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Characteristics of industrial effluents and their possible impacts on quality of underground water

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Abstract

This study was conducted to evaluate various industrial effluents of Hayatabad Industrial Estate (HIE), Peshawar, and assess the possible impacts of such effluents on quality of underground water. A total of 12 samples including 7 from industrial effluents at the discharge point of each industry (marble, matches, steel, aluminum, pharmaceutical, beverages, ghee industries), 1 from main drain receiving effluents of all industries and 4 from tube or dug wells in the vicinity of the Estate were collected in March, 2003 and analyzed for temperature, pH, electrical conductivity, total dissolved salts, total suspended solids, biological oxygen demand and heavy metal contents (Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn). The characteristics of effluents varied with the industry. The pH of one effluent (from aluminum industry) was beyond the limit and of the remaining within the permissible limit whereas TSS of one effluent (Pepsi industry) was within and of the remaining beyond the permissible limits comparing with the National Environmental Quality Standards (NEQS). The BOD was above the permissible limit in almost all of the effluents. Among heavy metals, Cd, Cr, Cu, Fe and Zn were within the permissible limits in all but Mn, Ni and Pb were beyond the permissible limits in one or more effluents. Variable results were also obtained for various parameters in underground water samples. The pH, TSS, TDS, Fe and Zn were within the permissible limits in all but Cd, Cr, Cu, Mn, Ni and Pb were above the permissible limits in one or more water samples compared with the WHO and US-EPA standards established for drinking water. These results suggested that effluents discharged from various industries showed variable characteristics and are potential threat to underground water contamination. It is thus recommended that wastewater treatment plants must be established with each industry. Further, efficient environmental laws and social awareness program must be undertaken for inhabitants of the estate and in the surrounding area with respect to potential threat of industrial effluents to the environment.

Key words: effluents, temperature, pH, EC, TSS, TDS, BOD, heavy metals

Introduction

Industrial estates are established to fulfill the demand of the growing population in the country. The introduction of industries on one hand manufactures useful products but at the same time generates waste products in the form of solid, liquid or gas that leads to the creation of hazards, pollution and losses of energy. Most of the solid wastes and wastewaters are discharged into the soil and water bodies and thus ultimately pose a serious threat to human and routine functioning of ecosystem. In Pakistan, main contributors to the surface and ground water pollution are the by-products of various industries such as textile, metal, dying chemicals, fertilizers, pesticides, cement, petrochemical, energy and power, leather, sugar processing, construction, steel, engineering, food processing, mining and others. The discharge of industrial effluents, municipal sewage, farm and urban wastes carried by drains and canals to rivers worsen and broadens water pollution. High levels of pollutants in river water causes an increase in biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), toxic metals such as Cd, Cr, Ni and Pb and fecal coliform and hence make such water unsuitable for drinking, irrigation and aquatic life. It has been reported that 60 % of population in developing countries has no access to pure drinking water (Chillers and Henrik, 1996). Presently, some 2.4 billion people lack adequate sanitation and 3.4 million die each year in the world from water related diseases (Anonymous, 2001).

Khan and Noor (2002) reported that TSS, BOD and COD in industrial effluents were above the permissible limits set by *NEQS*. The study of Shivkumar and Biksham (1995) carried out in the

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industrial area in India suggested that highly variable pH of the industrial wastewater can leach heavy toxic metals from the sediments, soils and rocks and increase the concentration of heavy metals in groundwater. In Pakistan, especially in NWFP, no proper treatment facilities are available for treating city and industrial wastes. Hence the effluents are dumped into various water bodies causing surface/ground water pollution and endangering biodiversity and lowering agriculture production. A study on Kabul river indicated that surface water resources are highly vulnerable to pollution as the entire stretch in the surrounding is heavily polluted with sewerage and uncontrolled application of chemicals, so their effect on surface and ground water is an emerging concern. The main source of drinking water in Peshawar is ground water but the aquifer contamination has also been reported (IUCN, 1996). The present study was therefore carried out to determine the important characteristics of various industrial effluents of Hayat Abad Industrial Estate, Peshawar (NWFP) and assess the possible impact of such effluents on quality of underground water in the proximity of the Estate.

Materials and methods

Background of the study area

The Hayatabad Industrial Estates is located in the west of Peshawar on main Jammrud road adjacent to modern residential Town Hayatabad, Peshawar. The industrial estate is comprised of about 50 industries of various kinds such as dying chemicals, pharmaceutical, textile, matches, ghee, food, drinks, rubber, marble, wood, steel and others. The effluents of all industries in the area are falling through small open drains into main drain known as *Malakandher Nala* and eventually into the Kabul river. This study was initiated to evaluate the various industrial effluents for physico-chemical characteristics at the discharge point and assess the quality of ground water in the surrounding area to know if the industrial effluents had any effect on the contamination of such water, used for drinking or irrigation purposes.

