Octa Journal of Environmental Research Oct. – Dec., 2014
International Peer-Reviewed Journal ISSN 2321 3655
Oct. Jour. Env. Res. Vol. 2(4): 321-328
Available online http://www.sciencebeingjournal.com

Research Article

Octa Journal of Environmental Research
(Oct. Jour. Env. Res.) ISSN: 2321-3655
Journal Homepage: http://www.sciencebeingjournal.com

ASSESSMENT OF POTABILITY OF GROUNDWATER AROUND FERTI-IRRIGATED AREA OF INDUSTRIAL REGION

Jaspal Singh Chauhan[a] and Jai Prakash Narayan Rai[b]
a. Himalayan Aquatic Biodiversity, Department of Zoology & Biotechnology, HNB Garhwal University, Srinagar Garhwal (Uttarakhand) India.
b. GB Pant University of Agriculture &Technology, Pantnagar India.
***Corresponding author's Email:jaspal.env@gmail.com**

Received: 22nd Nov. 2014 **Revised**: 25th Dec. 2014 **Accepted**: 30th Dec. 2014

Abstract: An experiment was conducted to evaluate the impact of ferti-irrigation with distillery effluents on groundwater quality around village Gajraula, UP, India. Groundwater sampling was carried out around ferti-irrigated field from an open-well (15m depth), tube-well (22m depth) and bore-well (22m depth) on monthly intervals consecutively for two years. A tube-well, depth 22m located 5Km away from the experimental site was selected for control. Samples were analyzed for relevant water quality parameters *viz.* pH, EC, Cl^-, SO_4^{2-}, NO_3^-, TDS, Na^+, K^+, Ca^{2+} and Mg^{2+} and were recorded significantly ($p<0.05$) higher than control following the trend: open-well>tube-well> bore-well> control. Ground water quality index (GWQI) was also calculated to categories the water samples on the basis of pollutant load and the results revealed that only open-well samples were severely polluted (GWQI 79.19). Statistical analysis showed that the common ionic pairs showing significant correlation ($p\leq0.05$) between open-well and tube-well were Na^+/Cl^-; Na^+/NO_3^-; Mg^{2+}/Cl^-, while that between tube-well and bore-well were Na^+/Cl^-; Na^+/NO_3^-; K^+/TDS; Mg^{2+}/Cl^-, suggesting that these ions are added in groundwater from a common source.

Keywords: Effluent; Ferti-irrigation; Groundwater; Wastewater; Water Quality Index.

Postal Address: Himalayan Aquatic Biodiversity, Department of Zoology & Biotechnology, HNB Garhwal University, Srinagar Garhwal (Uttarakhand) India Tel: +919410168529

