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Seasonal Heavy Metal Variations in Soil of an Active Municipal Solid Waste Dumpsite

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Abstract : *The implication of solid waste disposal and its leachate on soil quality is gaining importance worldwide due to seepage of heavy metals from the waste heaps into the soil strata affecting the soil physico-chemical properties. Heavy metals from landfill wastes eventually bio-accumulate into the food-chain affecting the higher trophic levels in an ecosystem. Since the top – soils are considered a productive layer for crop growth it has become an important aspect in terms of soil contamination studies. The present paper is an attempt to study the implication of MSW disposal on soil and the seasonal variations in soil heavy metal concentrations in an active dumpsite since two decades. In the present study the dumpsite soil samples were analyzed for Fe, Pb, Ni, Cr and Cd which revealed higher metal levels in pre-monsoon than in post-monsoon. The mean concentrations of heavy metal sequence in soil samples was in the order of Fe>Pb>Ni>Cr>Cd in both the pre and post-monsoon seasons. However the study indicated Pb and Cd levels beyond the standards prescribed for soil. The study indicated a considerable leaching of metals in the dumpsite which might have resulted in low metal levels in post-monsoon season.*

Keywords : *Heavy metals, Municipal Solid Waste dumpsite soil, Seasonal variations, AAS, Correlation*

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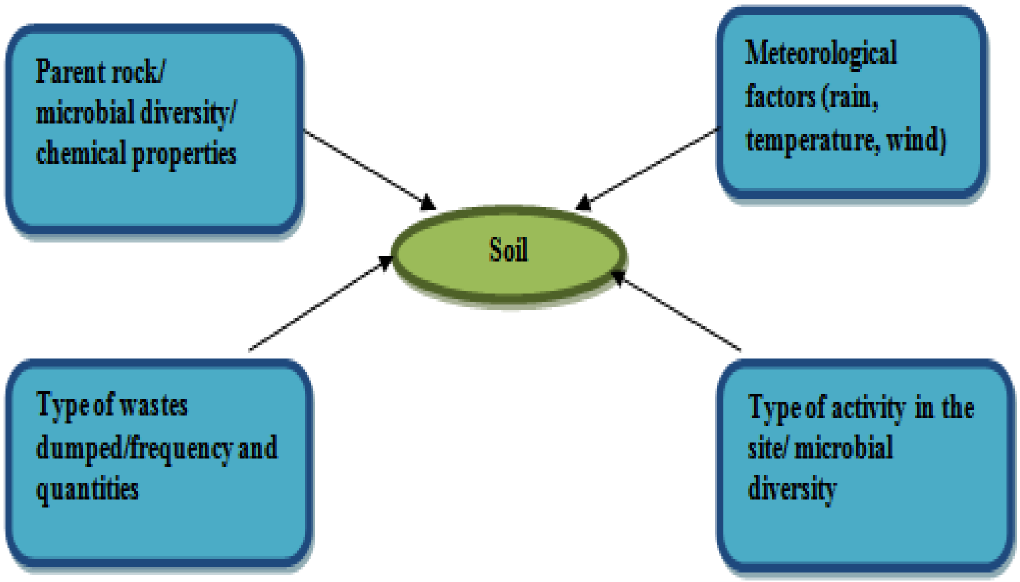
I. Highlights

1. The present work is the first ever assessment carried out in the study area.
2. The dumpsite is active since two decades which gives substantial information on the impact of MSW leachate on soil.
3. The study provides baseline data on the extent of metal leaching into the soil.

Graphical Representation of Factors Influencing Metal Accumulation in Soil



II. Introduction

The sustenance of life on the earth is dependent on many factors of which soil is one vital component. This very natural resource is being over-exploited and contaminated by innumerable sources. Though soil is considered as a "*natural sink*" with self- replenishing capability yet the anthropogenic activities due to technological advancement and industrialization to meet the needs of growing population is out –growing the fertility of the soil. Management of municipal solid waste is an easier said, than done aspect in almost all the developing and developed countries due to unpredictable constraints. In this milieu open dumping of municipal solid wastes emerged as the lone option for getting purge off the vast amounts of wastes generated. The unavailability of secure and engineered landfills on the other end is contaminating the soils in the dumpsites to an extent of trepidation in years to come. The present paper is an attempt to study the seasonal variations in soil heavy metal concentrations in an active dumpsite and to assess the level of soil contamination.

