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ASSESSMENT OF GROUNDWATER CONTAMINATION FROM LAND-USE/COVER CHANGE IN RURAL-URBAN FRINGE OF NATIONAL CAPITAL TERRYTORY OF DELHI (INDIA)

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Abstract: This study examines the relationship between groundwater depletion/pollution and land-use/cover change in rural-urban fringe of Delhi, where agro-ecosystems and populations are dependent on access to reliable groundwater supplies. Results indicate a significant relationship between high proportionate decrease in groundwater and land being removed from irrigation. The higher values of most of the parameters were found in the agricultural field and industrial area. The study results suggest that most of the elements exceeding the general acceptable limit. This indicates the land-use/cover change from agriculture to industrial and residential area and also the impact of excess use of chemical fertilizer/pesticides in agricultural land.

Keywords: *groundwater, contamination, North-West district, Land-use/cover, Delhi, seasonal variation*

I. INTRODUCTION

Water is one of the most important commodities that mankind has exploited more than any other resources for the sustenance of life. Only 1% of the earth's water is fresh water and more than 1.2 billion people still have no access to safe drinking water. Eighty-five percent of total human consumptive water use is for agriculture, and food production may soon be limited by water availability (Gleick 2003; Kettle et al. 2007). The availability of water both in terms of quality and quantity is essential for the very existence of mankind (Datta, 2005; Datta et al. 2009). Adequate and reliable water supplies are insufficient to support current agricultural, industrial, and domestic uses, and future water use demands are predicted to increase as developing countries seek new levels of economic growth and prosperity (Jury and Vaux, 2005; Parris, 2011). Increasing urbanization and extension of the urban boundaries into the countryside coupled with industrial growth has led to increased discharge of pollutants via drains into rivers and lakes (Kulabako et al. 2007). In India, 90% of the household wastewater is discharged into water bodies without effective pre-treatment, leading to levels of contamination beyond the acceptable limits (Sarawgi et al. 2009; Rai and Dubey, 2009).

Groundwater is used for irrigating nearly two-thirds of the area under irrigation in the Delhi region. Nearly 50% of the domestic and industrial supply of water is met from groundwater; the remaining is supplied by Yamuna river surface water conveyed by canals (Datta et al. 1997; Rai, 2011). Although, the net sown area and the area sown more than once have decreased considerably due to urbanization, the remaining cropped area is about 50% of the total geographical area (Delhi Administration, 1991-92). Thus, the large-scale need for food security and urban drinking water supply is dependent on groundwater.

It is the result of alarming degradation in water quality caused due to toxic pollutants of various kinds like organic, inorganic, and organometallics etc. which are continuously discharged into the water bodies from domestic, agricultural and industrial sectors. Increasing groundwater use and pollution generation has crossed the sustainable limits in many parts. Water quality is highly variable over time and space due to both natural and human factors (Park and Kim, 2003). Due to these spatial and temporal variations in water chemistry, a monitoring programme that will provide a representative and reliable estimation of the quality of groundwater is necessary. So for no study has been carried out to see the correlation of land-use/cover change with groundwater contamination in this study area. However, the only work of Datta et al. (1997) represents NO_3 and K composition in groundwater. Thus, this research was carried out to assess the relationship between land-use/cover change and degree of pollution of groundwater quality in selected sites of rural-urban fringe of Delhi. To assess the degree of pollution, several water quality parameters have been measured. This region is characterised by practice of intensive agriculture for half of century. This region is not only characterised by intensive agriculture but it also a hub of commercial and industrial activities. Thus, the level of groundwater development has surpassed its replenishable limit with falling water-table at an alarming rate.

II. PROFILE OF THE STUDY AREA

Rural-urban fringes are characterised by a wide variety of land uses. The study area includes rural areas, which fall in the North-West district of National Capital Territory (NCT) of Delhi beyond the corporate limit of urban regions. North-West district of NCT Delhi has fertile soil, especially near the river and the quality of groundwater also makes the area quite suitable for cultivation. The main road running towards Amritsar (G.T. road) separates the district an eastern and western part. The eastern part has relatively more land under intensive cultivation and yields better harvests, including horticulture crops. The western part contains more urban sprawl and the soils are less fertile in some places. Alipur block of North-West district clearly constitutes a rural-urban fringe, according to the model of urbanization (Kumari, 2011).