INTRODUCTION

Growing population is causing tremendous pressure on the water resources, which calls for constant, reliable, cheap and effective strategy to conserve every drop of water to keep pace with development. Ferti-irrigation, a concept of using wastewater in agriculture is often practiced as one of the promising approach to reduce the pressure on natural resources of water supply. Utilization of industrial wastewater for land irrigation is gaining momentum owing to the fact that it provides treatment to the wastewater with recycling and reuse of nutrients (Witherow and Bledsoe, 1986; Juwarkar *et al*., 1995). Further, it also promotes replenishment of natural resources, reduction in use of fertilizers and recharge of groundwater. Several countries including India (Bester *et al*., 1977; Greef, 1975), wherein food industry wastewater could be used for ferti-irrigation as it contains appreciable amount of essential macro and micro nutrients required for plant growth. Ferti-irrigation could only be effective if it is done after proper treatment following standard guidelines. Otherwise, it deteriorates the soil, crop and groundwater and also raises risks of microbial infection to all associated people (Castro *et al.,* 2014; Chauhan and Rai, 2010; Buechler and Scott, 2006; Butt et al., 2005; Minhas and Samra, 2004; Bradford et al., 2003). It has been noticed that excessive effluent loading without knowing the soil-plant assimilative capacity resulted in soil sickness, salinity and sodicity (Liang *et al.,* 2014; Juwarkar and Juwarkar, 1987). Furthermore, Joshi *et al*., (2000) reported that non-judicious use of post-methanated distillery effluent (PDME) adversely affected crop growth and increased soil salinity. Despite of all these, wastewater disposal on land without proper treatment has become an easy and regular practice for most of the industries, which creates environmental problems (Müller *et al*., 2007; Rahmani, 2007; Ghosh, 2005; Jain *et al*., 2005; Kisku *et al*., 2003). Therefore, it is important that while implementing ferti-irigation the other environmental components (soil, water, plant, etc) should not be neglected. A proper plan of wastewater dose and pattern of application for the crop is necessary for making the process worth (Chauhan and Rai, 2012). Pathak *et al*., (1999) suggested dilution of PMDE to bring down BOD to 1000mgL^{-1} before application in standing crops of rice and wheat for higher yield and improved soil qualities. Groundwater quality in ferti-irrigated area is also impaired by the inorganic and organic ions added by effluent irrigation (Jain *et al*., 2005). Therefore regular monitoring of groundwater quality is essential before using it for drinking purpose. The suitability of water quality for drinking purposes can be examined by determining its quality index (Tziritis *et al.,* 2014). Groundwater quality index (GWQI) is defined as a technique of rating that provides the composite influence of individual water quality parameters on the overall quality of water. It is calculated from the point of view of human consumption. The present study was designed with the objectives of to monitor the effect of distillery effluent irrigation on groundwater quality in ferti-irrigated region of Gajraula (UP) and to assess the suitability of groundwater in ferti-irrigated region for drinking purpose.

EXPERIMENTAL

Geographical background of Experimental site

An experiment was conducted at village Gajraula in the district of Jyotiba Phule Nagar, Uttar Pradesh, situated at 29^0, 4ʹ N latitude, 77^0, 46ʹE longitude. It has an altitude of 237 m above mean sea level and is 100 km far from Delhi, on NH-24 towards Lucknow. It is an industrial area running distillery industry which is continuously practicing ferti-irrigation. The ground water hydrology of this region is characterized by unconfined and semi-confined aquifers at a depth of about 20-25 m below ground level. The map of study area is given as Figure 1.

