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Appraising the Heavy Metal Contamination of Surface Dust from Waste Electrical and Electronic Equipment (E-Waste) Recycling Sites in Moradabad, India

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Abstract: *The objective of this study was to appraise the levels of heavy metals contamination within the vicinity of the Moradabad well known as Brass city. Surface dust samples were collected from various points at the e-waste burning sites and its environment. Atomic absorption spectrophotometer preceded by acid digestion was used to evaluate the concentration of the heavy metals in the samples. Heavy metals such as Cd, Cu, Zn, Ni, Pd, Cr, Ar, and Hg which were very high than the levels for which intervention is required. The scrap weighing site, the electronic waste dismantling site and the burning site (where electrical cables are burnt to retrieve metals) recorded the highest levels of heavy metals. Index of geo accumulation which was employed to determine the level of pollution, indicating extreme pollution from all the sites. Results also indicate that children living around the scrap market face a very high risk from the ingestion of toxic metals such as Pb, Cd, Ar and Hg.*

Keywords*: Electronic waste, heavy metals, environmental pollution, Brass city.*

I. Introduction

Illegal e-waste burning in Moradabad is one of the major sources of increasing toxic heavy metal concentration in soil. Owing to the rapid development of information technology and constant upgrade of electronic products, electronic waste (e-waste) has become the fastest growing stream of municipal solid waste over the last decade (Schmidt, 2002; Ni and Zeng, 2009; Robinson, 2009). A majority of e-waste is produced by the developed countries in which the US alone generated over 9.4 million tons in 2012 (StEP: http://step-initiative.org/index.php/Overview_USA.html). To handle the e-waste many developed countries tend to export it (ca. 50%– 80%) to the developing countries (e.g., India, Bangladesh China, Pakistan and Vietnam) for recycling and disposal in view of lower labour costs and less stringent environmental regulations (Schmidt, 2002; Ni and Zeng, 2009). Now days India has become the second largest importer of e-waste in the world, receiving over millions of tons of e-waste from US and European countries every year (Widmer et al., 2005). According to some estimations, India not only generates close to 40,000 tonnes of e-waste annually, but India is also importing another 50,000 tonnes of e- waste illegally from countries like the US and CANADA (e-wasteguide.ifo/scrappedout). Developed countries find it easy to import e- waste to developing countries in the name of free trade (Toxic Link, 2004).

Moradabad a western city in Uttar Pradesh is situated at the bank of river Ramganga. This city is traditionally famous for bangles and brass works and is known as “Peetal nagri” or the Brass City. It has the distinction of being the biggest exporter of brasswares in the country. Many households, which were engaged in brass works earlier, were left with no choice but to explore other mean of livelihood. E-waste was one of the natural choices because of their metal processing knowledge (Toxic link 2010). E-waste recycling in India, till a few years back, was concentrated in large cities like Delhi, Kolkata, Mumbai, Bangalore and Chennai. But with the increase in the generation of e-waste and increasing land cost in big cities, the recycling centres have started spreading in neighbouring cities and towns. Moradabad is one such example, recyclers in Moradabad buy PCbs (Printed Circuit Boards) from various big cities. According to some estimation, 50% of the printed circuit boards used in appliances in India ends up in Moradabad. The unscientific process of burning the electronic goods to recover the metal poses not only an environmental threat, but the poisonous toxic are being inhaled by the people of this city. Unaware of these poisonous fumes, 60% of the city’s workers engaged in the illegal e-burning business which is worth of cores. Many studies done on e-waste in Moradabad have found that the level of heavy metal contamination in areas in and around the city’s is extremely high. Collected soil samples from the three main locations which are situated on the ban of river Ramganga, the water of river is used for washing by residents and for drinking in downstream.

It is noteworthy that none of these laws and regulations emphasise remediation of contaminated soil and water in the vicinity of e-waste recycling sites; therefore, the pollutants remaining in abandoned e-waste recycling sites can still pose hidden danger to the surrounding environments (Lopez et al., 2011; Zhang et al., 2014).