Sampling of effluents and underground water

Effluents samples were collected at the discharge point of selected industrial units of Hayatabad Industrial Estate, Peshawar i.e. Shakeel marble, Lahore steel, Sohail vegetable ghee, Sana aluminum, Pepsi industries, Bilour matches and Hizat pharmaceutical in March, 2003. During the same period ground water samples were also collected from different tube and dug wells of the surrounding area to see if any contamination has occurred. The main drain where effluents of all industries are fallen was also sampled. The samples were collected in clean plastic containers of 1.5 L volume in such a way that no bubbles were formed in the containers. A total of 12 samples including 7 from industrial effluents 1 from the main drain and 4 from tube wells in the vicinity of the Estate were collected.

Chemical analysis

Effluents and underground drinking water of the surrounding area were analyzed for various important characteristics such as temperature (US-EPA, 1998), pH (Richards. 1954), electrical conductivity (Richards, 1954), total soluble solids (APHA, 1992), total dissolved solids (Richards, 1954), biological oxygen demand (Hamer, 1986) and heavy metals concentration (APHA, 1992).

Results and discussion

To evaluate the pollution load in the industrial effluents and in ground water of Hayatabad Industrial Estate (HIE), the samples were analyzed for various physico-chemical parameters and the results were compared with values of National Environmental Quality Standards (NEQS, 2000) for industrial effluents. Similarly, values of ground water were compared with the standards of World Health Organization (WHO, 1981) and United States-Environmental Protection Agency (US-EPA, 1998) for drinking water. The results obtained on characteristics of effluents and underground tube well water are presented and discussed.

Temperature

Temperature is an important indicator of water quality with regards to survival of aquatic organisms. The effluents temperature depends on the process of production in the industry. The temperature values of various industrial effluents ranged from 13.0–33.9 ^{o}C with a mean value of 24.5 ^{o}C (Table 1). The highest value was found in the effluents of Sohail vegetable ghee, while lowest in that of Bilour match. The temperature values in all the effluents were within the permissible limits of NEQS. These results are supported by the recent work of Khan and Noor (2002). As Sohail

Table 1. Some characteristics of industrial effluents

Effluents	Temperature °C	pH	EC	TSS (mg L^{-1})	TDS (mg L^{-1})	BOD (mg L^{-1})
Shakeel marbles	14.5	8.07	288	1980	288	180
Lahore steel	28.5	8.16	275	240	275	189
Sohail vegetable ghee	33.9	7.80	288	426	288	110
Sana aluminium	27.3	4.44	1920	521	6400	340
Bilour match	13.0	6.90	832	1225	832	191
Pepsi industry	30.5	8.90	832	125	832	77
Hizat pharmaceuticals	23.0	6.00	384	1125	384	98
Main drain	25.5	7.56	640	380	640	415
Means	24.5	7.23	682.4	753	2485	200
NEQS, 2000	40.0	6-10	-	150	3500	80

vegetable ghee show high temperature in the effluents causing thermal pollution (Roven *et al.*, 1998) due to the usage of water for steam production and cooling processes. The temperature of ground water ranged from 32-33.2°C with a mean value of 33.3 °C (Table 2). The highest temperature was noted in water of Dug well-1, while lowest in Tube well near HIE. Results revealed that all values were within the permissible limits compared with the WHO and US-EPA standards for drinking purposes.

of Pepsi industries may be due to the excessive use of carbonated water in the production of cold drinks. Regarding the pH of ground water, the values varied between 7.53-7.88 with a mean value of 7.71 (Table 2). The maximum pH in the water of Dug well-1 and minimum in the water of Tube well near main drain was recorded, all the pH values for drinking water were found within the permissible limits compared with the WHO and US-EPA standards. Hamill and Bell (1986) reported that the pH of most natural waters ranges from 6.0 to 8.5.

