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Quality of effluents from Hattar Industrial Estate

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Abstract: Of 6634 registered industries in Pakistan, 1228 are considered to be highly polluting. The major industries include textile, pharmaceutical, chemicals (organic and inorganic), food industries, ceramics, steel, oil mills and leather tanning which spread all over four provinces, with the larger number located in Sindh and Punjab, with smaller number in North Western Frontier Province (NWFP) and Baluchistan. Hattar Industrial Estate extending over 700 acres located in Haripur district of NWFP is a new industrial estate, which has been developed with proper planning for management of industrial effluents. The major industries located in Hattar are ghee industry, chemical (sulfuric acid, synthetic fiber) industry, textile industry and pharmaceuticals industry. These industries, although developed with proper planning are discharging their effluents in the nearby natural drains and ultimately collected in a big drain near Wah. The farmers in the vicinity are using these effluents for growing vegetables and cereal crops due to shortage of water. In view of this discussion, there is a dire need to determine if these effluents are hazardous for soil and plant growth. So, effluents from different industries, sewage and normal tap water samples were collected and analysed for pH, electrical conductivity (EC), total soluble salts (TSS), biological oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen, cations and anions and heavy metals. The effluents of ghee and textile industries are highly alkaline. EC and TSS loads of ghee and textile industries are also above the National Environmental Quality Standards (NEQS), Pakistan. All the effluents had residual sodium carbonates (RSCs), carbonates and bicarbonates in amounts that cannot be used for irrigation. Total toxic metals load in all the effluents is also above the limit i.e. 2.0 mg/L. Copper in effluents of textile and sewage, manganese in ghee industry effluents and iron contents in all the effluents were higher than NEQS. BOD and COD values of all the industries are also above the NEQS. On the whole, these effluents cannot be used for irrigation without proper treatment otherwise that may cause toxicity to soil, plants and animals as well add to the problems of salinity and sododicity. Similarly, these effluents cannot be used for fish farming.

Key words: Industrial effluents, Biological oxygen demand (BOD), Chemical oxygen demand (COD), pH, Residual salts, Lead, Zinc, Copper, Nickel, Manganese, Sewage

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INTRODUCTION

Biosphere pollution by chemicals and heavy metals such as cadmium, nickel, zinc, lead, copper, etc., is accelerated dramatically during the last few decades due to mining, smelting, manufacturing, use of agricultural fertilizers, pesticides, municipal wastes, traffic emissions, industrial effluents and industrial chemicals, etc. Some of these metal ions, e.g. Na^+, K^+, Mg^{2+}, and Ca^{2+} are most essential for life and behave more like major elements such as P with respect to their cycling rates and accumulation patterns (Løbersli and Steinnes, 1988). The metal ions of transition metals essential for life include vanadium, manganese, iron, cobalt, nickel, copper, zinc, and molybdenum. These metal ions play a variety of functions in biological systems as important structural components in proteins. But higher levels of these metal ions are highly toxic to animals including humans as well as plants, and their solubility in water is considered to be one of the major environmental issues.

As vegetation is usually the first interceptor of heavy metals (HMs) in the soils and water (Rauser, 1990; Chaudhry *et al*., 1998), it is very important to clean up soils and groundwater, which is a challenging proposition for a range of technical and economical reasons. Movement of HMs through soils is largely dependent on the organic matter (OM) contents of the soil, i.e. the greater the OM contents of the upper horizon of soil, the greater the affinity of that horizon for HMs (Schnitzer, 1978). There are OM/HM interactions (metallo-organic complexes) in the soils with most of the OM in soils being comprised of humic substances. Many terms such as chelation, complexation, absorption, etc. are used to describe them. Higher concentrations of HMs in soils have been reported to inhibit plant growth, nutrient uptake, physiological and metabolic processes. This also results in chlorosis, damage to root tips, reduced water and nutrient uptake and damage to enzymes (Baisberg-Påhlsson, 1989; Sanità di Toppi and Gabbrielli, 1999). Heavy metals, like other environmental stressors, also induce increased antioxidant enzyme activities in plants (Iannelli *et al*., 2002).

