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An Analytical Study of Heavy Metal Concentration in Soil of an Industrial Region of Chhattisgarh, central India

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Abstract- Major generators of the industrial solid wastes are coal based thermal power plants and integrated iron and steel industries. A large amount of industrial solid wastes like fly ash and slag are yet to be utilized and still remains in the form of uncontrolled dumping sites in the study area. Leachate pollution should get appropriate attention as it may be a source of heavy and toxic metal in soil and it is possible to percolate and may lead to water pollution in the surroundings water sources. In the present investigation the soil samples were collected from the identified area for heavy metal analysis. The heavy metal pollution of the soil samples resulted that, concentration of certain heavy metals is above permissible limit. The heavy metals like Cr, Cd, Fe, Mn, and Pb, shows highest concentration, while metals such as Cu, Cd and Pb shows low concentration. The heavy metal pollution indicates that leachate produced by uncontrolled and unscientific disposal of industrial solid wastes contaminates soil samples of the identified area.

Index Terms- Industrial solid waste, Leachate, Heavy metals, Soil, Disposal, Fly ash

I. Introduction

In recent years, with the development of the global economy, both the type and content of heavy metals in the soil caused by human activities have gradually increased, resulting in the deterioration of the environment (Han et al., 2002; Sayyed and Sayadi, 2011; Jean-Philippe et al., 2012; Raju et al., 2013; Prajapati and Meravi, 2014; Sayadi and Rezaei, 2014; Zojaji et al., 2014). Heavy metals are highly hazardous to the environment and organisms. It can be enriched through the food chain. Once the soil suffers from heavy metal contamination, it is difficult to be remediated (Chao et al., 2014). Inorganic residues in industrial waste cause serious problems as regards their disposal. They contain metals which have high potential of toxicity. Industrial activity also emits large amounts of arsenic fluorides and sulphur dioxide (SO_2) (Richardson et al., 2006). Copper, mercury, cadmium, lead, nickel, arsenic are the elements which can be accumulated in the soil, if they get entry either through sewage, industrial waste or mine washings. Some of the fungicides containing copper and mercury also add to soil pollution. Smokes from automobiles contain lead which gets adsorbed by soil particles and is toxic for the plants. The toxicity can be reduced by building up soil organic matter, adding lime to soils and keeping the soil alkaline (Zorge et al., 1996).

Variety of trace elements, some of them are potentially toxic and are transferred to the surrounding environment through different pathways (Goodarzi et al. 2008). The disposal of such huge quantity of fly ash can be a major problem, which leads to the leaching of pollutants into surface water and soil. The impact of coal ash leachates on receiving surface waters sources, apart from increased elemental concentrations cause changes in water pH with implications for trace element mobility (Carlson and Adriano, 1993). Solid waste disposal sites are potentially serious sources of pollution to the environment, especially when located very close to water sources and operated haphazardly. The high pollution potential of these sites is due to the fact that they usually contain almost all types of pollutants from the source community. The contaminants can leach out through the soil, contaminating the soil itself, ground water, and surface water. In the study reported here, environmental pollution impacts of a solid waste disposal site were investigated (Gabriel et al., 2009).

About 70% of India's annual coal production is used in about 72 power generating plants and produce more than 90 million tons of coal ash per year. It is likely that it may cross over 100 million tons during 2001–2010 AD (Muraka et al., 1987). Major industrial regions of Chhattisgarh have become the power generation and steel hubs of central India. The disposal and dumping of the industrial solid wastes may leads to leaching problem and resulted in the heavy metal contamination of the soil (http://en.wikipedia.org). The major issues of concern for fly ash and steel slag wastes are unscientific dumping sites are surrounded very close to the populated area. These wastes are considered harmful and may create environmental hazard due to release of leachate to the human health and also soil and water. Utilization of fly ash and steel slag can reduce the extent of the Leachate problems (http://industries.cg.gov.in). Slag is generated in an integrated steel plant, 2 to 4 tonnes of wastes (including solid, liquid and gas) are generated for every tonne of steel production. With increasing capacities, disposal of large quantities of slag becomes a big environmental concern and a critical issue for steel makers. Also the leached metals uptake by the plants is affected by the soil properties (http://www.flyash.indiaflyash).The environmental impact of coal fly ash has been fully recognized. Most ash disposal methods ultimately lead to the dumping of fly ash on open land. Irregular accumulation and inappropriate disposal of fly ash will lead to its disposal over vast areas of land, with resultant degradation of the soil and danger to both human health and the environment (Z.T. Yao et al., 2015).