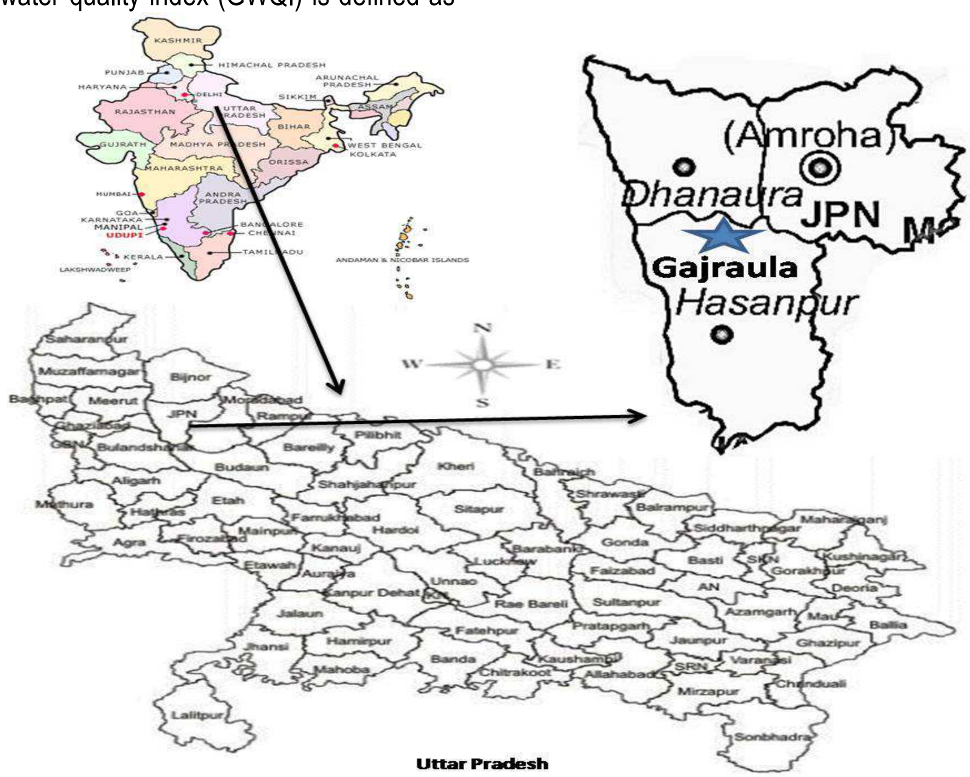

Figure 1. Map of study area

Groundwater Monitoring and Analysis

Groundwater samples around ferti-irrigated field were collected from an open-well, tube-well and bore-well at the depths of 15m, 22m and 22m respectively. For control, a tube-well of depth 22m at a distance of 5Km away from the experimental sites was selected where groundwater irrigation was done. Samples were collected on monthly basis for two consecutive years (2006 and 2007) after effluent irrigation. The samples were collected in 600 ml polyethylene bottles and were stored at 4^{0}C until further analysis. Samples were analyzed for the physico-chemical characteristics *viz.* pH, EC, Cl^-, SO_4^{2-}, NO_3^-, TDS, Na^+, K^+, Ca^{2+} and Mg^{2+} according to standard methods given by American Public Health Association, Washington, DC (APHA 1998). TDS was determined by evaporation method. For pH analysis, pH meter (Systronics) and for conductivity, conductivity meter (Systronics) were used. Contents of Na^+, K^+ and Ca^{+2} in the samples were determined by Flame Photometer (Systronics 128, ASE Ltd) and Mg^{2+} by Versinate titration method. The anions NO_3^- and SO_4^{2-} were determined by Spectrophotometer (UV-5704 ECIL) and Cl^- by Mohr's method.

Water quality index (WQI)

WQI was calculated by weighted index method to determine the suitability of groundwater for drinking purposes (Banerjee and Srivastava, 2009; Padmanabha and Belagali, 2005; Tiwari and Mishra, 1985).The standards for drinking purposes as recommended by Bureau of Indian Standards (1991) have been considered for the calculation of GWQI. The weights for various water quality parameters are assumed to be inversely proportional to the recommended standards for the corresponding parameters (Naik and Purohit, 2001). Out of analyzed parameters, pH, TDS, NO_3^-, Cl^-, SO_4^{2-}, Ca^{+2} and Mg^{+2} parameters were considered for the computation of water quality rating and water quality index was calculated by the formula

$$WQI = \sum_{i=1}^{n} w_i q_i \quad \text{............(i)}$$

In equation (i), w_i is the weightage factor of the ith parameter, q_i is the quality rating of the ith parameter. The w_i can be calculated from the following equation.

$$w_i = \left(K / S_n \right)$$

$$K = \frac{1}{1/V_{s1} + 1/V_{s2} + 1/V_{s3} + \text{.........} + 1/V_{sn}}$$

S_n = standard value of ith parameter

$$q_i = \left(\frac{V_a - V_i}{V_s - V_i} \right) X\ 100 \quad \text{.........(ii)}$$

where, Va is actual value obtained from laboratory analysis of ith parameter

Vs = standard value of ith parameter from standard table.

Vi = ideal value (for pH= 7 and for other parameters it is equivalent to zero)

Using the water quality index, all samples were categorized into five classes (Table 1.) based on their suitability for human consumption.

Statistical analysis

The experimental data were processed for statistical analysis using SPSS for Windows (version 10.0) for correlation coefficient was calculated using Microsoft EXCEL between ion pairs.

