International Journal of ChemTech Research
CODEN(USA): IJCRGG ISSN : 0974-4290
Vol.4, No.3, pp 1229-1240, July-Sept 2012

Evaluation of Heavy Metal Contamination in Surface Soil around Industrial Area, Tamil Nadu, India

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Abstract: Impact of anthropogenic activities of man and his environment as a result of the growing rate of industrialisation in Tamilnadu, India is of a great concern. The objective of this research was to evaluate the physical properties and heavy metal concentration of soil in different industrial areas. Soil samples were collected from seven industries like welding, cement, steel, printing, textile, paint and tannery which releases heavy metals to environment. Electrical Conductivity (EC), pH, Cation Exchange Capacity (CEC), Organic Matter (OM), Organic Carbon (OC) and heavy metals *viz.* Cu, Mn, Cr, Pb, Zn and Fe were analysed. Except tannery and steel industry all samples have alkaline pH. The maximum EC 6.41 dSm^{-1} was noticed in the soil sample collected from textile industry. The results showed that very high level of OC and OM were found in the soil contaminated by printing industry. The soil samples contaminated with cement and printing industries pollutants showed high CEC 26.4 and 38.7 m.eq /100g of soil. Different metals were found to be in higher level in different areas. High level of copper 28.9 ppm is noticed in sample collected from Tannery. The manganese level in increasing order is Textile < Cement < Steel < Painting < Tannery < Welding. The maximum level of iron 46.6 ppm and zinc 13.6 ppm is noticed in sample collected near welding industry. The soil sample of tannery industry showed high level of chromium 32.5 ppm and lead 15.7 ppm. However, comparing these concentrations with those obtained from locations of industrial activity, relatively high levels of heavy metals were recorded, with different industries. Considering all the heavy metals obtained at the study area, Zn, Pb and Cr dominated in all the investigated zones of high industrial impact. This is attributed to the indiscriminate disposal of industrial waste as well as anthropogenic point source contamination. The extremely high contents of the heavy metals generally recorded at the study area are terribly alarming in terms of environmental pollution. Therefore, the inhabitants (mostly children) and the numerous workers, who reside and work at such polluted environment, are at serious risk of heavy metal toxicity and awareness needs to be created as such.

Key words: soil pollution, industries, pH, CEC, EC, heavy metals.

Introduction

A substantial and unfortunate fact about industrialization and industrial production is generation and release of toxic waste products. Although these wastes can be treated, reused and recycled still thousands of chemicals are released and find their way into the environment. Unfortunately, the inadequate information regarding waste toxicity and post-disposal behaviour, poor planning, improper disposal and poor management of disposal sites stimulates serious contamination problems at industrial and hazardous waste disposal sites. An example is several available reports about the genotoxicity of soils contaminated with chemicals originated from industrial sources [1]. Heavy metals are among these chemicals and constitute a main group of soil pollutants that their contamination in environment affects all ecosystem components [2]. Although heavy metals are present as natural components of soils, toxic contamination may frequently occurs at industrial and mining sites.[3] Heavy metals such as Cu, Zn, Mn and Fe are essential for plant growth, many of them do not have any significant role in the plant physiology. The uptake of these heavy metals by plants is an avenue of their entry into the human food chain with harmful effects on health [4] Although the nutrient content of wastes makes them attractive as fertilizers, when untreated wastes are used in crop production, consumers risk to contact diseases like cholera and hepatitis, or to undergo heavy metal contamination [5].

Soil samples are differed in their properties and in content of Cd, Co, Mn, Ni, and pH depending in climate soil origin composition and human activities. In recent years, heavy metals in the soil have received attention as environmental contaminants because of their extended persistence, and toxicity to many organisms including plants.[6] There are several problems dealing with heavy metals contaminated soils which effect human health and environmental quality. The anthropogenic sources of the heavy metals, in soils are either primary sources, i.e. the heavy metals are added to the soil as an outcome of working the soil, such as fertilization or secondary sources where heavy metals are added to the soil as a consequence of a nearby activity, such as smelting or aerosal deposition.[7]. Even today, the most commonly used methods for heavy-metal pollution are still either the extremely costly process of removal and burial or simply isolation of the polluted land. Contaminated sites often support some plant species, which are able to accumulate or tolerate high concentrations of metals such as Pb and Zn [8]. A small number of species are capable of growing on soils containing high levels of metals, and also accumulate these pollutants in high concentrations in the parts above ground. These plants are known as hyper accumulators [9] The present study aims to assess physical properties heavy metal contamination in soils of the industrial area and to study their possible sources and potential health effects on human life, which can further enable medical investigations to be targeted.

Materials and Methods

Study Area: Soil samples were collected from sites chosen for their industrial activities at surface level (0–10 cm in depth) and from 0 to 500m at 100m interval. Sampling was conducted at seven locations (Textile – Thirupur, Cement- Ariyalur, Steel - Salem, Printing - Sivakasi, Tannery - Dindigul, Welding - Karur) in Tamilnadu. The study was conducted with the help of soil science department of Tamil Nadu Agricultural University, Coimbatore.

Heavy metal analysis: The collected soil samples were air-dried and sieved into coarse and fine fractions. Well-mixed samples of 2 g each were taken in 250 ml glass beakers and digested with 8 mL of aqua regia on a sand bath for 2 hours. After evaporation to near dryness, the samples were dissolved with 10 mL of 2% nitric acid, filtered and then diluted to 50 mL with distilled water. Heavy metal concentrations of each fraction was analysed by Atomic Absorption Spectrophotometry using Model Spectra 200. [10,11].

Physical parameters: EC of the soil samples were determined from saturation extract by conductivity meter. Measurement of pH, Organic Matter and Organic Carbon of soil samples were done (soil and water ratio 1:25) by using the procedures outlined by Jackson [12] Walkley and Black [13]. Cation Exchange Capacity was determined by the method of Thomas [14]. All chemicals were supplied from Merck (Germany) with appropriate purity grade, “for analysis” and de-ionized water was used through the experiments.

