International Research Journal of Environment Sciences ISSN 2319–1414
Vol. **1(3),** 32-36, October **(2012)** *I. Res. J. Environment Sci.*

Impact of Industrial Effluent Discharge on Physico-Chemical Characteristics of Agricultural Soil

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Available online at: www.isca.in
Received 05th October 2012, revised 12th October 2012, accepted 12th October 2012

Abstract

Rapid industrialization affects the environment in different ways by discharging the large amount of effluent as waste water in the surrounding water bodies, causing the serious problems to environment. Due to lack of irrigation water in the present study area canal water was used in which effluents from various industries were being discharged. Canal water was containing high COD, BOD values and higher heavy metal content and the soil irrigated with this water was showing the poor status of the nutrients and high contamination of heavy metals. The present study was to evaluate the various adverse effects on the soil characteristics irrigated with discharged water.

Keywords: Effluent water, heavy metal, nutrient status, COD, BOD.

Introduction

Various devastating ecological and human disasters of the last four decades implicate industries as a major contribution to environmental degradation and pollution[1-3]. Environmental pollution due to increase of industrial activities are one of the most significant problems of the century. Pollution in soil and water is strictly related to human activities such as industry, agriculture, burning of fossil fuels, mining and metallurgical processes and their waste disposal[4]. An industry which uses the large amount of water in their processes includes chemical manufactures, steel plants, metal processors etc. All types of effluents and most of byproducts from any kind of industry create a most serious pollution to the water bodies and soil bodies[5]. The contamination of soil is often a direct or indirect consequence of industrial activities[6]. With the ever increasing demand on irrigation water supply, farmlands are frequently faced with utilization of poor quality irrigation water. Due to shortage of canal irrigation water formers use industrial effluents which being discharged in canal[7]. Since, the use of such effluents as irrigation water may introduce some metal ions, which may accumulate in the plants[8]. Soil physiochemical properties are adversely affected by high concentration of heavy metals, rendering contaminated soils unsuitable for crop production[9-10]. Metals can also be transported from soil into groundwater resulting in to soil contamination and inhibiting growth of plants[11]. Soils contaminated with toxic metals from point sources are potential exposure routes for surrounding population[12-14]. The heavy metals accumulate in the plant material grown in these soils, which will ultimately go to human body through food chain directly or indirectly causing a number of physico-mental problems.

The objective of the present study is to assess the impact of industrial effluent discharged on soil of agricultural field and to analyze physicochemical characteristics of water and soil.

Material and Methods

Study area: Study area was selected around the Iron and Steel industry situated at Bhandara, Maharashtra state (India). Mostly the water source for irrigation was only water canal passes via industry. The existing industry has been discharging their liquid wastes into a nearby canal. Accordingly some of the farmers of villages are using this canal water for irrigating different crops including rice, wheat, vegetables and fruits etc. By keeping this view it was thought that this activity of the industry may cause the adverse effect not only over environment but also over the farmers, the effects over farmers are in the form of health hazards as well as over the socioeconomic strata of them.

Samples collection for Effluent Water: Four water samples were collected from four locations and three to four replicate analysis was carried out for each sample. The water samples were collected in polyethylene bottles directly from the outlet of the factory linked to canal. Sampling locations were selected after each 0.5 km from discharging points. Initial three samples were taken from 0.5 km distance each, while first location was 0.1 km from first discharging point. On the other hand fourth sample was collected from approximately 0.1 km distance from the second discharging point. Collected water samples were analyzed for physico-chemical characteristic, heavy metal and sulphide content.

Samples collection for Soil: Five soil samples were collected from different fields and three to four replicate analysis was carried out for each samples. Mainly the sampling locations were selected approximately each 0.5 km from both the discharging points. The first sample was collected from 0.1 km distance from the first discharge point; sequentially the other two samples were collected by variable distances from the discharge point. On the other hand fourth sample was collected at the distance of 0.5km from first discharge point and the fifth soil sample was collected from approximately 0.1 km from second discharging point. Soil samples were collected at depth 0-20cm from five spots each by using zigzag sampling and analyzed for chemical characteristics and mineral metal content in the soil. In zigzag sampling method, four points were selected by zigzag manner and samples were dig out at depth 0-20cm and collected in the Ziploc polythene bag. Then these samples were kept for drying. After drying, samples were crushed and sieved through 2 mm sieve separately.