Table 1. Classification of water samples on the basis of groundwater quality index

GWQI	Category
0-25	Excellent
26-50	Good
51-75	Moderately Polluted
76-100	Severely Polluted
above 100	Unfit

RESULTS AND DISCUSSION

The concentration of all the studied parameters were found significantly ($p<0.05$) higher in the groundwater samples of open-well, tube-well and bore-well than the control which followed the pattern: open-well>tube-well> bore-well >control (Table 2). The open-well had the lowest depth and hence it was more susceptible to pollution by irrigated effluent than others. In ferti-irrigation, the soils works as an effluent treatment system and as effluent passes through different layers of soil, pollutants of solid and liquid origin are stabilized through degradation, adsorption, precipitation and utilization by crops. The wastewater, while passing through the soil matrix, provides filtration of pollutants on the soil surface leading to removal of pollutant from effluent (Thawale *et al*., 2006). Hence deeper wells were better as compared to shallower ones. Fridrich *et al.* (2014) also observed high contamination of low depth groundwater resulted due to wastewater from pig farm lagoons. Groundwater samples from all sites for both the years showed alkaline nature having pH from 7.2 to 8.0. Electrical conductivity value ranged from 173 to 804 µS/cm in overall analysis indicating the presence of electrolytes, which was confirmed by the presence of cations (K^+, Na^+, $Ca^{2+}$and Mg^{2+}) and anions (Cl, SO_4^{2-} and NO_3). The range of TDS was found to be 167.1-623.9 mg/l, and was markedly higher for tube-well samples probably due to higher concentration of salts at lower depth. High salt content and TDS in groundwater around effluent irrigated region have also been reported by (Joshi, 1999). The cations showed significant ($p<0.05$) increase as compared to control ranging (in mg/l) from 10 to 58.6 (Ca^{2+}), 5 to 25 (Mg^{2+}), 6 to 42 (Na^+) and 4 to 26 (K^+). High concentrations of Na^+, Mg^{+2} and Ca^{2+} in the groundwater are attributed to cation exchange among minerals in addition to the filtration of pollutants from effluents. However, availability of K^+ may result due to application of some pesticides in the field, which percolate with the effluent water to reach groundwater. Among anions, $NO3^{-}$ was found to be higher than the limit (50mg/l) for open-well samples during both years. For year 2006, the percent increase in nitrate content compared to control was calculated to be 492.4, 204.2 and 142.8% from samples of open-well, tube-well, and borew-ell, respectively, while for 2007 it was 672.5, 366.6 and 285.2% (Figure 2 and 3). Moreover, significant ($p<0.05$) positive correlation was found for Na^+/NO_3^- pair in the three studied sites, indicating the common source of pollution *i.e.* ferti-irrigation. Furthermore ferti-irrigation has tendency to flush off the soil-stored nitrate and cause it to leach down to shallow groundwater, increasing its concentration (Baram *et al.,* 2014; Albus and Knighton, 1998). Sulphate content in groundwater was recorded below permissible limits of 500mg/l (WHO, 2006). For the year 2006, the percent increase in SO_4^{2-} content compared to control was calculated to be 343.7, 215 and 103.5 % from samples of open-well, tube-well and bore-well, respectively, while for 2007 it was 407.3, 298.4 and 130.3%. Chloride ions showed a positive correlation with both Mg^{2+} and Na^+ for all the samples as proved by statistical analysis. The potability of drinking water is adjudged by water quality index based on Indian standard drinking water specification of Bureau of Indian Standards (BIS, 1991). The results showed that open-well samples were severely polluted (GWQI 79.19) and moderately polluted (GWQI 73.96) for year 2006 and 2007 respectively (Table 3). This is probably due to the fact the shallower water is more prone to get polluted by the leached chemicals released by the effluent irrigation. In contrast, the tube-well and bore-well samples were taken from greater depths and, therefore, the chemicals are filtered through the larger soil column more efficiently, thus resulted in the water quality indices of 46.42, 50.03 and 16.23, 28.71 for 2006 and 2007, respectively. This indicates that tube-well and bore-well water is good for human consumption than open-well water. The groundwater samples of control area shows excellent category as it has GWQI of 7.23 and 15.36 for the two consecutive years. Comparison of WQI for the year was slightly more as compared to 2006 (Figure 4). This may be because of continuous ferti-irrigation done over the years, which had exhibited a sort of cumulative effect on increasing concentration of different pollutants in water.

