International Journal of Applied Environmental Sciences
ISSN 0973-6077 Volume 12, Number 3 (2017), pp. 527-540

http://www.ripublication.com

Can We Use Textile Effluent As A Source Of Irrigation: A Case From Bhagwanpur, Uttarakhand (India)

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Abstract

Water scarcity in many parts of India is compelling farmers to use wastewater generated from industries for irrigating agricultural fields. An ignorant approach towards the usage of wastewater can lead to longterm repercussions on the soil fertility. There has been many precedents where textile effluent is recommended for watering the fields. In the present study an attempt has been made to characterize the effluent from a textile industry to check its feasibility for use in agricultural fields.The effluent was studied for its physico-chemical properties and was compared with the tubewell water. The values for pH, BOD, DO, COD, EC, TDS, TSS were found to be significantly higher than the tube well water. Also, variation has been observed in the parameters during different season and along the transects. BOD in the textile effluent was eight times higher as compared to the tube well water. Heavy metals like Cr, Pb, Fe, Ni were also found to be in considerable level which is reported to have deleterious effects on crops. It was evident from the study that the concentration of key parameters of the textile effluent was above the permissible limit. Therefore, it is suggested that textile effluent should be treated prior releasing into the agriculture fields.

Keywords: Textile effluent, Heavy metals, Physico-chemical analysis.

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INTRODUCTION

The urbo-industrialised countries are confronting the problem of water pollution because of the establishment of various industries. In most of the cases, after the consumption of water, the waste water generated in the industries is released without any treatment into the soil and water bodies. Consumption of water in various industries is based on the type of industry and the processing unit. Comparatively among all the industries, consumption of water is larger (60-400 l/kg) in the textile industry. Chemicals used in textile industry consists of varying group of organic and inorganic compounds that are incorporated during the fabric processing and parts of chemicals, which are not utilized in the products go off as waste. Most of the industries release such waste directly into the water bodies or on the agricultural field considering it the cheap and easy method of disposal and neglecting the environmental issues linked with it. Discharge of untreated waste water into the soil and water is resulting in the accumulation of harmful chemical compounds in the soil and water ecosystem (**1**).

Presence of chemicals, dyes, pigments imparts high colour intensity, biological oxygen demand, chemical oxygen demand, pH, temperature, total suspended solids and total dissolved solids to the textile effluent (**2,3,4**). Besides this the effluent discharge from the textile industries also comprises of considerable amount of heavy metals. Though small amount of heavy metals are required in the soil for the proper microbiological functioning but slight increase or decrease in their concentration may cause dysfunctioning in biological activity (**5**). Thus, disposing textile effluents in the water bodies is causing damage to the nearby aquatic system, soil ecology and groundwater system and ultimately entering into the food chain causing bioaccumulation of these compounds in plants and animals (**6**). With growing requirements of water for irrigation, the global researchers are debating on utilization of waste water after the pre-requisite treatment. Notwithstanding, the farmers in the vicinity of textile industries do considering the effluents as a cost-effective source of irrigation, with prevalent ignorance on environmental pollution, however.

Therefore, the present study characterises the physico-chemical properties of textile effluents used in local irrigation and compare with those of tubewell water, which is otherwise potable, to assess at conclusion the feasibility of textile effluent in irrigating agriculture fields.

MATERIAL AND METHODS

Geographic location

The present study site is situated in the Bhagwanpur industrial area, Uttarakhand, India located at an altitude of 293 m, 29° 01’ 30”N latitude and 79° 30’ 01”E longitude (figure 1). The site falls in humid sub-tropical climatic zone locally known as the *tarai* region. The average annual rainfall in the region is around 1350 mm.