Method of analysis for effluent water: The pH of the samples was determined using the pH meter, by calibrating the pH meter using the buffer solutions of known pH values. Electrical conductivity (EC) was determined using the conductivity meter calibrated with conductivity standard (0.01 m KCl with conductivity 1413 μ Scm^{-1}). Total suspended solids (TSS) consist of the organic as well as some of the inorganic matter which remains on the filter paper and it was determined by gravimetric method. Chlorides of the samples were determined by using argentometric method of precipitation. Oil and grease was determined by using the partition gravimetric method. Chemical oxygen demand (COD) determines the oxygen equivalent of organic matter that is susceptible to oxidation with the help of strong chemical oxidant. COD was determined by using open reflux method. Biochemical oxygen demand (BOD) is expressed as the weight of oxygen consumed per unit volume of water during defined period of time and temperature for this the samples was incubated for 5 days.

For the analysis of the heavy metals 50 ml sample was taken and 5 ml conc. HNO_3 was added then samples were digested. The digested samples were filtered through whatman filter paper no. 42 after filtration the volume was made to 50 ml with the deionized water. Samples were analyzed on atomic absorption spectrophotometer for concentration by using specific cathode lamp. AAS was calibrated for each element using standard solution of known concentration before sample injection[15].

Method of analysis for soil: The pH of soil samples were estimated by dipping the pH electrode in the saturated paste, in the same suspension conductivity and concentration of NO_3 -N was measured using conductivity meter (Orion, EA 940 USA). Known amount of soil was leached with neutral ammonium acetate solution. Leachate was preserved to estimate the soluble cations such as sodium (Na^+), potassium (K^+), and calcium (Ca^{++}) and magnesium (Mg^{++}) ions. Available potassium was estimated by leaching the soil with ammonium acetate and determining the potassium using flame photometer as described in manual on receiving land quality evaluation, available nitrogen was determined by Kjeldhal method[16-17]. Soil organic carbon was estimated using Walkley-Black method[18]; available phosphorous was determined by Olsen's method[19]. Heavy metal contents in soil were determined by digesting soil with perchloric acid and conc. nitric acid followed by analysis on atomic absorption spectrophotometer.[15]

Results and Discussion

Physical parameters: Temperature of the water sample was varied from 30 to 34^0C. The pH of these samples was ranged from 8.4 to 10.5. The pH values were found to highest in the location 4 showing the alkaline nature of the water. The EC of all the four samples were ranged from 400 to 470μScm^{-1}. The conductivity values were high in the sample of the fourth location. The turbidity of the samples was measured in the NTU units and the turbidity was ranged from 21.3 to 74.5 NTU results are depicted in table-1.

Chemical parameters: The COD Values were ranged from 256 to 300 mg/l. The fourth of location was showing the highest COD value representing the high organic load in the water. BOD values of the water were ranged from 29 to 56 mg/l. In this case it was seen that the samples collected from the 0.1 km distance of second discharge point was showing the high values of COD and BOD. Oil and grease values were ranged from 8 to 20 mg/l. The fourth location was showing the little variations in the value of oil and grease as compared to rest of three locations. Chlorides was found to be in the range of 118 to 241 mg/l. Alkalinity was also found to be high in the fourth location whereas it was found low in the sample collected from 0.5 km distance of first discharge point. Sulphide values were ranged from 26 to 72 mg/ l results are depicted in table-1.

Heavy metals content of water: Heavy metal concentration was varied as Ni 0.136 to 0.303 mg/l, Cd 0.045 to 0.051 mg/l, Pb BDL to 0.082 mg/l, Fe 2.70 to 21.9 mg/l, Mn 0.053 to 2.24 mg/l. The Fe values were found to be highest in the sample near second discharge point. Results are depicted in table-2.

Soil environment: Soil pH: Soil pH is a measure of the concentration of hydrogen ions in the soil. It is known to be related to the availability of macro and micronutrients for plants. Soil pH ranged from 7.4 to 11.5. The highest pH range was found in fourth location which was 0.1 km from second discharge point.

Soil salinity: Soil salinity refers to the amount of dissolved salts in the soil solution. Effluent or the combined effect of effluent and fertilizers may raise soluble salt level to the extent that they impede plant growth. However, the concentration in the soil at which salt is hazardous varies soil texture and plant species.

