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Impact of Improper Household Solid Waste Management on Environment: A Case Study of Karachi City, Pakistan

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Karachi is facing tremendous pressure of household solid waste (HSW) management (6000 tons per day). To identify the contribution of HSW in polluting the environment in Karachi, Cu was analyzed in soil, water, dust and plant samples from Deh Jam Chakro HSW landfill facility and compared to corresponding unpolluted samples. Copper is an important metal, nutrient, toxicant and ecological indicator. Samples from the landfill facility were analyzed quarterly for 1½ years, to identify the propagation of Cu from HSW to soil, water, dust and plants. Soil of landfill facility had higher [Cu] (199.452 ppm) compared with soil from unpolluted area (Cu = 42.587 ppm). Moreover the temporal increase in [Cu] in soil of landfill facility exhibited sinusoidal pattern. [Cu] in water (4.510 ppm), dust (47.909 ppm) and plant (*Prosopis juliflora* 28.124 ppm) was identified to be correlated with [Cu] in soil in a complex relation, nevertheless the general trend in [Cu] was established to be towards increase.

Keywords: Household solid waste management, Landfill facility, Municipal waste management, *Prosopis juliflora*.

INTRODUCTION

Karachi is world's 3rd most densely populated city and is 7th largest urban agglomeration. According to 1998 census population of the city was 9,802,134[1]. The population increase in Karachi has exploded abruptly since 1881 from 73,056 to 9,802,134 in 1998[2]. However the developments of the city infra-structure and civic facilities have not grown proportionally[3]. Generation of house hold solid waste was proportional to the population thus it has also increased with the same percentage that is 13417.92 % from 1881 to 1998. According to City District Government Karachi in 2007 estimates the city is holding a population of 18 million[4]. Generation of daily house hold solid waste (HSW) in Karachi is 6000 tons per day[1].

The existing capacity of Karachi Metropolitan Corporation to remove household solid waste is about 4500 tons per day. Thus only 75 % of this HSW is collected and transported to landfill sites for final disposal. Even to this 75 % of collected HSW, there is no system of segregating waste for its recycling and proper disposal. All the collected HSW of the city, with exception to medical wastage, is dumped at any one of the five designated landfill sites. During this process of HSW collection, transportation and dumping various stages, the scavengers collect and remove certain items of economic value. Thus the HSW dumped at landfill site contains toxic pollutants, metals and non-biodegradable synthetic materials. After dumping at landfill site the HSW is burnt in open air, with this HSW management comes to its conclusion.

This study deemed to identify the amount of pollution caused by the household solid waste. To determine the pollution due to household solid waste copper metal was selected because it is a micro nutrient and is naturally present in soil, whereas its presence in daily household is also adequate[5]. Copper is considered ideal, to determine the expected decrease in pollution by proper segregation and recycling as it is non-magnetic and is not separated easily by scavengers, who separate metals which are attracted to magnet, also copper has significant economic value and is easily recyclable.

EXPERIMENTAL

Site collection: Karachi city is facing a huge problem due to household solid waste management; the intensity of the problem varies from locality to locality. In almost every area, illegal HSW dumping sites are created by the residents due to absence of proper management system. These HSW dumping sites are short time storage of HSW. The authorities collect HSW from these localized sites and transfer it to one of the five designated HSW dumping sites of the city. A survey has been done of the whole city before site selection and finally Deh Jam Chakro is selected, as it is a main dumping site. It is also installed with incineration facility, which is under utilized

and HSW is burnt in open air. The authors selected the site of Deh Jam Chakro landfill facility because of it being the largest in the city and being surrounded by the huge population.

Site demarcation: The site of sample collection *i.e.* Deh Jam Chakro landfill facility was demarcated for collection of sample in a scientific and un-biased manner. To do so systematic sampling procedure was adopted for collection of samples. The sample site was distributed on a geometrical grid of 3 square feet area and collection was done from every corner point of the square. To abide to the square geometry and equidistant collection point, a net of jute rope was prepared before proceeding for sampling. The area of net was 15 square feet with square grids of 3 feet size.