Table 2. Some characteristics of underground water in the surrounding area of HIE*, Peshawar

Ground water	Temperature (°C)	pH	EC	TSS (mg L^{-1})	TDS (mg L^{-1})	BOD (mg L^{-1})
Tube well –1	32.3	7.64	352	2.03	352	1.05
Tube well near main drain	33.0	7.53	390	2.10	390	0.39
Dug well-1	33.2	7.88	294	1.80	294	0.50
Tube well in HIE*	32.0	7.81	314	2.01	314	0.29
Means	33.3	7.71	339	1.98	337	0.56
WHO, 1981	12.0	6.5-9.2	400	5.00	500	-
US-EPA, 1998	-	6.0-8.5	300	5.00	500	-

*HIE = Hayatabad Industrial Estate

pH

The pH of the various industrial effluents ranged from 4.44-8.90 with a mean value of 7.23 (Table 1). The effluents of Sana aluminium had lowest pH, while Pepsi industries had highest pH. Comparing with NEQS standards, the pH value in the effluents of Sana aluminium was beyond the permissible limit and may adversely affect the aquatic life due to its high acidic nature. These results are in line with the findings of Khan and Noor (2002) and Shah (1999). The high pH value

Electrical conductivity (EC at 25 °C)

Electrical conductivity is a function of total dissolved solids (TDS) known as ions concentration, which determines the quality of water (Hem, 1989). Electrical conductivity of the various industrial effluents ranged from 288-1920 mg L^{-1} at 25 °C with a mean value of 682.4 mg L^{-1} (Table 1). The lowest EC was noted in the effluents of Lahore steel, while highest in the Sana aluminium. However, all the EC values in effluents were within the safe limits except that in the effluents of Sana aluminium, which showed saline conditions. Similarly, the EC of ground water ranged from 294-390 mg L^{-1} at 25 ^oC with a mean value of 339 mg L^{-1} at 25 ^oC (Table 2). The EC values for all ground water samples were found within the permissible limits compared with the WHO and US-EPA standards established for drinking water and can be used for irrigation purpose as well (Richards, 1954).

Total suspended solids (TSS)

The total suspended solids in various industrial effluents ranged from 125-1980 mg L^{-1} with a mean value of 753 mg L^{-1} (Table 1). It is evident from the results that the wastewaters of all the industries had high TSS and were above the permissible limits of NEQS except that of Pepsi industry. The highest TSS recorded in the effluent of Shakeel marbles while lowest in the Pepsi industry. The highest TSS in marble industries was due to the water used for crushing processes that carries away the solid particles and increase the TSS level in the effluents. Results suggest that these effluents may cause handling problem, if directly applied to agricultural field or if discharged in to river or stream it will not be suitable for aquatic life. These results agreed with the findings of Khan and Noor (2002). Total suspended solids in the ground waters ranged from 1.80-2.10 mg L^{-1} with a mean value of 1.98 mg L^{-1} (Table 2). However, all values were within the permissible limits compared with the WHO and US-EPA standards set for drinking water. The presence of TSS in underground water, however, even in a small amount does indicate the impact of industrial effluents in the close proximity.

Total dissolved solids (TDS)

The total dissolved solids in various industrial effluents ranged from 275-6400 mg L^{-1} with a mean value of 2485 mg L^{-1} (Table 1). Comparing with the NEQS, it was observed that the TDS values in effluents of all the industries were within the permissible limits except in that of Sana aluminium. The effluents with high TDS value may cause salinity problem if discharged to irrigation water. Similar results were also reported by Shah (1999) and Khan and Noor (2002). The TDS in underground water ranged from 294-390 mg L^{-1} with a mean value of 337 mg L^{-1} (Table 2). Comparing with WHO and US-EPA standards, all samples of underground water were within the permissible limits set for drinking water purposes.

Biological oxygen demand (BOD)

Biological oxygen demand measures the biodegradable materials in water and helps in the development of bacteria and other organic by-products (Manahan, 1994). The biological oxygen demand in various industrial effluents ranged from 77-415 mg L^{-1} with a mean value of 200 mg L^{-1} (Table 1). Results showed that BOD in the effluents of Pepsi industry was lowest while that in main drain was highest. It was observed that BOD values in the wastewater of Shakeel marble, Lahore steel, Sohail vegetable ghee, Sana aluminium, Bilour match, Hizat pharmaceutical and main drain were above the NEQS i.e. 80 mg L^{-1} indicating if such effluents mixed with rivers or stream water, it will have adverse effects on aquatic life due to depleted O_2 level in water. Similar conclusions were also drawn by Shah (1999) and Khan and Noor (2002). The BOD in underground waters ranged from 0.29-1.05 mg L^{-1} with a mean value of 0.56 mg L^{-1} (Table 2) suggesting that all the underground water samples were within the safe limits compared with WHO and US-EPA standards for drinking water. In general, the BOD of groundwater must be zero because organic matters are normally filtered through subsurface strata and thus leaving no room for the development of microorganisms responsible for water born diseases. The indication of BOD in the groundwater samples suggested that the industrial effluents might have contributed some organic C to such water, which is potential threat of water contamination in future.

