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Contamination of Ground Water as a Consequence of Land Disposal of Dye Waste Mixed Sewage Effluents: A Case Study of Panipat District of Haryana, India

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Abstract Spatial samples of surface and ground water collected from land disposal site of dye waste mixed sewage effluents at Binjhole, in Haryana, India were analyzed to evaluate its effect on quality of pond, hand pumps and ground waters for human health and irrigation purposes. It was found that average COD and TDS of dye houses discharge (310 and 3,920 mg/L) and treated sewage (428 and 1,470 mg/L) on mixing acquired the values of 245 and 1,780 mg/L and only Pb (0.24 µg/L) was above the permissible limit for irrigation purpose. Disposal of this mixed water to village pond changes the COD and TDS to 428 and 1,470 mg/L, respectively. COD and TDS of hand pump water samples were 264 and 1,190 mg/L, where as in tube well water these values were 151 and 900 mg/L. Though the ground water contamination seemed to decrease with the increasing distance from the pond but COD, TDS and BOD values continued to be quite high in water samples drawn from the hand pumps up to a distance of 500 m from pond. However, the major cause of the concern in these waters was Pb (0.11–0.45 ppm). Crops grown with this water shows accumulation of heavy metals like Pb,Cd, Fe, Mn, Ni, Cu, and Zn but in few crops they (Zn, Pb and Cd) exceed the safe limits. Regular consumption of these crop products may lead heavy metal toxicity. It was concluded from this study that the deep seepage of effluents led to deterioration of ground water quality for drinking purposes and the well waters rendered unfit for irrigation purposes within a span of 2 years. This warrants appropriate disposal measures for sewage and dye industry effluents in order to prevent deterioration of ground water and health of human and animals.

Keywords Waste water · Health hazard · Ground water contamination · Pathogenic contamination · Heavy metal · Dye industry effluents

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Large-scale urbanization and industrialization in India is leading to production of huge quantities of effluents, and thus problems related to their disposal. The facilities to treat waste waters are woefully inadequate e.g. only five per cent of the total waste water is collected in class-I cities and about one-fourth of this is treated (Govt. of India 1999). The magnitude of damage caused to water resources with disposal of untreated sewage can be judged from the fact that about 70 per cent of rivers and streams of the country contain polluted water. Textile industry in India produces about 15–20 per cent of industrial effluent and land disposal of these waters without treatment has the environmental impacts in terms of soil pollution, toxicity to flora and fauna in addition to health hazards to local inhabitants. This is as a consequence of high amounts of chemicals (e.g. sulphuric acid and acetic acid), dyes (e.g. chrome and metal dyes), suspended solids and other toxic elements in their waste. Such not easily biodegradable problematic groups of dyes have been extensively reviewed (Cirini 2006; Swami and Budhi 2006). Thus, when these waste waters stored in disposal ponds for longer periods, it induces great risks to contaminate ground waters especially in areas with shallower water levels. Even when discharged into river waters e.g. in Luni river basin and Jajori river bed of Jodhpur, contamination of wells situated on their banks has been reported (Srivastava and Aditya 1991; Khandelwal 1996). The use of such well waters for irrigation further lead to increased uptake of heavy metals by crop plants and thus finding their way in food chain. Thus, diseases may be transmitted through direct physical contact to waste waters and/or consumption of products irrigated with contaminated waters (FAO/RNE 1993; Minhas and Samra 2004; Scott et al. 2004; Minhas et al. 2006). A similar situation exists in the industrial (mainly textile) town of Panipat as it is famous for its handloom industry. The city has two sewage water treatment plants, one (10 mld capacity) of which is located in southeast of the city along the boundary of the village Binjhole. This disposes its treated effluent to a drain that also carries effluent from number of dye houses situated along this drain. Earlier due to smaller quantities of effluent from these industrial dye houses, the discharge used to dry down in the drain itself. However, with the commissioning of the treatment plant about 2 years ago and also a dramatic rise in the dyeing units, quantity of the effluent now being transported through this drain increased tremendously. This is now dumped into a village pond (excavated over 12 ha) before being carried to an adjoining drain. The farmers of the area have been complaining about the foul smell and appearance of froth in drinking water of the hand pumps and/or tube wells. Their apprehension is that seepage from pond that is being regularly fed with the effluent has rendered the ground water to be unfit quality. The present study was taken up to assess quality of ground water and quality of crop products from this area.