Soil sample collection: The 15 square feet net was carefully laid on the ground and sample was collected using 2 1/4" standard soil Augers from each corner point of the grid. Thus 30 in number samples were collected from site on each visit.

Dust sample collection: Dust samples were carefully collected from those places where dust was accumulated since long periods of time, like outside brinks of the houses of the people living inside the boundary of the landfill site. The samples were collected using painting brush and plastic tray then these samples was transferred in plastic jars. Samples were collected from about more than 50 places in each visit.

Plant sample collection: The sample plants (*Prosopis juliflora*) were collected from the area within 500 meters radius of the site of soil sample collection and identified by the Department of Botany, University of Karachi. The part of the plant selected for analysis is the mature leaves of the plants collected from 20 plants within the defined area. Leaves having highest surface are among all other parts of the plant are more exposed to the effect of pollutants in the air, similarly as they have a fine system of veins for transportation of nutrients, thus even minute changes in the concentration of pollutants in the plant are noteable.

Water sample collection: Water samples were collected from the boring wells in the adjacent area. All the bores were selected which were having depth between 50 to 80 feet.

Sample collection time: The samples were collected on first day of every quarter. Thus the samples were continuously collected for 1½ year period on quarterly interval.

Soil storage and transportation: The collected samples were mixed and transferred in a plastic bucket. The lid of the bucket was closed and was marked with sample location and date. The pretreatment of samples were started immediately after transportation to the lab which is about 60 min distance.

Soil and dust samples pretreatment: The collected samples were brought in laboratory where each of the samples was thoroughly mixed with the help of a plastic trowel. Then representative sample of about 20 g (approx.) was drawn and finely ground. It was then passed through a 20 mesh (0.841 mm grid opening). 5 g of sieved sample was transferred into Erlenmeyer flask.

Plant sample pre-treatment: Plant samples were dried and finely grinded in an electric grinder. About 3 g of this sample was transferred in a 100 mL beaker. 20 mL mixture of HNO_3 and $HClO_4$ prepared by mixing these acids in 2:1 ratio respectively was poured into the beaker. The mixture was heated at about 80 °C for a time until the powdery sample was completely dissolved and then further 10 % dilution was carried out in 10 % $HClO_4$ and then filtered through Whatman No. 40 filter papers. The filtrate was collected into 50 mL volumetric flask and the volume was adjusted up to the mark with 10 % $HClO_4$.

Water sample pre-treatment: All water samples after being mixed to make one representative sample, was filtered with Whatman® No 42 filter paper and 100 mL was transferred to Erlenmeyer flask. 20 mL of Aqua Regia was added in the sample for digestion and kept for overnight at RTP, The moisture was then concentrated by evaporation at 30-35 °C and necessary dilutions were carried out with deionized water.

Blank preparation: To carry out analysis on atomic absorption spectrometry (AAS), separate blanks were prepared for soil, dust, plant and water analysis. The blank preparation process was identical to the sample pretreatment, but respective samples were not added.

Chemical analysis of samples: All chemicals used during analysis were AnalR grade. Aqua Regia solution was prepared for digestion of sample by mixing equal volumes of 0.05 N HCl and 0.025 N H_2SO_4. 20 mL of aqua regia was added to Erlenmeyer flask, 20 min the mixture was stirred using magnetic stirrer and filtered through a Whatman® No 42 filter paper into a 50 mL volumetric flask and made up to the mark with aqua regia solution. The analytical reagent blanks containing only acids (aqua regia) were prepared for base line calibration and for AAS cleaning between the sample run. Concentration of heavy Cu was determined by flame atomic absorption spectrometer (Perkins Elmer model 2380).