Results and Discussion

Physicochemical properties of soil

The soil samples were analyzed for various physicochemical properties and the data were furnished in Table 1 and Fig 1. The values given in table from 500 to 5000m are based on forecast analysis from the actual data belongs to 0 to 500m. The soils contaminated by steel and tannery industry effluent showed acidic soil reaction. (6.18 & 5.84 collected from Salem and Dindigul). Genrally during stripping process (removing rust and scales) nitric, sulphuric and hydrochloric acids are used in electroplating industry. [15] This might be the reason for acidic pH of these soils. On the other hand, alkaline soil reaction was noticed in soils contaminated by cement, textile and paint industry effluents and the values are 8.94, 8.92 & 8.52 respectively. This might be attributed to the addition of alkali metals like Na and earth metals like Ca & Mg in the discharge from these industries. Similar results have been reported[[16]. Soil pH is important because it influences the availability and plant uptake of micronutrients including heavy metals [17].The results obtained showed various EC values for different samples. The highest EC value was noticed in textile industry soil (6.41dSm^{-1}) which might be due to higher salt concentration of effluents [15]. Other samples showed EC values in the range of 0.5 – 1.48 dSm^{-1} The salt rich dye effluents and sludge disposal on sampling sites are the possible reasons for highest soluble salt content in soil. Very high percentage of organic carbon (11.77%) and organic matter (20.29 %) was present in printing industry soil due to the addition of high soluble organic matter trough sewage material [18] . The lowest CEC was found in textile industry soil and (15.6m.eq/100g soil) and highest (38.7 m.eq/100g soil) in soil collected from printing industry. The CEC parameter particularly measures the ability of soils to allow for easy exchange of cations between its surface and solution. The relatively low levels of silt, clay, OM and CEC indicate the high permeability, hence leachability of heavy metals in the soil and suggest that it might be amenable to remediation by soil washing [19,20].

Total heavy metal content

The levels of the metals in the soil at various sampling points are presented in Table 2, Fig 2.Chromium levels around the study area ranged from 3.25 – 32.5 ppm, and is considerably higher in the sample collected near tannery. The normal range of Cr in soils is 100 mg/kg. Cr exists in two possible oxidation states in soils: the trivalent Cr (III) and hexavalent Cr (VI). Hexavalent Cr (VI) being mobile and extremely toxic is more harmful than trivalent Cr (III). As the surrounding rocks are predominantly granite, where chromium concentration is always below 40 mg/kg. It is not possible to derive such high levels of Cr from rocks. Therefore, the source of Cr appears to be anthropogenic from some industries producing steel, textiles in the area [21]. Very high Cr levels in soil, i.e. up to 1,220 mg/kg were found in some industrial areas of India. Chromium is an essential trace element required for the metabolism of lipids and proteins and to maintain a normal glucose tolerance factor. High doses of chromium cause liver and kidney damage and chromate dust is reported to be carcinogenic.

The levels of copper and zinc in soil normally reflect the concentrations in the parent rocks. Like copper in igneous basaltic rocks (90 mg/kg) and soils from calcareous rocks normally have the higher levels of zinc. Copper is retained in soils through exchange and specific adsorption mechanisms. Zinc is readily adsorbed by clay minerals, carbonates. High concentrations of Zn and Cu was found to present in Welding (13.6 ppm) and Tannery (28.9ppm) respectively. Also high doses of Copper and Zinc are said to be toxic and carcinogenic. Overdoses of copper may also lead to neurological complications, hypertension, liver and kidney dysfunctions. Higher contamination of zinc causes hematological disorders [23,24]. The results indicates that the soil collected around tannery shows high level of lead(15.7 ppm. The presence of lead reduces the enzymatic activity of the biota, and in consequence, incompletely decomposed organic material accumulates in the soil [7]. Lead is the least mobile element among toxic metals, which is attributed to binding of the metal to organic matter [25,26]. The organic matter finally binds the lead in complexes and removes it from water by absorbing into the soil. [27,28] Lead had long been recognized as an industrial hazard. Pb impedes the synthesis of hemoglobin and accumulates within the red cells as well as the bones to give rise to anemia, headache and dizziness.

Low level of iron was present (6.17 ppm) in tannery soil and high level (46.6) was noticed in welding industry . Regarding manganese 4.56 ppm manganese was recorded in textile industry soil and 48.3 ppm in printing industry soil. This may be due to the usage of these metals in those industries. Precautionary measures should be taken in industrial area while discharging the waste materials.

Table 1: Comparison of observed and predicted values for physico-chemical properties of soil samples collected from various industrial areas

Industries		DISTANCE (m)	pH	EC DS/m	ORGANIC CORBAN %	ORGANIC MATTER %	CEC m.eq/100 g of soil
Welding Industry	Observed values	**0**	**7.9**	**0.56**	**1.44**	**2.47**	**19.3**
		100	**7.8**	**0.56**	**1.4**	**2.49**	**19**
		200	**7.7**	**0.51**	**1.38**	**2.56**	**19.8**
		300	**7.6**	**0.51**	**1.35**	**2.63**	**19.5**
		400	**7.5**	**0.48**	**1.31**	**2.74**	**19.9**
		500	**7.3**	**0.44**	**1.3**	**2.79**	**20**
	Forecast analysis	**1000**	6.7320	0.3199	1.1829	3.0781	20.7022
		1500	6.1312	0.1930	1.0685	3.3775	21.4111
		2000	5.5228	0.0645	0.9559	3.6729	22.1197
		2500	4.9156	-0.0638	0.8435	3.9669	22.8240
		3000	4.3086	-0.1919	0.7311	4.2612	23.5269
		3500	3.7014	-0.3201	0.6186	4.5555	24.2296
		4000	3.0943	-0.4482	0.5062	4.8499	24.9324
		4500	2.4871	-0.5763	0.3937	5.1442	25.6352
		5000	1.8800	-0.7045	0.2813	5.4385	26.3380
Printing Industry	Observed values	**0**	**7**	**1.48**	**11.77**	**20.29**	**38.7**
		100	**7**	**1.45**	**11.71**	**20.2**	**38.5**
		200	**6.8**	**1.41**	**11.45**	**20.33**	**39.2**
		300	**6.8**	**1.43**	**11.4**	**20.41**	**39**
		400	**6.6**	**1.4**	**11.32**	**20.56**	**39**
		500	**6.5**	**1.35**	**11.28**	**20.68**	**38.6**
	Forecast analysis	**1000**	5.9535	1.2481	10.9453	20.9016	38.5938
		1500	5.3859	1.1344	10.6568	21.1529	38.3419
		2000	4.8195	1.0174	10.3696	21.4040	38.0646
		2500	4.2551	0.9010	10.0816	21.6511	37.7958
		3000	3.6909	0.7849	9.7939	21.8984	37.5266
		3500	3.1266	0.6687	9.5064	22.1460	37.2564
		4000	2.5623	0.5526	9.2189	22.3935	36.9862
		4500	1.9980	0.4364	8.9314	22.6410	36.7161
		5000	1.4337	0.3202	8.6438	22.8885	36.4461
Tannery Industry	Observed values	**0**	**5.8**	**0.77**	**0.49**	**4.4**	**30**
		100	**5.8**	**0.75**	**0.47**	**4.46**	**30**
		200	**6**	**0.72**	**0.43**	**4.6**	**30.5**
		300	**6.2**	**0.69**	**0.36**	**4.71**	**30.6**
		400	**6.2**	**0.65**	**0.33**	**4.84**	**30.6**
		500	**6.4**	**0.61**	**0.3**	**4.96**	**30.7**
	Forecast analysis	**1000**	7.0395	0.4663	0.1199	5.4299	31.2925
		1500	7.6736	0.3165	-0.0535	5.9025	31.7838
		2000	8.3139	0.1665	-0.2249	6.3745	32.2780
		2500	8.9570	0.0167	-0.3970	6.8463	32.7790
		3000	9.6000	-0.1331	-0.5692	7.3182	33.2793
		3500	10.2429	-0.2829	-0.7414	7.7901	33.7790
		4000	10.8857	-0.4327	-0.9136	8.2620	34.2788
		4500	11.5286	-0.5825	-1.0858	8.7338	34.7786
		5000	12.1714	-0.7323	-1.2580	9.2057	35.2784