HMs are found to induce tumor and mutations in animals at higher concentrations (Degraeve, 1981). They are capable of causing genetic damage to germ cells of male and female animals including humans (Hayes, 1984; Groten and Vanbladeren, 1994; Wagner, 1993). They are regarded as cumulative toxins which through biomagnification in plants affect human health (Groten and Vanbladeren, 1994). Heavy metals persist in soils and can be adsorbed in soil particles or leached into ground water. Human exposure to these metals through ingestion of contaminated food or uptake of drinking water can lead to their accumulation in humans, animals and plants (Khan, 2006a).

Pakistan, a land of marvels with an area of 2 million acres, is the 9th most populous nation of the world. It has a variety landscape encompassing mountains, semi arid and arid areas and fertile lush green Indus Plain. The increasing trends towards artificial high life standards and industrialization are compelling the nation towards resource misuse which poses challenges to meet the demands of the ever increasing population on the shrinking good quality lands and environmental degradation due to mismanagement of natural resources. In Pakistan, like other developing nations, not only good quality lands are degraded due to wind and water erosion, water-logging and salinity, loss of organic matter and biodiversity, but also contamination with heavy metals with the expansion of industries on good quality lands of rural and urban areas, farmers are irrigating their lands with industrial effluents. This in turn is not only threatening the biodiversity but is also creating very serious problems to human environment (Government of Pakistan, 1991). In many areas of Pakistan, especially in big cities, industrial units are established without environmental impact assessment and planning (EIAP). The air, soil and water are increasingly becoming polluted by industrial pollutants such as organic and inorganic chemicals and toxic metals (Irshad *et al*., 1997). Due to not so strict environmental planning guidelines in Pakistan, industries and factories dump their solid and liquid wastes in spaces adjacent to these sites, sewer, nullahs, and streams, which are mixed with groundwater raising levels of HMs, higher than the levels recommended by WHO and cross the limits of NEQS (Gulfraz *et al*., 1997; 2002).

In the race towards industrialization, a number of industrial estates were established at Faisalabad, Gadoon Amazai, Nooriabad, Sheikhupura, G.T. Road, etc. in Pakistan. Of 6634 registered industries in Pakistan, 1228 are considered to be highly polluting. The major industries include textile, pharmaceuticals, chemicals (organic and inorganic), food industries, ceramics, steel, oil mills and leather tanning, which are spread all over the four provinces of Pakistan, with the larger number located in Sindh and Punjab, smaller number in NWFP and Baluchistan. However, no proper planning, especially regarding environmental protection, was done. HM contaminated land is increasingly becoming an environmental, health, economic, and planning issue in Pakistan (Hussain *et al*., 1996). The rapid increase in population, together with unplanned industrial effluent discharge, has increased the threat of soil pollution in Pakistan. The outcome of this pollution includes soil degradation along with a decreased biodiversity, irreversible extinction of many sensitive organisms and the selection of adaptable ones (Mufti *et al*., 1997). After the Qasoor and such other disasters, the Pakistan government became alerted to environmental safety and it was proposed that new industrial estates should be established with proper planning for environmental safety.

According to Saleemi (1993) an amount of 40×10^9 L with 20000 t of BOD are discharged daily into water bodies by the different industries. Most of the industries in Pakistan do not control their wastewater effluents by processing, waste recycling or end-of-pipe treatment. Even the well-planned capital city of Islamabad lacks proper management of effluents in its two industrial estates and industrial and slaughterhouse wastes are drained into the Sawan River (Mian *et al*., 1998). So effluents with toxic substances are being discharged into water bodies without paying any attention to the environmental consequences.