The present study was conducted in an abandoned e-waste processing and recycling sites, Moradabad, India. Nawabpura is main hot bed for e-waste burning, processing and acid leaching. It is also situated near the bank of river Ramganga where the washing of circuit boards is done. After washing burning and many recycling process takes on the bank of river which is indirectly polluting the river water. Since the local people situated near the river usually rely on river water for irrigation and drinking, the potential ecological risk of heavy metals in the vicinity of abandoned e-waste processing sites should not be overlooked. Second site is the industrial site Peetal Nagri famous area for all the brassware industries, most industries related to brass work are situated in this area of Moradabad. We aim to elucidate the contamination of heavy metals in these areas by examine their concentrations in soil samples collected from these areas. The findings can emphasise focus on the environmental impacts of heavy metals in abandoned e-waste recycling and industrial waste sites and thus can raise awareness to the local resident and authorities concerned to take necessary steps for remediation.

Index of Geo Accumulation (Igeo):

The index of geo accumulation (Igeo) is widely used in the assessment of contamination by comparing the levels of heavy metal obtained to background levels originally used with bottom sediments (Muller, 1969). It can also be applied to the assessment of road dust contamination (Lu *et al*., 2009, 2010; Gowd *et al*., 2010). It is calculated using the equation:
The Igeo was calculated using Muller and Abrahim & Parker method as follows:

Igeo = log 2 ([sediment]/ 1.5* [reference sample])

Where Cn is the measured concentration of the heavy metal in road dust, Bn is the geochemical background concentration of the heavy metal (crustal average) (Taylor and McLennan, 1985). The constant 1.5 is introduced to minimize the effect of possible variations in the background values which may be attributed to lithologic variations in the sediments (Lu *et al*., 2009).
The following classification is given for geo accumulation index (Huu *et al*., 2010; Muller, 1969) **: <0 = practically unpolluted, 0-1 = unpolluted to moderately polluted, 1-2 = moderately polluted, 2-3 = moderately to strongly polluted, 3-4 = strongly polluted, 4-5 = strongly to extremely polluted and >5 = extremely polluted.**

Contamination Factor And Degree Of Contamination:

To assess the extent of contamination of heavy metals in the surface soil samples, contamination factor and degree of contamination has been used (Rastmanesh *et al*., 2010). The C^i_f is the single element index which is determined by the relation:

$$C^i_f = \frac{C^i O\text{-}1}{C^i n}$$

where; $C^i f$ is the contamination factor of the element of interest; C^i O-1 is the concentration of the element in the sample; Cs^i n is the background concentration in this study the continental crustal average has been used (Taylor and McLennan, 1985). $C^i{}_f$ is defined according to four categories: <1 low contamination factor; 1-3 moderate contamination factor; 3-6 considerable contamination factor and >6 very high contamination factor. The sum of the contamination factors of all the elements in the sample gives the degree of contamination as indicated in the equation below:

$$C_{deg} = \sum C^i_f$$

Four categories have been defined for the degree of contamination as follows; <8 (low degree of contamination); 8-16 (moderate degree of contamination); 16-32 (considerable degree of contamination) and >32 (very high degree of contamination). The threat posed by heavy metals to human health are caused by a combination of their chemical characteristics, association with particulate matter of fine grain sizes, residence time in the atmosphere and easy transport from emission sources (Dongarra *et al*., 2003). Exposure to heavy metals in surface dust can occur by means of ingestion, inhalation and dermal contact. In toxicological risk assessment for non-carcinogenic toxicants, a reference dose or tolerable daily intake is assumed to be tolerated by the organism with low or no risk of adverse health effects (Ferreira-Baptista and De Miguel, 2005). Populations that are worst affected by exposure to Contaminants are children, pregnant women and the aged.

Children have a greater exposure rate to toxicants than adults because they breathe more rapidly than adults, can breathe through their mouth and often engage in a lot of outdoor activities which lead to high risk of exposure. The susceptibility of children to the ill health effects of heavy metals is due to their immature immune system and developing organs. Exposure to heavy metals can affect their respiratory, nervous, endocrine and immune systems and could increase the risk of cancer in later life.
The risk of exposure to a particular toxicant is the Hazard Quotient (HQ) which is given by:

$$HQ = \frac{DI}{RfD}$$

Where, *DI* is the dose intake by a given route of exposure for a particular contaminant R*f*D is the reference dose fore particular element through a particular route of exposure. It is assumed that the toxic risks due to the heavy metals were additive, therefore the HQ value for each metal at a location were summed to generate the Hazard Index (HI) (Leung *et al*., 2010).