Heavy metals concentration

The results obtained on heavy metal contents (Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn) in various industrial effluents are presented in Table 3. Results showed that the levels of Mn, Ni and Pb were above the permissible limits compared with NEQS standards. These results confirmed the early work of Banaras (1994). The main source of Mn in the effluents appeared to be aluminium industries which reduced the pH and thus Mn was released in the wastewater. Perhaps Ni in the industrial effluents was due to certain industries e.g. ghee and oil, chemicals, kitchen appliances, surgical instruments, steel alloys and automobiles batteries. While, Pb might have been released from a number of sources including industries such as mining and automobiles. Similarly, almost all heavy metals except Fe and Zn in ground waters were found beyond the permissible limits compared with the WHO and US-EPA standards used for drinking water (Table 4).

Table 3. Heavy metals concentration in industrial effluents (mg L^{-1})

Effluents	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**
Shakeel marbles	0.06	0.42	0.73	0.28	0.14	0.29	1.38	0.01
Lahore steel	0.07	0.23	0.31	0.05	0.14	0.30	0.88	0.11
Sohail vegetable ghee	0.02	0.30	0.39	0.46	0.02	0.88	0.43	0.01
Sana aluminium	0.07	0.73	0.40	0.05	1.99	1.62	3.71	3.20
Bilour match	0.05	0.13	0.44	0.05	0.09	0.16	0.60	0.11
Pepsi industry	0.02	0.16	0.35	0.16	0.11	1.59	0.27	0.01
Hizat pharmaceuticals	0.01	0.05	0.22	0.07	0.20	0.56	0.12	0.04
Main drain	0.04	0.06	0.36	0.42	0.16	1.25	0.70	0.01
Means	0.04	0.26	0.40	0.19	0.36	0.83	2.02	0.44
NEQS, 2000	0.10	1.00	1.00	2.00	1.50	1.00	0.50	5.00

Table 4. Heavy metals concentration (mg L^{-1}) in ground water in the surrounding area of HIE*, Peshawar.

Water source	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Tube well –1	0.06	0.03	0.40	0.20	0.22	0.38	0.97	0.09
Tube well near main drain	0.03	0.16	0.45	0.01	0.08	0.67	0.97	0.23
Dug well-1	0.01	0.07	0.25	0.07	0.11	1.75	0.20	0.07
Tube well in HIE*	0.02	0.10	0.34	0.05	0.06	0.74	0.49	0.01
Means	0.03	0.09	0.36	0.08	0.12	0.88	0.66	0.10
WHO	0.05	0.05	-	0.30	0.05	-	0.05	5.00
US-EPA	0.01	0.10	0.05	0.30	0.10	0.01	0.05	5.00

*HIE = Hayatabad Industrial Estate

High Cd in drinking water may be through effluents discharges of marbles, steel and aluminium industries as well as from mining and metal plating. Cr is present in various concentrations in lithosphere, hydrosphere and atmosphere and is incorporated to the soil-water system mainly through corrosion from its sources. Sources of Cu are industrial wastes, agrochemicals, and corrosion of household plumbing and erosion of natural deposits. In environment, Mn arises from industrial wastes, acid mine water and microbial activities in water. The presence of Ni in underground water was perhaps leaching from the discharge of ghee and oil industries in the surrounding area. Pb in water might have originated from atmosphere and geological sources, corrosion of household plumbing system and erosion of natural deposits. These results revealed that the discharge of industrial effluents into open drains increased the heavy metal contents (Cd, Cr, Cu, Mn, Ni and Pb) both in the drain and in underground water and made them unsuitable for irrigation or drinking purposes comparing with WHO and US-EPA standards.

Conclusions

The characteristics of effluents varied with the industry. The pH of one effluent (from aluminum industry) was beyond and of the remaining within the permissible limit whereas TSS of one effluent (Pepsi industry) was within and of the remaining above the permissible limits comparing with the NEQS. The BOD was above the permissible limit in almost all of the effluents. Among heavy metals, Cd, Cr, Cu, Fe and Zn were within the permissible limits in all but Mn, Ni and Pb beyond the permissible limits in one or more effluents. Variable results were also obtained for various parameters in underground water samples. The pH, TSS, TDS, Fe and Zn were within the permissible limits in all but Cd, Cr, Cu, Mn, Ni and Pb were beyond the permissible limits in one or more water samples compared with the WHO and US-EPA standards established for drinking water.

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