There is large variability in the quality of industrial effluents which varies with industrial processes. The effluents discharged by different industries contain a high range of physico-chemical parameters like temperature, pH, conductivity, hardness, alkalinity, COD, TSS, nitrates, nitrites, cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) and anions (Cl^-, CO_3^{2-}, HCO_3^-, SO_4^{2-}). These effluents from different industries also contain heavy metals and trace metals including chromium, cadmium, copper, lead, nickel, zinc, cobalt, magnesium, iron and arsenic (Ali *et al*., 1996). Although Pakistan is blessed with one of the best canal irrigation systems of the world, there is a shortage of good quality surface irrigation water with this shortage being met by the conjunctive use of good quality irrigation water. Farmers in the suburbs of big cities and where water from natural surface drains is not easily available, use sewage and water of natural drains for crop production, due to their being less expensive (Lone and Rizwan, 1997) and having quite large amount of beneficial nutrients (Ghafoor *et al*., 1994). Therefore, urban agricultural soils of Pakistan are often irrigated with city effluents for growing vegetables (Qadir *et al*., 1998).

Generally, the growers are unaware of ion toxicity, which could be introduced into the food chain by vegetables and crops irrigated with effluents. These toxic ions may retain in soil or leach out through the soil and may contaminate ground water along with the soil itself and finally enter the food chain and cause health hazard in animals and plants. So there is dire need to quantify these toxic elements in the effluents prior to their use for irrigation, drinking and other purposes. So, the present study was conducted to investigate the quality of industrial effluents, sewage and normal tap water for their suitability for irrigation purpose in Hattar area.

LOCATION AND METHODS

Location

Hattar Industrial Estate is a new estate which has been developed in Pakistan with proper planning for management of industrial wastes. The government of NWFP Province approved this estate in 1985 in Harripur district at a distance of approximately 55 km from Islamabad on Taxila-Harripur Road. This estate was developed in different phases. Installation of infrastructure facilities was over at the end of 1989. An area of 700 acres was allotted to different industries such as ghee industry, fertilizer industry, chemical industry (sulphuric acid manufacturing plant and synthetic fiber manufacturing plant) and textile industry. This industrial estate has a large number of natural surface drains and all of the industries are depositing their effluents in their nearby natural drains. Similarly city sewage containing the pollutants also falls into nearby natural drains. At the Dingi village, all of the natural drains carrying toxic elements in the effluents of different industries ultimately go into a relatively wider nullah called "Jari Kass". The nullah goes along and falls into the Haro River.

Methods

Five effluent samples from each site of the discharge outlets points of different industrial units (textile industry, ghee and chemical manufacturing industry), sewage and normal tap water from Hattar industrial area were collected and brought to the laboratory for various chemical parameters analyses.

The electrical conductivity and pH of the water samples were determined by the corresponding method from US Salinity Laboratory Staff (1954). Methods for the determination of TSS carbonates, bicarbonates, chlorides were as per methods of US Salinity Laboratory Staff (1954). Measurements of residual sodium carbonate (RSC) were made following methods described by Malik *et al*.(1984). BOD and COD were also determined (Bock, 1979) and the contents were compared with the National Environment Quality Standards (NEQS), Pakistan.

Methods for estimation of trace metals ($\times10^{-6}$) such as Fe, Zn, Cu, Pb, Ni, and Mn in the industrial effluents used for irrigation in the Hattar area were as per methods from Malik *et al*.(1984).

RESULTS AND DISCUSSION

The general physical and chemical analyses of the effluents are given in Table 1. The pH values of all the effluents except tap water were alkaline. The pH of the effluents from the textile industry and ghee industry was greater than NEQS for municipal and liquid industrial effluents (6 to 10). Continuous application of these effluents will render the soils unfit for further cultivation as most of our soils are already alkaline. However, the buffering capacity of soil tends to bring homeostasis and lower the pH of the effluents applied according to pH of the soil (Nyle, 1984). According to (David *et al*., 1996), the optimum pH of irrigation water ranges from 6.5 to 8.5, while the permissible limit is 9. Hence the effluents of ghee and textile industries have very high pH that hampers crop growth. It is therefore necessary that complete restraints should be observed for the application of these effluents to the cultivable land. Treatment to lower the pH is essential before throwing these effluents out of the mills; otherwise it may culminate in a big disaster.