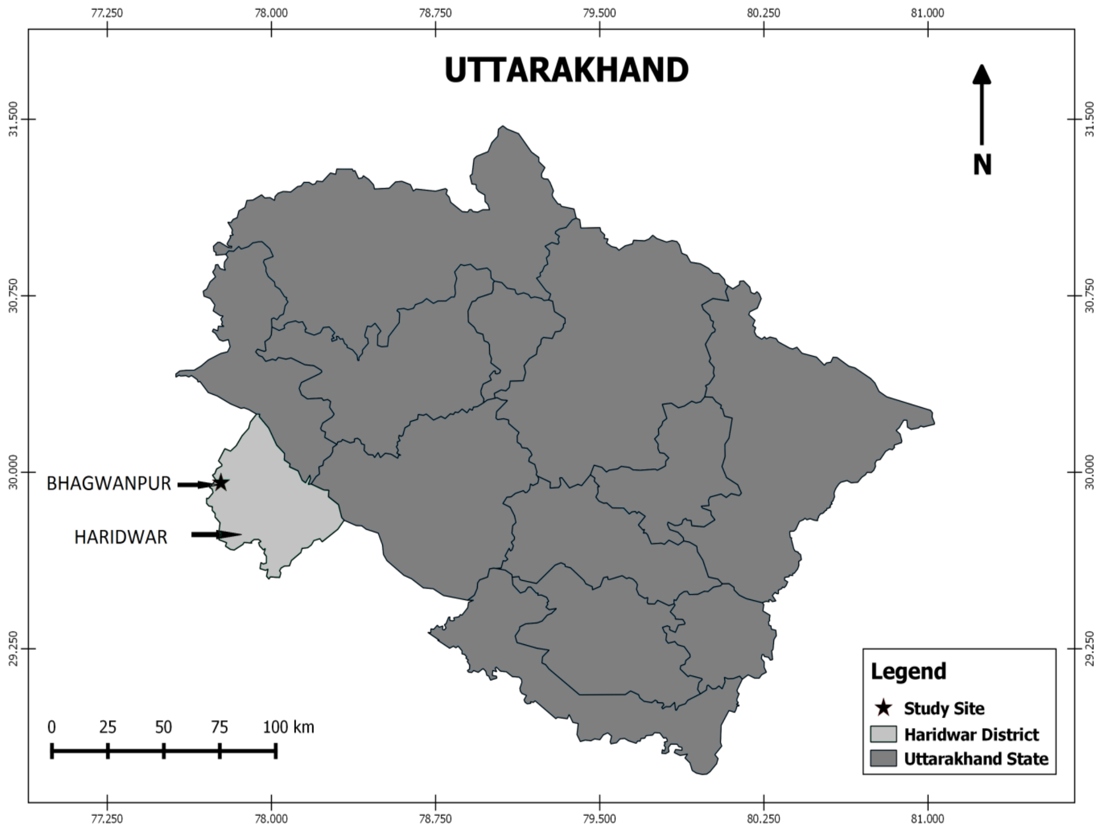

Figure 1. Map showing the study site in Uttarakhand, India

Climate

Bhagwanpur experiences moderate to subtropical to humid climate with three distinct season's *viz*., summer, followed by rainy and winter seasons. In the summer, temperature varies from 29.1˚C to 39.2˚C. Temperature begins to fall in the mid of June with the commencement of monsoon season. During winter, temperature ranged 6.1˚C and 10.5˚C. The weather parameters for the study period (Jan 2013-dec 2014) were recorded from the meteorological observatory located at National Institute of Hydrology; Roorkee located 25km away from the experimental site. The mean daily maximum temperature ranged from 13˚C to 40˚C, whereas, the mean daily minimum temperature ranged 4˚C to 27˚C. The approximate variation in total monthly precipitation ranged from trace amount 0.1 mm to 325 mm. The site has normally relative humidity of 37-90% throughout the year. The wind speed during the study period varied between 1.8 km hr^{-1} to 11 km hr^{-1}.

Textile Effluent Sampling and Analysis

Established in 2009, this textile industry falls under the category of Red type and large scale industry and is engaged in manufacturing of stuffed toys and home furnishing products. Bleaching, dyeing, printing and scouring is carried out in this industry. Source of water is tubewell and about 890 kilolitre/day water is consumed for various processes.