The NCT of Delhi presently comprises of 9 districts and 27 Tehsils. North-West district of NCT Delhi is the largest district having an area of 440 km² and 3615261total population with population density of 8298 person km^{-2} in 2011. It lies in the north-western part of NCT Delhi. The district lies between 76°56´54" and 77°13´31" E and 28°39´59" and 28°52´42" N (Fig 1).

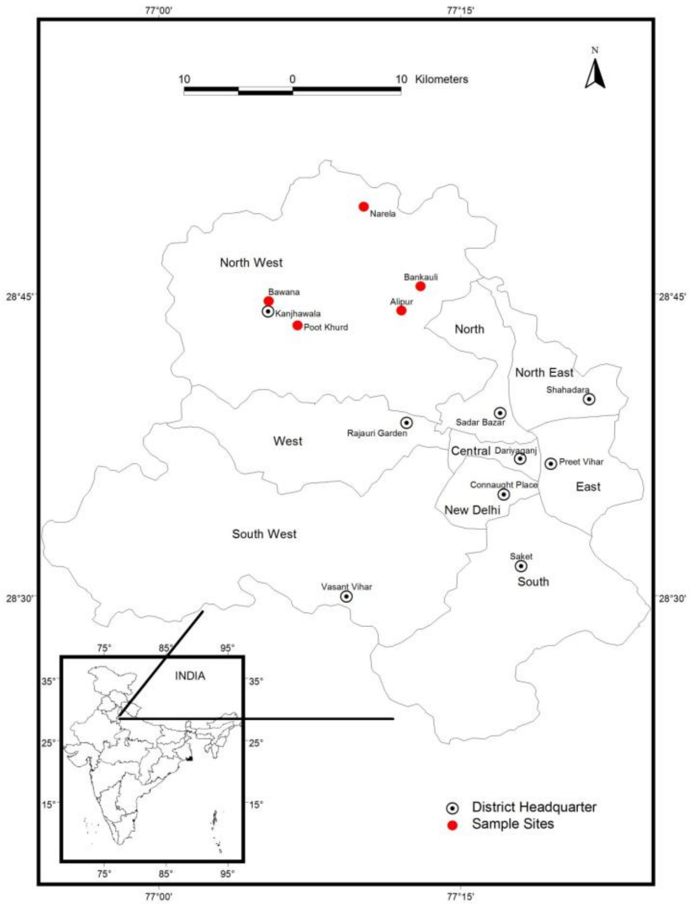

Fig 1. Location map of National Capital Territory of Delhi and sample sites

The district is well connected by road and rail network. All villages are connected with metalled road. The district consists of 19 census towns, Delhi Municipal Corporation (Urban) area (Statutory city area) and 66 villages. The urban settlements in the district are confined to south-eastern and central part of the district. The predominantly rural areas are confined to north-eastern and western part of the district. In the North-West district there are three **Tehsils viz.,** Narela, Saraswati Vihar and Model Town. With respect to area, Narela Tehsil is the largest Tehsil of the district. It comprises 60 villages, which are predominantly agriculture based, except few, which have larger area under industry i.e. Narela and Bawana. For micro-level study five sample sites were selected for detailed study viz., Alipur, Bankauli, Narela, Pooth Khurd and Bawana (Fig 1). The site was selected to investigate the plausible hydrologic and water quality impacts of climate and land-use changes, because this predominantly agricultural area has been undergoing a rapid urbanization process, and its water resources are deteriorating. Historically, most of the land area in the region was used for agricultural activities, but in recent decades, the population in the region has grown substantially, and the area has undergone a rapid urbanization process. The process of urbanization is higher in Alipur and Narela, because of the vicinity to the ever spreading metropolitan city. The other reason for increasing urbanization level is the high level of connectivity. Alipur is situated on National Highway no. 1. Also in these sites the dependency on agriculture is decreasing due to land acquisition and villagers are moving to urban areas for employment. Bankauli and Pooth Khurd are pure agricultural sites. The climate is semiarid. The area experiences erratic spatial and temporal distribution of annual rainfall (average 500-1000mm), periodic droughts and 30-45 °C mean maximum temperature during summer (March-June), which falls by 5-10 °C with the onset of monsoon period (June-September).