Correlation between quality pairs of groundwater samples from open-well, tube-well and bore-well in effluent irrigated field are shown in (Table 4). The common ionic pairs showing significant correlation ($p<0.05$) for open-well and tube-well were Na^+/Cl^-; Na^+/NO_3^-; Mg^+/Cl^-, while for open-well and bore-well were Na^+/Cl^-; Na^+/NO_3^-; K^+/TDS; Mg/Cl^-. This suggested that there was a common source of pollution which contains various salts applied and formed during industrial processes.

Table 2. Groundwater quality at experimental sites during study period

Parameter	For year 2006				For year 2007			
	Openwell	Tubewell	Borewell	Control	Openwell	Tubewell	Borewell	Control
pH	8	7.6	7.2	7.2	7.8	7.6	7.2	7.2
EC(µS/cm)	775.2	498.4	310.7	173.2	804.2	530.6	300.4	192.1
TDS (mg/l)	601.3	367.8	232.8	167.1	623.9	384.5	246	173.8
NO_3^-(mg/l)	70.5	36.2	28.9	11.9	78.8	47.6	39.3	10.2
SO_4^{2-}(mg/l)	88.3	62.7	40.5	19.9	96.9	76.1	44	19.1
Cl-(mg/l)	53.5	39.8	20.3	11.8	66.8	45.5	23.6	11.1
Ca^{2+}(mg/l)	42.4	32.7	21.8	10.5	58.6	30.2	23.6	11
Mg^{2+}(mg/l)	21.9	15.6	10.5	5.1	25.3	16.9	13.5	5.7
Na^+(mg/l)	38.4	25.7	17.4	6.2	42.8	30.4	21.5	7.5
K^+(mg/l)	26.1	14.7	8	4	25.5	16.9	10.9	5.7

Samples were collected at monthly interval for each year (n=12)

Table 3. Variation of water quality index with year at different location

Parameters	Qi										
	Sn and Vs	Wi	Vi	For 2006				For 2007			
				OW	TW	BW	C	OW	TW	BW	C
pH	8.5	0.595	7	66.67	40	0	0	53.33	40	13.33	13.33
TDS	500	0.010	0	120.26	73.56	46.56	33.42	124.78	76.9	49.2	34.76
NO_3^-	45	0.112	0	156.67	80.45	64.22	26.44	175.11	105.78	87.33	22.66
SO_4^{2-}	200	0.025	0	44.15	31.35	20.25	9.95	48.45	38.05	22	9.55
Cl^-	250	0.020	0	21.4	15.92	8.12	4.72	26.72	18.2	9.44	4.44
Ca^{2+}	75	0.067	0	56.53	43.6	29.06	14	78.13	40.26	31.46	14.67
Mg^{2+}	30	0.168	0	73	52	35	17	84.33	56.33	45	19
∑WiQi				76.19	46.42	16.23	7.47	73.96	50.03	28.71	15.36

OW-Open well, TW-tube-well, BW-bore-well and C- control

Table 4. Correlation coefficient between quality parameter pairs of the groundwater samples from Open-well, tube-well and bore-well for year 2006 and 2007