Sampling of textile effluent was done in five sampling points across a line transect of 700 m, during May, August and December representing pre-monsoon, rainy and winter seasons, respectively. From each point, three subsamples were collected for the study (2013-2014). Polyethylene bottles used for sample collection were soaked overnight in 10% HNO_3 and rinsed thoroughly with MiliQ water before use. All samples were analysed for the concentration of heavy metals present in it. Standard methods were used for the analysis of effluent. Some of the physical and chemical parameters like color, odour, pH, dissolved oxygen, were recorded in the field using field portable device. The remaining parameters, samples were taken to the laboratory and stored at a temperature of 4˚C. The pH and electrical conductivity of the samples was measured by using glass electrode digital pH meter and EC meter after standardization. Chemical oxygen demand (COD) was measured according to the method described in Indian Standard methods of sampling and test (physical and chemical) for water and wastewater (**7**). Biochemical oxygen demand (BOD) was measured by Azide Modification of Iodometric method as described in APHA (2005). For heavy metal analysis of effluent, US EPA microwave assisted digestion method was followed. For this purpose, 20 ml of effluent was taken in Teflon vessels and 7 ml of HNO_3 and 2 ml of $H2O_2$ was added to it. After digestion, digested sample was filtered through Whatman 42 filter paper and the sample was make up to 50 ml with deionised water. Sample was analysed with Inductively Coupled Palsma-Optical Emission Spectroscopy (ICP-OES). Tube well water collected from the locality was used as control.

RESULTS

The local people use tubewell water for both drinking and irrigation purposes. In Bhagwanpur area, the farmers cultivate crops such as rice during *kharif* and wheat during *rabi*. For irrigation, most farmers depend on the effluents as it is available at no cost, although they do admit the adversibility of the effluents on crops. Wheat was harvested in May, following which paddy was cultivated during *kharif* month, which was harvested in October.

Table 1. Comparison of physico-chemical characteristics of textile effluent and tubewell water

Parameters	Textile effluent				Tubewell (Control)				
	Summer	Rainy	Winter	Average	Summer	Rainy	Winter	Average	% variation between effluent and tubewell
Colour	Brownish red	Slightly colored	Brownish red		Colorless	Colorless	Colorless		
BOD mg/l	150±0.51	110±2.0	145±0.90	135.0	18.9±0.45	17.8±0.60	15.7±0.32	17.5	672.9
DO (mg/l)	0.42±0.01	1.1±0.10	0.61±0.04	0.7	5.8±0.17	4.9±0.19	5.7±0.31	5.5	-87.0
COD (mg/l)	580±1.57	240±3.06	565±1.56	461.7	18±0.46	80.9±0.26	85.6±0.45	51.8	791.2
Alkalinity (mg/l)	96±0.28	75±2.08	88±0.76	86.3	25±0.31	23.4±0.17	24±0.64	24.1	257.7
pH	9.6±0.13	8.2±0.05	9.45±0.20	9.1	7.2±0.06	7.3±0.05	7.2±0.12	7.2	25.6
EC (μs/cm)	362±0.61	237±1.53	335±0.68	311.3	134±0.20	130±0.40	128±0.53	130.7	138.3
Temperature (˚C)	35±0.12	28±0.29	32±0.20	31.7	30±0.60	30±0.2	25±0.2	28.3	11.8
TSS (mg/l)	259±13.45	180±1.0	253.4±1.29	230.8	75.8±0.40	75.3±0.75	74.8±0.1	75.3	206.5
TDS (mg/l)	1090±7.64	762±11.85	986.7±2.48	946.2	200±0.60	180±0.50	200±0.34	193.3	389.4
Na (mg/l)	93.2±0.27	73.5±0.84	108.8±0.93	91.8	12.89±0.01	13.1±0.65	13.64±0.2	13.2	595.2
K (mg/l)	146.48±0.89	121.3±1.07	127.09±0.43	131.6	16.91±0.72	15.6±0.2	18.73±0.2	17.1	670.6
Mg (mg/l)	38.41±0.16	30.4±0.42	36.49±0.50	35.1	143.67±0.24	141.6±1.3	142.71±0.41	142.7	-75.4
Cl (mg/l)	610±0.52	410±5.58	418.3±0.99	479.4	218±0.17	190±0.60	187±0.6	198.3	141.7

Tube well water was colourless and the effluent was brownish red in colour. All parameters studied recorded for the textile effluent was higher when compared to tube well water (Table1). Effluent used for irrigation in the selected experiment site was alkaline in nature with average pH range of 9.4-9.6. The Electrical Conductivity (EC) and Dissolved Oxygen ranged from 362-335 µS cm^{-1} and 0.4-0.6 mg/1, respectively. The lowest values of BOD was in rainy season (110mg/l) and in summer and winter it was comparatively high (150 mg/l to 145 mg/l). Similar trends were concluded from the data of DO and COD. The total dissolved solids content was 1090 mg/l in summer and 986 mg/l in winter, The TSS of the effluent was 259 and 253.4 mg/l in summer and winter, respectively (Table 1).