II. Materials And Methods

Various samples were taken from many areas of Moradabad city which is widely recognized as electronic waste areas. The samples were taken from burning sites, dismantling areas, industrial areas and other residential areas within the vicinity. At sampling sites, about 250g of composite soil samples were collected, a soft touch brush was used for sweeping and plastic dust pan for collection, separate plastic dust pan brush was used for sampling collection from each site into pre-treated polythene bags to avoid contamination (Singh et al., 2016). A minimum of three samples were collected from each points, with the distance of some kilometres in the same selected area. The samples were labelled carefully and taken to the Pollution Ecology Research Laboratory of Moradabad for further analysis. The samples were carefully air-dried at room temperature for three days and sieved through 200µm mesh nylon sieve to remove debris. For each sample, 0.5g of dry soil was weighted and digested with mixed acids. Soil samples were digested with 15ml of concentrated HNO_3, H_2SO_4, and $HCLO_4$ (5:1:1) at 80^oC until the transparent solution was obtained (Allen et al., 1986)**.** The digested solution was cooled, filtered using Whatman's Number 42 filter paper and then diluted with deionised water before metal determinations concentrations of Cu, Cr, Cd, Ni, Pb and Zn. The filtrate was kept at room temperature for further analysis of heavy metals. Heavy metals were determined by inductively coupled plasma atomic emission spectroscopy (ICP- AES) and (ICP- AAS). Any sample exceeding the calibration range was diluted accordingly, in duplicate, and re-analysed (Jensen et al., 2000; Yang et al., 2009).

III. Results And Discussion

The mean concentration of the heavy metals obtained from seven soil samples was compared with the certified values by calculating the ratio of experimental values to certified reference values.

Table 1 reveal that the concentration of Pb were in the range 409 to 1833 mg/kg respectively with the highest value recorded at SI known as Nawabpura where the burning of electronic waste occurs frequently and Pb is the one of the major components of burning PCB's, Printed Circuit Boards most burning component in Moradabad city. During the burning high amount of smoke is released hence the risk of inhalation. Other sites also recorded concentration which was thousand times higher than standards set for interventions.

In table 1 it is also seen SVII is Residential site that is jeegar colony is of particular concern because it is residential area and Pb is known to affect the brain and nervous system and exert its effect on children such as lowering IQ, many mental disorders and can cause cancer in later coming life (Atiemo *et al*., 2010). The level of Cd found in the range of 52 and 231mg/kg. The toxicity of Cd and its adverse impact on human and environment cannot be overemphasized (Atiemo e al., 2012).

The soil samples collected from electronic waste burning site recorded the highest concentration of the Cd these were Nawabpura and Daulatbagh that are SI and SII respectively. The residential area where the sampling was done, the recorded Cd concentration was 52mg/kg which is about 500% times more than the value that can trigger intervention. The concentration of Cu and Cr ranges between 0 and 13647mg/kg. The highest concentration of Cu and Cr was at SI and SVII respectively. SVII is Jeegar Colony, residential area and the concentration is more than thousand times the concentration requiring intervention (Lacatusu *et al*., 2009). Zn and Ni recorded value that exceed both alert and intervention level for the sample from the SI and SII both are the electronic waste burning sites

Table 2 shows that the analytical values for normal content at the alert threshold and intervention threshold present the same pattern. Thus, the interval up to the alert threshold contains most of the samples, between 18% (Ni) and 72% (Pb). The range between the alert and intervention threshold contains between 10% (Cu) and 82% (Ni), and the range over the intervention threshold contains between 3% (Cd) and 16% (Cu) of the analyzed samples. The general pedogeochemical abundance index (GPAI) represents the ratio between an average chemical element's value in the analyzed samples and the general chemical element average content in a soil (Lăcătuşu & Ghelase, 1994) (Lacatusu *et al*., 2009). Table 4 shows that there are only a few values of Cd, Mn, Ni and Pb situated between the alert threshold limit (AT) and the intervention threshold limit. Only 2% of all the Cd values are over the intervention threshold. (Lacatusu *et al*., 2009).

Table 1: Heavy Metal concentration in soil sample from the vicinity of E-waste sites (Mg/kg).