Rural-urban fringe of NCT Delhi is characterized by a wide variety of land-uses. The general land-use pattern is classified into five categories, i.e., (i) land put to non-agricultural use, (ii) barren and uncultivated land, (iii) fallow land, (iv) land under miscellaneous trees and groves, and (v) net area sown. The category of land put to non-agricultural use accounts about 20.14% and 19.78% in 2001 and 2010, respectively in rural-urban fringe of North-West district of Delhi Metropolitan Region. Area under barren and uncultivated covers about 14.69 and 18.19%, respectively during both the periods. Fallow land occupied about 14.16 and 22.53%, respectively in 2001 and 2010. The total net sown area in the rural-urban fringe of North-West district of Delhi as per Land Revenue Record, Government of Delhi, accounts for 50.20 and 38.91% in 2001 and 2010, respectively (Table 1).

Selected sample sites wise, area under land put to non-agricultural use is dominated by Pooth Khurd in 2010 (40%). Narela site has the highest (21.43%) area under barren and uncultivated land among all sample sites, while, the lowest

(4.76%) is recorded in Bankauli. Area under fallow land covers about 1/3 to 1/4 of their geographical area. Bawana replaces Pooth Khurd with having 48.66% area under this category in 2010, while in 2001 it was only 27.25%. Area under net sown, Bankauli records the highest percentage, while Alipur records the lowest percentage in 2010. Bawana, Pooth Khurd and Narela have equal (24%) geographical area devoted to net sown area.

The rate of change in land-use/cover has been phenomenal in rural-urban fringe of North-West district of Delhi. The land-use/cover change detection (2001-2010) showed that the most dramatic changes are the increase in fallow land and decrease in net sown area (Table 1). Considering all the facts, the net sown area has decreased from 50.20% in 2001 to 38.91% in 2010 in rural-urban fringe of North-West district of Delhi. A sample site wise, it was recorded highest decrease (59.05%) was in Pooth Khurd, followed by Narela (46.97%) and Alipur (45.27%) in 10 years period of time.

Table 1. Land-use pattern of rural-urban fringe of Delhi region

Land-use	2001		2010		Variation (2001-2010)
	(ha)	(%)	(ha)	(%)	(%)
Land put to non-agricultural use	5,427	20.14	5,328	19.78	-1.82
Land under misc. trees and groves	218	0.81	156	0.57	-28.57
Barren & uncultivated	3,959	14.69	4,901	18.19	23.78
Fallow land	3,816	14.16	6,069	22.53	59.05
Net area sown	13,523	50.20	10,482	38.91	-22.48
Total land under non-agricultural activity	13,414	49.79	16,455	61.08	22.66

Source: Land Revenue Records (Government of Delhi), 2001 and 2010

Cropping pattern of the area has changed remarkably in last one decade. The productivity of crops increased due to high irrigation facilities and heavy consumption of fertilizers/pesticides. Chemical fertilizer consumption is very high in the area. On an average in each village used about 550-650 kg ha^{-1} of DAP and Urea for cultivation of wheat or paddy. Generally, farmers uses 60-80 kg ha^{-1} more Urea for cultivation of paddy than wheat (Primary Survey). Pesticides and herbicides are also used in good amount. On per hectare cropped area, about 2.15 liter pesticides are used (personal communication).

III. METHODS

Study periods were selected based on variations in groundwater depletion and availability of data. The study is based on both primary as well as secondary sources of data, which have been collected through field survey and government records. In order to select suitable sampling sites for groundwater water collection; a preliminary survey was conducted to determine the sources of groundwater extraction. On the basis of survey, 30 sampling points (15 hand-pumps and 15 Tube-wells), covering five sample sites were selected. The sampling points (6 sample points in each site) were selected considering land-use/cover and different groundwater source for detailed analysis in 2010-2011.

Samples are collected in air-tight, sterilised polythene bottle of one litre and brought to laboratory for various chemical analyses. Before collecting water samples hand-pumps and tube-wells were run continuously for 5-10 minutes, to avoid any turbidity in water due to presence of fine mud and sand particles. The selected parameters for the estimation of groundwater quality characteristics are: Electrical Conductivity (EC), Hydrogen-ion concentration (pH), Bicarbonate alkalinity (HCO_3), Chloride (Cl), Calcium (Ca), Magnesium (Mg), Sodium (Na), Nitrate (NO_3), Sulphate (SO_4), Potassium (K) and Fluoride (F). The water samples were collected on seasonal basis i.e. summer, rainy and winter. Precaution has been taken while collecting water samples, that the source of water sample should be same (the same hand-pump or tube-well) for all seasons. Otherwise, it will give erroneous result and present different picture of the study area, which have no resemblance with the reality.