A leachate is a liquid that, in the course of passing through matter, extracts soluble or suspended solids, or any other component of the material through which it has passed (http://en.wikipedia.org). Leachate is the fluids generated by the release of excess water from solid waste, and by seepage of rain water through a stratum of solid waste that is basically found in a state of decay (Uguccioni and Zeiss 1997). Leachate production deals with the creation of contaminated liquid at the base of a landfill. It involves the elements of a water balance in which precipitation either runs off from the landfill or infiltrates. Some infiltration will evapotranspire, some may be stored within the landfill, and the balance becomes percolate and eventually leachate. Landfill technology has evolved from the open, burning dump to highly engineered sites designed which can minimize tile impact of contaminants in the waste on the adjacent environment (*Farquhar, 1988)*. The key influences on leachate generation are rainfall and waste moisture content (Kortegast et al., 2007).

The landfill leachates have proved to be toxic and recalcitrant; land filling still remains one of the main methods for municipal and industrial solid waste disposal (Lopez et al., 2004). Furthermore, landfill leachate generation remains continuous when water comes in contact with the solid waste. The discharge of landfill leachate can lead to serious environmental problems, since leachate contains four groups of contaminants: dissolved organic matters; inorganic compounds such as ammonium, calcium, magnesium, sodium, potassium, iron, sulphates, chlorides and heavy metals such as cadmium, chromium, copper, lead, zinc, nickel; and xenophobic organic substances (Kjeldsen et al., 2002). Heavy metals present in leachate can migrate away from the disposal site boundaries and may constitute a serious pollution threat for the water table and the soil around the landfill (Matejka and Rinke, 1999 ; Zairi et al., 2004). The impact of landfill leachate on the surface and groundwater has given increase to a number of studies in recent years (Lopez et al., 2004). Soil is sink for the removal of contaminants from industrial wastes including FA, which may comprise of many of the toxic metals like As, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, V, Zn, etc. These elements are found either on the surface of the ash particles, in the aluminosilicate matrix phase, or in both (Smith, 1987). The toxic elements of concern in Indian FAs are generally present in lower concentrations than those found in ash from other parts of the world, and well within the limits prescribed for soil application of waste materials. Trace metals (e.g., As, B, Cd, Co, Cr, Cu, Hg, Ni, Pb, Se, V, Zn, U, Th, and Cs) in FA are considered as potential elements of environmental concern; their concentration level and mobility decide their concern, safe disposal, and utilization (Saraswat P. K. and Chaudhary K., 2014).

II. Materials and Methods:

The study area – Chhattisgarh

Chhattisgarh is a state in Central India. It is the 10th largest state in India, with an area of 135,190 km^2 (52,200 sq mi). With a population of 25.5 million, Chhattisgarh is the 16th most-populated state of the nation. It is a source of electricity and steel for India. Chhattisgarh accounts for 15% of the total steel produced in the country. Chhattisgarh is one of the fastest-developing states in India. Chhattisgarh is rich in minerals. It produces 20% of the country's total cement produce. It ranks first in the nation for coal production and second in reserves, third in iron ore production and first in tin production. (http://en.wikipedia.org/).

The soil samples were collected from sampling site - 1 and 2, located about 1.5 km from disposal sites of slag and fly ash, at different horizontal and depth by removing the top layer of about 30 cm. All the samples are labeled properly for the identification of sources in thick quality polythene bags and are immediately brought to laboratory for further analysis. The heavy metals can pollute the surface water sources due to leachate released from the dumps and may be transported to water bodies and soil due to the presence of moisture available in the atmosphere and rain water.

Figure 1: Location of study area

Digestion of soil: The samples were first air dried, then placed in electric oven at a temperature of 40 °C approximately for 30 minutes. They were then homogenized which was previously ground and sieved through IS sieves of stainless steel 2 mm mesh. A 0.1g sample is weighed out and transferred to reaction vessel. 2.0 ml of concentrated nitric acid and 5.0 ml of concentrated hydrochloric acid were then added to each vessel. Vessels then placed in the rotor and the rotor is microwave at the given instrument condition. At the end of the microwave program, the vessels were allowed to cool for a minimum of 25 minutes before removing them from the microwave system. The vessels were carefully uncapped and the digests were filtered through Whatman No. 41 filter paper (or equivalent) and the filtrate was collected in a 100-mL volumetric flask, the volume was adjusted to 100 ml with 0.5% HNO_3.