RESULTS AND DISCUSSION

The samples of soil, dust, plant and water collected from Jam Chakro landfill site on 1st day of each quarter were analyzed to determine concentration of Cu in soil by flame atomic absorption spectroscopy method. Each sample run was repeated ten times to gain reliability in the data. Copper concentration in each repetitive run of the sample is given in Table-1. The estimation of Cu in soil shows a gradual increase in concentration of copper, with time. In January 13 average copper in soil was 180.277 ppm and after 18 months the concentration was 219 ppm, however the increase in concentration is not continuous because, an abnormal decrease in copper concentration was observed in October 13 (Fig. 1). The dust samples analyzed also exhibit gradual increase in copper concentration, with a slight decrease in October 13, the same duration when copper concentration in soil was also observed to decrease (Fig. 2). The overall rise in copper concentration in soil during 18 months period (Jan 13 to Jul 14) is determined to be 5.755 ppm. Copper concentration in leaves of *Prosopis juliflora* plant were analyzed and the results showed slight increasing trend throughout the year with an exception of October 13 when the change in concentration was significantly higher than other months. Rise in copper concentration during overall period from Jan 13 to July 14 is 4.929 ppm.

The plot of copper concentration in water against time, shows that the concentration of copper is increasing gradually, however in October 13 when the concentration was analyzed

TABLE-1
CONCENTRATION OF COPPER (ppm) IN SOIL SAMPLES OF JAM CHAKRO LANDFILL SITE

Sampling date	Site temp. at sample collection time (K)	Soil		Dust		Plant		Water	
		Average [Cu] ppm (n = 10)	SD (n = 10)	Average [Cu] ppm (n = 10)	SD (n = 10)	Average [Cu] ppm (n = 10)	SD (n = 10)	Average [Cu] ppm (n = 10)	SD (n = 10)
January 01, 2013	299	180.277	2.631	44.884	3.487	23.616	3.662	2.621	0.905
April 01, 2013	305	187.839	3.976	46.574	2.668	24.351	2.526	3.081	0.905
July 01, 2013	308	201.151	3.198	47.226	3.344	24.961	3.297	2.730	0.727
October 01, 2013	310	192.202	3.026	47.308	3.801	38.770	3.141	9.634	0.884
January 01, 2014	294	203.063	3.000	48.952	2.510	29.662	3.622	6.721	0.800
April 01, 2014	305	211.810	2.386	49.779	4.123	26.966	3.417	2.917	1.030
July 01, 2014	305	219.821	2.525	50.639	3.769	28.540	3.555	3.864	1.090

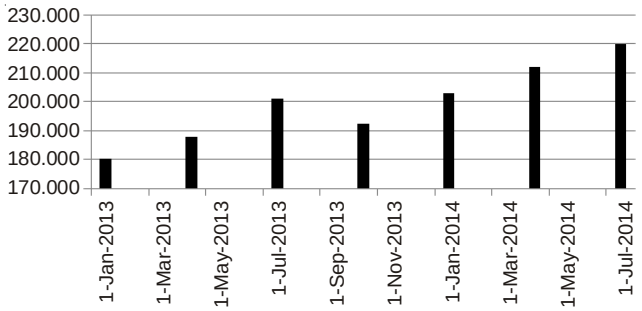

Fig. 1. [Cu] in soil, collected from Deh Jam Chakro landfill facility Karachi, Pakistan

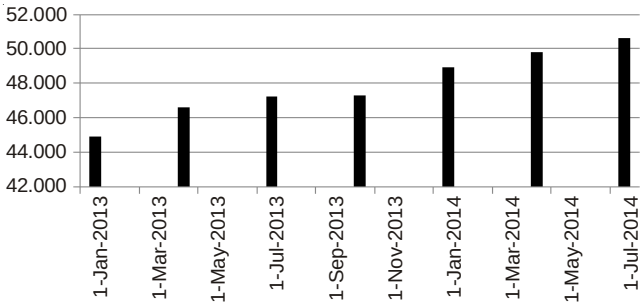

Fig. 2. [Cu] in dust, collected from Deh Jam Chakro landfill facility Karachi, Pakistan

to decrease in soil and dust samples, copper concentration in water was significantly increased. The magnitude of increase is clearly notable in Fig. 3.