The pH of all water samples were measured immediately after collection, because its reading changes quite rapidly due to chemical changes, such as reduction and oxidation, decomposition of organic matter etc. It was determined with a digital pH meter system-361 (Systronic, India) using a double function reference electrode. The Electrical Conductivity (EC) of samples was determined by electrical conductivity meter Mode-306 (Systronic, India). Others parameters were analysed by adding the appropriate reagent and were stored in clean glass test-tubes fitted with screw cops and analysed in laboratory within a week following standard method (Eaton et al. 1995).

The bicarbonate content was determined by Potentiometric Titration Method (APHA, 1995). Bicarbonate standard ranging from 100-1000 mg/l was prepared from $NaHCO_3$. 50 ml sample and a series of bicarbonate standards were titrated against 0.02 N HCl. The end point was noted at pH 4.5. Chloride is one of the major organic anion in water and waste water. In potable water, the salty taste produced by chloride concentrations is variable and dependent on the chemical composition of the water. Chloride was determined by using Mohr's Titration Method. First, the standard solutions of chloride of various concentrations were prepared. These were titrated with 0.1 N $AgNO_3$ solutions. Then the samples were titrated with the same concentration of silver nitrate ($AgNO_3$) solution. Potassium chromate (K_2CrO_4) was used as indicator. A standard graph was plotted against the concentration of standard chloride and volume of silver nitrate consumed. The chloride in the various samples was determined by comparing their consumption of silver nitrate with the standard graph.

Calcium was analyzed using Flame-Photometer. It is considered to be non-toxic to human beings at reasonable concentration. Magnesium salts have a laxative and diuretic effect on health. WHO allows 50 mg/l concentration of Mg. Sodium is a natural constituent of raw water, but its concentration is enhanced by rock salt treatment of road surfaces, precipitation run-off and soapy solutions and detergents. These cations were analyzed using Flame-Photometer.

Concentration of nitrate in water samples was determined by brucine-sulphanilic acid method. The method is based on the reaction of the nitrate ion with brucine sulphate. The colour of resulting complex is measured at 410 nm. 10 ml of standard and samples were pipette out into a 50 ml tube. 10 ml of 13N H_2SO_4 solution was added to each tube with swirling and allowed tubes to come to thermal equilibrium in the cold bath. 0.5 ml brucine-sulphanilic reagent (prepared by dissolving 1 gm bromine sulphate and 0.1 g sulphanilic acid in 70 ml hot distilled water, 3 ml of HCl was added to this solution and volume maintained to 100 ml with distilled water) was added to each tube and mixed thoroughly. The tube rack was then kept in water bath at 100^oC for 25 minutes. After that tubes were removed from the water bath and allowed to reach room temperature and the absorbance was measured at 410 nm against reagent blank.

Sulphate was determined by turbid metric method (APHA, 1995). The method is based on the principle that SO_4 is precipitated in an acetic medium with barium chloride ($BaCl_2$), so as to form barium sulphate crystal of uniform size. Light absorbance of barium sulphate suspension is measured by UV/VIS spectrophotometer at 420 nm and the concentration is determined by comparing the reading with standard curve. 100 ml of standard and samples were measured in a volumetric flask and 20 ml of buffer solution (prepared by dissolving 30 g of $MgCl_2.6H_2O$, 5 g of sodium acetate, 1 g potassium nitrate and 0.111 g of sodium sulphate and 20 ml of acetic acid in 500 ml of distilled water and then the total volume was made up to 1000 ml) was added and mixed with the help of magnetic stirrer. While stirring a spoon full of $BaCl_2$ crystal was added. This was stirred for 60 seconds with constant speed. After the stirring period, solution was poured into the absorbance cell of the photometer and absorbance reading was taken at 420 nm after 5 minutes. Sulphate concentration was determined by comparing reading with calibration curve prepared by carrying sulphate standard through the entire procedure. Potassium was analyzed using Flame-Photometer.

Impact of groundwater on health related information was collected through primary survey. The survey has been conducted in the month of May, 2011. About, 190 patients were surveyed using open ended questionnaire. After taking interview of patients, the registered government doctors were also interviewed to get information about the water-borne diseases, which are very frequent occurring and their possible causes.