Steel Industry	**Observed values**	**0**	**8.2**	**0.17**	**0.49**	**0.84**	**28.2**
		100	**8**	**0.12**	**0.47**	**0.86**	**28**
		200	**7.7**	**0.07**	**0.34**	**1.11**	**28.4**
		300	**7.7**	**0.05**	**0.31**	**1.19**	**28.8**
		400	**7.5**	**0.04**	**0.29**	**1.2**	**29.2**
		500	**7.5**	**0.05**	**0.21**	**1.25**	**29.9**
	Forecast analysis	**1000**	6.8166	-0.0712	0.0532	1.5185	30.3874
		1500	6.1964	-0.1714	-0.0861	1.7217	30.8929
		2000	5.5827	-0.2702	-0.2279	1.9212	31.4118
		2500	4.9678	-0.3702	-0.3705	2.1240	31.9232
		3000	4.3534	-0.4701	-0.5128	2.3266	32.4351
		3500	3.7391	-0.5699	-0.6550	2.5288	32.9475
		4000	3.1249	-0.6697	-0.7973	2.7311	33.4597
		4500	2.5106	-0.7695	-0.9395	2.9335	33.9718
		5000	1.8963	-0.8693	-1.0818	3.1358	34.4840
Paint Industry	**Observed values**	**0**	**8.5**	**0.25**	**1.44**	**2.47**	**21.4**
		100	**8.3**	**0.2**	**1.42**	**2.49**	**21.9**
		200	**8.1**	**0.17**	**1.31**	**2.72**	**22**
		300	**8**	**0.13**	**1.28**	**2.89**	**21.9**
		400	**7.8**	**0.11**	**1.18**	**2.93**	**22.7**
		500	**7.2**	**0.08**	**1.1**	**3.12**	**22.6**
	Forecast analysis	**1000**	6.0719	-0.0411	0.8487	3.5743	22.4545
		1500	4.8006	-0.1555	0.5871	4.0156	22.6873
		2000	3.4941	-0.2702	0.3246	4.4633	22.9336
		2500	2.1935	-3848	0.0637	4.9117	23.1760
		3000	0.8941	-0.4995	-0.1971	5.3599	23.4173
		3500	-0.4059	-0.6141	-0.4580	5.8081	23.6590
		4000	-1.7060	-0.7288	-0.7188	6.2562	23.9007
		4500	-3.0060	-0.8435	-0.9797	6.7044	24.1423
		5000	-4.3060	-0.9581	-1.2406	7.1526	24.3840
Textile Industry	**Observed values**	**0**	**8.9**	**6.46**	**0.46**	**0.79**	**15.6**
		100	**8.9**	**6.41**	**0.44**	**0.87**	**15.6**
		200	**8.7**	**6.31**	**0.42**	**0.89**	**16.1**
		300	**8.6**	**6.25**	**0.37**	**0.92**	**15.8**
		400	**8.6**	**6.21**	**0.33**	**0.99**	**15.8**
		500	**7.6**	**6.1**	**0.29**	**1.29**	**15**
	Forecast analysis	**1000**	6.5603	5.9294	0.2039	1.4772	14.5607
		1500	5.2521	5.7378	0.1032	1.7877	13.8000
		2000	3.8715	5.5418	0.0035	2.1161	12.9915
		2500	2.4990	5.3471	-0.0951	2.4395	12.1928
		3000	1.1285	5.1524	-0.1939	2.7625	11.3948
		3500	-0.2430	4.9576	-0.2929	3.0860	10.5956
		4000	-1.6146	4.7628	-0.3918	3.4095	9.7965
		4500	-2.9860	4.5680	-0.4907	3.7329	8.9976
		5000	-4.3574	4.3732	-0.5896	4.0563	8.1986
Cement Industry	**Observed values**	**0**	**8.9**	**0.26**	**0.26**	**0.45**	**26.4**
		100	**8.7**	**0.21**	**0.24**	**0.47**	**26.9**
		200	**8.7**	**0.2**	**0.21**	**0.49**	**26.9**
		300	**8.5**	**0.18**	**0.13**	**0.7**	**30**
		400	**8.4**	**0.16**	**0.11**	**0.74**	**30**
		500	**8**	**0.12**	**0.1**	**0.83**	**30.4**

	Forecast analysis	**1000**	7.2108	0.0163	-0.0404	1.1372	34.1103
		1500	6.3276	-0.0920	-0.1681	1.4438	37.4675
		2000	5.4244	-0.2022	-0.2920	1.7448	40.6962
		2500	4.5246	-0.3121	-0.4164	2.0456	43.9434
		3000	3.6249	-0.4218	-0.5410	2.3471	47.2025
		3500	2.7249	-0.5317	-0.6656	2.6487	50.4605
		4000	1.8249	-0.6415	-0.7901	2.9502	53.7178
		4500	0.9249	-0.7513	-0.9147	3.2517	56.9753
		5000	0.0249	-0.8611	-1.0393	3.5532	60.2329

Table 2: Comparison of observed and predicted values for heavy metals of soil samples collected from various industrial areas