The percent variation in biological oxygen demand of effluent was higher than the BOD of tube well water. Average annual TSS and TDS in the study were 2-4 times greater than the tube well water (Table1). The percent variation between the chromium of effluent was significantly higher than the tube well water (Table 2). The average concentration of heavy metal in the effluent and tubewell water from control is given in the (Table 3). The results showed the concentrations of some of the metals were in permissible limits; however concentration of some of the metals Fe, Cr, Mn, Cu exceeded prescribed limits. Above 50% variation was observed for other elements like Na, Al, and K.

Table 2. Standards for effluents from textile industry

Parameter	**Concentration not to exceed, milligram per litre (mg/l), except pH**	**Textile effluent**	**Tubewell water**
pH	5.5 – 9.0	9.1	7.2
Total suspended solids	100	230.8	75.3
Bio-chemical oxygen demand (BOD)	30	135.0	17.5
Chemical oxygen demand (COD)	250	461.7	51.8
Total chromium as Cr	2	0.405	0.04

Environment Protection Rules, 1986 (MoEF)

Table 3. Concentration of different elements (in mg/l) in effluent and tube well water

Elements	**Effluent (A)**	**Tubewell water**	**Percent variation**	**drinking water permissible limit (B)**	**Permissible limit for effluent water to be used for irrigation (WHO) (C)**	**ISI standard for drinking and irrigation water (D)**	**Compare A to B**	**A to C**	**A to D**
Cadmium	0.013±.0001	0.001±0.001	92.3	0.01	<1.0	0.01	=	<	
Cobalt	0.041±0.0001	0.01±0.005	75.6			0.05	<	-	
Nickel	0.236±0.001	0.2±0.005	15.3		0.5	0.2	<	<	>
Lead	0.079±0.001	0.03±0.001	62.0	0.05/no relaxation	<1.0	0.1	>	<	<
Chromium	0.405±0.001	0.04±0.001	90.1	no relaxation	0.05	0.05	>	>	>
Manganese	0.425±0.002	0.43±0.005	-1.2		0.5	0.1	-	<	<
Iron	2.306±0.005	1.84±0.010	20.2	1	-	0.3	>	-	>
Copper	0.184±0.001	0.14±0.001	23.9	1.5	<1.0	0.05	<	<	>
Zinc	0.356±0.002	0.12±0.001	66.3	0.1	0.1	5	>	>	<

Along transect, TSS in the effluent was higher (259- 253.7 mg/l) in the sample from source point as compared to the sample from tube well. Overall, significant load of COD as compared to BOD was noticed in the effluent though the trend is declining in both cases i.e. decreasing from source to sink. However, the underground water of the tube well which was used to irrigate the control site was having negligible organic and pollutant load.

BOD, pH and TDS in the textile effluents were lower during rainy season (Table 1), whereas, higher values were recorded during summer. Dissolved oxygen was much lower (-86%) in textile effluent as compared to tube well water, although pH in the latter did not very much.

When correlation between BOD and other parameters like COD, pH, alkalinity, EC were analysed a high significance was noted (at $p<0.01$). Decrease in the DO and increase in BOD depict strong negative correlation ($r=-0.967$, at $p<0.01$). Similarly, a high significance has been observed between COD, alkalinity, pH and EC. Variation among the elements *viz.* K, Mg and Cl were also highly correlated (at $p<0.001$ and $p < 0.01$) as the value depicts (table 4).