The data were prepared and processed in SPSS 11.0 software package (version 13.0). The methods of bi-variate correlation analysis (with the Pearson's correlation coefficient - r) at two tailed significance level has been used. The variables used here are mean values of all three seasons for all observations, so that generalise picture of yearly water quality can be known, with their relationship among themselves.

IV. RESULTS AND DISCUSSION

IV.1. Groundwater quality

The descriptive statistics of the analyzed water quality parameters in selected sites of rural-urban fringe of Delhi are depicted in Table 2 and Table 3. The groundwater of the study area is slightly alkaline (mean value 7.26), but it comes under the acceptable limit of 6.8 to 8.7. The pH varies from 6.99 to 7.45 (Table 2). In general, groundwater pH is slightly alkaline due to influx of bicarbonates (HCO_3) ions in the groundwater aquifer, which is due to percolation of either rain water or irrigation water through soils (Datta, 1997). The Electrical Conductivity is an indicator of salinity and also signifies the amount of Total Dissolved Solids (TDS). The mean value of electrical conductivity of collected water samples ranges from 1625 to 2228 millimhos/cm. The highest (2228) Electrical Conductivity has been found in Bankauli and lowest (1625) in Bawana (Table 2). The source of water sample in Bankauli was tube-well. TDS indicates the inorganic pollution load.

Table 2. Mean/Average groundwater quality parameters in selected sites of rural-urban fringe of Delhi region

Parameters	Alipur	Bankauli	Narela	PoothKhurd	Bawana
EC (millimmhos/cm)	2038.33	2228	1856.33	1957	1625.33
pH	6.99	7.23	7.29	7.34	7.45
Ca (mg/l)	45.97	33.46	37.47	27.87	36.78
Mg (mg/l)	31.48	27.11	41.32	30.54	37.01
HCO_3 (mg/l)	628.5	398.4	365.83	408.83	498.23
Na (mg/l)	566.4	625.66	445.16	650.18	637.56
K (mg/l)	4.87	6.93	6.02	5.49	6.39
Cl (mg/l)	444.33	415.66	449	559.66	358
SO_4 (mg/l)	634.66	1036.33	612	900.33	815
NO_3 (mg/l)	27.93	18	47.22	14.08	23.67
F (mg/l)	0.91	0.84	2.15	0.81	2.17

Table 3. Seasonal variation in groundwater quality in sample sites of rural-urban fringe in Delhi region***

Site	Season	EC	pH	Ca	Mg	HCO_3	Na	K	Cl	SO_4	NO_3	F
Alipur	Summer	1680	6.11	31.91	8.15	579.5	490.2	3.21	454	508	32.15	0.67
	Rainy	1939	7.45	99.4	77.35	586	496	4.6	397	578	22.33	1.21
	Winter	2496	7.41	6.6	8.96	720	713	6.8	482	818	29.31	0.86
Bankauli	Summer	2197	6.7	24.63	6.74	378.2	855	3.51	510	962	17.01	0.83
	Rainy	2733	7.71	69.35	67.65	427	654	7.4	411	1460	18.98	0.98
	Winter	1754	7.28	6.41	6.94	390	368	9.9	326	687	18.02	0.73
Narela	Summer	1134	6.72	20.47	11.03	292.5	361.5	2.66	255	218	22	2.12
	Rainy	1824	7.51	86.44	104.9	390	261	6.8	567	558	73.98	2.38
	Winter	2611	7.65	5.52	8.04	415	713	8.6	525	1060	45.69	1.96
Pooth Khurd	Summer	1346	6.65	18.53	9.73	189.5	316.56	1.29	430	508	14.13	0.59
	Rainy	2918	7.84	60.77	77.95	720	1006	9.6	539	1210	16.84	1.2
	Winter	1608	7.55	4.32	3.94	317	628	5.6	710	983	11.28	0.64
Bawana	Summer	2110	6.5	26.78	8.83	579.7	758.7	5.51	553	720	48.03	2.17
	Rainy	1139	7.43	83.02	101.4	512	901	11.3	241	923	8.66	2.34
	Winter	1627	8.44	0.54	0.81	403	253	3.1	280	802	14.34	2.01

