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Research Paper

Characteristics of Industrial Effluents and their Possible Impact on Groundwater Quality

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***Abstract** - This study was conducted to evaluate industrial effluents of Ahmednagar Industrial Estate, Ahmednagar, and assess the possible impacts of such effluents on quality of groundwater. A total of 11 samples including 4 from industrial effluents at four discharge point in the drain receiving effluents of all industries and 7 from dug wells in the vicinity of the Estate were collected in August, 2010 and analyzed for pH, electrical conductivity, total dissolved salts, total suspended solids and heavy metal contents (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn, Cu). The pH, Ec and TDS values for all industrial effluent samples were found within the permissible limits compared with the NEQS. It is evident from the results that the industrial effluents had high TSS and were above the permissible limits of NEQS and suggest that these industrial effluents may cause handling problem, if directly applied to agricultural field or if discharged in to river or stream. The levels of Fe, Mn, Zn, Cu, Ni, Cd, Co Mn, in industrial effluents were within the permissible limits compared with NEQS standards. The analysis of the groundwater showed that, the pH, EC, TSS and TDS values for groundwater 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 for drinking water. The values of heavy metal contents (Fe, Mn, Zn, Cu, Ni, Cd, Co, Cr and Pb) in the groundwater samples were within the permissible limits compared with the WHO and US-EPA standards. These results revealed that the discharge of industrial effluents into open drains increased the heavy metal contents (Fe, Mn, Zn, Cu, Ni, Cd, Co, Cr and Pb) both in the drain and in groundwater. Also, the presence of TSS in groundwater, however, even in a small amount does indicate the impact of industrial effluents in the close proximity.*

Keywords: Industrial effluents, Groundwater, pH, EC, TSS, TDS, Heavy metals.

Introduction

Ground water is about 20% of the world resources of fresh water and used in large amount for industry, irrigation and domestic activity. In recent days ground water is deteriorating at alarming rate due to increased industrial activity in rural area of Maharashtra state. Ground water is an indispensable commodity in the very limited quality to man and other living beings. Most of the Indian towns and cities do not have access to safe drinking water. Naturally ground water recharged through rain water. Ground water areas that are recharged at higher rate generally more vulnerable to pollution. The ground water can pollute by landfills, septic tank, livestock yards, petroleum tanks, fertilizers and pesticides. The quality of vital concern for mankind since it is directly linked with human welfare. Polluted water is the culprit in all such cases. The major source of water pollution is domestic waste from urban and rural areas and industrial waste which is discharge into natural water bodies. Rapid industrialization has resulted with growing contamination of air, water and soil thus affecting its quality. Since water is essential for every living organism on earth. The type of water reserves and their utility needs to explore. The fresh water present in the from of ground water has been depleting rapidly in several parts of the world including India. Water has been used for manufacturing processes and out of total consumption industries generates 80% water as waste water. It creates water pollution hence major source of water pollution is industrial effluent. These entire factors get percolated into ground water through rain water causes ground water pollution. The composition of different kinds of micronutrient and heavy metal like zinc, iron, copper, manganese, lead, nickel, cadmium, mercury, chromium etc. are changes which get affect on soil fertility and ultimately on quality of ground water. Industrial development results in the generation of industrial effluent, and if untreated results in water, sediment, soil pollution [4,5]. Heavy metals from industrial processes are of special concern because they produce water or chronic poisoning in aquatic animals [3]. High levels of pollutants mainly organic matter in river water cause an increase in biological oxygen demand [10], chemical oxygen demand, total dissolved solids, total suspended solids and fecal coliform. They make water unsuitable for drinking, irrigation or any other use [6]. The study of Shivkumar and Biksham (1995) carried out in the 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.

It is essential to monitor such type of pollution and major pollutant levels. The Ahmednagar MIDC area is located in Ahmednagar district of Maharashtra. In this industrial area around 750 industries are situated which generate lot of industrial effluent and discharge it in ground as well as river water, which leads to the groundwater pollution around area. The present study was therefore carried out to determine the important characteristics of various industrial effluents of Ahmednagar MIDC area, Ahmednagar and to assess the possible impact of such effluents on quality of groundwater in the proximity of the Industrial Estate.