Quality parameter Pairs	Coefficient of correlation (r)					
	For 2006			For 2007		
	Open-well	Tube-well	Bore-well	Open-well	Tube-well	Bore-well
Na^+-Cl^-	1.000*	0.997*	1.000*	0.999*	0.999*	0.999*
Na^+-NO_3^-	0.998*	0.999*	0.998*	1.000*	0.998*	0.974
Na^+-SO_4^{2-}	0.999*	0.991	0.954	1.000*	0.481	0.625
Na^+-TDS	1.000*	0.849	0.702	0.893	0.682	0.827
Ca^{2+}-Cl^-	0.327	0.432	-0.272	0.078	0.553	0.099
Ca^{2+}-NO_3^-	-0.442	0.165	-0.076	0.246	-0.441	-0.341
Ca^{2+}-SO_4^{2-}	0.706	0.546	0.529	0.665	0.489	-0.524
Ca^{2+}-TDS	0.082	0.714	0.998*	0.260	0.995	0.940
Mg^{2+}-Cl^-	0.999*	1.000*	0.998*	1.000*	1.000*	0.998*
Mg^{2+}-NO_3^-	-0.543	0.579	0.187	0.084	0.466	0.091
Mg^{2+}-SO_4^{2-}	-0.448	-0.530	0.088	0.001	-0.268	-0.361
Mg^{2+}-TDS	0.999*	0.585	0.432	0.998*	0.496	0.473
K^+-Cl^-	0.659	1.000*	0.754	0.542	0.999*	0.511
K^+-NO_3^-	0.465	0.750	0.534	0.819	0.996	0.910
K^+-SO_4^{2-}	0.540	-0.146	-0.525	-0.332	0.078	-0.182
K^+-TDS	0.385	0.999*	0.998*	0.780	0.998*	0.998*

* is significance at 5% probability levels.

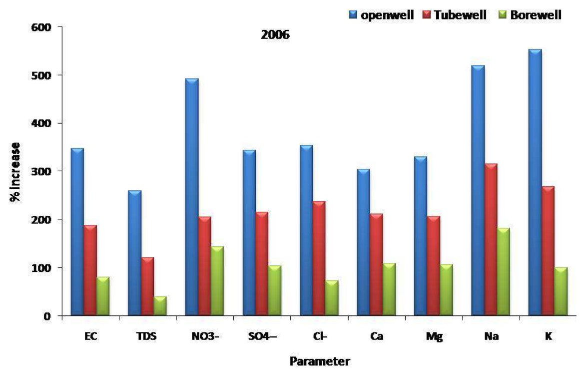

Figure 2. Percent increase in various parameters compared to control for 2006

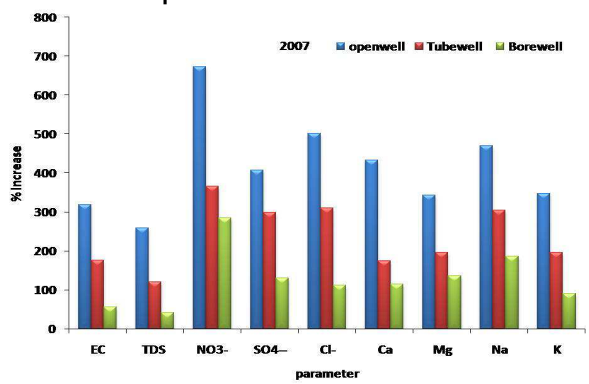

Figure 3. Percent increase in various parameters compared to control for 2007

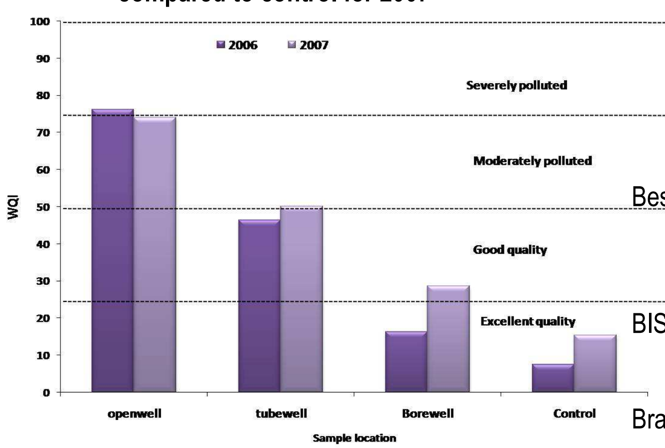

Figure 4. Comparison of water quality index at different location for two experimental years