Soil conductivity: The conductivity of the soil samples was ranged from 0.540-0.522 dSm^{-1}. The range was highest in the fifth location which nearly 0.1 km from the second discharge point.

Table-1
Physico-chemical analysis of water

Parameter	Location 1	Location 2	Location 3	Location 4
Temperature (^{0}C)	34 ± 0.53	30 ± 1.00	32 ± 1.00	32 ± 1.00
pH	8.8 ± 0.36	8.8± 0.40	8.4 ± 0.31	10.5 ± 1.00
Turbidity (NTU)	21.3 ± 0.55	22 ± 1.08	52 ± 1.01	74.5 ± 1.01
Conductivity (µScm^{-1})	400 ± 0.04	410 ± 0.65	430 ± 0.53	470 ± 0.20
TSS (mg/l)	110 ± 1.53	102 ± 2.00	112 ± 1.53	120 ± 1.00
Total alkalinity (mg/l)	65 ± 1.96	117 ± 1.20	107 ± 1.00	125 ± 1.00
Chlorides (mg/)	230 ±1.08	118 ± 0.85	152 ± 1.07	241 ± 1.00
COD (mg/l)	283 ± 1.53	272 ± 1.53	256 ± 1.00	300 ± 1.00
BOD (mg/l)	39 ± 1.00	35 ± 1.73	29 ± 1.00	56 ± 1.00
Oil and grease (mg/l)	10 ± 0.76	12 ± 1.00	8 ± 0.58	20 ± 1.00
Sulphide (mg/l)	26 ± 1.53	30 ± 1.00	56 ± 1.00	72 ± 1.00

Table-2
Heavy metals content of water

S. No.	Sample Location	Ni	Cd	Cr	Cu	Pb	Fe	Mn	Zn	CO
		(mg/l)								
1	Location-1	0.136 ± 0.002	0.046 ± 0.002	0.012 ± 0.001	-	0.05 ± 0.001	3.28 ± 0.015	0.053 ± 0.001	0.24 ± 0.010	0.084 ± 0.002
2	Location-2	0.150 ± 0.002	0.045 ± 0.002	0.018 ± 0.001	-	-	3.37 ± 0.015	0.116 ± 0.001	0.08 ± 0.021	0.074 ± 0.002
3	Location-3	0.150 ± 0.002	0.046 ± 0.002	0.007 ± 0.002	-	0.08 ± 0.002	2.70 ± 0.015	0.081 ± 0.002	0.10 ± 0.015	0.081 ± 0.002
4	Location-4	0.303 ± 0.002	0.051 ± 0.002	0.008 ± 0.002	-	0.01 ± 0.001	21.9 ± 0.15	2.24 ± 0.025	0.13 ±0.015	0.151 ± 0.002

Table-3
Chemical Characteristic of Soil Extract

Parameter	Location 1	Location2	Location3	Location 4	Location 5
pH	7.9 ± 0.10	7.7 ± 0.03	7.6 ± 0.17	7.4 ± 0.10	11.5 ± 0.50
Conductivity (dSm^1)	0.79 ± 0.02	0.12 ± 0.06	0.54 ± 0.01	0.36 ± 0.01	0.52 ± 0.04
Ca^{++} (meq/l)	10.40 ±0.03	9.98 ± 0.01	76.15±0.02	9.00 ± 0.17	32.93 ± 0.02
Mg^{++} (meq/l)	0.29 ± 0.03	1.70 ± 0.06	1.03 ± 0.01	0.94 ± 0.01	45.24 ± 0.02
Na^+ (meq/l)	2.76 ± 0.14	3.15 ± 0.02	1.25 ± 0.01	2.60 ± 0.10	5.41 ± 0.02
K^+ (meq/l)	0.43 ± 0.02	0.05 ± 0.01	0.04 ± 0.01	0.05 ± 0.01	0.24 ± 0.01
Organic carbon %	1.39 ±0.02	2.20 ± 0.06	1.39 ± 0.01	0.65 ± 0.02	1.2 ± 0.15
Nitrogen (kg/ha)*	218 ± 0.38	122 ± 0.02	149 ± 0.01	137 ± 0.58	200 ± 0.58
Phosphorous(kg/ha)*	5.35 ± 0.04	0.64 ± 0.01	1.80 ± 0.10	0.87 ± 0.01	0.64 ± 0.02
Potassium (kg/ha)*	61.95 ± 0.26	60 ± 0.02	64.6 ± 0.10	65.57 ± 0.02	70.28 ± 0.02