***EC (millimhos/cm), Ca, Mg, HCO_3, Na, K, Cl, SO_4, NO_3, F (mg/l)

The Ca and Mg are the most abundant element in the groundwater. Calcium may dissolve readily from carbonate rock and limestone or to be leached from soil. However, the dissolved Mg concentration is lower than Ca in the groundwater. Calcium is an essential nutritional element for humans and helps in maintaining the structure of plant cells and soils. Mg is a constituent of bones and is essential for normal metabolism of Ca (Mor et al. 2008). The observed average calcium contents in sample water ranged from 27.87 to 45.97 mg/l. The highest concentration is recorded in Alipur, while lowest in Pooth Khurd. The concentration of Ca is under acceptable limit of BIS standards (Bureau of Indian Standard) (Table 4). The average value of magnesium content varies from 27.11 to 41.32 mg/l. When a comparison of these samples has been done to BIS standards (30 mg/l), except Bankauli, all sites pose beyond the standard level (Table 4).

Chloride is soluble in water and moves freely with water through soil and rocks. High content of chloride may give a salty taste to groundwater and can corrode pipes, pumps. The average value of chloride concentration in the study area varied from 358 to 559 mg/l. Sulphate is a major contributor to total hardness. Its concentration more than 200 mg/l is objectionable for domestic purposes, beyond this limit; sulphate causes gastro-intestinal irritation. All the water samples of selected sites have SO_4 content not only beyond the acceptable limit, but also beyond the maximum desirable limit (Table 4).

Table 4. Comparison of groundwater quality parameters of selected sites with drinking-water quality standards

Parameters	BIS		WHO	
	Acceptable	Allowable	Acceptable	Allowable
pH	7 – 8.5	6.5 – 9.2	7-8.5	6.5 - 9.2
EC	1625 - 2228	-	-	
Ca	75	200	75	200
Mg	30	150	50	150
HCO_3	-	-	-	150
Na	-	50	-	200
K	4.87 - 6.93	-	-	200
Cl	200	1000	200	600
SO_4	200	400	200	400
NO_3	45	45	45	45
F	1.0	1.5	1.0	1.5

BIS: Bureau of Indian Standard; WHO: World Health Organization

The anthropogenic sources of sodium and potassium concentration in the groundwater are industrial and domestic wastes making it unsuitable for domestic use. High concentration of sodium in drinking water may cause heart problems. The average value of sodium content of groundwater varied from 445 to 650 mg/l, which is far beyond the maximum desirable limit of BIS and WHO (Table 4). Although, in the saturated zone of groundwater, the potassium content is diluted by convective mixing, diffusion and adsorption occur along the hydraulic gradient (Datta et al. 1997). Potassium is an important cation and plays a vital role in intermediate metabolism. The mean value of potassium content varies from 4.87 to 6.93 mg/l.

The main source of nitrate and fluoride in the groundwater is high consumption of fertilizers, pesticides, herbicides, and weedicides etc. The mean value of concentration of nitrate varies from 14.08 to 47.22 mg/l. It is under the acceptable (Table 4) and well within the safe limits, except in one sample site i.e. Narela. The average concentration level in this site is 47.22 mg/l (Table 2). Similar results and findings have also been reported by Datta et al. (1997). The status of fluoride concentration is also not good, as two sample sites have its concentration more than desirable limit. These sites are Narela and Bawana. Report (2006) published from CGWB, Faridabad stated that in almost 30% of the area in NCT

Delhi, the groundwater is showing high concentration of fluoride and is more than WHO prescribed maximum permissible concentration in drinking water i.e. 1.5 mg/l (Table 4). The areas spread mainly in the South-western and Western part of the city, comprising South-West, West and North-West districts. Thus, it is evident that quite significant part of the Delhi area is affected by fluoride contamination in the groundwater beyond the maximum permissible limit. Groundwater with very high fluoride levels clearly suggests the possibility of point-source contamination. Most of these wells are located adjacent to brick industries which commonly use fluoride salts.

Among all sample sites, Narela and Bawana are industrial hubs. These industries are also located in the vicinity of agriculture field and contributing in contamination of aquifer lying below. In these areas industrial lands are allotted by DSIBC (Delhi State Industrial Development Corporation). They have big industrial zones. There are more than 500 industries in these villages. These are small-scale industries, mainly of leather goods, decorative goods, tobacco and tobacco products, paper and paper products, printing, petroleum, coal products, cosmetics, plastic and synthetic rubber goods, etc. Alipur also have some small scale industries ranging 10 to 15 in number. These industries are more than 20 years old and situated within the *Lal dora* area. Among them there is a famous industry i.e. *Lalten industry*. In Pooth Khurd also there are few industries. In Bankauli, industrial plots are allotted, but there is no any industry has been setup here till date.