Materials and Methods

To characterize the effluent, sewage water samples were collected in three neutral plastic bottles of one-liter capacity. In one of the bottles, 0.8 ml of concentrated sulphuric acid was added to preserve the nitrogen. The water in the remaining two bottles was used for analyzing the other chemicals parameters. A layout plan for samples

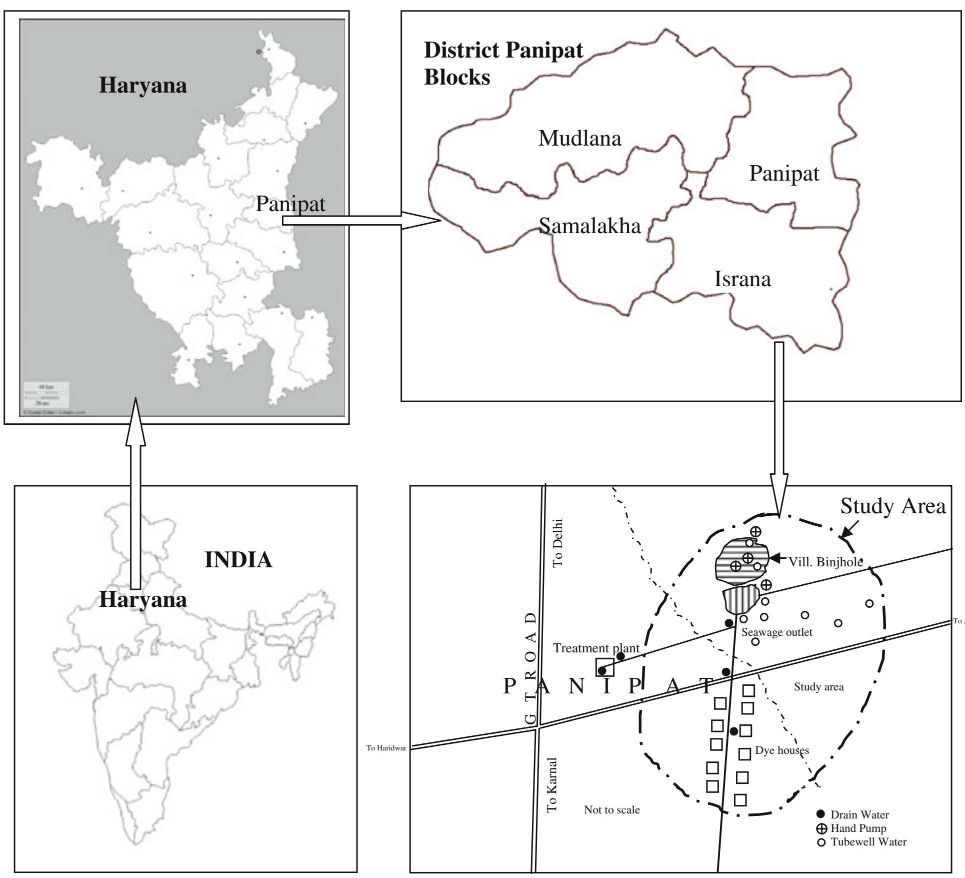

Fig. 1 Schematic diagram of the study area

drawn from tube wells and hand pumps is depicted in Fig. 1. A total of 13 ground water samples i.e. four from hand pumps and nine from tube wells were collected. Apart from these the effluent from dye house, raw and treated sewage from treated plant, drain carrying effluent from dye industries (just before the mixing with treated sewage) and pond water were collected. Several parameters were measured separately, pH and EC with the procedure described by USSL (1954), DO, BOD, COD, TDS, cations-Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, anions-Cl^{-}, NO_3^{-}-N, NH_4^{+}-N and P as per the method given by APHA-AWWA-WPCE (1995). Micronutrients and heavy metals like Fe, Cu, Mn, Zn, Pb, Cd and Ni were estimated after wet digestion with 1:4 mixture of $HClO_4$ and HNO_3, followed by measurement of respective concentrations with the help of atomic absorption spectrophotometer.

Plant samples of crops grown under dye waste mixed sewage irrigated conditions were also collected from the study area. After processing, these plant samples were digested with $HClO_4$-HNO_3-HCl acid mixture for determination of heavy metals with AAS.

Results and Discussion

Composition of Effluents

Chemical composition of effluent from dye houses, sewage (raw and treated) and pond water are given in Table 1. The pH of effluents varied from 7.5 to 8.2 indicating towards their alkaline nature. The EC of a typical dye house effluent and the sample representing mixed dye house effluent was 5.9 and 7.7 dS/m. EC of raw sewage was 1.96 dS/m that increased to 2.92 dS/m after the treatment. EC of the sample collected from the