III. Literature Review

Many studies earlier revealed industrial and municipal solid wastes as major sources of soil contamination by metals (Kebir and Bouhadjera 2011). Though deterioration of the soil is a long-term process the incessant disposal of wastes in the same area leads to build – up of soil heavy metals mostly like Zn, Fe, Mn and Pd in top-soils (Ibitoye et al., 2005). Adding to this the hideous management of solid wastes further affects the quality of the soils in the vicinity of these waste dumpsites leaching toxic substances from the waste heaps. This has become a gruesome situation in most of the urban and rural areas as the management and disposal of solid waste is far from standard recommendations due to fiscal constraints. Karbassi (2004) reported heavy metals such as Cu, Cr, Cd, Ni, and Pb as potential soil and water pollutants. These heavy metals entering the environment persist for longer periods which are hazardous to animals, plants and humans (Alloway and Ayres 1997).Though dumpsites receive wastes from many non-point sources, dumpsites ultimately become a point source for environmental pollution with reference to air, water and soil pollution. Studies showed a positive correlation between soil heavy metals and their bioaccumulation in crops and vegetables (Ademoroti 1990). The accumulation of heavy metals in the soil is due to their high affinity to the soil organic matter. Many researchers found heavy metals in the soils of these waste dumpsites (Adelekan and Alawod 2011) which in a long –run leading to health ailments entering into the body of humans and animals through contaminated crops and vegetables cultivated in the waste dumpsites and also those grown in the vicinity of dumpsite due to the leachate migration from the waste heaps which are capriciously dumped. It is a well acknowledged fact that municipal solid waste alone is not responsible for soil contamination with heavy metals, as several other factors like industrial activities and most predominantly the kind of management at the dumpsite influence the metal levels and their availability in the soils. Thus total heavy metal content in soil alone does not provide predictive insights on their bioavailability, mobility (Uba et al., 2009). These heavy metals get redistributed into different geochemical forms and toxicity (Shiowatana et al., 2001) and their identification in soil is merely not possible by observation which made researchers to analyze the soils and vegetation in the contaminated sites for bioaccumulation studies. Earlier studies proved soils as a good indicator of heavy metal content in an area but not a possible means to indicate metal availability to the biota (Rao et al., 2008).

IV. Experimental Methodology

4.1. Study Area

Greater Visakhapatnam is a city of natural harbour and one among the major industrial cities in the state of Andhra Pradesh. The city is known for its cosmopolitan nature welcoming people from all over the world due its scenic beaches and eco-tourism spots. The city is covered by deciduous forests around 33.33km^2 (Jagadeeswara Rao 2010) and most often referred to as "Industrial city" and "Steel city", covering an area of about 1143km2 while Greater Visakhapatnam Municipal Corporation (GVMC) covers an area of 545 km2 with an estimated population of 20lakhs. The city has 72 wards divided into 6 zones for administration purpose by the municipal authorities. The city generates 1000 -1050MT/day of waste transferred to the dumpsite which is located 25kms away from the city spread in an area of 85 acres (Figure - 1). The dumpsite is an open landfill which is operational since two decades with no scientific management of waste dumped (Figure - 2).

Fig. 1: View of Kapuluppada Village showing Open Dumpsite

Fig. 2: View of Burning of Waste Heaps in the Dumpsite

4.2 Sampling Methodology:

Soil samples were randomly scooped from a depth of 10-15cms with the help of a soil auger at different points in the dumpsite and were combined to form a composite sample (Anake.WU et al., 2009). All the samples were transferred into air tight polythene bags for further analysis in the laboratory. The samples were collected in both pre and post-monsoon seasons. The collected samples were later air dried and ground to a homogenized sample with the help of mortar and pestle. The ground sample was made to pass through 2mm sieve prior to heavy metal analysis.