Groundwater quality is very much influenced by the quality of recharging water. Salinity is the major problem in the semi-arid region. In these regions there is absence of natural flushing by fresh water, thus it makes groundwater prone to enhanced salinization (Singh 2006). In the present study area alluvial plain consists of clay and fine-grain sand. The sticky clay helps in confining the water under artesian condition, obstructing the drainage. This leads to the accumulation of sodium and magnesium salts thus giving rise to salt encrustations and rendering the soil infertile along with water.

IV.2. Seasonal variation of groundwater quality

Seasonal variation in groundwater quality is presented in Table 3. All the selected physico-chemical parameters reflect a seasonal pattern, displaying a higher value during the rainy season. The measured value of pH of all the samples are slightly acidic (6.11) in summer to alkaline (8.44) in rainy and winter season (Table 3). The higher value during rainy and winter was attributed to greater ionic concentration. The trend of electrical conductivity (EC) is fluctuating in all the seasons of selected sites. At some observation point it is highest during rainy season and at some point it is highest in summer and winter time. The measured value of EC range varies from 1134 millimhos/cm to 2918 millimhos/cm among the sites, during whole period of consideration (Table 3).

The trend of concentration of calcium is very sharp and clear, showing very high increase in rainy season, varies from 60.77 to 99.4 mg/l. The concentration is lowest in winter season, which ranges from 4.32 to 20.54 mg/l. The seasonal effect is quite significant for this component, especially for rainy season. The status of magnesium is quite similar to calcium; it has also highest concentration in rainy season, ranges 67.65 to 104.9 mg/l. The lowest concentration has been recorded in winter season, which varies from 3.94 to 7.81(Table 3).

The seasonal impact on the concentration of bicarbonate is again fluctuating. There is no any similar kind of pattern recorded on all observation sites. The reading for bicarbonate varies from 190 mg/l to 720 mg/l in whole period of considerations. The same status has been observed for sodium also. The concentration level of sodium varies from 253 mg/l to 1006 mg/l. The concentration of potassium is highest during winter season, varies from 3.1 to 9.9 mg/l (Table 3). The chloride concentration is also ambiguous and there is no any seasonal pattern. This concentration varies from 241 mg/l to 567 mg/l. The concentration of sulphate varies from 218 mg/l to 1060 mg/l for all seasons. On this component also seasonal impact has not been recorded much (Table 3).

The highest concentration of nitrate is primarily due to changes in farming system. Much use of chemical fertilizers especially urea, pesticides are responsible factors. There is significant impact of seasons on the concentration level of nitrate in all samples. The highest concentration has been observed in rainy period and lowest in summer season. During rainy season concentration varies from 16.84 mg/l to 73.98 mg/l. There is significant impact of seasons on concentration of fluoride. Highest concentration has been recorded in rainy season, while lowest in winter season. The level of concentration in rainy season varies from 0.98 mg/l to 2.34 mg/l (Table 3).

Thus, it is quite clear from the above analysis that some chemical components of water do have impact of seasons while others not. Calcium and magnesium provides the best example for that group, which has great bearing of seasons. Along with their seasonal impact, the chemical components also have strong relationship among themselves. In other words, the changing values of one component do affect the reading of other components.

IV.3. Correlation analysis

To find the relationship among the selected parameters, Pearson Correlation method has been used. There are five observations and eleven variables have been used to calculate the correlation. The variables used are mean values of all three seasons and give a generalised yearly picture. The correlation matrix describes the interrelationship among selected variables (Table 5). pH was found to be negatively correlated with EC (r = -0.630), Ca (r = -0.680), HCO_3 (r = -0.595), Cl (r = -0.123) and NO_3 (r = -0.118). It shows a moderate degree of positive correlation with Mg, Na, K SO_4 and F (Table 5).