Table 4. Correlations between various physico-chemical parameters of effluent

Parameters	BOD	DO	COD	ALKALINITY	Ph	EC	TEMPERATURE	TSS	TDS	NA	K	Mg	Cl
BOD	1	-.967**	.985**	.982**	.994***	.965**	.677	.847	.711	.546	.773	.787	.893*
DO			-.793	-.782	-.725	-.896*	-.791	-.817	-.697	.003	-.761	-.753	-.831
COD				.995***	.971**	.971**	.648	.919*	.753	.548	.772	.803	.909*
ALKALINITY					.966**	.966**	.625	.925*	.742	.556	.755	.790	.899*
Ph						.941*	716	.798	.750	.596	.815	.825	.911*
EC							.724	.902*	.708	.341	.774	.782	.897*
TEMPERATURE								.462	.826	.188	.946*	.898*	.869
TSS									.652	.370	.599	.659	.787
TDS										.566	956*	.984**	.943*
NA											.461	.531	.518
K												.991***	.963**
Mg													.976**
Cl													1

***. Correlation is significant at the 0.001 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

DISCUSSION

Impact of industrial effluent on agricultural system

Expansion of industries and release of waste from these industries in different system like soil, water and air are putting extensive pressure on soil and environment. Continuous use of industrial effluent on agriculture field is reported to influence soil ecology by deteriorating its chemical and biological properties. Soil bulk density, pH, total porosity and hydraulic conductivity have been reported to decrease because of irrigation with industrial effluent, resulting in decreased soil productivity and crop production consequently. Various researches have provided details on the changes in physico-chemical parameters of soil due to application of industrial waste water (**8,9,10,11**). Clogging of field with effluent turns the fertile land into barren land, and the heavy metals present in the wastewater when released into the agriculture field accumulated in the soil (**12**) and pose risk of phytotoxicity and bioaccumulation through food chain. The physico-chemical properties of textile effluent have been discussed in the following paragraph, comparing them with tubewell water, to evaluate its use for irrigation.

Colour of the effluent may be attributed to the presence of various dissolved chemicals and dyes. The change in colour may be the result of reaction between different chemical compounds which absorb and reflect light at particular wavelength. Along the transect, colour intensity of effluent decrease with distance from the source enabling differential biotic and abiotic interactions in the agriculture fields **(13).** Hydrogen ion concentration is the measure indicator of the waste water quality. In the present study, the pH of the effluent was exceeding the standard limits prescribed for the release of effluent on the agriculture land. Data revealed the alkaline nature of the effluent and the value ranging from 9.4 to 9.6. Whereas tube well water which is used for irrigating fields in the control site had neutral pH. The pH value is varying in different seasons during summer and winter the value was alkaline in nature whereas during monsoon it was near neutral. The Pearson's correlation coefficient relation between pH and chloride shows a positive relation but was significant at $p<0.05$. High alkalinity may cause negative effect on permeability of soil and microbial population. Several researchers reported increasing pH by effluents (**14,15).** The optimum range of pH in the soil for better crop growth is considered to be 6.5-8.5 (**16**). A recent study by **Patil et al. (2014)** showed that higher pH of the soil due to its exposure to the alkaline effluent discharge from the industry resulted in the accumulation of salts in the agricultural soil. To that extent, it is also reported that the pH of the treated wastewater was near neutral **(18).**

Electrical conductivity indicates the total ionized constituents of water. It is directly related to the sum of the cations (or anions), as determined chemically and is closely correlated, in general, with the total salt concentration. Change in the EC (362-365 µs/cm) in the contaminated sites could be attributed to the presence of high concentration of sodium and potassium salts in effluent due to which electrical conductivity and exchangeable sodium and potassium concentration increases in soil **(19).**

The amount of dissolved oxygen is an important indicator of water quality. Dissolved oxygen is important factor for microorganisms present in a water system for its purification. Lower DO indicates pollution load in a particular system. According to Department of Environment, Bangladesh values lower than the standard values (4.5 to 8 mg/l) of DO in water may not prove to be healthy for the crop production **(20)**. Values obtained for dissolved oxygen in the study carried out showed values less as compared to prescribed limit *i.e.* 0.42 mg/l to 0.61 mg/l. At the sampling point nearest to the discharge of waste water DO value was found to be lower and at the distant sampling site it was comparatively higher (Figure 2).