4**.3 Metal Extraction Procedure**

The homogenized soil samples were digested as per the standard procedures of (NEPM, 1999; USEPA 3050B). 1gm of the homogenized soil sample was placed in a digestion flask to which 3:1 ratio concentrated aqua-regia acid mixture (HCl and HNO3) was added for extraction of heavy metals. During the digestion the contents were moistened with little water and further heated. The soil sample along with the acid mixture was boiled on the hot-plate until 5ml of the residue is left in the digestion flask which was allowed to cool down. The process is repeated until complete digestion and 5ml of the residue remains in the digestion flask. The digested mixture was cooled and filtered through a Watman filter paper which was made up to 50ml with deionized water for further elemental analysis in Atomic Absorption Spectoroscopy (AAS).

4.4 AAS Specifications

Atomic Absorption spectroscopy is one among the validated methods in literature to analyze the elements and their composition as stated by Cullen and Barwick (2004). It is based on the reading of the spectra produced by excitation of sample by radiation where the atoms absorb visible or ultra-violet radiations. Atomic absorption spectroscopy (AAS) is the widely used analytical instrument for metals or metalloid samples as it is relatively interference free.

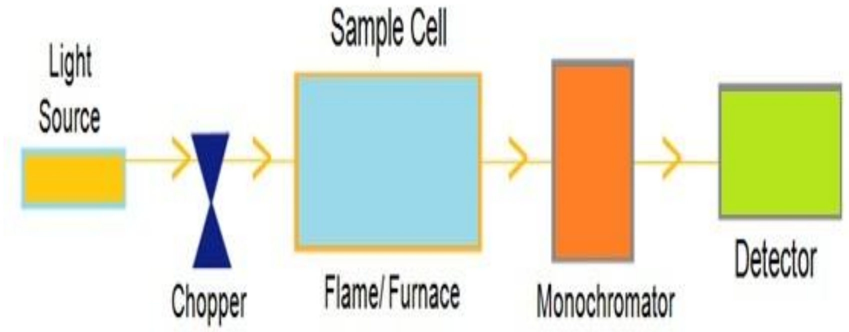


Fig. 3: Schematic Diagram of AAS (Csuros, M., Csuros, C., 2002)

V. Statistical Analysis

The results obtained were subjected for correlation coefficient to know the relation between individual metal quantities in the dumpsite soil samples at 0.05% level of significance.

VI. Results And Discussion

The results tabulated (Tables 1; Table 2) clearly indicated that the mean concentrations of heavy metal sequence was in the order of Fe>Pb>Ni>Cr>Cd in both the pre and post-monsoon seasons. The overall mean Fe levels of the soil were 139.32mg/kg and 60.74mg/kg which were well within the ranges (3000-250,000mg/kg) recommended by WHO (2004) in both pre and post – monsoon seasons (Table 1; Table 2). The mean Pb content in the soil samples was 35.62mg/kg in pre- monsoon and 20.48mg/kg in post-monsoon which were beyond the limit (15-25 mg/kg) set by WHO (2004). However the overall Pb levels were within the ranges reported by Aluko et al., (2003) in previous studies. Lead is present in the soils naturally in most of the geographical regions however elevation of Pb levels in soils is from the contributions of lead based paints, batteries and leaded gasoline emissions which get deposited on the soils contaminating the soils. Many previous studies showed learning disabilities and mental retardation in people exposed to Pb even at low dosages which is more severe in children. The mean Ni (8.61mg/kg and 4.77mg/kg) and Cr levels (2.67mg/kg and 2.48mg/kg) in both pre and post- monsoon seasons and were within the limits recommended by WHO (2004) (0-100 mg/kg and 0-85mg/kg) and within the ranges reported by Radojevic and Bashkin (2006). While Cd mean concentrations (1.69mg/kg and 1.39mg/kg) though within the natural ranges reported by Vacera et al., (1999) for soil (2-200 mg/kg) yet slightly above the ranges prescribed for agricultural soils (1.0 mg/kg) in both pre and post – monsoon seasons (Alloway 1990). The values of Cd reported were lower than all the other metals which were in accordance with the findings of Olarinoye et al., (2010). Cd has no biological role which makes it toxic even at low concentrations as it has the ability to accumulate into the plant body contaminating the higher level organisms. It was evident from the results that there was a considerable amount of heavy metal content in the dumpsite soils which are of concern. The overall mean heavy metal content in the soil samples was higher in pre-monsoon compared to the post-monsoon season which was similar to the findings of Osobamiro and Olufemi (2015). Weather and climatic changes have a significant influence on the metal availability in the soil as higher temperatures in pre- monsoon may concentrate metal content in the soil recording higher metal levels than in post - monsoon. Leaching from waste heaps and runoff in the dumpsite might have resulted in lower metal levels in soil in post - monsoon (Teutsch et al., 1999). The study showed consistent lowering metal levels in dumpsite soil in the post-monsoon than in pre-monsoon which might be due to the leaching of metals into the sub-surface layers in the dumpsite and also the inclined nature of the dumpsite leading to surface run-off.