CONCLUSION

The study suggests that water at greater depth in ferti-irrigated area is safe for drinking purpose while that from shallower region is impaired and proved unfit for human consumption. Since the ferti-irrigation serves dual purpose *i.e.* saving potable water used in irrigation and synthetic fertilizer application, it is imperative to have a thorough understanding of characteristics, dose and application pattern of industrial effluent vis-à-vis soil characteristics, and water table and crop responses for devising environment friendly strategies of ferti-irrigation.

Acknowledgements: The authors are thankful to Department of Environmental Sciences, CBS&H, GB Pant Agriculture and Technology University, Pantnagar for the support to carry out this research work.

REFERENCES

Albus, W.L., and Knighton, R.E. (1998). Water quality in a sand plane after conversion from dry land to irrigation: Tillage and cropping systems compared. *Soil tillage Research*, 48: 195-205.

APHA (1998) Standard Methods for the Examination of Water and Wastewater. American Public Health Association Inc., New York

Banerjee, T. and Srivastava R.K. (2009). Application of water quality index for assessment of surface water quality surrounding integrated industrial estate-Pantnagar. *Water Sci Technol.* 60(8): 2041-53.

Baram, S. Kurtzman, D. Ronen, Z. Peeters, A. and Dahan, O. (2014). Assessing the impact of dairy waste lagoons on groundwater quality using a spatial analysis of vadose zone and groundwater information in a coastal phreatic aquifer. *Journal of Environmental Management.* 132: 135-144

Bester, D.H., Fouche, P.S. and Veldman, G.H. (1977). Fertilizing through drip irrigation systems on orange trees. *Proc. Int. Soc. Citriculture,* 1: 46-49.

BIS (1991). Indian standards specifications for drinking water. Bureau of Indian standards, IS:10500. New Delhi.

Bradford, A., Brook, R. and Hunshal, C.S. (2003). Wastewater Irrigation in Hubli-Dharwad, India: Implications for Health and Livelihoods. *Environment and Urbanization*, 15 (2): 157-70.

Buechler, S. and Scott, C. (2006). Wastewater as a controversial, contaminated yet coveted resource in South Asia. Occasional Paper 36, Human Development Report Office, UNDP.

Butt, M.S., Sharif, K., Babar, E.B. and Aziz, A. (2005). Hazardous effects of sewage water on the environment: Focus on heavy metals and chemical composition of soil and vegetables. *Management of Environmental Quality: An International Journal,* 16 (4): 338-346

Castro, C. Lopes, A. R. Vaz-Moreira, I. Elisabete, Silva, F. Célia, M. Olga, M. and Nunes, C. (2014). Wastewater reuse in irrigation: A microbiological perspective on implications in soil fertility and human and environmental health. *Environment International.*75:117-135

Chauhan, J. S., and Rai, J.P.N. (2010). Monitoring of impact of ferti-irrigation by post-methanated distillery effluent on groundwater quality. *Clean Soil Air Water*. 38 (7): 630–638.

Chauhan, J. S., and Rai, J.P.N. (2010). Reuse of Distillery Wastewater with Designed Dose and Pattern for Sugarcane Irrigation. *Clean-Soil Air Water*, 40(8): 838–843.

Fridrich, B. Krčmar, D. Dalmacija, B. Molnar, J. Pešić, V. Kragulj, M. and Varga, N. (2014) Impact of wastewater from pig farm lagoons on the quality of local groundwater. *Agricultural Water Management.*135(31): 40-53

Ghosh, P. (2005). Drug abuse: Ranbaxy, Dutch Pharma put paid to groundwater. *Down to Earth*, 14(17): 7-8.