BOD accounts for the amount of the oxygen required for the degradation of organic pollutant by microorganism. In this study, the COD (580-565 mg/l) was significantly higher than the biochemical oxygen demand (150-145 mg/l). Similar reports for COD were obtained from the industrial effluent of Panipat by **Bharti et al. (2013)**. The fact behind high COD than BOD is that the BOD accounts for the degradation of organic waste present in the waste water whereas COD accounts for the degradation of both organic and inorganic waste. BOD and COD value in the effluent is above the value of BOD and COD in tubewell water, as the effluent consists of high organic and inorganic pollutants while the presence of these wastes is negligible in tubewell water.

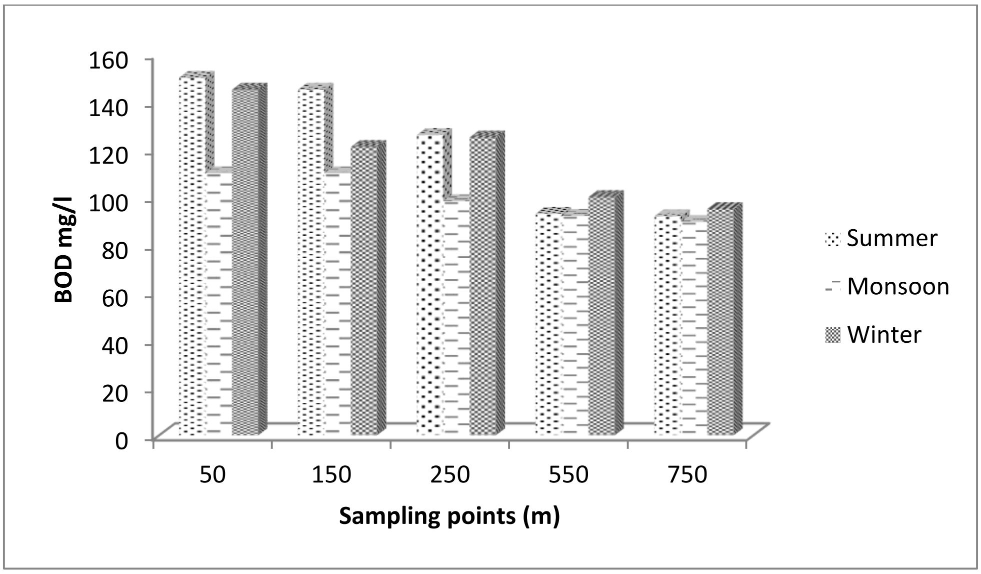

Figure 2: BOD across sampling points on different seasons.