Industries		**DISTANCE**	**Copper (ppm)**	**Manganese (ppm)**	**Iron (ppm)**	**Zinc (ppm)**	**Chromium (ppm)**	**Lead (ppm)**
Welding Industry	**Observed values**	**0**	**2.59**	**42.5**	**46.6**	**13.6**	**8.44**	**10.6**
		100	**2.45**	**41.9**	**46.32**	**13.31**	**8.03**	**10.28**
		200	**2.2**	**41.36**	**45.92**	**13.06**	**7.81**	**9.95**
		300	**2.11**	**41.03**	**45.47**	**12.72**	**7.49**	**9.61**
		400	**1.96**	**40.88**	**45.19**	**12.24**	**7.12**	**9.27**
		500	**1.87**	**40.43**	**44.91**	**11.96**	**6.97**	**8**
	Forecast analysis	**1000**	1.1445	38.6180	43.2869	10.4236	5.6595	6.2283
		1500	0.4525	36.8859	41.7115	8.8570	4.3867	4.1647
		2000	-0.2373	35.1344	40.1461	7.3035	3.1294	2.0406
		2500	-0.9284	33.3778	38.5778	5.7539	1.8727	-0.0690
		3000	-1.6192	31.6227	37.0090	4.2035	0.6154	-2.1774
		3500	-2.3099	29.8679	35.4405	2.6528	-0.6418	-4.2872
		4000	-3.0006	28.1130	33.8720	1.1023	-1.8991	-6.3969
		4500	-3.6913	26.3580	32.3035	-0.4482	-3.1563	-8.5065
		5000	-4.3820	24.6030	30.7350	-1.9988	-4.4135	-10.6161
Tannery Industry	**Observed values**	**0**	**7.84**	**48.3**	**28**	**9.25**	**3.56**	**3.18**
		100	**7.44**	**48.02**	**27.75**	**9.03**	**3.12**	**2.94**
		200	**6.96**	**47.87**	**27.31**	**8.87**	**2.87**	**2.51**
		300	**6.52**	**47.41**	**27.1**	**8.4**	**2.54**	**2.2**
		400	**6.13**	**47.12**	**26.84**	**8.06**	**2.1**	**1.88**
		500	**5.92**	**46.94**	**26.51**	**7.91**	**1.91**	**1.56**
	Forecast analysis	**1000**	3.9187	45.4967	25.1638	6.5839	0.4992	0.1980
		1500	2.0045	44.0782	23.8276	5.2753	-0.8945	-1.1597
		2000	0.1063	42.6759	22.4847	3.9891	-2.2734	-2.5149
		2500	-1.7958	41.2724	21.1417	2.7033	-3.6494	-3.8691
		3000	-3.6983	39.8677	19.7994	1.4161	-5.0259	-5.2231
		3500	-5.6004	38.4631	18.4571	0.1289	-6.4026	-6.5772
		4000	-7.5025	37.0585	17.1147	-1.1582	-7.7791	-7.9313
		4500	-9.4047	35.6540	15.7724	-2.4454	-9.1557	-9.2854
		5000	-11.3068	34.2494	14.4300	-3.7325	-10.5323	-10.6394
	Observed values	**0**	**28.9**	**32.1**	**6.17**	**7.79**	**39.5**	**15.7**
		100	**28.53**	**31.88**	**5.84**	**7.41**	**39.12**	**15.41**
		200	**28.09**	**31.42**	**5.43**	**7.1**	**38.94**	**15.01**
		300	**27.91**	**31.19**	**5.12**	**6.75**	**38.51**	**14.84**
		400	**27.53**	**30.89**	**4.83**	**6.36**	**38.16**	**14.51**
		500	**27.12**	**30.51**	**4.55**	**5**	**37.94**	**14.16**

	Forecast analysis	**1000**	**25.4280**	28.9349	2.9620	2.7174	36.8594	13.2214
		1500	23.7135	27.3503	1.4129	0.1039	35.8110	12.2753
		2000	21.9879	25.7573	-0.1349	-2.5857	34.7774	11.3227
		2500	20.2644	24.1644	-1.6847	-5.2608	33.7486	10.3767
		3000	18.5417	22.5720	-3.2343	-7.9340	32.7184	9.4309
		3500	16.8188	20.9796	-4.7836	-10.6088	31.6880	8.4847
		4000	15.0960	19.3873	-6.3330	-13.2836	30.6577	7.5385
		4500	13.3731	17.7949	-7.8825	-15.9582	29.6274	6.5924
		5000	11.6503	16.2025	-9.4319	-18.6328	28.5971	5.6463
Tannery industry	**Observed values**	**0**	**1.38**	**15.3**	**12.5**	**1.19**	**6.24**	**3.88**
		100	**1**	**12.89**	**12.2**	**1.01**	**6.02**	**3.51**
		200	**0.84**	**12.54**	**11.83**	**0.86**	**5.81**	**3.13**
		300	**0.66**	**12.13**	**11.41**	**0.41**	**5.51**	**2.86**
		400	**0.43**	**11.91**	**11.19**	**0.19**	**5.16**	**2.44**
		500	**0.16**	**11.74**	**10.94**	**0.04**	**4.92**	**2.12**
	Forecast analysis	**1000**	-0.9428	9.0985	10.0528	-0.6836	4.1997	1.2394
		1500	-2.0594	6.8795	9.2630	-1.3468	3.4891	0.3882
		2000	-3.1832	4.6425	8.4746	-1.9971	2.7822	-0.4657
		2500	-4.3056	2.3921	7.6861	-2.6465	2.0808	-1.3132
		3000	-5.4275	0.1457	6.8973	-3.2971	1.3789	-2.1605
		3500	-6.5496	-2.1000	6.1086	-3.9479	0.6765	-3.0084
		4000	-7.6718	-4.3463	5.3198	-4.5985	-0.0257	-3.8562
		4500	-8.7939	-6.5927	4.5310	-5.2492	-0.7279	-4.7039
		5000	-9.9161	-8.8390	3.7423	-5.8998	-1.4302	-5.5517
Paint Industry	**Observed values**	**0**	**2.95**	**29.6**	**18.1**	**3.75**	**10.44**	**8.22**
		100	**2.51**	**29.47**	**17.86**	**3.32**	**10.11**	**8**
		200	**2.1**	**29.17**	**17.51**	**3.1**	**9.88**	**7.72**
		300	**1.89**	**28.84**	**17.18**	**2.84**	**9.41**	**7.41**
		400	**1.36**	**28.41**	**16.94**	**2.53**	**9.13**	**7.16**
		500	**1.11**	**27.99**	**16.54**	**2.21**	**8.94**	**6.91**
	Forecast analysis	**600**	0.7007	27.7737	16.3037	1.9678	8.6149	6.6867
		700	0.3571	27.3734	15.9771	1.7042	8.3148	6.4195
		800	-0.0003	27.0090	15.6853	1.4146	8.0270	6.1832
		900	-0.3840	26.6575	15.3877	1.1379	7.7864	5.9544
		1000	-0.7155	26.3305	15.0804	0.8740	7.5035	5.7167
		1500	-2.5300	24.5888	13.6013	-0.4792	6.1115	4.5315
		2000	-4.3361	22.8478	12.1150	-1.8358	4.7359	3.3509
		2500	-6.1398	21.1110	10.6287	-3.1902	3.3583	2.1703
		3000	-7.9433	19.3737	9.1424	-4.5446	1.9796	0.9892
		3500	-9.7469	17.6361	7.6561	-5.8992	0.6011	-0.1918
		4000	-11.5504	15.8986	6.1698	-7.2538	-0.7773	-1.3727
		4500	-13.3540	14.1611	4.6835	-8.6083	-2.1558	-2.5537
		5000	-15.1576	12.4236	3.1973	-9.9629	-3.5343	-3.7347
Textile industry	**Observed values**	**0**	**5.45**	**4.56**	**42.5**	**1.97**	**5.46**	**10.5**
		100	**5.12**	**4.12**	**42.12**	**1.51**	**5.11**	**10.11**
		200	**4.84**	**3.81**	**41.87**	**1.27**	**4.83**	**9.82**
		300	**4.51**	**3.47**	**41.41**	**1.02**	**4.33**	**9.41**
		400	**4.27**	**3.18**	**41.03**	**0.84**	**4.1**	**9.17**
		500	**3.94**	**2.93**	**40.84**	**0.43**	**3.88**	**8.94**
	Forecast analysis	**1000**	2.4623	1.3439	39.1017	-0.8487	2.4138	7.5610
		1500	0.9885	-0.1961	37.4047	-2.1364	1.0176	6.2444
		2000	-0.4893	-1.7325	35.7259	-3.4398	-0.3624	4.9388
		2500	-1.9680	-3.2709	34.0456	-4.7426	-1.7456	3.6311