To know the level of concentration of selected elements in study area due to leachate on surface water quality, ten samples from different location around a major industrial region were collected in pre monsoon and post monsoon season. The samples were collected in sterilized polythene bottles and prior to the sampling, all the sampling containers were washed and rinsed with the available surface water. Sampling points were chosen to cover all different directions of dumping/disposal site after preliminary survey of area. The samples were collected and preserve with the help of 1 N HNO_3 and were sealed and brought to the laboratory to know the heavy metal concentration by AAS analysis.

Metal Analysis: The of selected trace metals in all soil and surface water samples i.e. Iron, Copper, Chromium, Lead, Copper and Manganese were analysed using Atomic Absorption Spectrophotometer (VARIAN GTA-120, AA240). Prior to analysis, the samples were diluted with 2% 1N nitric acid solution. Table 1 shows the operating conditions of AAS for selected elements.

Table 1: Operating conditions of AAS

Instrument Condition	Lead	Chromium	Iron	Manganese	Zinc	Copper
Lamp	Lead Hollow Cathode	Chromium Hollow Cathode	Iron Hollow Cathode	Manganese Hollow Cathode	Zinc Hollow Cathode	Copper Hollow Cathode
Slit	4	3	3	4	4	4
Wavelength	283.3 nm	358.3 nm	248.3 nm	279.8 nm	670.8 nm	324.7 nm
Fuel	Acetylene	Acetylene	Acetylene	Acetylene	Acetylene	Acetylene
Oxidant	Air	Air	Air	Air	Air	Air
Type of flame	Oxidizing	Reducing (slightly	Oxidizing	Oxidizing	Oxidizing	Oxidizing

		yellow)				

III. Results and Discussions

From the Atomic Absorption Spectrophotometer (AAS) selected heavy metal concentrations results of surface water samples shows that the total concentrations of the heavy metals vary seasonally in small variation with more variation of chromium (Cr). The concentration of heavy metals in Surface water near the disposal/dumping sites during pre-monsoon and post monsoon is presented in fig. 1and 2 respectively. Also it was observed that the concentration of Mn, Fe and Cr have the high concentration in pre monsoon surface water samples. In post monsoon analysis of surface water samples only the Cr has been found with high concentration. It is observed from above analysis that after monsoon seasons the heavy metals may be transported or diluted by rain water and thus concentration of metals is less.

Samples	Concentration (mg/l)					
	Cr	Cu	Fe	Pb	Mn	Zn
1	0.326	0.002	0.822	0.26	0	0.0533
2	0.642	0	1.368	0.22	2.557	0.0246
3	0.811	0.005	0.76	0.2	0.088	0.0377
4	0.498	0.003	0.366	0.17	0.057	0.0095
5	0.3	0.014	3.505	0.2	2.931	0.0891
6	1.832	0.012	2.192	0.15	0.233	0.3967
7	2.398	0.033	0.755	0.21	0.209	0.1112
8	3.298	0.005	1.541	0.2	0.155	0.1068
9	3.192	0.006	0.697	0.21	0.341	0.0631
10	1.879	BDL	0.697	0.26	0.343	0.062

Table 2: Pre Monsoon Surface Water Analysis

Sample	Concentration (mg/l)					
	Cr	Cu	Fe	Pb	Mn	Zn
1	1.45	0.007	BDL	0.08	0.088	0.161
2	1.648	0.007	0.199	0.12	1.272	0.1584
3	2.16	0.008	0.731	0.09	0.559	0.204
4	2.013	0.007	BDL	0.09	0.046	0.127
5	1.853	0.008	0.019	0.08	0.327	0.1532
6	2.085	0.008	0.408	0.08	0.066	0.204
7	1.929	0.008	0.263	0.07	0.087	0.1085
8	2.185	0.008	0.269	0.1	0.097	0.1782
9	2.316	0.009	0.353	0.07	0.166	0.3411
10	2.149	0.009	0.352	0.07	0.656	0.2191