The values of the EC and TSS present in the different effluents are also presented in Table 1. They are directly proportional to each other. These results are consistent with those of Bohn *et al*.(1976). There was a wide range of TSS in the industrial wastes. The effluents from ghee industry showed highest EC and TSS, which was above the NEQS (3500×10^{-6}). So, ghee industry effluents are most injurious to soil and plant health. The reports suggest that the liquid wastes from ghee and textile industry are not fit for irrigation regarding EC and TSS (Bohn *et al*., 1976; Abbas, 1991). Effluents from chemical industry, juncture and city sewage were found to be suitable for crop cultivation. However, some sensitive varieties showed restricted growth even at the levels present in these effluents (Abbas, 1991). So, the long-term use of these effluents for irrigation purpose should be discouraged.

Ghee industry's effluents show the highest RSC followed by the juncture effluents (Table 1). Carbonates were not so high yet the amount of bicarbonates in all the effluents including tap water are beyond the limit fit for irrigation (Table 1). These results agree with those of others (Soil Fertility Survey and Soil Testing Institute, 1972). Precipitation of calcium carbonates from these effluents lowers the concentration of dissolved calcium, increases the sodium adsorption ratios and exchangeable sodium levels of the soil, waters with RSC greater than 2.5 are hazardous for crop plants in all conditions (Bohn *et al*., 1976). So none of the effluents is fit for irrigation purpose regarding RSC and anions HCO_3^- and CO_3^{2-} . There is enough calcium and magnesium present in the effluents to sustain the crops. High pH is conducive for the non-availability of these elements and generally no toxicity/deficiency of these elements occurs in Pakistan soils (FAO, 1984).

The BOD and COD values of the effluent samples are given in Table 2. The organic contents in the wastewaters were much higher than the permissible limit (80 mg/L). This permissible limit of BOD is higher in the case of NEQS of Pakistan as compared to 30 mg/L set by the Bureau of Indian Standards (Sharma and Lai, 1998). Wastes containing high BOD and COD are responsible for a heavy depletion of oxygen levels in the particular sector of the stream or soil. Furthermore, if these wastes are discharged into public sewage and are used for irrigation, they will exert additional BOD and COD load on the sewage. The microorganisms present in the sewage

Table 1 Physical and chemical analysis of different industrial effluents used for irrigation in Hattar area (Values are means of 5 samples and are significant at *P*>0.05)

Source of effluent	pH	*EC* (dS/m)	*TSS* (mg/L)	Residual sodium carbonate (milliequivalents)	Chlorides (mg/L)	HCO_3^- (mg/L)	CO_3^{2-} (mg/L)	$Ca^{2+}+Mg^{2+}$ (mg/L)
Tap water	7.04	0.60	420	–	1.0	4.7	–	5.8
Textile	10.35	3.00	2100	–	4.6	10.6	0.6	2.5
Ghee	10.65	8.14	5698	27.1	13.0	30.8	0.8	3.0
Chemical	8.69	1.13	791	3.4	3.8	7.5	1.0	5.0
Juncture	7.89	1.58	1100	8.5	6.0	13.5	0.5	8.0
City sewage	7.52	1.00	700	0.5	1.3	9.5	1.0	10.4
NEQS	6.10	4.00	3500	2.5	100.0	–	–	–

will reduce the nitrate into nitrite and ammonia, sulphates into sulphides and ferric iron into ferrous iron at very low concentrations of oxygen. Therefore, they will constitute a great nuisance for the environment (Robson and Neal, 1997). Hence the BOD of these effluents renders them unfit for irrigation.