Sample No	Fe	Pb	Ni	Cr	Cd
S-1	184.2	26.42	2.44	0.84	**BDL**
S-2	456.52	5.01	1.45	2.60	3.20
S-3	46.08	3.22	2.61	0.44	2.48
S-4	208.48	1.66	0.35	1.46	0.45
S-5	174.33	82.48	0.22	5.23	2.22
S-6	48.65	34.62	1.26	0.66	0.32
S-7	71.62	44.52	4.78	1.43	0.47
S-8	101.35	74.63	6.89	0.42	0.62
S-9	12.64	82.36	51.26	2.32	0.03
S-10	42.30	1.26	3.41	6.48	1.23
S-11	36.08	0.44	0.26	0.10	**BDL**
S-12	11.22	1.0	0.81	1.03	0.42
S-13	2.66	0.26	0.20	0.23	1.22
S-14	4.60	1.26	2.42	**BDL**	0.60
S-15	3.22	2.31	0.13	1.14	**BDL**
S-16	0.64	0.84	2.20	**BDL**	0.14
S-17	5.28	5.16	1.28	1.21	2.16
S-18	8.58	4.52	4.10	0.50	**BDL**
S-19	1.22	0.40	3.15	**BDL**	0.68
S-20	43.22	1.66	1.20	2.01	1.60
Mean	**139.32**	**35.62**	**8.61**	**2.67**	**1.69**

BDL – Below detection level

Table. 1: Heavy Metal Content in the Dumpsite Soil in Pre- monsoon

Sample No	Fe	Pb	Ni	Cr	Cd
S-1	48.53	2.12	2.18	0.02	**BDL**
S-2	62.20	0.48	6.02	1.01	0.03
S-3	14.62	10.22	0.42	2.11	**BDL**
S-4	3.28	24.12	3.42	1.06	1.0
S-5	12.48	2.68	1.23	4.12	2.30
S-6	66.42	32.44	1.44	0.08	1.10
S-7	12.30	4.18	2.61	3.42	0.82
S-8	78.92	58.36	8.20	0.80	1.02
S-9	103.26	52.42	4.92	1.22	0.12
S-10	32.72	12.62	2.38	2.30	0.01
S-11	22.10	0.24	2.06	**BDL**	**BDL**
S-12	146.24	1.66	1.02	0.23	2.60
S-13	8.06	4.28	2.80	1.28	1.43
S-14	6.28	2.8	1.40	0.64	0.80
S-15	2.81	3.42	5.23	1.40	0.31
S-16	4.01	0.64	1.76	0.10	**BDL**
S-17	4.03	0.33	1.25	1.90	**BDL**
S-18	2.60	1.12	0.10	2.40	0.20
S-19	2.38	0.80	0.40	0.78	1.20
S-20	4.62	0.11	1.26	1.22	1.03
Mean	**60.74**	**20.48**	**4.77**	**2.48**	**1.39**