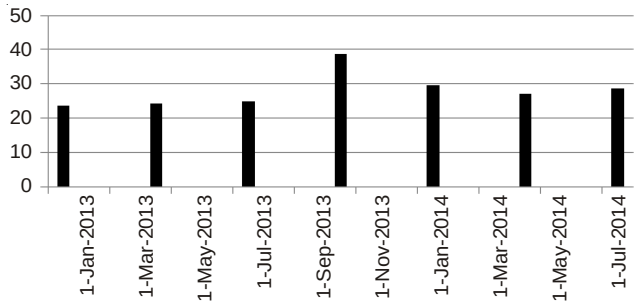

Fig. 3. [Cu] in plant, collected from Deh Jam Chakro landfill facility Karachi, Pakistan

The study reveal that an effective way of metal removal from soil of Deh Jam Chakro landfill facility is required for removal of Cu as discuss by earlier researchers. Bhada[5] after studying world metropolitan cities reached at the conclusion that improving solid waste management, especially in low income countries, is an urgent priority. Ceçen and Gürsoy[6] in their study have proposed an effective way of removal of heavy metal from water

The average concentration of Cu found in soil of Deh Jam Chakro landfill facility is199.452 ppm, which is significantly high compared to the unpolluted soil concentration which is 30.916 ppm. The elevated concentration of Cu is indicator of continuous dumping of HSW at the site with improper management of waste. The trend in concentration change of Cu in soil of Jam Chakro landfill site indicated a gradual increase in concentration. However in monsoon season the concentration of Cu in soil was observed to decrease. The observation leads to inference that significant amount of Cu was washed off by the rain water or leached into the ground water, in both cases pollutant under consideration moved from landfill site to other areas. The decrease in concentration (Table-1 and Fig. 1) of Cu in month of October can be attributed to rain. In August to October the concentration of Cu in soil was observed to decrease. The observation leads to inference that significant amount of Cu was washed off by the rain water or leached into the ground water, in both cases pollutant under consideration moved from landfill site to other areas.

The dust samples collected from Deh Jam Chakro landfill facility have Cu 47.909 ppm. As dust is mostly composed off by the process of weathering, therefore it is not unusual to find alleviated concentrations of Cu in dust. In monsoon season dust accumulation in soil is reduced due to leaching and runoff, therefore the same was observed to decrease in dust also. The interdependency of [Cu] in dust on soil is a proof that the hazards of improper household solid waste management are not confined to the site. The contents of HSW are dispersed in the environment through dust particles. The [Cu] in plant leave samples, collected from Deh Jam Chakro landfill facility is elevated (28.124 ppm). The periodic determination of [Cu] shows a slow but continuous increase in concentration with passage of time. The Cu present in HSW dumped at this landfill facility has shown tendency of mixing with soil and then travelling to plants, thus it has entered in food chain. The results of [Cu] analysis in water samples from Dek Jam Chakro landfill facility are higher than normal (4.510 ppm) (Fig. 4). Cu present in soil reaches water, through leaching and run off caused during rain, therefore the [Cu] in water was observed to increase in rainy seasons, whereas at same time it decreased from soil (Fig. 5). The Cu present in water enters into food chain and disturbs the ecosystem. The outcomes of this investigation suggest that rise in concentration of Cu in various sample