Greef, P.F. (1975). Ferti-irrigation of fertilizer materials by means of micro-irrigation systems—Part 1. The Dedicuous Fruit Grower. 213-217.

Jain, N., Bhatia, A., Kaushik, R., Kumar, S., Joshi, H.C. and Pathak, H. (2005). Impact of post-methanation distillery effluent irrigation on groundwater quality. *Environment Monitoring and Assessment*, 110(1): 243-255.

Joshi, H.C., Pathak, H., Chaudhary, A., Joshi, T.P., Phogat, V.K. and Kalra, N. (2000). Changes in soil properties with distillery effluent irrigation. *Journal of Environment Research*, 6 (4): 153–162.

Juwarkar, A.S. and Juwarkar, A. (1987). A case study on the use of sewage for crop irrigation – Indian experience. Food and Agriculture Organization, Rome.

Juwarkar, A.S., Thawale, P.R., Juwarkar, A.A. and Khanna, P. (1995). A case study of environmental problems in the use of wastewater for crop irrigation. National Workshop on Health, Agriculture and Environmental Aspects of Wastewater use, UNEP–WHO–NEERI.

Kisku, G.C., Barman, S.C. and Bhargava, S.K. (2003). Contamination of soil and plants with potentially toxic elements irrigated with mixed industrial effluent and its impact on the environment. *Water Air and Soil Pollution*, 120 (1-2): 121-137.

Liang, Q. Gao, R. Xi, B. Zhang, Y. Zhang, H. (2014) Long-term effects of irrigation using water from the river receiving treated industrial wastewater on soil organic carbon fractions and enzyme activities. Agricultural Water Management. 135:100-108

Minhas, P.S. and Samra, J.S. (2004). Wastewater Use in Peri-Urban Agriculture: Impacts and Opportunities. Central Soil Salinity Research Institute, Karnal, India.

Müller, K., Magesan, G.N. and Bolan, N.S. (2007). A critical review of the influence of effluent irrigation on the fate of pesticides in soil. *Agriculture Ecosystem and Environment*, 120 (2-4): 93-116.

Naik, S. and Purohit, K.M. (2001). Studies on water quality of River Brahmani in Sundargarh district, Orissa. *Indian Journal of Environment and Ecoplanning*, *5* (2): 397–402.

Padmanabha, B. and Belagali, S.L. (2005). Comparative study on water quality index of the four lakes in the Mysore city. *Indian Journal of Environmental Protection*, *25* (10): 873-876.

Pathak, H., Joshi, H.C., Chaudhary, A., Chaudhary, R., Kalra, N. and Dwiwedi, M.K. (1999). Soil amendment with distillery effluent for wheat and rice cultivation. *Water, Air and Soil Pollution*, 113(1-4): 133-140.

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

Thawale, P. R., Juwarkar, A. S., Kulkarni, A.B. and Juwarkar, A.A. (1999). Lysimeter studies for evaluation of changes in soil properties and crop yield using wastewater. *International Journal of Tropical Agriculture*, 17: 231–244.

Tiwari, T.N. and Mishra, M. (1985). A preliminary assignment of water quality index of major Indian rivers. *Indian Journal of Environmental Protection, 5*(4): 276-279.

Tziritis, E, Panagopoulos, A. Arampatzis, G. (2014). Development of an operational index of water quality (PoS) as a versatile tool to assist groundwater resources management and strategic planning**.** *Journal of Hydrology,* 517: 339-350

Vijayakumar, P.S. and Udayasoorian, C. (2007). Anatomical response of chenchrus grass chenchrus celiaris to the paperboard effluent. *World Journal of Agricultural Sciences*. 3 (4): 553-557

Witherow, J.L. and Bledsoe, B.E. (1986). Design model for overland flow process. *Journal of Water Pollution Control Federation*, 58: 381.

World Health Organisation (WHO). (2006). Guidelines for Drinking Water Quality, First Addendum to third ed., vol. 1, Recommendations.

Source of Support: Nil
Conflict of interest: None declared.