Sites / H.Metals		Pb	Cd	Cu	As	Cr	Ni	Zn
Site I	Mean SD	1833 1610.79	231 25.48	13647 254.82	120.78 10.09	0	540 96.56	9842 169.54
Site II	Mean SD	557 44.28	111 0.08	8551 1061.17	182.41 153.62	237 215.01	2274 144.78	6722 1755.11
Site III	Mean SD	693 181.04	83 23.57	915 93.08	80.32 29.86	163 145.22	503 78.23	1005 59.47
Site IV	Mean SD	739 402.77	96 10.58	4797 667.08	107.65 6.07	269 369.46	512 51.02	6435 214.65
Site V	Mean SD	655 292.55	93 31.39	3557 1127.57	23.26 3.24	80 101.37	371 202.21	2681 823.54
Site VI	Mean SD	533 162.10	83 30.61	2080 43.58	17.08 1.67	0	331 120.61	5669 175.43
Site VII	Mean SD	409 137.94	52 18.33	638 212.80	10 0.65	409 56.88	327 169.19	1719 643.91
	AT	50	3.0	100	-	100	75	300
	IT	100	5.0	200	-	300	150	600

SI&SII: Nawabpura & Daulatbagh resp (Burning Sites); SIII: Nagphani (Acid Processing); SIV: Karula (Dismantling Segregation); SV: Peetal Nagri (E-Waste Dumping); SVI: Mughalpura (Industrial Area); SVII: Jigar Colony (Residential Area) AT: Levels for which attention is required; IT: Levels for which an intervention is required (Lacatusu *et al*., 2009).

Table2: Percentage distribution (%) of soil samples (n = 74) from the Rosia Montana area by heavy metals abundance classes, depending on the alert (AT) and intervention threshold values (IT), according to the Order no.756/1997 of the Ministry of waters, forests and environment protection. (Lacatusu *et al*., 2009)

Chemical Elements	Value classes			
	normal	Upto alert threshold (AT) limit	between the alert (AT) and intervention threshold (IT) limits	over the intervention threshold (IT) limit
Cd	20	67	10	3
Co	17	43	35	5
Cr	49	51		
Cu	3	58	23	16
Mn	62	21	14	3
Ni		18	82	
Pb		72	28	
Zn	7	70	12	11

Table3: Percentage distribution (%) of the soil samples (n = 153) from the Rosia Montana area, by heavy metals abundance classes, depending on the alert (AT) and intervention threshold (IT) values, according to the Order no. 756/1997 of the Ministry of waters, forests and environment protection. (Lacatusu *et al*., 2009)

Chemical Elements	Value classes			
	normal	Upto alert threshold (AT) limit	between the alert (AT) and intervention threshold (IT) limits	over the intervention threshold (IT) limit
Cd		97	1	2
Co		34	53	13
Cr	50	50		
Cu	64	36		
Mn	80	17	3	
Ni		83	17	
Pb		84	16	
Zn	52	48		

Table 4: Results of index of geo-accumulation (Igeo)

Samples	Pb	Cd	Cu	As	Cr	Ni	Zn
SI	6	6	4	4	2	-2	6
SII	5	4	6	3	0	1.9	8
SIII	6	6	4	1	2	0.2	7
SIV	4	6	5	2	1	-1.2	8
SV	6	6	5	0	0	0.6	8
SVI	5	5	3	2	1	3	6
SVII	4	3	2	0	1	-1.8	7

Table 5: Contamination factor of sampling sites

Metals/ Sites	SI	SII	SIII	SIV	SV	SVI	SVII
Pb	348	259	301	55.3	20.9	91.2	55.4
Cd	255	437	28.9	97.8	184.6	1.1	75.6
Cu	596.7	31.98	375.76	317.9	148.9	109	119
As	18.9	11.27	20.8	15.6	89.0	4.8	6.9
Cr	90	25	11.9	1.2	8.6	0.7	1.3
Ni	68	125	119.87	76.54	18.76	25	15.6
Zn	158	147	326	289	136	24	17.9