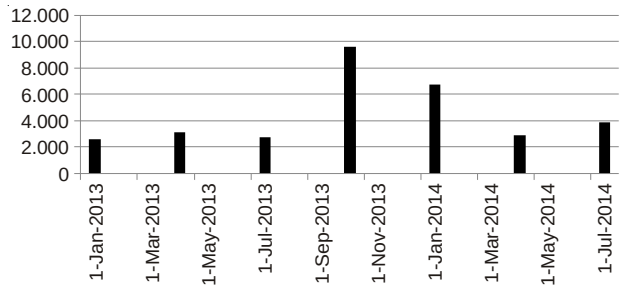

Fig. 4. [Cu] in water, collected from Deh Jam Chakro landfill facility

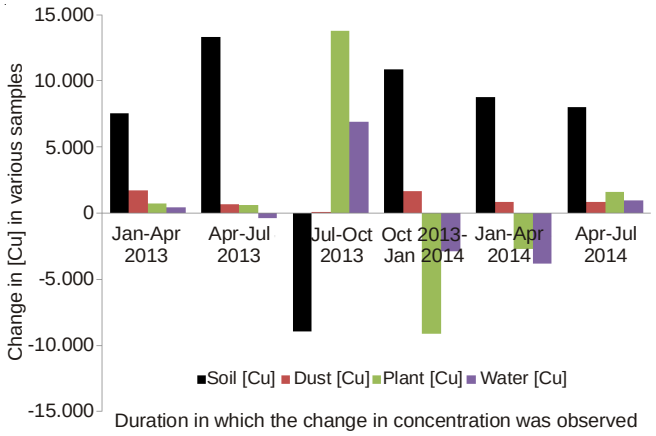

Fig. 5. A comparison of change in [Cu] in soil, dust, plant and water collected from Deh Jam Chakro landfill facility Karachi, Pakistan

exhibited as an environmental indicator that provide evidence on burdens in the environment, environmental conditions and societal responses and as a metal the ecological processes of Cu will continuous and may also be refer as a ecological indicator.

In light of the results of chemical analysis carried out in this research study, null hypothesis is rejected and following facts are established:

• Household solid waste management system adapted in Karachi city is not able of controlling pollution.

• Proper procedures are not followed while managing HSW at Deh Jam Chakro landfill facility and are thereby causing environmental pollution.

• Concentration of Cu in soil of landfill site is significantly more than unpolluted soil.

• Copper being metal will not decay and will persist in the soil, however it may leave soil and mix into air or water and thus travel in food chain through absorption by plants.

• Implementation of complete household solid waste management system is necessary to avoid increase of pollution in the environment.

• Increase in concentration of Cu in soil means, Cu is continuously being dumped in the landfill site. Thus segregation and recycling of copper can be economically feasible.

• Concentration of heavy metals in the landfill site is increasing due to improper burning of HSW in open air where carbon components converted into CO_2 and H_2O and metal left in soil resources and move by air pressure or run off in rainy season and contaminated the running as well as ground water. In this way accumulates in food chain by movement in through plants and water from soil.

• The increases concentration of Cu was the clear evidence of pressure on ecological system and responsible for welcoming the resistant microbial lives causes serious diseases in city.

The problems created due to generation of household solid waste are studied by various researchers all over the world which one way or other do support the findings of this paper. Medina[4] studied the retain-ability of Cu in soil and reported that Cu was mainly associated with the soil residual and was EDTA extractable. Thus it also establishes that Cu is retained in the soil of the sites where it is dumped as found in current research[7]. Munaf *et al.*[8] studied the problem of Municipal solid waste management in Malaysia in relation with the rapid economic development and population growth, inadequate infrastructure and expertise. The management of municipal solid waste was classified as one of Malaysia's most critical environmental issues and highlights the problem of Household solid waste management as a critical environmental issue of Karachi. The lack of understanding over a diversity of factors that affect the different stages of waste management and linkages necessary to enable the entire handling system functioning, were discussed by Guerrero *et al.*[9] in relation with high costs associated to its management[10]. While Cu up take by plants like *Prosopis juliflora* directly related with the available Cu concentration in soil[11,12] as reported in present research.

Conclusion

It is concluded that this investigation can provided relevant information of toxicants current pressure on eco-state and trends in the environment which can be helpful for decision-makers and the general public with helping decision-makers better understand cause and effect relationships between the choices and practices of businesses and policy-makers *versus* the environment.

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