Nature Environment and Pollution Technology
An International Quarterly Scientific Journal | ISSN: 0972-6268 | Vol. 11 | No. 3 | pp. 377-380 | 2012

Original Research Paper

Hydro-Chemical Assessment of Groundwater Considering Distillery Effluent Irrigation

Bineet Singh, J. S. Chauhan* and Anuraag Mohan
Department of Chemistry, Bareilly College, M. J. P. Rohilkhand University, Bareilly-243 006, U. P., India
*Department of Environmental Science, College of Basic Science & Humanities, G. B. Pant University of Agriculture and Technology, Pantnagar-263 145, Uttarakhand, India

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 1/1/2012
Accepted: 1/3/2012

Key Words:
Distillery effluent irrigation
Groundwater contamination
Gajraula

ABSTRACT

The objective of this study is to evaluate contamination of groundwater due to distillery effluent irrigation. The groundwater chemistry was studied in a series of eight multi-level depth locations of Gajraula and its suburb of JP Nagar district in Uttar Pradesh. The treated distillery effluent was used twice @ 225-50 m^3/ha as a pre-sown irrigation. The study was conducted in pre-irrigation and post-irrigation phase for the year 2008-2009. The comparative analysis showed that private wells (shallower hand pumps) have high NO_3^-, BOD and Fe concentrations as compared to the public supply wells (deep boreholes) during the post irrigation. The TDS, Cl^- and Ca^{+2} values were found near to IS:10500 permissible limit values i.e., 500 mg/L, 250 mg/L and 75 mg/L respectively. However, negative effect of the effluent irrigation on groundwater quality was reported at R-1, R-2, R-3 and R-4 sites, which may have been influenced by industrial, local agricultural practices, distillery lagoon and effluent irrigation as mixed sources.

INTRODUCTION

Scientists working closely on issue of wastewater reuse are far from having solved all concerns related to this practice. As public health concerns are normally among the main constraints for reuse, any scenario will need to include detailed risk assessments. To achieve an adequate risk assessment, data pertaining to physical and chemical factors are necessary. Used water after industrial, agricultural and domestic processes is generally considered as wastewater and disposed into surrounding environment (Rahmani 2007). The farmers in the vicinity of distilleries always used the wastewater particularly distillery effluent in an organized or unorganized way into their fields without considering its impact on groundwater. Although, from an important point of view, the chemical nature of treated distillery spent wash is important to crop but also sufficient to cause accumulation or contamination in groundwater because of high salt and nutrients still remain due to variation in feed stocks, alcohol manufacturing process and treatment methodologies.

Several researchers have shown positive effects of effluent irrigation on soil fertility and crop yields on short term basis (Pathak et al. 1999, Saha et al. 2005). However, on long term basis such practices might increase the potential risk to groundwater quality (Joshi et al. 2000). In addition, safe utilization of wastewater for irrigation requires the use of proper treatment and several precautionary measures in place like dilution, as it may cause environmental and human health problems (Buechler & Mekala 2005, Bradford et al. 2003). Therefore, study of groundwater chemistry beneath the effluent irrigation site is important for maintaining its quality particularly in a rural settlement because of risk to leaching of chemicals and other toxic ions from effluent.

MATERIALS AND METHODS

Experimental site and groundwater monitoring: The experiments were conducted at Gajraula and its suburbs of JP Nagar in Uttar Pradesh, India. The site falls under the Indo-Gangetic plains at 28°50'N latitude, 78°13'E longitude and an altitude of 273 m above mean sea level. The groundwater samples were collected from eight multi-level depths locations i.e., R-1 Azadpur (12m), R-2 Sahbazpur (15m), R-3 Sultanther (18m), R-4 Mahmoodpur (15m), R-5 Sihali (22m), R-6 Raja Farm (27m), R-7 Basti (30m) and R-8 Alipur (32m) surrounding Gajraula. The treated effluent was used twice between early spring to till start of monsoon season. The water samples were collected into two phases i.e., pre-irrigation (February to June, 2008) and post-irrigation (September, 2008 to January, 2009) respectively (Table 1 & Table 2). Collected samples were analysed for physico-chemical characteristics including pH, Cl^-, NO_3^-, BOD, TDS, Na^+, K^+, Ca^{+2}, Mg^{+2}, Zn, Pb and Fe as per standard methods given by APHA (1995). All the chemical analysis was performed in Eco-technology laboratory, Department of Environmental Science, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India.

