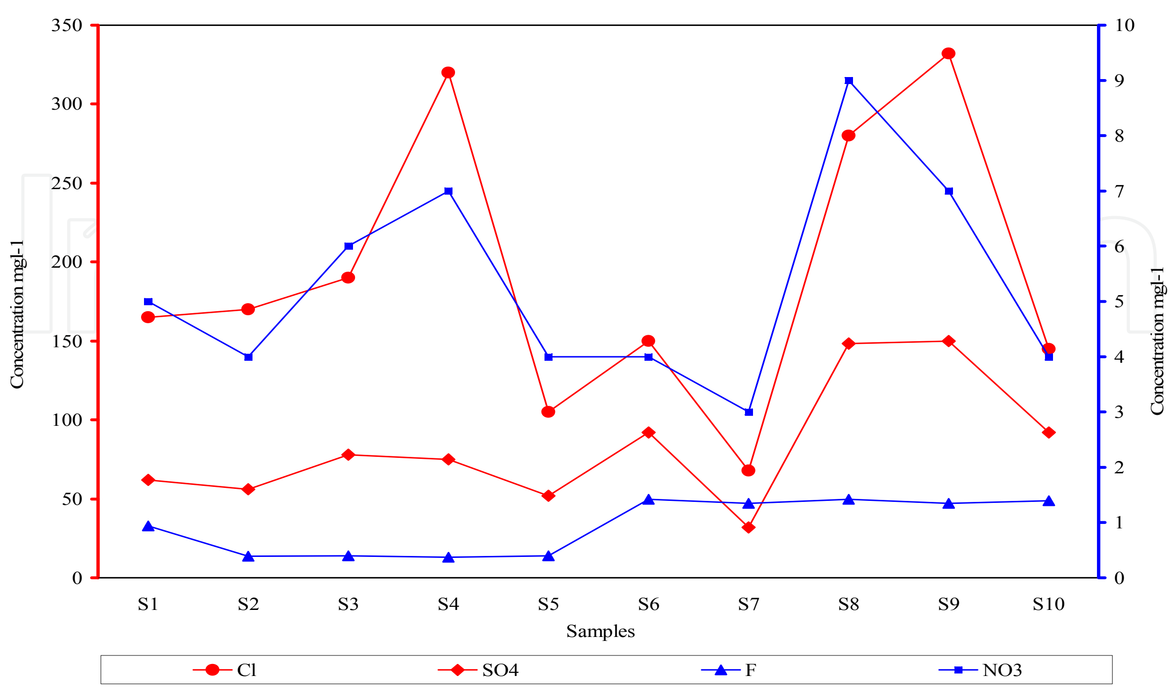



Fig. 2. Average concentrations of anion of GW sample

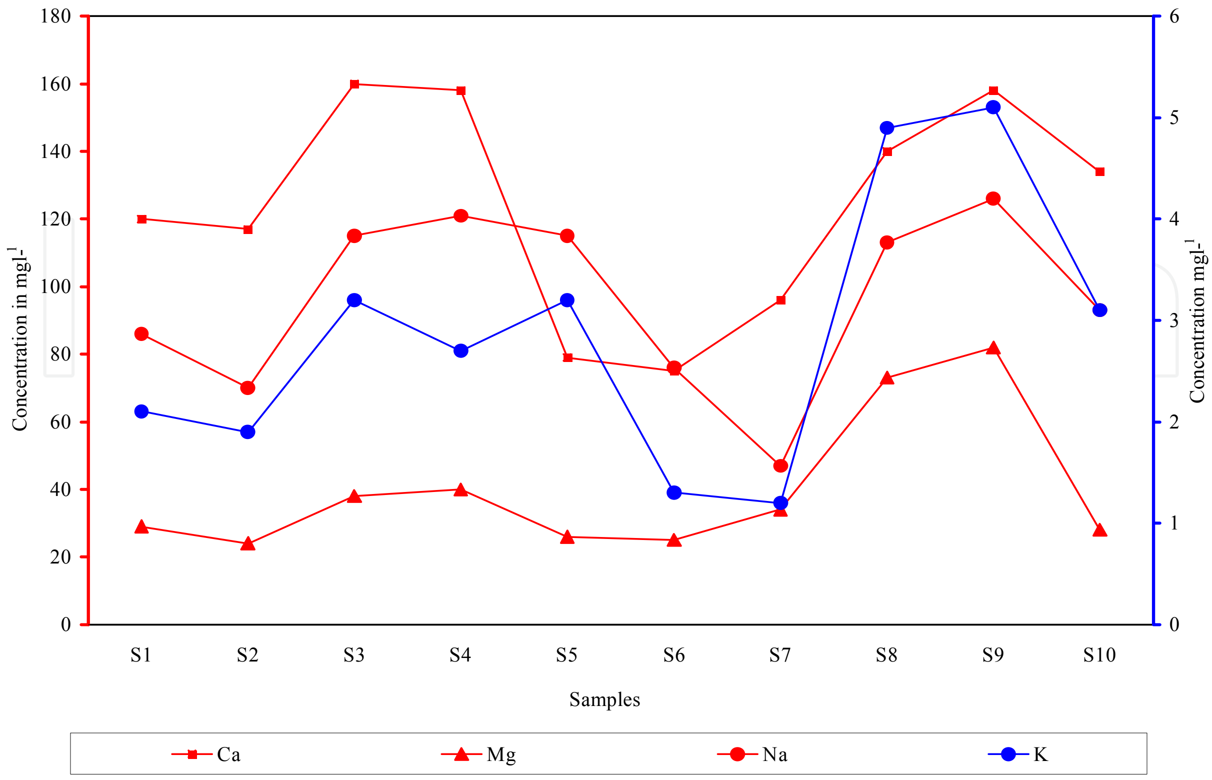



Fig. 3. Average concentrations of cation of GW sample

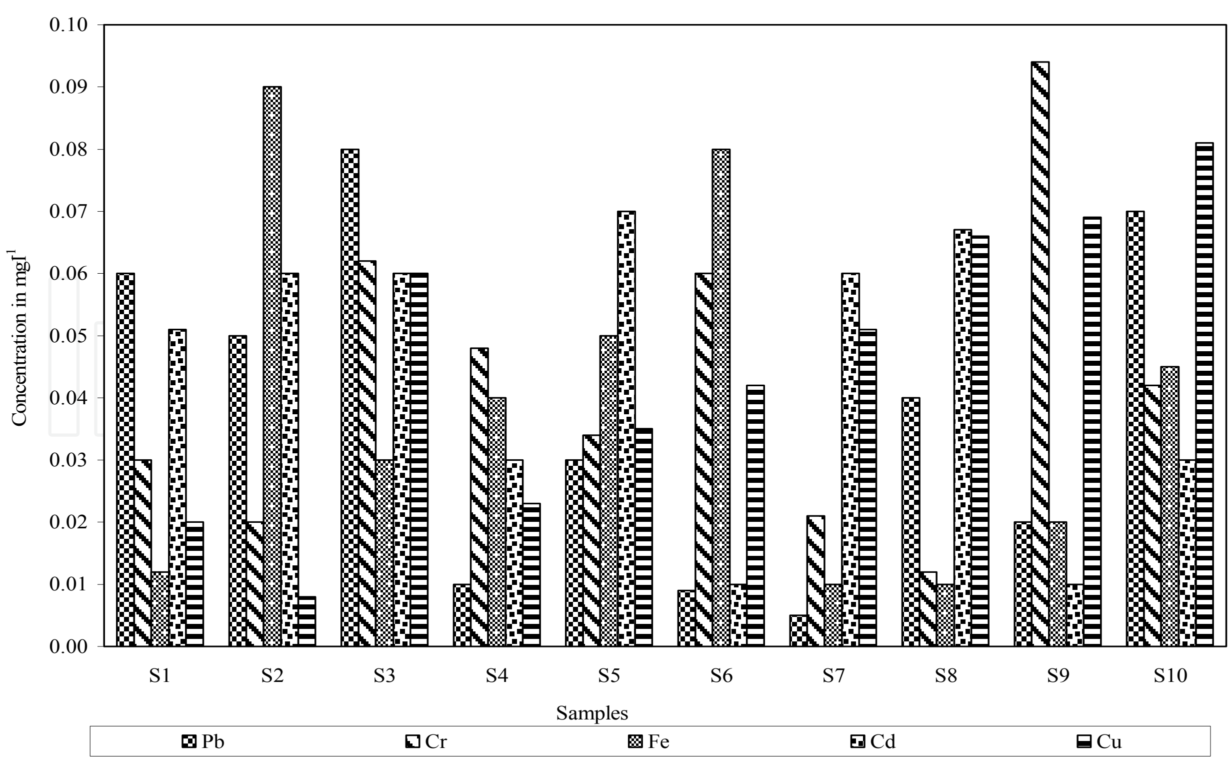



Fig. 4. Average concentrations of heavy metals of GW sample

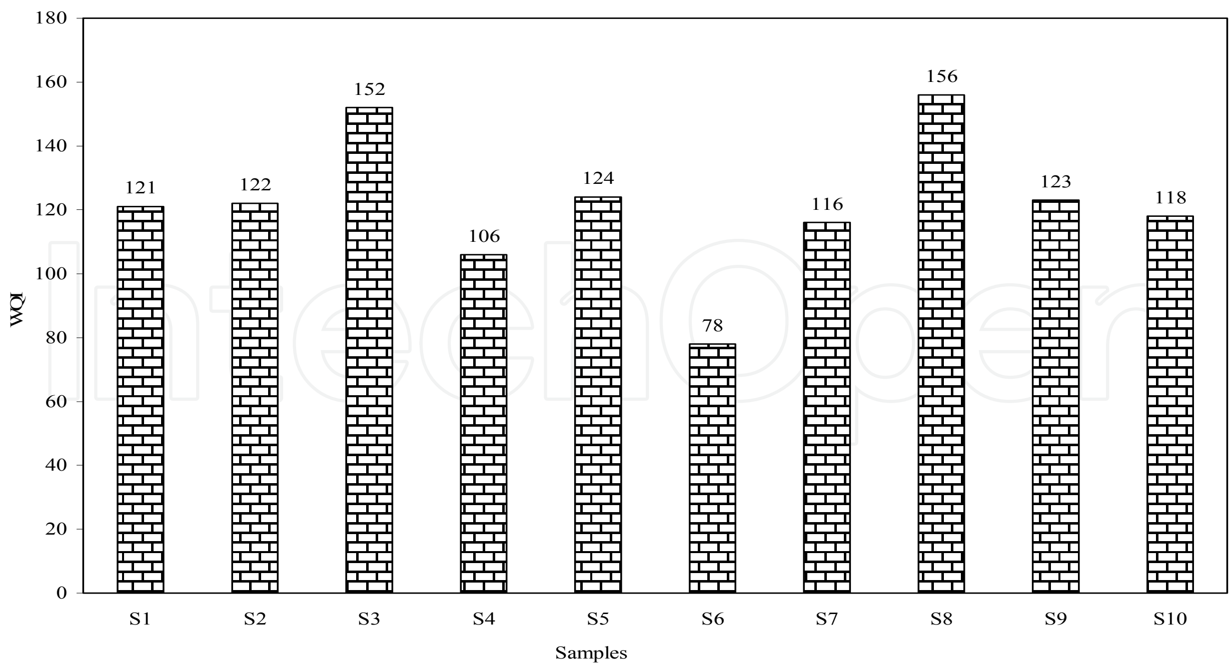



Fig. 5. WQI graph of GW Samples

Location wise concentration of trace metals is presented in Fig. 4. The average concentrations of Fe, Cu, Pb, Cr and Cd were 0.04 ± 0.03, 0.04 ± 0.02, 0.03 ± 0.03, 0.04 ± 0.03 and 0.04 ± 0.02 mg/litre, respectively.

Pb is generally present in GW samples due to plumbing accessories and industrial waste. At few locations, Cu, Cr, Fe and Cd concentrations could be high due to disposal of electroplating and dye industrial waste. Some significant correlations were observed between