Material and Methods

Study area

The Ahmednagar is located in the Central part of the Deccan Plateau on the eastern flank of Harishchandra hill range in the upper basin on the left bank of the Sina River. This city is situated between 19^0 04'N to 19^0 08'N latitude and $74^0 44'$E to $74^0 46'$E, longitude at the height of 656.54 m from the mean sea level. The Ahmednagar MIDE area is comprised of about 750 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 *Nala* and eventually into the Sina River. This study was initiated to evaluate the industrial effluents for physicochemical 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 irrigation or drinking purposes.

Sampling of industrial effluents and groundwater

Effluents samples were collected at four discharge point of industrial units of Ahmednagar MIDC area during the period From August, 2010 to November, 2010. During the same period ground water samples were also collected from seven tube and open 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 lit. volume in such a way that no bubbles were formed in the containers. A total of 11 samples including four from industrial effluents and 7 from tube wells and open dug wells in the vicinity of the industrial area were collected.

Physico-chemical analysis

Industrial effluent and groundwater samples of the surrounding area were analyzed for various important characteristics such as pH [12], electrical conductivity [12], total suspended solids [1], total dissolved solids [12] and heavy metals concentration [2]. The physico-chemical analysis of industrial effluent and groundwater sample was performed following standard methods as described below.

pH: The pH was determined by potentiometric method using pH meter already standardized by using buffer solutions of known value before analysis by means of glass electrode given by Richards (1954).

Electrical conductivity (EC): EC is the measure of the ability of an aqueous solution to convey an electric current. This ability depends upon the presence of ions, their total concentration, mobility, valence and temperature. Electrical conductivity was determined by conductivity meter following the procedure of Richard (1954).

Total suspended solids (TSS): Total suspended solids are the portion of solids that usually remains on the filter paper. Suspended solids consist of silt, clay, fine particles of organic and inorganic matter, which is regarded as a type of pollution because water high in concentration of suspended solid may adversely affect growth and reproduction rates of aquatic fauna and flora. For TSS analysis, known amount of sample was filtered through the pre weighed filter paper. Filter paper was then dried at 103- 105°C. Then the TSS was determined by using the formula (Anon, 1992). TSS (mgL^{-1}) = [(Final weight-Initial weight)/Amount of sample taken] X 1000.

Total dissolved solids (TDS): Total dissolved solids (TDS) is the measure of total inorganic salts and other substances that are dissolved in water. TDS was determined following the procedure of Richard (1954) by using Electrical Conductivity (EC) meter. TDS was determined by using the formula, TDS (mgL^{-1}) = EC (ds/cm) X 540.

Heavy metals: For the analysis of heavy metals viz. Copper (Cu), Zinc (Zn), Iron (Fe), Manganese (Mn), Nickel (Ni), Cadmium (Cd), Led (Pb) and Chromium (Cr) the samples were analyzed on Atomic Absorption Spectrophotometer (Perkin Elmer Model 2380) for concentration by using specific cathode lamp. AAS was calibrated for each element using standard solution of known concentration before sample injection (APHA, 1992).

Results and Discussion

To evaluate the characteristics of the industrial effluents and in ground water surrounding the Ahmednagar Industrial Estate, Ahmednagar, 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 groundwater from wells are presented and discussed below.

pH: The pH of the industrial effluents ranged from 7.80–8.20 with a mean value of 8.06 (Table 1). pH values indicated that the pH of industrial effluent is of within the permissible limits for industrial effluents set by NEQS. Regarding the pH of groundwater, the values varied between 7.32-8.00 with a mean value of 7.54 (Table 2). The maximum pH in the water of Dug well-1 and minimum in the water of Dug well-3 and 4 near main drain was recorded, The pH values for all groundwater samples were found within the permissible limits compared with the WHO and US-EPA standards established for drinking water.

Electrical conductivity (EC): Electrical conductivity is a function of total dissolved solids (TDS) known as ions concentration, which determines the quality of water (Hem, 1989) [7]. Electrical conductivity of the industrial effluents ranged from 0.63–1.22 ds/m with the mean value of 0.97 ds/m (Table 1). The EC values for industrial effluent samples were found within permissible limits compared with NEQS. Similarly, the EC of ground water ranged from 0.95–2.45ds/m with a mean value of 1.53 ds/m (Table 2). The EC values for all groundwater 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 the industrial effluents ranged from 330 - 1750 mg L^{-1} with a mean value of 890 mg L^{-1} (Table 1). It is evident from the results that the effluents had high TSS and were above the permissible limits of NEQS. 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 groundwaters ranged from 380 - 670 mg L^{-1} with a mean value of 490 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 groundwater, 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 the industrial effluents ranged from 340 - 659 mg L^{-1} with a mean value of 524 mg L^{-1} (Table 1). Comparing with the NEQS, it was observed that the TDS values in effluents of all the samples were within the permissible limits. Similar results were also reported by Shah (1999) and Khan and Noor (2002). The TDS in groundwater ranged from 513-1323 mg L^{-1} with a mean value of 824 mg L^{-1} (Table 2). Comparing with WHO and US-EPA standards, all samples of groundwater were within the permissible limits set for drinking water purposes.