RESULTS AND DISCUSSION

pH and TDS: Hydrogen ion concentration in groundwater samples was alkaline in nature both in pre and post-irrigation period. The pH ranged from 6.6 to 7.8 in the all samples. As the pH is related to a variety of different parameters, it is not possible to determine whether pH has a direct relationship with human health but it is argued that pH has an indirect effect as it can effect water treatment processes (Aramini et al. 2009).

The TDS values were found to be relatively higher in post-irrigation phase in respect to pre-irrigation phase. The total dissolved solids values fluctuate between 151 mg/L and 642 mg/L throughout the experimental year. The higher TDS values were found to be 642.3, 581.2 and 517.1 mg/L respectively at R-1, R-2 and R-3 sites during post-irrigation as compared to pre-irrigation phase values i.e., 318, 305 and 301.8 mg/L respectively. The percentage increase in dissolved solids between both phases were also represented i.e., R-1 (101 %), R-2 (90.4 %), R-3 (72.2%), R-4 (50 %), R-5 (53.4 %), R-6 (41.3 %), R-7 (35.7 %) and R-8 (33.2 %) respectively (Fig. 1). This may be due to percolation of salts from industrial effluent. Similarly Joshi (1999) reported high salt content and TDS in groundwater due to effluent irrigation. Effluent irrigation induces a groundwater cycle that increases the salinity in the upper aquifer through irrigation return flow (Stigter et al. 2006), thereby increasing the concentrations of all ions present in solution. Water with the higher solid residues is normally less palatable and may induce an unfavourable physiological reaction.

Nitrate: The analysis showed that concentration of nitrate decreased with increasing sampling depth. Concentration of NO_3^- was found to be maximum at the depth of 12m and minimum at 32m during both pre and post-irrigation. Among all the experimental locations, R-1, R-2 and R-3 locations showed higher nitrate concentration i.e., 71.2, 61.1 and 46.5 mg/L respectively during post-irrigation phase while at R-1 sites in pre-irrigation phase was maximum nitrate i.e., 45.4 mg/L (Table 1 & Table 2). These nitrate levels were discovered in hand pumps installed adjacent to distillery wash lagoon that is centre-point irrigation systems located in area. This is probably due to the fact that the shallow water is more prone to leached nitrate released by lagoon, agricultural and effluent irrigation practices.

Table 1: Mean concentration of the groundwater characteristics during pre-irrigation period.

Sites	Depth (m)	pH	Cl^-	$N0_3^-$	BOD	TDS	Na^+	K^+	Ca^{++}	Mg^{++}	Pb^{++}	Zn^{++}	Fe^{++}
		Parameter											
R-1	12	6.6±0.2	41.1± 4.1	45.4±5.5	3.6±0.4	318±22.3	31.8±9.2	11.6±1.8	40.6±11.2	16.4±3.4	0.018±0.002	0.20±0.005	0.771±0.08
R-2	15	6.6±0.1	37.6±3.0	40.0±6.2	3.0±0.2	0305±14.2	28.4±5.4	10.2±1.2	36.7±9.1	13.6±2.2	0.015±0.001	0.14±0.003	0.621±0.03
R-3	18	7.2±0.1	28.0±2.4	28.1±2.0	2.4±0.2	301.8±17.4	24.4±7.0	8.0±0.3	25.3±6.2	10.6±0.0	0.007±0.0006	0.101±0.003	0.498±0.09
R-4	22	7.2±0.3	18.5±4.0	22.2±3.2	2.4±0.4	264.2±19.0	19.6±3.2	6.0±0.8	20.8±4.0	12.4± 1.3	0.007±0.0002	0.071±0.002	0.348±0.06
R-5	25	7.3±0.1	18.2±2.3	13.1±3.1	2.4±0.2	215.2±24.1	15.3±4.2	4.5±0.2	16.9±5.3	8.1±1.0	0.004±0.0001	0.063±0.00	0.348±0.04
R-6	27	7.4±0.2	12.2±3.0	10.4±0.6	2.0±0.2	198.4±15.2	10.2±1.2	4.7±0.5	11.1±0.8	7.0±0.5	0.003±0.0001	0.043± 0.003	0.221±0.03
R-7	30	7.2±0.1	7.5±1.3	6.2±0.3	1.8±0.1	151±21.0	5.4±3.0	2.5±0.5	8.09±0.4	5.0±0.7	0.004±0.0	0.012±0.004	0.226±0.04
R-8	32	7.2±0.2	4.9±0.4	5.0±1.0	1.8±0.3	158±11.4	5.0±2.1	1.2±0.1	8.4±0.2	4.2±0.3	0.003±0.0	0.012±0.005	0.221±0.04
Permissible Limit (IS:10500)		6.5-8.5	250	45	3	500	*	*	75	30	0.05	5	0.3