mixing point of sewage and dye effluent (WMP) was 3.51 dS/m and it was reduced to 2.92 dS/m for the pond water. The TDS value in dye house waste water was 4,090 ppm and it was 3,920 ppm in mixed dye effluent where as the values in raw sewage and effluents from mixing point (WMP) were 1,330 and 1,780 ppm, respectively. The treated sewage water and pond water showed a similar TDS value of 1,470 ppm. Dissolved oxygen (DO) of the dye house waste water was higher in comparison to the sewage water (1.2 ppm) where as it was improved in treated sewage water (6.2 ppm DO). The impact of DO was also quite obvious on BOD of the waters. The maximum value of BOD (170 ppm) was found in raw sewage water followed by 90 ppm for treated sewage water. Dye effluents had BOD of 31 ppm as compared to 33 ppm of the water samples collected from the drain. The COD of the dye waste water was very high being 734 ppm but its values for the samples drawn from raw sewage, treated sewage water, pond water and mixed water (WMP) were 496, 428, 428 and 245 ppm, respectively. K contents of effluents ranged between 0.19 and 0.97 me/L. Since NaCl is mostly used for fixing dyes, therefore, the Na content of dye effluent (9.9 me/L) was quite high where as the Na content in rest of the samples varied between 2.9 and 4.7 me/L. Cl content of effluents was also high and varied between 2 and 9 me/L. The P content of the water from dye house effluent (4 ppm) was lower than treated sewage water (10 ppm). The values of the NH_4-N in dye effluent and raw sewage water was very high having values of 60.9 and 29.8 ppm, respectively as compared to rest of effluents. The effluents from dye houses also contain higher amount of NO_3-N (3.5 ppm), however, its content was maximum (21 ppm) in the dye mix water (DMW) samples. Concentration of heavy metals/trace elements like Ni, Cd, Zn, Mn, were quite low. While the contents of Fe and Cu was found to be slightly higher. Fe content ranged between 0.07 and 0.3 ppm where as Cu ranged between 0.03 and 0.13 ppm. Pb was also noticed in most the samples.