BDL – Below detection level

Table. 2: Heavy metal content in the Dumpsite Soil in Post- monsoon

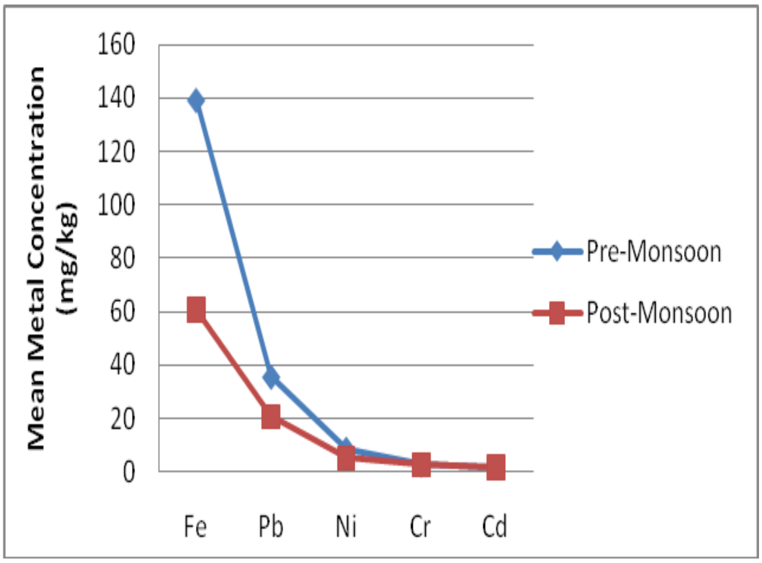


Fig. 4: Mean Metal Concentrations in Pre and Post- Monsoon

VII. Correlation Coefficient

The correlation between different metals was analyzed by Pearsons correlation coefficient method. Correlation of +1 or -1 indicates a significant and an insignificant relation between metals.In pre-monsoon a moderate correlation was found between Fe and Cd (0.49), Pb and Ni (0.55) while all the other metals were negatively correlated or correlated with very least values (Table -3). In post- monsoon Fe showed slightly moderate correlation with Pb, Ni and Cd (0.48, 0.33, 0.28) while Pb with Ni (0.60) (Table – 4). Rest all the metals were negatively correlated or correlated with very least values (Tripathi and Misra 2012). From the study it was found that there is no significant correlation between different metals and their concentrations which stresses the fact of changing complexity of wastes being dumped and leaching phenomenon.

	Fe	Pb	Ni	Cr	Cd
Fe	1				
Pb	0.13622	1			
Ni	-0.13807	0.557429	1		
Cr	0.309511	0.292373	0.110837	1	
Cd	0.496614	-0.05219	-0.23128	0.39395	1

Table.3: Correlation Coefficient (Pre-monsoon)