Figure 1: Component Graph Showing Standard Errors

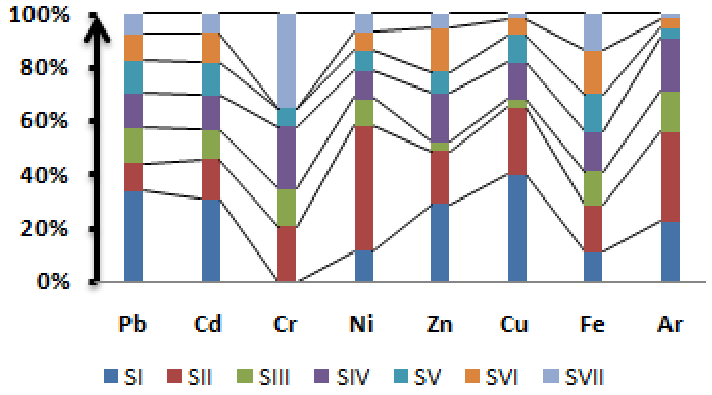


Figure 2: Percentage Concentration of Heavy Metals on Different Site.

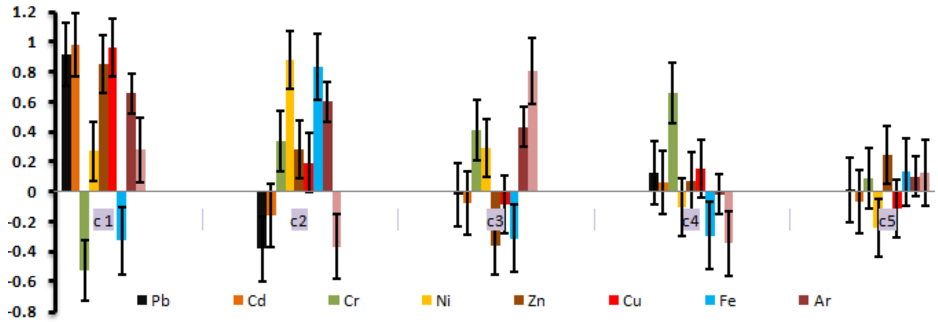
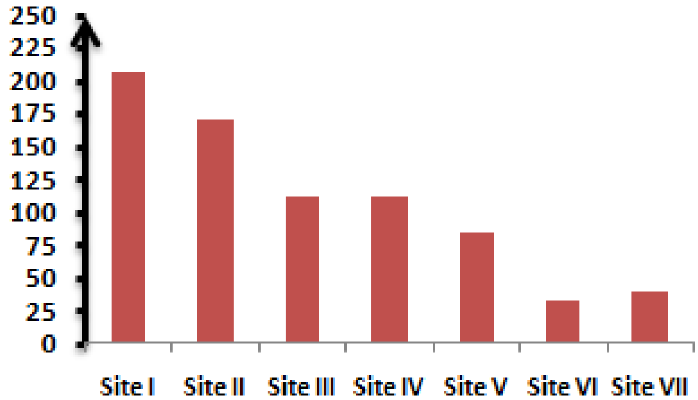


Figure 3: Contamination Factor of Sampling Sites



The index of geo-accumulation (Table 4) was calculated to determine the level of pollution of surface dust from the sampling site by the various elements. The results show that Pb, Cr, Cu and Zn indicated high level of pollution from all the sites since all the Igeo values for these elements fell below two. However, minimal pollution was observed for at Cr and Ni with an Igeo values on various sampling sites. This was a bit surprising because Cu is one of the metals that are retrieved in the e-waste burning. However, it is known that Copper forms an integral part of PCB's and therefore high concentrations have been found in soil sample studies

(Atiemo *et al*., 2012; Thorpe and Harrison, 2008). Zinc (Zn), lead (Pb) and cadmium (Cd) showed extreme case of pollution from all the sites with Igeo values in the range 6.7-8.2, 4.2-8.1 and 3.0-7.8, respectively.