Table 5. Correlation co-efficient matrix of physico-chemical data of groundwater in rural-urban fringe of Delhi region

Parameters	EC	pH	Ca	Mg	HCO_3	Na	K	Cl	SO_4	NO_3	F
EC	1	-0.63	-0.04	-0.765	-0.065	0.082	0.34	0.312	0.403	-0.292	-0.82
pH		1	-0.68	0.363	-0.595	0.256	0.571	-0.123	0.348	-0.118	0.552
Ca			1	0.231	0.764	-0.441	-0.431	-0.478	-0.703	0.486	0.162
Mg				1	-0.166	-0.695	-0.035	-0.256	-0.714	0.826	0.921
HCO_3					1	0.173	-0.616	-0.252	-0.384	-0.12	-0.194
Na						1	0.161	0.47	0.763	-0.97	-0.481
K							1	-0.507	0.625	-0.097	0.281
Cl								1	0.05	-0.223	-0.545
SO_4									1	-0.802	-0.467
NO_3										1	0.668
F											1

Note: Significant at 0.05 levels (Pearson Correlation coefficient)

Correlation is significant at 0.05 levels. EC is mainly contributed by salts of Na, K, SO_4, and Cl. It is clear from the Table 5 that these components have moderate degree of positive correlation with EC. Ca has high degree of positive correlation with HCO_3 (r = 0.764) and a moderate degree of positive correlation with Mg, NO_3 and F. It has high degree of negative correlation with SO_4 (r = -0.703). Mg has a very high positive degree of correlation with NO_3 (r = 0.826) and F (r = 0.921). HCO_3 has low degree of positive correlation with Na (r = 0.173) and high to moderate degree of negative correlation with K, Cl, SO_4, NO_3 and F (Table 5). Na and K has high degree of positive correlation with SO_4 (r = 0.763 and 0.625, respectively). Cl has negative correlation with NO_3 and F and a very insignificant positive relation with SO_4. SO_4 has very high negative correlations with NO_3 (r = -0.802) and F. NO_3 has a high positive correlation with F (r = 668).

IV.4. Groundwater and health

The result shows that about 28% of the respondents are affected by water-borne disease. Among these diseases, intestinal infection is the highest. These patients are suffered from stomach pain, loose motion, vomiting, gastritis, etc. The section which is most affected by these diseases are children belonging to age group of 1-15 years. The second most affected section is male population of both age groups, young and old. The second most prevalent disease is typhoid and jaundice. In this disease male outnumber the females and there is a huge difference. This may be because they conduct more outdoor work and have water from many sources irrespective of its quality. Apart from this few patients were also affected by stomach worm. Fluorosis is an important toxicological problem in the study sites. It has been noted during field survey that the situation of dental patients is much more pathetic. More than 70% of the dental patients are affected by this disease with varying degree. The rate of prevalence of fluorosis is higher in adolescent girls and females than adolescent boys and males residing in this area. More than 60% of the total fluoride intake per day is derived from water used for drinking and food processing (Viswanathan et al. 2010). The characteristic symptoms are, mottling, staining hypo-calcification, pitting, and abrasion of teeth. During survey, children were not found affected by dental fluorosis disease.

To protect the groundwater quality and to prevent its further depletion, water extraction has to be somehow balanced by the recharge. Furthermore, the zones of groundwater recharge need to clearly identified and revised in relation to land-use/cover changes, in order to restrict or eliminate waste disposal activities in these areas. This it is quite evident that from the point of groundwater management, the choice lies between merely tapping an often minimal renewable natural resources or exploiting a much more plentiful non renewable resource until it is exhausted.

V. CONCLUSIONS

The land-use/cover has been changed rapidly in the study area. Analysis of data reveals that overexploitation of groundwater resource to increase the cropping and irrigation intensity for obtaining maximum output in agriculture has severely impacted the quality of groundwater. The physico-chemical analysis of groundwater is also showing that approximately all the parameters of groundwater is crossing the WHO and Indian Standards. Because the use of such groundwater for irrigation is likely to increase with time, the high levels of the contaminant constituents in groundwater should be taken into consideration for recommending the fertilizer nitrogen, potassium and sulphur doses for crops. Farmers are using fertilizers and changing the cropping pattern without considering its impact on groundwater.

Indiscriminate discharge of wastes on land and in drains has also contributed to high levels of these ions at some places. Using land for waste disposal, recreation, agriculture, residential development and industries releases different types of quantities of chemicals to the environment. These chemicals often end up in shallow groundwater, where they impair water quality. Sources of chemicals from nonpoint or area-wide sources have a special character. In this area, Nitrate and Fluoride concentration is much higher than in other kind of land-uses. An increase in the concentration of Na, K, Ca, Mg, Cl, and other ions is the main cause of the salinization in North-West district of Delhi region.

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