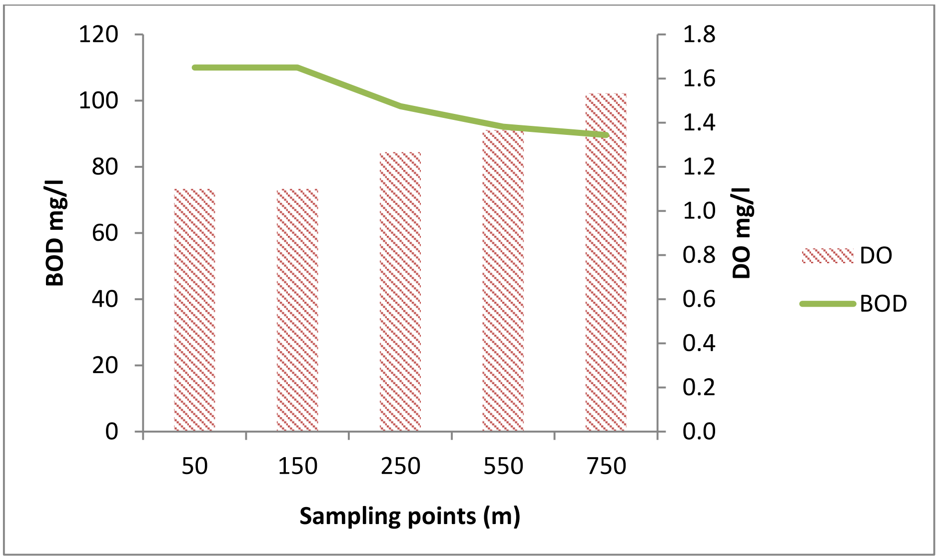

Figure 3: Trends in dilution of BOD and DO in textile effluent

Heavy metals have been reported in most of industrial effluents. Even if the concentration of heavy metals in the effluent using for irrigation is low, still it may pose threat to agriculture field if irrigation with same effluent is in practice for long-term. Accumulation of heavy metals in the soil may alter the enzymatic activity of microorganisms present in soil by denaturing the enzyme protein, interacting with the enzyme substrate complex or by interacting with the protein active groups (**22**). Decline in microbial composition and microbial biomass carbon have been reported in various studies (**23,24,25**). Soil contaminated with heavy metals also poses a serious threat to crop productivity. Accumulation of metals in the agriculture soil tends to get accumulate in the soil and different parts of plants. Due to this accumulation there are negative responses in plants as decrease in seedling germination rate, plant growth, root and shoot length (**26,27**). Even the senesced leaves in contaminated areas showed higher concentration of heavy metal (**28**). Also, biochemical and physiological activities like proline content, soluble protein concentration and chlorophyll are affected with the deposition of metals in high concentration in cellular parts of the plants affecting overall growth (**29,30**).

Analysis of the textile effluent released from the industry showed the presence of different metals in the effluent *viz*. cadmium, cobalt, nickel, zinc, and chromium. Chromium is one of the important metals of major concern which is present in the textile effluent and causes skin diseases in human beings. Chromium affects seed germination, root and shoot growth thus impacting the total dry matter production and yield (**31, 32,33,34,35)**.

Average concentration of lead was 0.079 mg/l which was above the drinking water permissible limit, but was lower than the permissible irrigation limit. Similar, result (0.08mg/l) was found in the treated textile effluent in Nigeria (**36**). Long-term use of effluent containing even very low amount of Pb may result into the bioaccumulation of the metal in the soil and living organism impacting the ecosystem processes thereby affecting the productivity of agro-ecosystem. Proline, caretenoid, and chlorophyll content get decreased in *Vigna mungo* seedlings, because of the lead contamination (**37**). Similarly, toxic effects of lead on *Zea mays* have been reported by **Hussain et al., (2013)**. Excess of lead concentration in plants may restricts photosynthesis activity, hormonal imbalance, causes chlorosis, stunted growth, blackening of root system, effects membrane permability and uptake of nutrients by plants (**39**). An increase in oxidative stress in *Oryza sativa* had been observed when its seedlings were grown in laboratory condition and treated with different concentration of lead resulting in increase in lipid peroxides thus indicating increase in oxidative stress (**40**).

Cadmium concentration obtained was found to be 0.013 mg/l (Table 3), which was lower as compared to the study (0.04mg/l) by **Manzoor et al. 2006.** Although the concentration obtain is less than the limit set for irrigation purpose, but is equivalent to the limit set for drinking water which pose risk in long term context. Decrease in chlorophyll content was reported in *Vigna mungo* under stress of Cd (**42**)

Presence of high concentration of iron in effluent may causes obnoxious effects like turbidity, astringent taste, discoloration and growth of iron bacteria contributing on making it unsuitable for irrigation purpose. Our study revealed that the average concentration of iron was 2.3mg/ l which was higher than the prescribed limit for the effluent to be released onto the agriculture field. The result obtained was supported by the study done by **(36, 34)**, where average concentration of iron in the textile effluent was in the same range 2.3 and 1.7.Neverthless, treatment of cadmium to soybean plants induced decline in nitrogen fixation and primary ammonia assimilation in nodules of plant as well (**43**).

Besides these, other metals were also detected, but all found to be within the permissible range. However, rapid and continuous use of same quality of effluent may result into the build up high concentration of these metals.

CONCLUSION

There is significant variation in physico-chemical parameters of textile effluent and tube well water. The textile effluent had higher concentration of Cr, Pb and Fe that has been reported to affect the plant growth and so presumably, in the present case, the agricultural fields may also be affected. Although the impact of this use of polluted water decreases with distance from source, it is recommended that preliminary treatment is advisable right before the effluent is let out. While techniques for this purpose are available, this however requires policy to regulate direct emittance of the effluents to the public domain that might provoke environmental concern across the food chain.

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