Heavy metals concentration: The results obtained on heavy metal contents (Fe, Mn, Zn, Cu, Ni, Cd, Co, Cr and Pb) in the industrial effluents are presented in Table 3. The Fe in the industrial effluents ranged from 0.077-0.14 mg L^{-1} with a mean value of 0.091 mg L^{-1}, Mn ranged from 0.007-0.027 mg L^{-1} with a mean value of 0.014 mg L^{-1}, Zn ranged from 0.009-0.017 mg L^{-1} with a mean value of 0.013 mg L^{-1}, Cu ranged from 0.005-0.015 mg L^{-1} with a mean value of 0.041 mg L^{-1}, Ni ranged from 0.026-0.038 mg L^{-1} with a mean value of 0.032 mg L^{-1}, Cd ranged from 0.001-0.009 mg L^{-1} with a mean value of 0.005 mg L^{-1} and Co ranged from 0.092-0.102 mg L^{-1} with a mean value of 0.096 mg L^{-1}. The Cr and Pb were absent in the samples. Results showed that the levels of Fe, Mn, Zn, Cu, Ni, Cd, Co Mn, within 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 aluminum industries which reduced the pH and thus Mn was released in the effluent. Perhaps Ni in the industrial effluents was due to certain industries e.g. oil, chemicals, kitchen appliances, steel alloys and automobiles batteries.

The results obtained on heavy metal contents (Fe, Mn, Zn, Cu, Ni, Cd, Co, Cr and Pb) in the groundwater samples surrounding the industrial estate are presented in Table 4. The Fe in the groundwater ranged from 0.053-0.071 mg L^{-1} with a mean value of 0.063 mg L^{-1}, Mn ranged from 0.001-0.076 mg L^{-1} with a mean value of 0.015 mg L^{-1}, Zn ranged from 0.002-0.08 mg L^{-1} with a mean value of 0.017 mg L^{-1}, Cu ranged from 0.004-0.015 mg L^{-1} with a mean value of 0.008 mg L^{-1}, Ni ranged from 0.032-0.101 mg L^{-1} with a mean value of 0.049 mg L^{-1}, Cd ranged from 0.003-0.012 mg L^{-1} with a mean value of 0.006 mg L^{-1} and Co ranged from 0.085-0.11 mg L^{-1} with a mean value of 0.094 mg L^{-1}. The Cr and Pb were absent in the samples. The presence of Cd in groundwater may be through effluents discharges of marbles, steel and aluminum industries as well as from mining and metal plating. 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 groundwater was perhaps leaching from the discharge of oil industries in the surrounding area.

These results revealed that the discharge of industrial effluents into open drains increased the heavy metal contents (Fe, Mn, Zn, Cu, Ni, Cd, Co, Cr and Pb) both in the drain and in groundwater.

Conclusion

The results of the industrial effluent were compared with National Environmental Quality Standards (NEQS), from the findings it was concluded that all industrial effluent samples were not harmful for irrigation purpose. All the results of ground water were compared with US-EPA and WHO standards, from the findings it was concluded that all ground water samples were safe for drinking and irrigation purpose. From the present research study, it can be concluded that although the results are somewhat inline with the safe limits of NEQS as well as US-EPA and WHO but the toxic level of harmful materials can mix up with the groundwater if no precautionary measures were taken for filtering of the industrial effluents.

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Table 1: Characteristics of selected samples of industrial effluents.