Table 1 Chemical properties of effluent disposed from dye houses and that of a pond water in the study area

Parameters		DW	DMW	SW	TSW	WMP	PW
EC	dS/m	5.87	7.70	1.96	2.92	3.51	2.92
TDS	ppm	29.30	3,920	1,330	1,470	1,780	1,470
pH		7.30	8.25	7.56	7.50	7.70	7.50
DO	ppm	7.70	3.60	1.2	6.20	1.10	6.20
BOD	ppm	31	33	170	90	63	90
COD	ppm	734	310	496	428	245	428
Na	me/L	9.90	2.88	4.67	4.34	3.15	3.42
K	me/L	0.36	0.19	0.94	0.97	0.94	0.12
Ca + Mg	me/L	11.20	7.20	6.6	8.40	7.50	8.40
Cl	me/L	2.20	3.70	5.6	2.00	9.00	5.60
CO_3	me/L	1.20	Nil	2.4	2.00	Nil	2.00
HCO_3	me/L	11.60	5.15	11.6	11.80	8.90	12.00
P	ppm	4.0	10.0	1.9	8.0	1.0	Nil
NH_4-N	ppm	60.90	2.45	29.75	3.50	4.90	3.50
NO_3-N	ppm	3.50	21.00	2.8	2.10	2.45	2.10
Mn	ppm	0.06	0.11	Nil	Nil	0.05	0.04
Ni	ppm	0.02	0.06	Nil	Nil	0.19	0.02
Fe	ppm	0.30	0.13	0.07	0.07	0.13	0.08
Cu	ppm	0.13	0.06	0.03	0.02	0.03	0.03
Cd	ppm	Nil	0.04	0.01	0.01	Nil	0.02
Pb	ppm	0.23	0.24	0.22	0.21	0.22	0.02
Zn	ppm	0.20	0.10	0.04	0.02	0.01	0.03
SAR		4.18	1.52	2.57	2.12	1.63	1.67
RSC	me/L	1.6	Nil	7.4	5.4	1.4	5.6

DW, Dye waste water; *SW*, Sewage water; *TSW*, Treated sewage water; *DMW*, Dye mix water (raw); *WMP*, Water at mixing point; *PW*, Pond water

The waste water from all the dye houses were discharged into a drain through a single outlet that also collects the sewage water at a later stage, and thus mixed waste water is then let into a village pond. Analysis of water samples collected along the drain shows that the mixed sewage + dye house waste water along the drain was alkaline in nature with pH of 8.2 (Table 1). It also contained a quite significant amount of salts as is indicated by its EC (7.7 dS/m) and TDS (3,920 ppm). DO of this was low (3.6 ppm). Its BOD was 33 ppm while COD was 310 ppm. Its final chemical composition is expected to depend upon the proportions of effluents from sewage and dye houses getting mixed up. The analysis of mixed water show that a major portion (10 MLD) was coming from sewage water only. Although the raw sewage water was being collected at the treatment plant is also carrying the textile industry effluents, which is being produced almost in every alternate house of the city. The effluents of this composition disposed in pond could cause irreversible damage to ground water resources. Though the water in pond remains stagnated for quite some time and luxuriant growth of Eichhornia that is reported to decontaminate waste waters, could also be observed (Ofosu-asoedi et al. 1999), but BOD and other chemical parameters of effluent from pond matched with that of the influent. RSC of raw sewage (7.4 me/L), treated sewage (5.4 me/L) and of pond effluent (5.6 me/L) was higher than the prescribed limits for irrigation purposes (Minhas and Gupta 1992). The continuous disposal of these effluents could create sodicity problem when used for irrigation of crops.

Ground Water Quality

Determination of ground water quality as a result of seepage from the pond is obvious from the increase in BOD and other parameters of water collected from the hand pumps extracting water from shallow depth (20 m) as well as from tube wells (20–110 m deep) in surrounding area (Tables 2, 3). The contamination of deeper aquifer (30 m) declined after a distance of about 500 m. However, ground water from hand pumps (20 m depth) contained considerably high BOD. Similarly the waters drawn from the shallow/deep tube wells have been rendered unfit for drinking purpose within 2 years of disposal of sewage/ industrial effluents into the pond. BOD and COD as well as EC/SAR though decreased with the increase in depth of water strata from which groundwater is being extracted (Fig. 2), but indicates that ground water aquifer to a depth of about 75 m has been affected due to seepage of water from the pond. COD was the maximum (264 ppm) at the depth of 20 m, and reduced to 65 ppm at 35 m depth of water table with the minimum of 20 ppm at 110 m depth. It shows that the contamination is going deep to the aquifer. EC of the ground water was considerably higher with a similar rise in the values of cations and anions in ground waters. No trend in water quality parameters could be visualized along the distance from the pond (Tables 2, 3), but an increasing trend in SAR was noticed with the increase of aquifer depth (Fig. 3).