The COD of the effluents, depicted in Table 2, showed that all the effluents except chemical industry effluents had higher COD values than the NEQS (150 mg/L). Therefore, these effluents need further elimination of COD through proper treatment methods before irrigation (Totawal *et al*., 1996). The data also revealed that the effluents in preset condition are not fit for discharge to land waterbodies, as it would be hazardous for human and aquatic life due to the high concentration of toxicants.

Results of analysis of heavy metals (i.e., iron, zinc, copper, lead, nickel, and manganese) in effluents are given in Table 3. The amount of iron present in the effluents except chemical industry effluents was above the NEQS. Copper contents in wastewaters from textile industry and sewage were higher than NEQS. Lead and nickel contents in all effluents were within the permissible limits, however, total amount of heavy metals permitted in the effluents i.e. 2×10^{-6} is being violated by all the industrial units. Hence, none of the effluents can be used for irrigation purpose or for throwing into water streams. Wastewaters from textile and ghee industry have the highest amount of heavy metals rendering them most hazardous for soil, plant and other organisms including human beings.

Table 2 BOD and COD of different industrial effluents used for irrigation in Hattar area effluent (Values are means of 5 samples; *P*>0.05)

Effluent	*BOD* (mg/L)	*COD* (mg/L)
Water	0	60
Textile	475	160
Ghee	918	740
Chemical	300	110
Juncture	1100	790
City sewage	225	500
NEQS	80	150

In plants, heavy metals like cadmium, lead and nickel are highly toxic at relatively low concentrations. Heavy metal toxicity is the result of complex interaction of major toxic ions with other essential or non-essential ions. The metals can cause a reduction in the hydrolysis products viz., α-amylase, phosphatase, RNAs and proteins. They interfere in the enzyme action by replacing metal ions from the metalo-enzymes and inhibit different physiological processes of plants (Agarwal, 1999).

In human beings and animals, heavy metals are highly toxic at relatively low concentrations. Eating food or drinking water with very high levels of heavy metals severely irritates the stomach leading to vomiting and diarrhea. Similarly high levels of lead may decrease reaction time, and cause anemia, a disorder of blood in human beings (ATSDR, 1993). Now it is our responsibility to advocate the proper use of different effluents in order to avoid water and soil contamination because soil is relatively valuable natural resource for mankind.

The work presented here only studied the chemical quality of the industrial effluents, it is equally important to extend this study to include (1) measurement of a range of biological as well as physico-chemical properties of the soil which receive this polluted effluent for irrigation purposes; (2) identification and chemical analyses of the plants growing on soils receiving this effluent; and (3) microbial characterization of the soil (Khan *et al*., 1998).

The colonization of HM contaminated soils and water by metal resistant and metal accumulating

Table 3 Heavy metals contents of different industrial effluents used for irrigation in Hattar area

Effluent	Fe (10^{-6})	Zn (10^{-6})	Cu (10^{-6})	Pb (10^{-6})	Ni (10^{-6})	Mn (10^{-6})
Water	0.50	0.050	0.030	0.001	0.00	0.15
Textile	9.90	0.201	1.094	0.050	0.00	1.00
Ghee	5.81	0.365	0.049	0.050	0.45	1.55
Chemical	1.38	0.143	0.033	0.050	0.00	1.25
Juncture	2.76	0.625	0.042	0.002~0.150	0.28	0.52
City sewage	2.46	0.215	1.200	0.002	0.32	0.25
NEQS	2.00	5.000	1.000	0.500	1.00	1.50

plants and their root associated microbes including ubiquitous arbuscular mycorrhizal fungi (AMF) requires detailed future studies. Its understanding may be a powerful tool for managing toxic wastes through the use of adapted plant species growing on HM contaminated mining and industrial sites, i.e. phytoremediation (Chaudhry *et al*., 1998; Hayes *et al*., 2003; Khan *et al*., 2000; Khan, 2006b). Plants growing on such sites need to be studied for HM contents and their role in phytoremediation, so conservation of mine vegetation can be economically important.

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