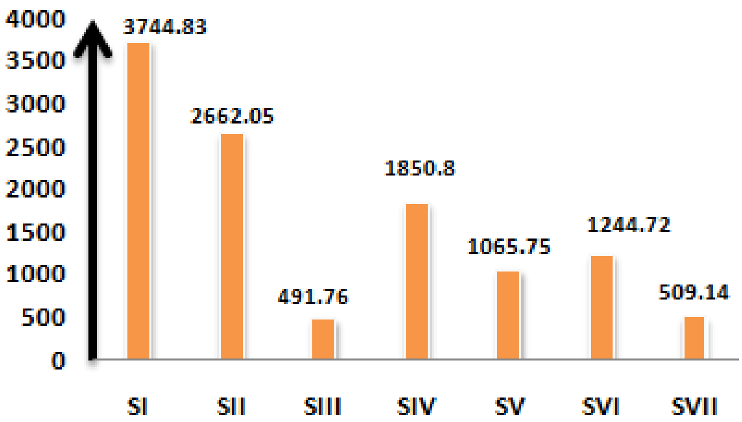
Results of the calculated contamination factor are presented in Table 5. It shows that contamination of surface soil with respect to Cr is very low at all the sites. Result of the elements Cu, Cd and Pb gave indication of very high contamination factor at all the sites with. Zn, As and Ni recorded very high levels of contamination at all the sites. The calculated degree of contamination in the sampling sites is presented in Fig. 3. The results show that the Mughalpura SVI has the lowest degree of contamination. This is because the SVI is industrial area so the electronic waste burning pollution is low as compared to other sites to the premises. The site I and II (Nawabpura and Daulatbagh) electronic waste burning sites showed extremely high degree of contamination. As a result of the location of Banks and other business entities at this site, there are intense human activities undertaken there. The thick cloud of smoke from the burning site blows in the direction of these buildings. Some of the particulates can drop as they pass over the buildings thereby leading to contaminations (Ateimo et al., 2012).

The Site V and VI serves as a place of rest to some of the people engaged in the scrap business during the night. This practice is likely to have resulted in the transport of contaminates from the adjacent scrap market to the various areas of the Moradabad city. The countless burning activities undertaken within the vicinity of the residential areas may also have contributed to the very high degree of contamination at the site. The contaminants in soil dust may come from exhaust or non exhaust sources (Atiemo *et al*., 2010). The Weighing Site, Dismantling Site and the Burning Site, respectively recorded the highest degree of contamination. These are sites with intense scrap activities within the yard where unscientific methods are used for dismantling, burning and weighing. All these activities release high levels of toxic substances into the environment leading to the exceptionally high degree of contamination.

Table 6: Hazard Quotient (HQ) for children exposed to heavy metals from E-waste recycling.

H.metals	Pb	Cd	Cu	As	Cr	Ni	Zn
SI	648.24	54.87	10.45	0.34	9.47	65	12.4
SII	268.59	23.98	43.87	0.21	0.54	98.6	65.8
SIII	316.86	11.26	98.57	0.76	8.54	23	98.34
SIV	298.12	21.87	342.76	1.45	0.34	6.4	0.54
SV	194.26	19.09	65.98	0.54	9.65	87.09	2.54
SVI	91.76	08.65	23.76	3.65	2.01	1.2	0.43
SVII	102,54	5.65	94.12	1.45	4.67	0.4	12.65

Figure 4: Total heavy metal concentration (TMC) on sites (mg/kg)



Exposure assessment calculations were done based on the parameters discussed in the introduction and the results are shown in Table 6. Exposure assessment involves quantifying the estimated intake of the contaminant by humans. The risk of non-cancerous or cancerous effect resulting from exposure to the heavy metals releasing from the burning of electronic waste and many more activities. In risk assessment studies the most vulnerable individuals considered are; children, the aged and pregnant women. In this study, noncancerous effect was estimated for children between the ages of 0-6 years using ingestion as the exposure pathways. Since Pb is a cumulative poison and neurotoxin hence prolong exposure can trigger neurological and developmental disorders in children. Cadmium is a very toxic heavy metal which can devastate children's immune system within a short period of exposure. Copper and zinc also recorded varied hazard quotients which are also major threat to children living in and around the electronic waste burning sites. the cumulative risks of exposure to surface dust for children living around the area. The startling results revealed that children living around the scrap market face strong risk of adverse effect from exposure to the toxic metals emanating from activities of the scrape market.