Table 2 Chemical properties of shallow ground waters (hand pumps) of study area

Parameters Distance (m)		HP1 10	HP2 50	HP3 500	HP4 1,000
EC	dS/m	2.37	1.39	3.90	3.13
TDS	ppm	1.19	0.75	1.58	1.57
pH		7.40	7.40	7.20	7.30
DO	ppm	7.50	6.80	4.60	6.80
BOD	ppm	57	48	44	27
COD	ppm	264	268	245	155
Na	me/L	3.80	0.65	2.88	3.34
K	me/L	0.15	0.12	0.16	2.10
Ca + Mg	me/L	11.00	10.60	17.20	10.40
Cl	me/L	3.90	1.00	6.20	5.60
CO_3	me/L	0.00	1.00	Nil	1.20
HCO_3	me/L	5.60	9.30	6.10	9.30
P	ppm	Nil	Nil	2.00	Nil
NH_4-N	ppm	Nil	2.45	5.25	2.80
NO_3-N	ppm	2.06	2.45	2.45	1.08
Mn	ppm	Nil	Nil	0.06	NA
Ni	ppm	0.12	0. 10	0.01	NA
Fe	ppm	0.13	0.03	0.09	NA
Cu	ppm	0.04	0.01	0.05	NA
Cd	ppm	0.02	0.01	0.01	NA
Pb	ppm	0.35	0.24	0.45	NA
Zn	ppm	0.01	0.13	0.07	NA
SAR		1.62	0.28	0.98	1.46
RSC	me/L	Nil	Nil	Nil	0.10

NA, Not analyzed; *HP*, Hand pump

The NH_4-N content in the ground water ranged between nil and 5.25 ppm. It was higher in water samples drawn from hand pumps as compared with well water samples (Tables 2, 3). Similar trend was observed in NO_3-N content. The nitrate content of pond water was 2.1 ppm. It appears that Eichhornia plants growing profusely in pond were taken up nitrates and there by reduces its content in pond water. Concentration of heavy metals like Pb, Zn, Ni, Mn, Cu, Fe, Cd, were quite low in most of the ground water samples and within the permissible limits (FAO 1985) except in sample collected from the tube well located at the end of drain carrying dye industries waste (TW_2). Concentration of Cd was 0.2 ppm and Zn content was 4.46 ppm in water from tube well located 10 m away from the drain (TW_1).

Crop Quality

The chemical analysis of the plants grown in the study area which is irrigated with contaminated ground water revealed