		3000	-3.4466	-4.8091	32.3644	-6.0446	-3.1296	2.3230
		3500	-4.9251	-6.3473	30.6834	-7.3468	-4.5133	1.0151
		4000	-6.4037	-7.8854	29.0024	-8.6491	-5.8970	-0.2928
		4500	-7.8823	-9.4236	27.3214	-9.9513	-7.2808	-1.6007
		5000	-9.3609	-10.9618	25.6403	-11.2535	-8.6645	-2.9086
Cement Industry	**Observed values**	**0**	**1.9**	**7.06**	**12.5**	**0.41**	**3.25**	**4.26**
		100	**1.64**	**6.87**	**12.16**	**0.35**	**3.08**	**3.99**
		200	**1.29**	**6.54**	**11.84**	**0.24**	**2.75**	**3.53**
		300	**0.84**	**6.21**	**11.55**	**0.16**	**2.36**	**3.26**
		400	**0.44**	**5.84**	**11.21**	**0.09**	**2.11**	**2.84**
		500	**0.13**	**5.32**	**10.99**	**0.01**	**11.96**	**2.69**
	Forecast analysis	**1000**	-1.7589	3.5769	9.5582	-0.3715	16.4623	2.7641
		1500	-3.6437	1.7470	8.1576	-0.7463	24.2463	2.4078
		2000	-5.5176	-0.0934	6.7655	-1.1209	32.8167	2.0995
		2500	-7.3920	-1.9303	5.3736	-1.4957	41.2560	1.8011
		3000	-9.2671	-3.7671	3.9815	-1.8705	49.6753	1.4999
		3500	-11.1422	-5.6042	2.5894	-2.2453	58.1091	1.1983
		4000	-13.0171	-7.4413	1.1974	-2.6201	66.5429	0.8970
		4500	-14.8921	-9.2783	-0.1947	-2.9948	74.9751	0.5957
		5000	-16.7671	-11.1153	-1.5868	-3.3696	83.4074	0.2943

Figure 1: Physicochemical analysis of polluted soil samples collected from industrial area (Line graph)