TDS, TH, $Ca^{++}$, $Mg^{++}$, $Na^{+}$, $K^{+}$, $Cl^{-}$, $NO_3^{-}$ and $SO_4^{--}$ is presented in Table 5. The WQI graph of GW samples is presented in Fig. 5.WQI values of GW samples varied from 78 to 156. Water quality with WQI value above 100 is considered as poor. The water is not fit for drinking purposes when WQI value is above 300. GW quality was most suitable only one particular location e.g., location of sixth number sample S6, where WQI value was 78. At other locations, WQI value varied from 106 to 156 during the study period. GW quality was poor at NIA, phase-I due to presence of more dissolved salt and trace elements. The qualitative analysis of study indicated though GW quality was poor at industrial areas of Delhi but more or less suitable for drinking purposes.

## 4. Conclusions

The assessment of GW quality of Naraina Industrial Area of Delhi by using the indexing method indicated that except one source, other sources of GW quality were poor due to presence of more amounts of dissolved salts and trace elements. Periodical assessment of GW quality and characterization of treated effluent of each orange type industry would provide an overall scenario about the sources of GW contamination. The augmentation of artificial GW recharge through rain water harvesting system and regulation of GW withdrawal might improve WQI value of GW samples. The GW quality is categorized as poor but overall safe for human consumption. Improvement of existing drainage system and scientific handling of industrial hazardous waste materials are the remedial techniques to be adopted for preventing and mitigating the GW contamination. The results of the study would be helpful in identifying the sources of GW contamination and open an avenue for better planning to achieve sustainable management of GW.