Location	pH	EC (ds/m)	TSS (mgL^{-1})	TDS (mgL^{-1})
L-1	8.20	1.220	1060	659
L-2	8.12	0.980	1750	529
L-3	8.13	1.050	420	567
L-4	7.8	0.630	330	340
Average	**8.06**	**0.970**	**890**	**523.75**

Table 2: Characteristics of the groundwater

Location	pH	EC (ds/m)	TSS (mgL^{-1})	TDS (mgL^{-1})
W1	8.00	0.950	480	513
W2	7.49	1.940	530	1048
W3	7.32	2.450	670	1323
W4	7.48	2.280	550	1231
W5	7.62	0.990	420	535
W6	7.58	1.050	400	567
W7	7.32	1.020	380	551
Average	7.54	1.530	490	824

Table 3: Heavy metal concentration (mgL^{-1}) in industrial effluents

Location	Fe	Mn	Zn	Cu	Ni	Cd	Co
L-1	0.082	0.027	0.017	0.011	0.038	0.006	0.102
L-2	0.140	0.008	0.014	0.015	0.026	0.004	0.094
L-3	0.066	0.012	0.009	0.005	0.036	0.009	0.092
L-4	0.077	0.007	0.010	0.010	0.029	0.001	0.096
Average	**0.091**	**0.014**	**0.013**	**0.041**	**0.032**	**0.005**	**0.096**

Table 4: Heavy metals concentration (mgL^{-1}) in groundwater

Location	Fe	Mn	Zn	Cu	Ni	Cd	Co
W1	0.065	0.076	0.008	0.010	0.035	0.009	0.099
W2	0.058	0.005	0.009	0.015	0.064	0.003	0.094
W3	0.059	o.oo1	0.007	0.007	0.036	0.004	0.099
W4	0.071	0.007	0.08	0.010	0.044	0.008	0.11
W5	0.053	0.002	0.009	0.006	0.101	0.012	0.085
W6	0.068	0.004	0.002	0.006	0.033	0.009	0.085
W7	0.065	0.010	0.006	0.004	0.032	0.003	0.085
Average	0.063	0.015	0.017	0.008	0.049	0.006	0.094

Table 5: National Environmental Quality Standards (NEQS) for Industrial Effluents

S. No.	Parameters	Standards
1.	Temperature	$40^{o}C$
2.	pH value (acidity/basicity)	6-10 pH
3.	5-days Biochemical Oxygen Demand (BOD) at $20^{o}C$	80 mg L^{-1}
4.	Chemical Oxygen Demand (COD)	150 mg L^{-1}
5.	Total Suspended solids	150 mg L^{-1}
6.	Total dissolved solids	3500 mg L^{-1}
7.	Grease and oil	10 mg L^{-1}
8.	Chloride (Cl)	1000 mg L^{-1}
9.	Fluoride (F)	20 mg L^{-1}
10.	Cyanide (CN)	2 mg L^{-1}
11.	Sulphate (SO_4^{-2})	600 mg L^{-1}
12.	Sulphide (S)	1.0 mg L^{-1}
13.	Ammonia (NH_3)	40 mg L^{-1}
14.	Pesticides, herbicides, fungicides and insecticides	0.15 mg L^{-1}
15.	Cadmium	0.1 mg L^{-1}
16.	Chromium	1.0 mg L^{-1}
17.	Copper	1.0 mg L^{-1}
18.	Lead	0.5 mg L^{-1}
19.	Mercury	0.01 mg L^{-1}
20.	Selenium	0.5 mg L^{-1}
21.	Nickel	1.0 mg L^{-1}
22.	Silver	1.0 mg L^{-1}
23.	Total toxic metals	2.0 mg L^{-1}

Table 6: US-EPA and WHO standards for drinking water

US-EPA and WHO standards for drinking water Contaminants	**U.S.EPA** ($mg\ L^{-1}$)	**WHO** ($mg\ L^{-1}$)
Color	Colorless	Colorless
Odor	Odorless	Odorless
Taste	Tasteless	Tasteless
Temperature ^{o}C	---	$12^{o}C$
PH	6.0-8.5	6.5-9.2
DO	4-6	3 ppm
TDS	500 ppm	500 ppm
TSS	0-5	5
Cl-	250	200-500
Sulphates	250	200-400
Nitrate/Nitrite	100	45
Calcium	100	100
Magnesium	30	150
COD	4.0	10
Sodium	20	200
Potassium	---	12
EC	300	400
Arsenic	0.05	0.05
Cadmium	0.01	0.05
Fluoride	2.2	1.5
Mercury	0.002	0.001
Iron	0.3	0.3
Manganese	0.05	0.1
Zinc	5.0	5.0
Selenium	0.01	0.01
Lead	0.05	0.05