Table 3 Chemical composition of tube well waters of study area

Parameters Distance (m)		TW1 D(10)	TW2 End of D	TW3 P(10)	TW4 P(20)	TW5 P(30)	TW6 P(40)	TW7 P(50)	TW8 P(80)	TW9 P(200)
EC	dS/m	1.51	1.33	1.78	2.25	2.29	3.05	2.55	1.90	1.50
TDS	ppm	830	650	890	1,120	1,120	1,510	1,270	950	740
pH		7.60	7.60	7.50	8.30	7.30	7.70	7.60	7.50	7.70
DO	ppm	0.30	4.90	1.00	9.10	6.00	7.50	7.00	6.80	0.80
BOD	ppm	81	51	102	69	33	111	96	21	45
COD	ppm	151	115	151	65	44	101	34	20	245
Na	me/L	6.30	2.71	7.90	4.94	5.60	4.56	7.23	7.45	4.56
K	me/L	1.02	0.16	0.83	0.31	1.10	0.26	0.16	0.13	1.18
Ca + Mg	me/L	9.20	7.60	7.00	7.00	7.50	9.80	8.80	7.60	5.80
Cl	me/L	7.20	2.00	1.00	3.40	3.30	6.00	5.00	1.40	2.20
CO_3	me/L	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00
HCO_3	me/L	4.30	5.01	5.35	4.16	4.20	7.60	5.60	3.90	4.00
P	ppm	0.00	0.00	0.00	5.00	2.00	2.00	0.00	0.00	1.90
NH_4-N	ppm	2.80	2.80	2.80	0.70	1.40	1.40	0.70	2.10	3.84
NO_3-N	ppm	4.20	3.50	6.30	4.20	1.40	0.00	2.10	2.10	1.75
Mn	ppm	0.01	0.02	0.06	0.23	0.00	0.04	0.23	0.03	0.15
Ni	ppm	0.07	0.04	0.13	0.07	0.11	0.04	0.00	0.12	0.00
Fe	ppm	0.22	0.06	0.00	0.00	0.35	0.00	0.00	0.01	0.19
Cu	ppm	0.01	0.02	0.03	0.04	0.04	0.01	0.00	0.01	0.03
Cd	ppm	0.01	0.29	0.01	0.00	0.01	0.00	0.00	0.01	0.01
Pb	ppm	0.23	0.21	0.42	0.11	0.31	0.27	0.24	0.40	0.21
Zn	ppm	4.46	0.04	0.05	0.03	0.01	0.01	0.01	0.02	0.06
SAR		2.94	1.39	4.22	2.64	2.89	6.58	3.45	3.82	2.68
RSC	me/L	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

D, Open drain; *P*, Village pond; *TW*, Tube well

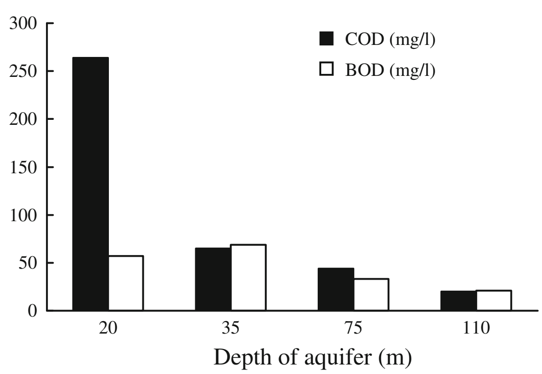

Fig. 2 BOD and COD of ground water being extracted from different depths

that the crops, namely, wheat, Egyptian clover, spinach, cauliflower, coriander and radish accumulated the heavy metals, namely, Pb, Cd, Fe, Mn, Ni and Cd. Zinc accumulation exceeded the safe limit in all the crops. Pb accumulation exceeded the safe limit both in shoots and roots of wheat, cauliflower and Egyptian clover, while in other crops only root tissue accumulated high amount heavy metals. In addition, Cd concentration in spinach

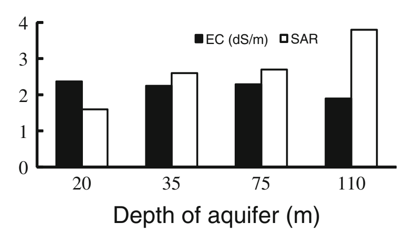

Fig. 3 Salinity and sodium adsorption ratio of ground water being extracted from different depths

leaves also exceeded safe limits (Table 4). In general the concentration of all the metals was noticed to be higher in roots than shoots of all the crops. The K and Na contents were higher in shoots as compared to roots of all the crops in sewage water use condition. The contents of K were as per general composition of the crop but that of Na were higher than normal water irrigated crops. From this study, it is evident that the use of deteriorated underground water led to deterioration of quality of some of the crops. Eichhornia plants removed from dumping pond was analyzed and it was observed that this plant accumulated very high contents of heavy metals like Pb (46.4 ppm) and Cu