*Range of major nutrient in soil

Nutrient status	Nitrogen	Phosphorus	Potassium
	(kg/hac)		
Level in poor soil	<280	<23	<133
Level in medium soil	280-560	23-57	133-337
Level in fertile soil	>560.0	>57.0	>337.0

Table-4
Heavy metals content of soil

S. No.	Sample Location	Ni	Cd	Cr	Cu	Pb	Fe	Mn	Zn	Co
		(mg/kg)								
1	Location-1	39.4 ± 0.64	5.7 ± 0.35	10.3 ± 0.21	17 ± 0.36	44 ± 1.53	2160 ± 2.89	393.7 ± 1.65	67 ± 1.0	23 ±0.76
2	Location-2	39.0 ± 1.04	5.5 ± 0.25	2.1 ± 0.20	4 ± 0.32	3 ± 0.10	545 ± 1.53	1231 ± 2.0	57 ± 1.07	32 ± 1.0
3	Location-3	33.0 ± 1.10	5.7 ± 0.20	1.0 ± 0.20	-	-	30 ± 2.08	416.5 ± 1.04	4 ± 0.10	16 ± 0.76
4	Location-4	36.± 0.85	5.0 ±0.30	5.8 ± 0.10	10 ± 0.50	10 ± 0.40	246 0± 3.20	487 ± 1.53	142 ± 1.53	23 ± 1.0
5	Location-5	43 .± 0.60	5.2 ± 0.12	4.0 ± 0.15	3 ± 0.15	12 ± 0.15	73 ± 0.20	1073 ± 0.15	12 ±00.21	40 ± 0.20

Nutrient status: In the nutrient status the organic carbon was found to be in the range of 0.65 to 2.20 % and nitrogen values was found to be in the range of 121.67 to 218.26 kg/ha. The phosphorus in the samples was found in the form of P_2O_5 were ranged between 0.64 to 5.34 kg/ha and potassium was found to be in the range of 60 to 70.28 kg/ha. Results are depicted in table-3. From the results it is clear that the soil category comes under the poor quality of the soil.

Heavy metals: Numbers of heavy metals present in the industrial effluent were being leached in soil by diverting effluent for irrigation purpose. The concentrations of heavy metals were in the range of Cd 5.0 to 5.7 mg/kg; Fe 30 to 2460 mg/kg, Mn 393.7 to 1231 mg/kg, Co 16 to 40 mg /kg as depicted in table-4. The Fe levels were high in the samples of fourth location which was approximate 0.5 km from the first discharging point.**Discussions:** As it was already mentioned, every manufactured product uses water during some part of the production process. The water discharged during the manufacturing processes of the above mentioned industry may cause the adverse effects over environment. In the same manner color and odor also changes. When the physico-chemical parameters are taken into consideration, the physical parameters shows that the pH, TSS are more while the turbidity is far more as compare to the normal values. The idea about inorganic parameters were total alkalinity and chloride content goes on decreasing while oil and Grease increases significantly in the fourth location. The decreases in chloride content means some quenchers are there in effluent. The high COD value from the effluent of the steel industry suggests that this industry is producing lots of organic substances. The level of sulfide was very high than the normal values. The heavy metals present in the effluent may come from the various metallurgical processes. The data suggest that near about concentrations of all the metals goes on decreasing which indicate that the effluent may contains metal quenchers; thus the trace elements required by the plants are not properly supplied which results the underproduction of the crops in a particular area. The fertility status of the soil was also tested and suggested that the fertility level of the surrounding fields are into very poor category. The above data also suggest that the effluent of the second discharge point cause comparatively deleterious effect over the surrounding environment.

Conclusions

Thus the present work concludes that the effluent from the industry causes the pollution problems in the surrounding environment. The nutrient status of the samples showed that the soil quality of the surrounding field was poor and the effluent discharged in the canal has been affecting the physicochemical characteristics of the soil. The heavy metals in the field were also showing the high concentration which also causes the adverse effects on the soil. Through this study, it is concluded that the industrial effluent has substantially changed the irrigation water quality diverted from canal and consequently some chemical elements also increased in the soil of the irrigated farmland.

Acknowledgements

The authors are thankful to Director, National Environmental Engineering Research Institute, Nagpur, India to provide the facilities required for research work.

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