Table 3: Post Monsoon Surface Water Analysis

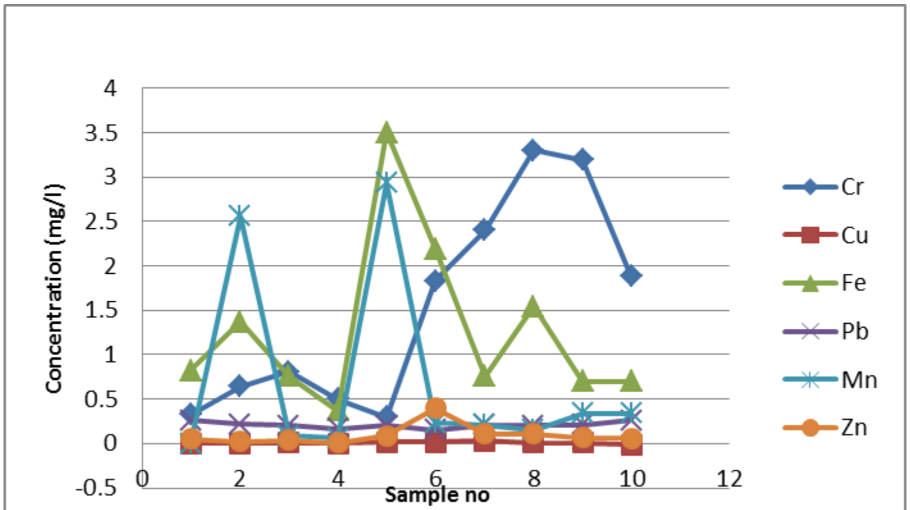

Figure 2: Pre Monsoon Surface Water Analysis

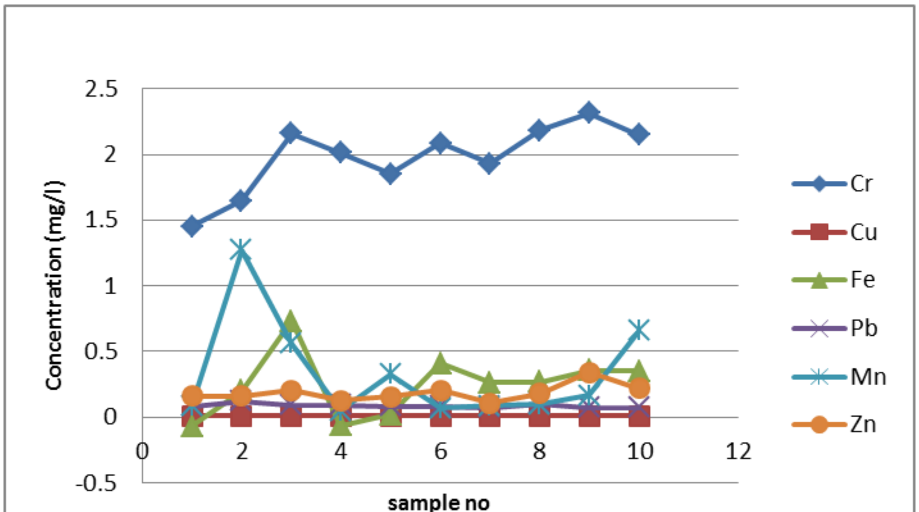

Figure 3: Post Monsoon Surface Water Analysis

The flame type Atomic Absorption Spectrophotometer (AAS) analysis was done for heavy metals concentration of soil samples which was collected for different distances and depths of ground from the surrounding of disposal/dumping sites of study area is presented in fig. 3. The concentration obtained (Zn > Pb > Fe > Cr > Mn) shows that heavy metals in the soil near the disposal/dumping sites is more and it is decreasing with respect to horizontal direction as well as with respect to depth also.

Distance (km)	Heavy matal concentration (mg/kg)				
	Fe	Pb	Mn	Zn	Cr
0.35	1.036	0.258	5..712	0.15	1.593
0.5	1.416	0.453	9.08	0.214	1.984
0.78	0.973	0.338	3.445	0.142	1.795
0.95	0.897	0.213	1.12	0.198	1.816
1.25	0.782	0.28	BDL	0.022	1.113
1.4	0.385	0.118	3.691	0.03	0.464
1.56	0.298	0.098	3.122	0.087	0.258
1.72	0.219	0.09	1.555	0.057	BDL
1.9	0.551	0.123	2.476	0.211	BDL
2.15	0.987	0.21	6.155	0.105	BDL

Table 3: Soil analysis for heavy metals (Distance wise sampling)