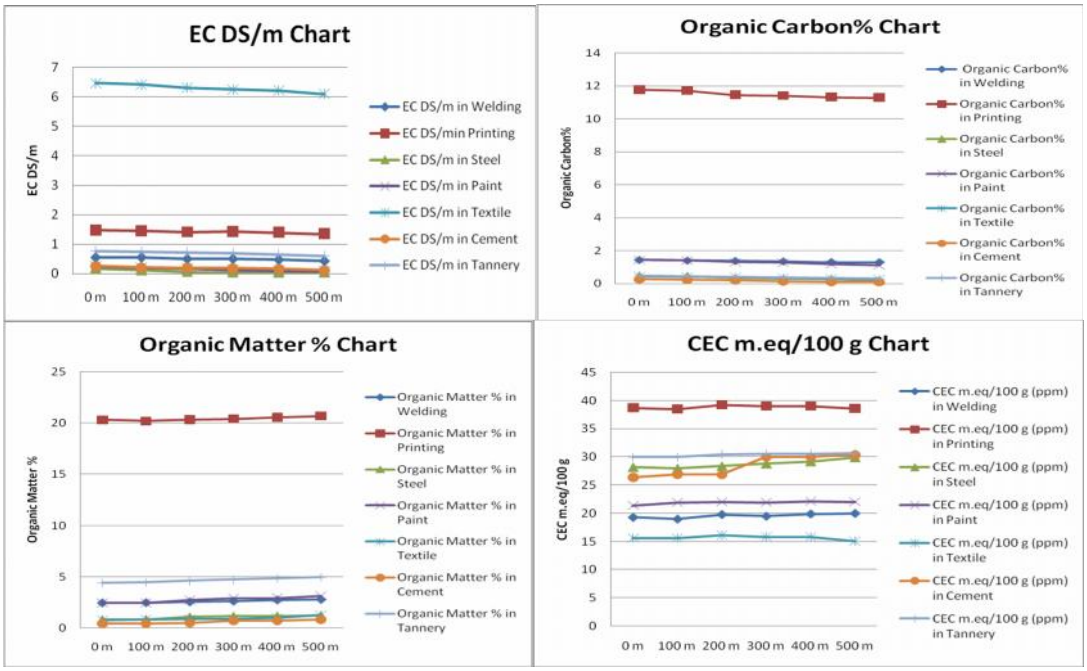


Figure 2: Heavy metal content of soil samples collected from industrial area

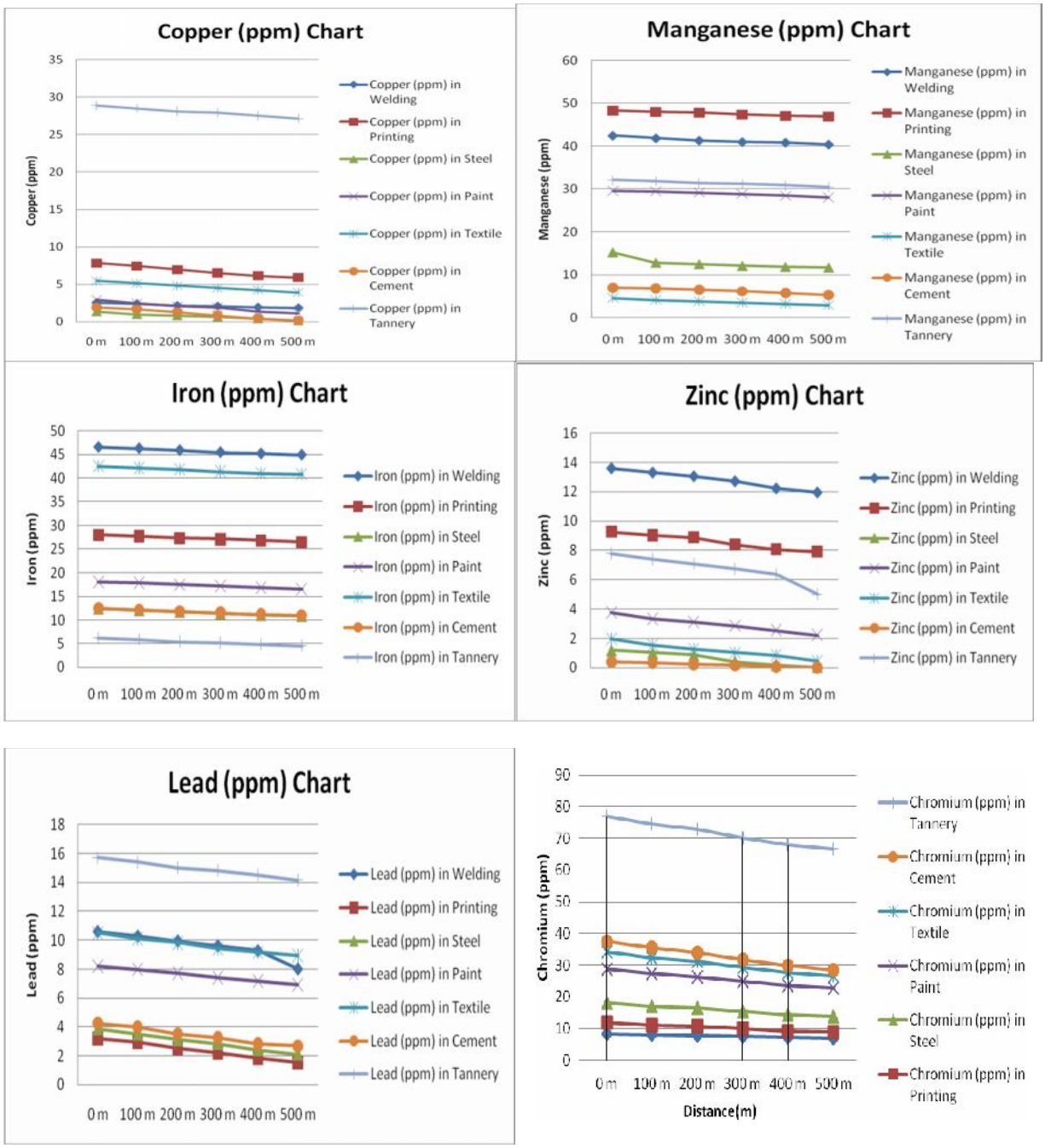
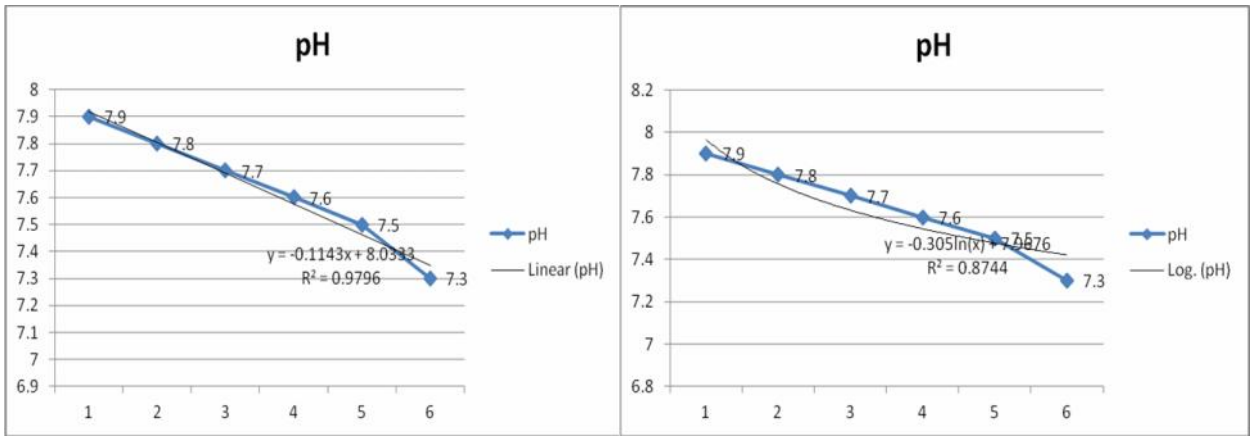


Figure 3: Comparison of laboratory measured pH in the test data set with their predicted values based on trend line analysis of soil collected from welding industry

Trend line (linear) **Trend line (Lograthimic)**



Trend Line (Polynomial)