IV. Conclusion

The objective of this study was to assess the concentration of heavy metals and the level of contamination within the vicinity of Moradabad e-waste areas. Soil sample were collected from various points and the level of contamination within few kilometres of radius. The atomic absorption spectrophotometer was used to evaluate the concentration of the heavy metals in the soil samples. The results revealed that heavy metal contamination is present in high level in the sampling areas. It was observed that the heavy metals such as Pb, Cr. Cd, Zn, Ni and Cu gave the concentrations which were over many times (thousand times) more than the levels for which intervention is required. This is happening due to lack of legislation or the limited legislation regulating the e-waste processing method. The e-waste burning, electronic waste dismantling, acid processing sites recorded the highest levels of the heavy metals. Soil samples also collected from the popular residential area Jeegar colony which also gave an alarming concentration of these heavy metals. Index of geo-accumulation which calculated to determine the level of the pollution of the various heavy metals, results showed that all the sites have been polluted heavily. Furthermore this result was confirmed by the calculating contamination factor, the most contaminated site is Mughalpura site I > daulatbagh SII both are e-waste burning sites, followed by the SIII Naghphani known for acid processing site for e-waste, after that it comes Karula SIV where dismantling and segregation of the waste mostly occurs, SV, SVI, SVII were also under the risk of high metal pollution due to e-waste activities. The results also indicate that the people especially children and pregnant women leaving around such places face a very high risk from the ingestion and inhalation of toxic metals such as Pb, Cd, Cr, Zn, Ni and Cu. The burning site I (TMC= 3744.83), burning site I (TMC= 2662.05), acid processing site III (TMC= 491.76), dismantling segregation IV (TMC= 1850.8), e-waste dumping site V (TMC= 1065.75), industrial area site VI (TMC=124.72), residential area site VIII (TMC= 509.14). it is highly recommended that government to take some serious steps for the regulation check on the e-waste burning. And also further research study be carried out into the effect of these toxic metals released in environment and also on the people living in those areas, and the people involved in the burning activity.

These sites are not fit for the people to stay, and are highly contaminated. Remedial measures should be required for the use of these sites for any purposes. Emergence of a small city like Moradabad as an e-waste recycling hub points out towards intensity of the e-waste problem India is facing today. It is important to look at the reasons and the find solutions; otherwise we will soon end up with toxic hotspots all over the country.

This study provides clear evidence that there is an urgent need for reducing the harmful impacts on environment as well as on human health due to the e-waste recycling activities. However, since the livelihoods of large population groups depends on the income from recycling activities, informal collectors continue to play a major role in the collection and recycling of e-waste, and informal processing often leads to detrimental effects on both the environment and the health and safety of workers and local communities.

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References

[1]. Atiemo, S.M.,F.G. Ofosu, I.J.K. Aboh and P.O. Yeboah, 2010. Determination of heavy metals and human health risk assessment of road dust on the Tema motorway and Tetteh Quarshie interchange in Accra, Ghana. J. Ghana Sci. Assoc., 12(2): 76-85.
[2]. Atiemo, S.M.,Ofosu, F.G., Kwame I.J. Aboh and O.C.Oppon, 2012. Levels and sources of heavy metal contamination in road dust in selected major highways of Accra, Ghana. X-Ray Spectrom, 41: 100-110.
[3]. Dongarra, G., G. Sabatino, M. Triscari and D. Varrica, 2003. The effects of anthropogenic particulate emissions on roadway dust and Nerium oleander leaves in Messina (Sicily, Italy). J. Env. Monit., 5:766-773
[4]. Ferreira-Baptista, L. and De Miguel, E.D., 2005.
[5]. Geochemistry and risk assessment of street dust in Luanda, Angola: A tropical urban environment. Atmospheric Environ, 9: 4501-45312.
[6]. Lacatusu, R., G. Citu, J. Aston, M. Lungu and A.R. Lacatusu, 2009. Heavy metals soil pollutionstate in relation to potential future mining activities in the RoÕia Montana area. Carpath. J. Earth Env. Sci., 4: 39-50.
[7]. Leung, A.O.W., N.S. Duzgoren-Aydin, K.C. Cheung and M.H. Wong, 2010. Heavy metals concentrations of surface dust from e-waste recycling and its human health implications in Southeast China. Env. Sci. Technol., 42 : 2674-2680.
[8]. Rastmanesh, F., F. Moore, M.K. Kopaei, B. Keshavarzi and M. Behrouz, 2010. Heavy metal enrichment of soil in Sarcheshmeh copper complex, Kerman Iran. Env. Earth Sci., DOI 10.1007/s12665-010-0526-2.
[9]. Taylor, S.R. and S.M. McLennan, 1985. The Continental Crust: Its Composition and Evolution. Blackwell Scientific Publications, Oxford.
[10]. Thorpe, A. and R.M. Harrison, 2008. Sources and properties of non-exhaust particulate matter from road traffic.