All parameters in mg/L except pH, *Not declared

Table 2: Mean concentration of the groundwater characteristics during post-irrigation period.

Sites	Depth (m)	pH	Cl^-	$N0_3^-$	BOD	TDS	Na^+	K^+	Ca^{++}	Mg^{++}	Pb^{++}	Zn^{++}	Fe^{++}
		Parameter											
R-1	12	7.8±0.4	58.0±11.4	71.2±16.2	5.4±0.7	642.3±18.5	46.5±11.1	21.3±4.4	71.±19.4	25.1±4.2	0.022±0.004	0.48±0.02	1.621±0.3
R-2	15	7.5±0.2	51.5±9.2	61.1±13.4	4.8±0.3	581.2±24.5	40.3±9.3	18.5±2.5	58.3±11.1	21.2±2.5	0.022±0.004	0.326±0.04	1.220±0.3
R-3	18	7.5±0.2	35.2±14.2	46.5±10.5	3.6±0.1	517.1±35.1	35.1±14.0	14.4±3.1	40.1±7.4	18.8±4.0	0.010±0.002	0.191±0.07	0.892±0.4
R-4	22	7.4±0.1	22.2±6.8	34.5±7.5	3.6±0.6	396.2±11.5	28.6±9.6	10.2±0.9	33.2±9.2	18.2±2.0	0.012±0.001	0.126±0.002	0.712±0.2
R-5	25	7.2±0.2	27.4±6.5	20.4±4.5	3.0±0.3	330.0±14.1	22.1±3.4	8.1±0.5	24.4±4.1	14.4±1.8	0.005±0.003	0.118±0.004	0.410±0.3
R-6	27	7.6±0.1	18.5±3.4	15.2±6.9	2.4±0.4	280.5±21.2	12.1±5.1	6.0±0.4	18.2±5.0	11.1±2.0	0.003±0.0003	0.072±0.002	0.386±0.6
R-7	30	7.4±0.2	10.0±2.0	7.0±0.8	2.4±0.1	205.1±17.3	6.4±2.7	3.0±0.6	11.1±3.2	5.8±0.6	0.004±0.00	0.010±0.004	0.347±0.4
R-8	32	7.4±0.2	6.1±1.2	5.9±1.2	2.4±0.3	210.5±24.0	5.8±1.8	2.4±0.3	11.4±1.1	6.2±0.8	0.003±0.00	0.017±0.002	0.276±0.2
Permissible Limit (IS:10500)		6.5-8.5	250	45	3	500	*	*	75	30	0.05	5	0.3

All parameters in mg/L except pH, *Not declared

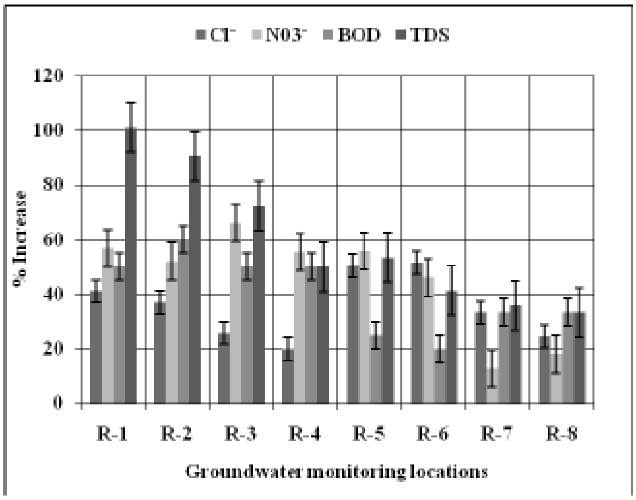

Fig.1: Percent increase in different parameters during post-irrigation period.