## 5. References

APHA (1998). American public health association, Standard Methods for Examination of waters and wastewaters, 20th Edition, Washington, DC, USA

Adhikary, P.P., Chandrasekharan, H., Chakraborty, D., Kamble, K. (2009). Assessment of groundwater pollution in West Delhi, India using geostatistical approach Environmental Monitoring and Assessment DOI 10.1007/s10661-009-1076-5

Ahmet, D., Fevzi, Y., Tuna, A.L., Nedim, O. (2006). Heavy metals in water, sediment and tissues of Leuciscus cephalus from a stream in southwestern Turkey Chemosphere 63, 1451-1458

CGWB (2006). Groundwater year book, NCT, Delhi, Report, Central Ground Water Board, Ministry of Water Resources, Government of India, New Delhi

Chatterjee, R., Gupta, B.K., Mohiddin, S.K., Singh, P.N., Shekhar, S., Purohit, R. (2009). Dynamic groundwater resources of National Capital Territory, Delhi: assessment, development and management options .Environmental Earth Sciences 59,669-686

Datta, P.S., Bhattacharya, S.K., Tyagi, S.K. (1996). Assessment of groundwater contamination from fertilizers in the Delhi area based on $^{18}O$ studies on recharge of phreatic aquifers and groundwater flow paths of mixing in the Delhi area. Journal of Hydrol 176, 25-36

Datta, P.S., Deb, D.L., Tyagi, S.K. (1997). Assessment of groundwater contamination from fertilizers in the Delhi area based on $^{18}O$, $NO_3$ and $K^+$ composition. Journal of contaminated Hydrology 27,249-262

Handa, B.K. (1998). Fluoride occurrence in natural waters in India and its significance.Bhu-Jal News, 3, 31-37

Kumar, M., Ramanathan, A.l., Rao, M.S., Kumar, B. (2006). Identification and evaluation of hydrogeochemical processes in the groundwater environment of Delhi, India. Environ Geol 50,1025-1039

Mondal, N.C., Saxena, V.K. (2005). Assessment of groundwater pollution due to tannery industries in and around Dindigul, Tamilnadu, India. Environ Geol 48,149-157

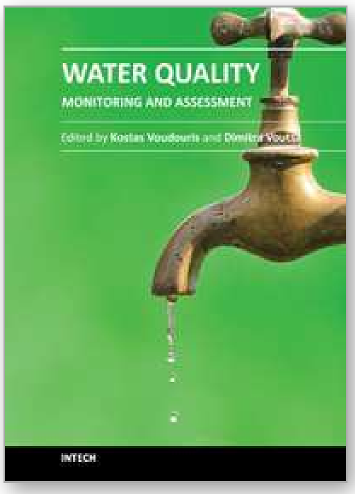
Saeedi, M., Abessi, O., Sharifi, F. (2010). Development of groundwater quality index. Environmental Monitoring and Assessment 142,263-268

Sahu, P., Sikdar, P.K. (2007). Hydrochemical framework of the aquifer in and around East Kolkata Wetlands, West Bengal, India. Environmental Geology 10.1007/s00254-007-1034-x

Sabahi, E.A.l., Rahim, S.A., Zuhairi, W.Y.W., Nozaily, F.A.l., Alshaebi, F. (2009). The Characteristics of Leachate and Groundwater Pollution at Municipal Solid Waste Landfill of Ibb City, Yemen. American Journal of Environmental Sciences 5 (3),256-266

Shekhar, S., Prasad, R.K. (2009). The groundwater quality in the Yamuna flood plain of Delhi (India) and the management options. Hydrogeology Journal 17:1557-1560

Shankar, B.S., Balasubramanya, N., Reddy, M.T.M. (2008). Impact of industrialization on groundwater quality –a case study of Peenya industrial area, Bangalore, India. Environmental Monitoring and Assessment, 142,263-268.




**Water Quality Monitoring and Assessment**
Edited by Dr. Voudouris

ISBN 978-953-51-0486-5
Hard cover, 602 pages
**Publisher** InTech
**Published online** 05, April, 2012
**Published in print edition** April, 2012

The book attempts to covers the main fields of water quality issues presenting case studies in various countries concerning the physicochemical characteristics of surface and groundwaters and possible pollution sources as well as methods and tools for the evaluation of water quality status. This book is divided into two sections: Statistical Analysis of Water Quality Data;Water Quality Monitoring Studies.