[11]. UNEP, 2005. E-waste: The hidden side of IT equipment's manufacturing and use. Early Warnings on Emerging Environmental Threats No. 5. United Nations Environment Programme.

[12]. Singh, A.: Pal, R.: Gangwar, C.: Gupta, A.: Tripathi, A: Release of heavy metal from industrial wasteand e-waste burning and its effect on human health and environment. *Int. J. of emerging research in management and technology*., **4**, 2278-9359 (2015).

[13]. Leung AOW, Duzgoren-Aydin NS, Cheung KC,Wong MH.(2008) Heavy metals concentrations of surface dust from e-waste recycling and its human health implications in southeast China. Environ Sci Technol 2008;42:2674–80.

[14]. Gowd, S.S., M.R. Reddy and P.K. Govil, 2010. Assessment of heavy metal contamination in soils at Jajmau (Kanpur) and Unnao industrial areas of the Ganga Plain, Uttar Pradesh, India. J. Hazardous Mater., 174: 113-121.

[15]. Huu, H.H., S. Rudy and An Van Damme, 2010. Distribution and contamination status of heavy metals in estuarine sediments near Cau Ong harbor, Ha Long Bay, Vietnam. Geol. Belgica, 13(1-2): 37-47.

[16]. Lu, X., L. Wang, K. Lei, J. Huang and Y. Zhai, 2009. Contamination assessment of copper, lead, zinc, manganese and nickel in street dust of Baoji, NW China. J. Hazardous Mater., 161: 1058-1062.

[17]. Lu, X., L. Wang, L.Y. Li, K. Lei, L. Huang and D. Kang, 2010. Multivariate statistical analysis of heavy metals in street dust of Baoji, NW China. J. Hazardous Mater., 173: 744-749.

[18]. Muller, G., 1969. Index of geoaccumulation in sediments of the Rhine River. J. Geol., 2: 108-118.

[19]. Lu C, Zhang L, Zhong Y, Ren W, Tobias M, Mu Z, et al. (2014)An overview of e-waste management in China. J Mater Cycles Waste Managements http://dx.doi.org/10. 1007/s10163-014-0256-8.

[20]. Lopez BN, Man YB, Zhao YG, Zheng JS, Leung AOW, Yao J, et al. (2011) Major pollutants in soils of abandoned agricultural land contaminated by e-waste activities in Hong Kong. Arch Environ Contam Toxicol 2011;61:101–14.

[21]. Ni HG, Zeng EY. (2009) Law enforcement and global collaboration are the keys to containing ewaste tsunami in China. Environ Sci Technol 2009;43:3991–4

[22]. Robinson BH. (2009) E-waste: an assessment of global production and environmental impacts. Sci Total Environ 2009;408:183–91.

[23]. Widmer R,Oswald-KrapfH, Sinha-Khetriwal D, SchnellmannM, BöniH (2005). Global perspectives on e-waste. Environ Impact Assess Rev 2005;25:436–58.

[24]. Yang WH. Regulating electrical and electronic wastes in China. Rev Eur Community Int Environ Law 2008;17:337–46.

[25]. Zhang JH, Min H.(2009) Eco-toxicity and metal contamination of paddy soil in an e-wastes recycling area. J Hazard Mater 2009;165:744–50.

[26]. Zhang Q, Ye J, Chen J, Xu H, Wang C, Zhao M. (2014) Risk assessment of polychlorinated biphenyls and heavy metals in soils of an abandoned e-waste site in China. Environ Pollut;185:258–65.

[27]. Schmidt, C W., 2002. E-junk explosion. Environmental health perceptive 110.

[28]. Allen et al., 1986 S.E. Allen, H.M. Grimshaw, A.P. Rowland Chemical analysis P.D. Moore, S.B. Chapman (Eds.), Methods in Plant Ecology, Blackwell Scientific Publication, Oxford, London (1986), pp. 285–344.