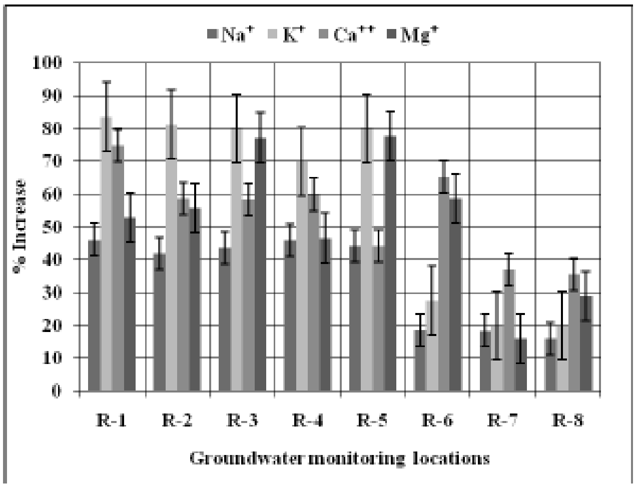

Fig. 2: Percent increase in cation concentrations during post-irrigation period.

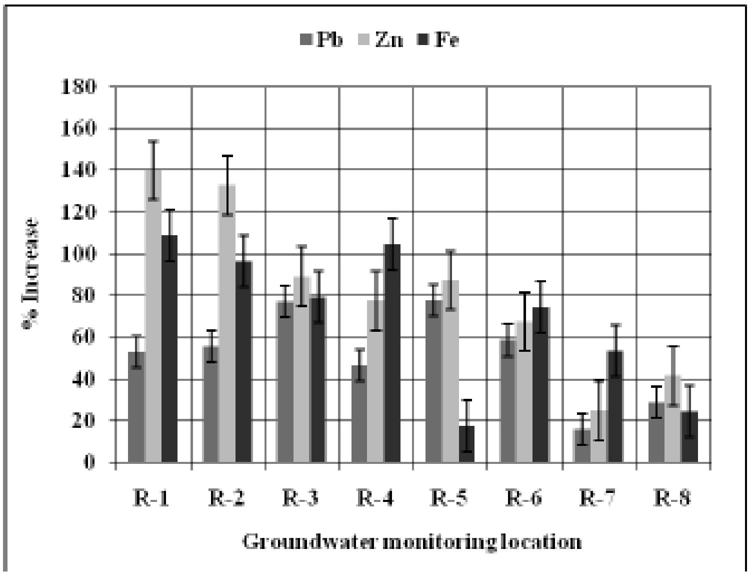

Fig. 3: Percent increase in metal concentrations during post-irrigation period.

Biochemical oxygen demand: The BOD values in post-irrigation phase were found to be higher in respect to pre-irrigation period for all the eight sites. However, the maximum BOD values were reported at R-1 (5.4 mg/L) and minimum at R-7 and R-8 sites (1.8 mg/L) during both the phases (Fig. 1). Higher BOD values of water samples clearly indicate pollution and may be attributed to the percolation of wastewater loaded with biodegradable compounds (Pitchammal et al. 2009).

Cations and anions: The mean concentration of Na^+, K^+, Ca^{+2} and Mg^{+2} were found to be more in water samples collected during the post-irrigation phase compared to water samples collected during pre-monsoon phase. The values of Na^+ were well within the prescribed limit but high concentration of sodium ion may pose a risk to persons suffering from cardiac, renal and circulatory diseases (Reddy et al. 2011). The K^+ values ranged from 1.2 to 21.3 mg/L in pre and post-irrigation phases. However, sites R-1, R-2 and R-3 showed similar trends in % increase in K^+ concentrations i.e., 83.6%, 81.3% and 80% respectively during the post-monsoon phase (Fig. 2). The significant change in K^+ value may be due to repeated application of irrigation leading to accumulations of said cation. Similar trends were observed for Ca^{+2} and Mg^{+2}. The Ca^{+2} values ranged from 8.09 to 71 mg/L, while Mg^{+2} values ranged from 4.0 to 25.1 mg/L respectively. The maximum and minimum % increase were reported in K^+ and Na^+ concentrations followed by other among the all the cations. The Cl^- anions ranged between 4.9 mg/L and 58 mg/L in all hand pumps during the study period. All the values recorded were well below the permissible limits i.e., 250 mg/L issued by BIS: 10500 (1991).