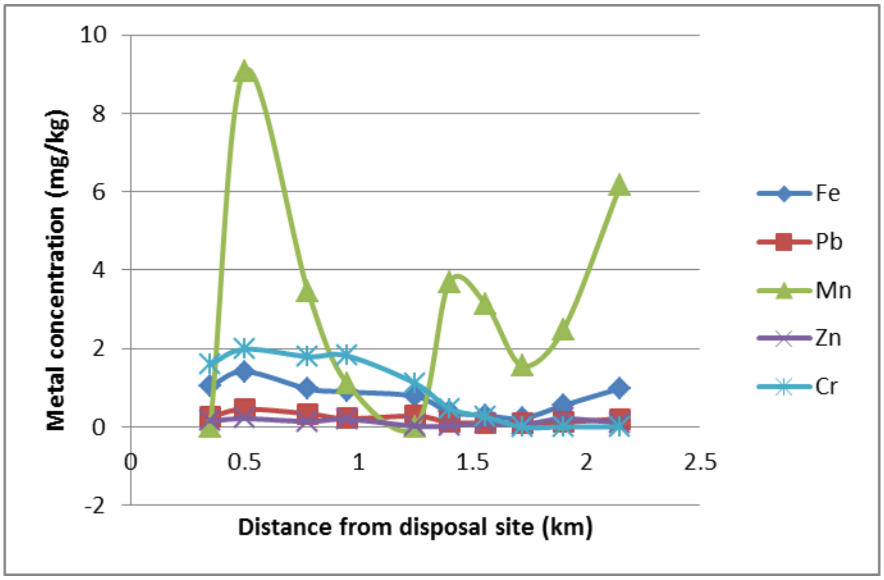

Figure 4: Heavy metal concentration in soil (Distance wise sampling)

Depth (m)	Heavy matal concentration (mg/kg)				
	Fe	Pb	Mn	Zn	Cr
0.25	0.9	0.256	3.85	0.163	0.948
0.5	0.769	0.231	4.29	0.083	0.839
0.75	0.767	0.196	3.47	0.08	0.739
1	0.687	0.188	2.039	0.158	0.698

Table 3: Soil analysis for heavy metals (Depth wise sampling)

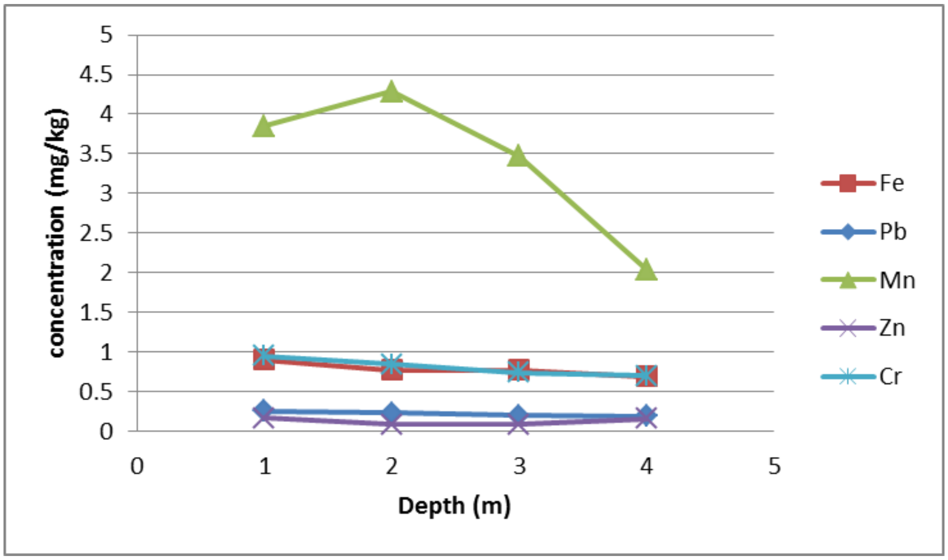

Figure 5: Heavy metal concentration in soil (Depth wise sampling)

IV. Conclusion and Recommendations

Soil and its biota are essential a component of the earth's living skin directly sustains life (Wilkinson et al., 2009). After the analysis of soil samples, a general conclusion that could be reached is that the concentrations of heavy metals in soil near to the dumping/disposal site is more and decreases as distance increases. Also in the depth wise analysis, it was observed that the in most of the soil samples, higher concentrations of selected heavy metals are observed near the surface of ground and magnesium which has highest concentration. The surface water analysis also indicated that the concentrations of Cr and Mn are higher before and after the monsoon. Leachate pollution can be reduced by using scientific designed dumping sites with liners and if possible the amount of industrial solid waste generation may be reduced with the help of process modification of particular products. Also the higher pH (alkaline) of the disposed industrial solid wastes may reduce the leachate generation, so suitable alternatives can be used for the same at the time of industrial solid waste disposal or dumping near populated vicinity.

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