Table 4 Effect of sewage water irrigation on mineral composition in plants

Crops	Plant part	Pb (mg kg^{-1})	Cd (mg kg^{-1})	Ni (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
Wheat	Shoot	10	0.2	15.6	144	16.0	271	4.0
	Root	16	ND	22	142	66.0	322	21.0
Egyptian clover	Shoot	18	ND	23.2	172	10.0	264	7.2
	Root	27	ND	30.2	165	57.6	193	8.3
Spinach	Shoot	0	2.1	32	142	39.5	274	24.0
	Root	21	ND	ND	172	35.0	122	12.0
Cauliflower	Shoot	24	ND	ND	215	23.0	284	10.3
	Root	28	ND	ND	196	45.2	156	16.2
Coriander	Shoot	ND	ND	15.6	107	36.0	266	2.8
	Root	22	ND	ND	179	36.2	152	6.2
Radish	Shoot	ND	ND	18.8	126	21.4	249	0.4
	Root	16	ND	ND	146	42.2	136	10.4
Safe limits[a]	Shoot	2.5 mg kg^{-1}	1.5 mg kg^{-1}				50 mg kg^{-1}	30 mg kg^{-1}

ND, Not determined

[a] *Source*: Prevention of food adulteration act of India (1954)

(70.2 ppm) and thus may be useful in removal of these metals from pond waste water.

Conclusion

It is evident from the study that seepage from pond has led to deterioration of ground water quality in the surrounding area within a span of 2 years. In addition to the drinking quality drawn from shallow strata by hand pumps, the tube well water have been rendered unfit for irrigation purpose. Further, food and fodder crops irrigated with this deteriorated underground water accumulated heavy metals, which exceeded safe limits as in case of Zn, Pd and Cd. Thus, if proper measures are not taken, whole aquifer is prone to contamination that will lead to poor quality drinking and irrigation water, and crop produce unsafe for human and animal consumption.

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References

APHA-AWWA-WPCE (1995) Standard methods for the examination of water and waste water. Franson Marry Ann H (ed) APHA, 1015, 15th Street, New Washington, DC 20005

Cirini G (2006) Non conventional low cost absorbents for dye removal: a review. J Bioresour Technol 97:1061–1085

FAO (1985) Water quality for agriculture. FAO Irrigation and Drainage Paper No. 29

FAO/RNE (1993) Monitoring waste water for irrigation. Tech Bull 7:18

Govt. of India (1999) Economic survey. Planing Commission, New Delhi

Khandelwal S (1996) Impact of dyeing industries waste water on vegetation of Luni catchment area. J Environ Pollu 3(2):77

Minhas PS, Gupta RK (1992) Quality of irrigation water-assessment and management. Information and publication section. Indian Council of Agriculture Research, New Delhi

Minhas PS, Samra JS (2004) Waste water use in peri-urban agriculture: impacts and opportunities. Bulletin No.1/2004. Central Soil Salinity Institute, Karnal, p 78

Minhas PS, Yadav RK, Sharma N, Joshi PK (2006) Prevalence and control of pathogenic contamination in some sewage irrigated vegetable, forage and cereal grain crops. Bioresour Technol 97:1174–1178

Ofosu-asoedi K, Oteino DA, Omolo JO, Etegni L, Englande AJ Jr (1999) Sewage re-use for irrigation in Tai river town Kenya: its implications on public health. Water Sci Technol 39(10–11):343–346

Scott CA, Faruquin NI, Raschid-Sally L (2004) Waste water use in irrigated agriculture. CABI Publ, Oxfordshire, p 193

Srivastava PN, Aditya P (1991) Bio-accumulation of heavy metals by algae and wheat plant fed textile effluents. J Ind Pollut Contr 7(1):25

Swami D, Budhi D (2006) Removal of contamination from industrial waste water through various non-convention technologies: a review. Int J Environ Pollut 27:324–346

USSL (1954) Diagnostic and improvement of saline and alkali soils. USDA Hand Book 60