Heavy metals: Water samples collected from both irrigation phases showed Pb and Zn values within the prescribed limit of 0.5 and 5.0 mg/L as given by BIS: 10500 (1991). However, after irrigation deep well hand pumps (25-32m) at R-5, R-6, R-7 and R-8 did not report any change in lead concentration with respect to lower depth hand pumps. In addition, the Zn concentrations showed appreciable % increase at R-1 and R-2 sites i.e., 140 % and 132 % respectively during the second phase study (Fig. 3).

The ferrous ion values were higher in all the hand pumps of the area for both the phases. In fact, the values were above the permissible limit of 0.3 mg/L issued by IS: 10500 (1991). However, maximum values of iron concentration were at R-1 and R-2 i.e., 1.62 and 1.22 mg/L with 109 % and 96.4 % increase respectively after the effluent irrigation (Table 2). The presence of iron in all hand pumps may be attributed to the dissolution of the rocks and mineral, landfill leachates, sewage and industrial effluents.

CONCLUSIONS

The study indicates that the use of secondary treated effluent could lead to significant leaching of inorganic components, which might join private wells (low depth hand pumps). It has the potential to affect of groundwater quality which is unsafe for drinking purpose available for the masses. Future studies incorporating individual exposure assessment about users of private wells, the population most at risk, should be considered. Future research could include long-term monitoring or surveillance of water systems vulnerable to contamination.

ACKNOWLEDGEMENT

The authors are grateful to Professor and Head Dr. Uma Melkaniya and Professor Dr. J. P. N. Rai, Department of Environmental Science, G.B.P.U.A & T, Pantnagar for providing financial support as well as laboratory facility to carry out this research. Finally, the authors also thankful to Dean (CBS&H) and Director (Experiment Station), G.B.P.U.A. and T., Pantnagar and Jubilant Organosys Ltd., Gajraula for their technical assistance during this study.

REFERENCES

APHA 1995. Standard Methods for the Examination of Water and Wastewater. 17th edition, American Public Health Association, Washington, D.C.

Aramini, J.M., McLean, M., Wilson, J., Holt, J., Copes, R., Allen, B. and Sears, W. 2009. Drinking Water Quality and Healthcare Utilization for Gastrointestinal Illness in Greater Vancouver. Environmental and Workplace Health Reports and Publication.

Bradford, A., Brook, R. and Hunshal, C. S. 2003. Wastewater irrigation in Hubli- Dharwad, India Implications for health and livelihoods. Environ. Urbanis., 15(2): 157-170.

Buechler, S. and Mekala, G.D. 2005. Local responses to water resource degradation in India: Groundwater farmer innovations and the reversal of knowledge flows. J. Environ. Develop., 14(4): 410-438.

BIS: 10500 1991. Indian Standard Drinking Water Specification. Bureau of Indian Standards, New Delhi.

Joshi, H.C., Pathak, H., Chaudhary, A., Joshi, T.P., Phogot, V.K. and Kalra, N. 2000. Changes in soil properties with distillery effluent irrigation. J. Environ. Res., 6(4): 153-162.

Joshi, H.C. 1999. Bioenergy potential of distillery effluent. Bioen. News, 3(3): 10-15.

Pitchammal, V., Subramanian, G., Ramadevi, P. and Ramanathan, R. 2009. The study of water quality at Madurai, Tamilnadu, India. Nat. Env. Poll. Tech., 8(2): 355-358.

Pathak, H., Joshi, H.C., Chaudhary, A., Chaudhary, R., Kalra, N. and Dwivedi, M. K. 1999. Soil amendment with distillery effluents for wheat and rice cultivation. Water, Air and Soil Poll., 113: 133-140.

Rahmani, H.R. 2007. Use of industrial and municipal effluent water in Esfahan province-Iran. Sci. Res. Essay, 2(3): 84-88.

Reddy, P.S. and Nandani, N. 2011. Leachate characterization and assessment of ground water pollution near municipal soil waste landfill site. Nat. Env. Poll. Tech., 10(3): 415-418.

Saha, N.K., Balakrishnan, M. and Batra, V.S. 2005. Improving industrial water use: Case study for an Indian distillery. Res. Cons. Recycl., 43: 163-174.

Stigter, T.Y., Ribeiro, L. and Carvalho Dill, A.M.M. 2006. Application of a groundwater quality index as an assessment and communication tool in agro-environmental policies-Two Portuguese case studies. J. Hydrol., 327: 578-591.