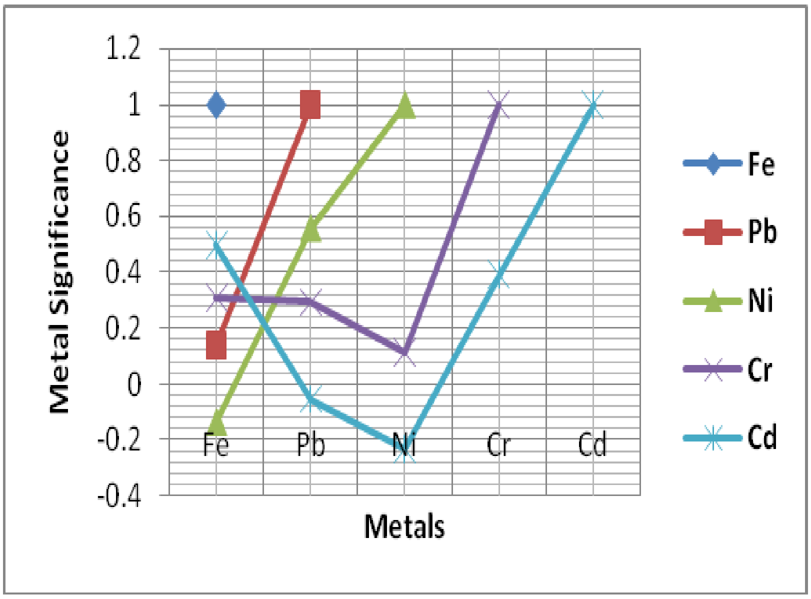


Fig. 5: Graphical Representation of Correlation Coefficient (Pre-Monsoon)

	Fe	Pb	Ni	Cr	Cd
Fe	1				
Pb	0.485003	1			
Ni	0.333433	0.60368	1		
Cr	-0.34396	-0.12983	-0.13104	1	
Cd	0.285574	0.000703	-0.15009	0.135614	1

Table. 4: Correlation Coefficient in Post –Monsoon

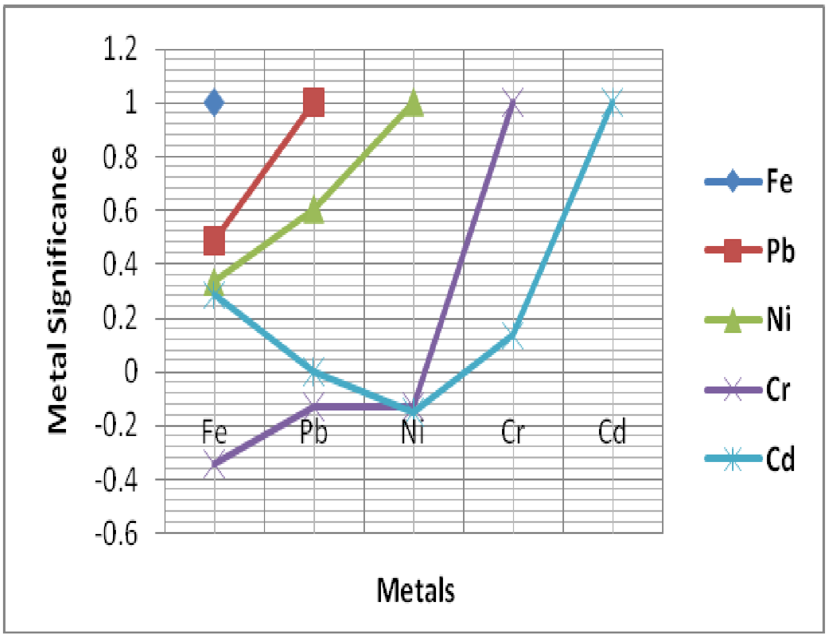


Fig.6: Graphical Representation of Correlation Coefficient (Post-Monsoon)

VIII. Conclusion

From the results it was revealed that the dumpsite soils were contaminated with Pb and Cd both in pre and post – monsoon seasons. However all the metal values were comparatively higher in pre- monsoon compared to post-monsoon. The study further emphasizes that the higher levels of metals in the soils of the dumpsite are mostly due to various anthropogenic sources rather than lithogenic occurrence. However the overall mean metal levels recorded are quite lower compared to previous studies elsewhere while the seasonal variations indicate substantial proof of leaching effect which might contaminate other vital resources near the dumpsite area. Although the city is emerging as a smart city, MSW management and disposal is still in its budding stage with no such scientific management at the dumpsite contaminating the soil, groundwater and vegetation. While the crude practices employed in the dumpsite to purge off the vast waste heaps is polluting the environment in manifold ways becoming a major problem to the people residing in the vicinity. Adding to this, changing life styles is increasing the complexity of waste generation which is further deteriorating the soil condition by the seasonal variations. Thus from the study it was revealed that there is an immediate need for an in depth analysis of the soil, to control unscientific practices and maintain a strict vigilance on the illegal dumping of waste in the dumpsite to control further worsening of resources available in the surroundings.

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