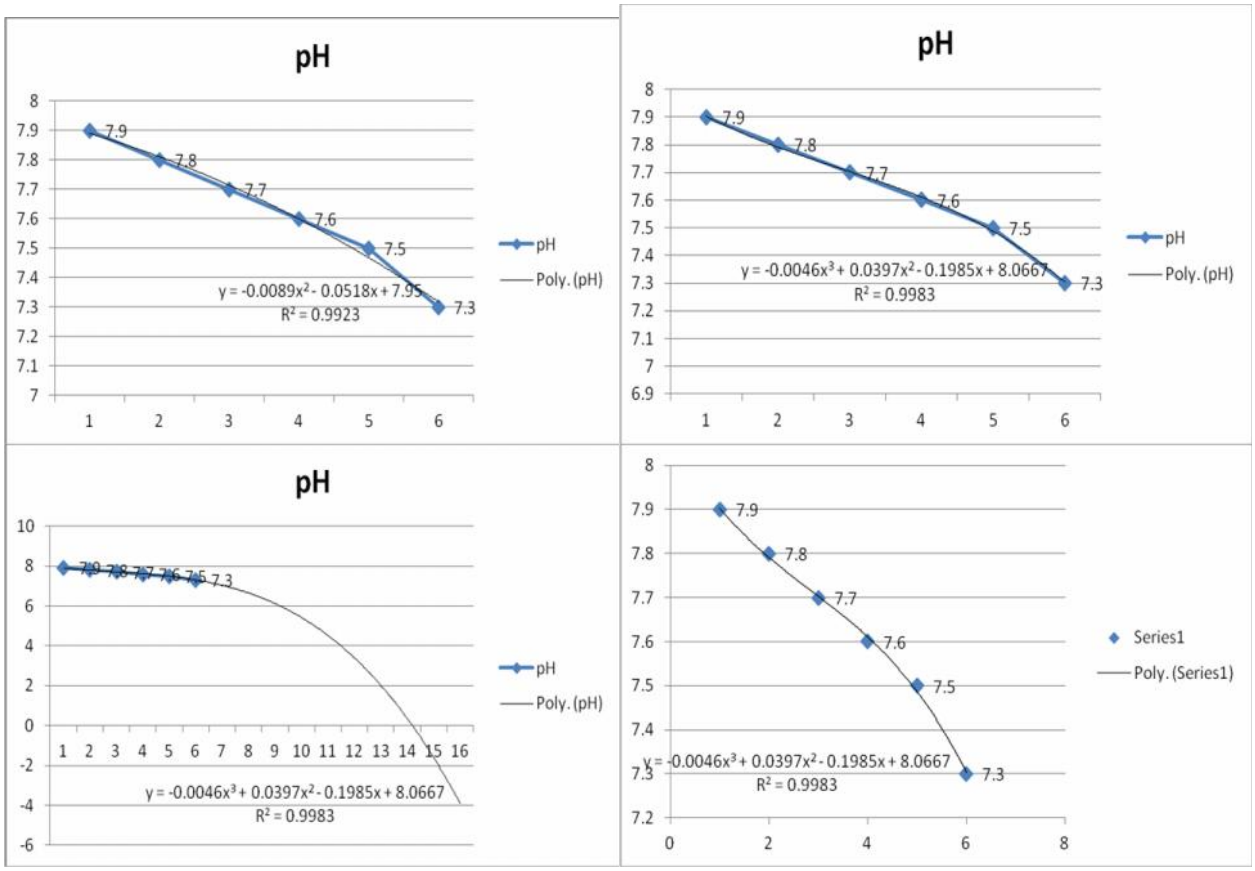
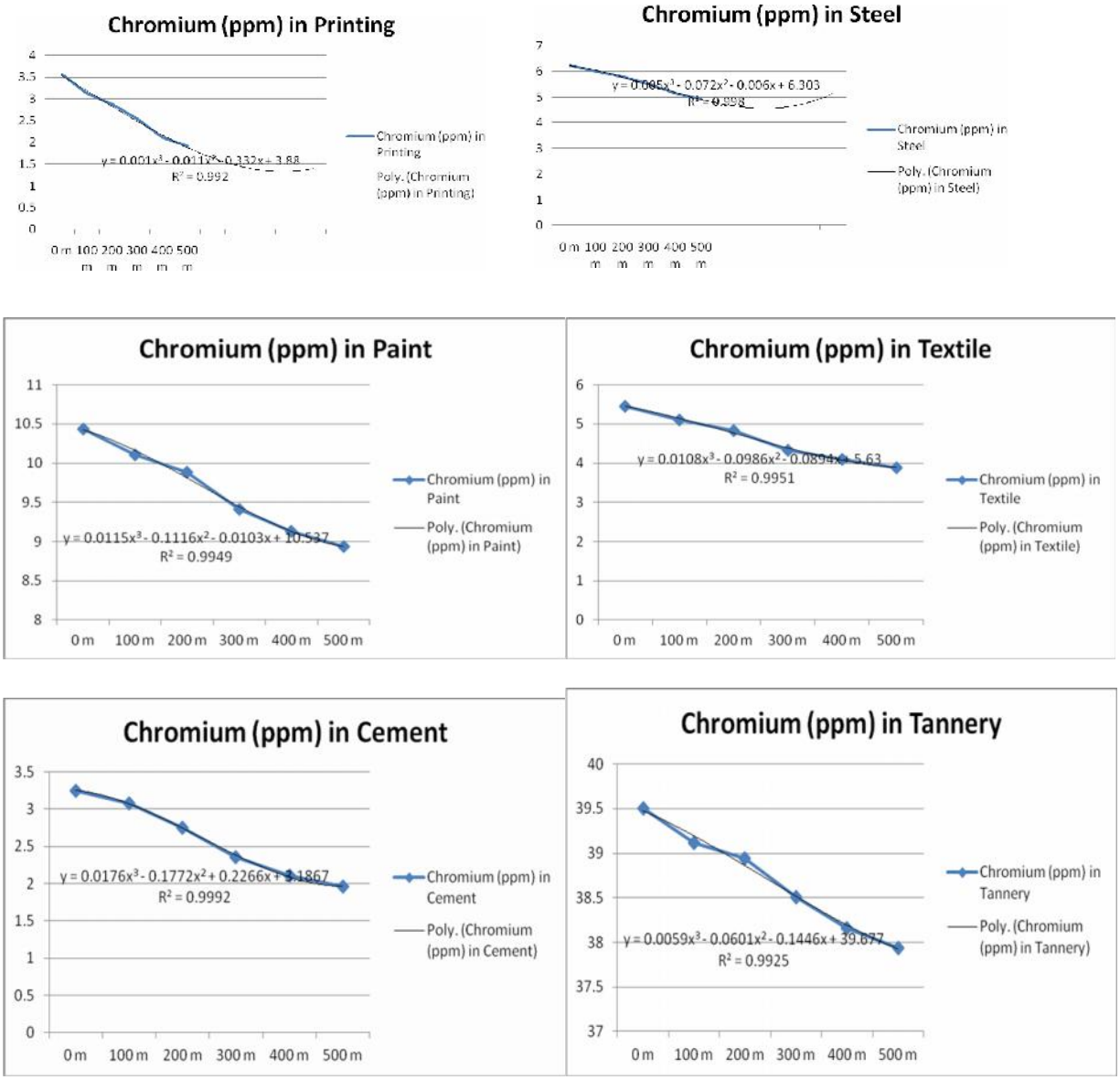


Figure 4: Comparison of laboratory measured chromium in the test data set with their predicted values based on trend line analysis of soil collected from printing industry

Trend line (polynomial) Trend line (exponential)



References

1. Watanabe, T. and T. Hirayama, 2001. Genotoxicity of soil. J. Health Sci., 47: 433-438.
2. White, P.A. and L.D. Claxton, 2004. Mutagens in contaminated soil:a review. Mutation Research- Reviews in Mutation Research, 567: 227-345.
3. Shaw, A.J., 1990. (Ed.), Heavy Metal Tolerance in Plants: Evolutionary Aspects. CRC Press, Boca Raton, FL.
4. Ihekoronye, A. I and Ngoddy P. O. (1985). Integrated Food Science and Technology for the Tropics. Macmillan Publishers. Pp. 75 – 77
5. Drechsel, P., C. Quansah and F. Penning de Vries. 1999. Stimulation of urban and peri-urban agriculture in West Africa - Characteristics, challenges, and need for action. In: O.B. Smith (ed.) *Urban agriculture in West Africa*. IDRC/CTA, Ottawa, Wageningen, page 19-40.

6. Hashem, A.R. and Al-Obaid, A.M. 1996. Effect of Cadmium on the Growth of *Aspergillus flavus* and *Ulocladium chalmydosporum. Internat. J. Exper. Bot*, 59 (1/2):171- 175.
7. Ferguson, J.E. 1990. The Heavy Element, Chemistry,Newyork, Pergamon press.
8. Kumar, P.B.A.N., Dushenkov, V., Motto, H., Raskin, I., 1995. Phytoextraction: the use of plants to remove heavy metals from soils. Environmental Science and Technology 29, 1232–1238.
9. Brooks, R.R., Lee, J., Reeves, R.D., JaGre, T., 1977. Detection of nickeliferous rocks by analysis of herbarium specimens of indicator plants. Journal of Geochemical Exploration 7, 49–58.
10. Ming Chen and Ma, Lena Q, *Soil Sci Soc Am J*., 2001, 65, 491–499.
11. Lark B S, Mahajan R K and Walia T P S, *Indian J Environ Health.*, 2002, 44, 164–167.
12. Jackson, M.L, 1973. Soil chemical analysis. Prentice – Hall of Indid Pvt. Ltd. New Delhi.
13. Walkley, A and C.A. Black, 1934, An estimation of digitrareff method for determining soil organic matter and proposed modification of the chromic acid titration method. Soil science,37: 29-38.
14. Thomas, G.W. 1982. Exchangeable cations. *In:* A.L. Page (ed.) Methods of soil analysis, Part 2 Chemical and microbiological properties, 2nd edition. Agronomy 9: 159-165.
15. Manivasakam, N., 1987. Industrial Effluents, origin, Characteristics, Effects, Analysis & Treatment. Sakthi Publications, Kovaiputhur, Coimbatore. Pp42.
16. Srinivasachari, M., M. Dhakshinamoorthy 7 G. Arunachalam, 2000. Accumulation and availability of Zn,Cu,mn& Fe in soils polluted with waste water. Madras Agric.J., 87:237-240.
17. Kirkham, M. B., (2006). Cadmium in plants on pollutedsoils: Effects of soil factors, hyper accumulation and amendments. Geoderma 137 (1-2), 19-32 .
18. Somasundaram, J., 2001, Evaluation of sewage sludge coir pith pellets on fodder crops and biotransfer of heavy metals. PhD thesis. Tamilnadu Agricultural University, Coimbatore.
19. Ehsan, S.; Prasher, S. O.; Marshall, W. D., (2006). A washing procedure to mobilize mixed contaminants from soil: II.Heavy metals. J. Environ. Qual., 35 (6), 2084-2091.
20. Atafar, Z.; Mesdaghinia, A.R.; Nouri, J.; Homaee, M.; Yunesian,M.; Ahmadimoghaddam, M.; Mahvi, A. H., (2010). Effect of fertilizer application on soil heavy metal concentration. Environ. Monitor. Assess., 160 (1-4), 83-89
21. Casas JM, Rosas H, Sole M, Lao C (2003) Heavy metals and metalloids in sediments from the Liobreget basin, Spain.Environ Geology 44:325–332.
22. Ansari AA, Singh IB, Tobschall HJ (1999) Status of anthropogenically induced metal pollution in the Kanpur-unnao industrial region of the Ganga plain, India. Environ Geology 38(1):25–33.
23. Larocque ACL, Rasmussen PE (1998) An overview of trace metals in the environment: mobilization to remediation. Environ Geology 33:85–91.
24. Rao MS, Gopalkrishnan R, Venkatesh BR (2001) Medical geology – An emerging field in environmental science. National Symposium on Role of Earth Sciences. Integrated and Related Societal issues. GSI Spl Pub No 65(II):213–222.
25. Govil PK, Rao TG, Krishna AK (1998). Arsenic contamination in Patancheru industrial area, Medak District. Andhra Pradesh. J Environ Geochem 1:5–9.
26. Nagaraju A, Karimulla S (2002) Accumulation of elements in plants and soils in and around Nellore mica belt, Andhra Pradesh, India-a biogeochemical study. Environ Geology 41:852–860.
27. Govil PK, Reddy GLN, Krishna AK (2001) Contamination of soil due to heavy metals in Patancheru industrial development area, Andhra Pradesh, India. Environ Geology 41:461–469.
28. Vazquez FG, Sharma VK, Perez-Cruz L (2002) Concentrations of elements and metals in sediments of the southeastern Gulf of Mexico. Environ Geology 42:41–46.

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