International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 16, No. 3, p. 352-361, 2020

INNSPUB

RESEARCH PAPER OPEN ACCESS

Assessment of heavy metals in air samples of Municipal solid waste (MSW) disposal sites and transfer stations of Lahore, Pakistan

Sana Hafeez[1*], Zulfiqar Ali[1], Shahid Sher[2], Zaheer Ahmed Nasir[3]

[1]*Environmental Health and Wildlife, Department of Zoology, University of the Punjab, Lahore, Pakistan*

[2]*Department of Microbiology and Molecular Genetics, University of the Punjab, Lahore, Pakistan*

[3]*School of Energy, Environment and Agrifood, Cranfield University, Cranfield, Bedfordshire MK43 0AL, United Kingdom*

Key words: Solid waste management, disposal sites, transfer stations, heavy metals, metrological parameters.

http://dx.doi.org/10.12692/ijb/16.3.352-361 Article published on March 29, 2020

Abstract

The presence of heavy metals in municipal solid waste is of emerging concern. In order to provide information on the concentration of heavy metals chromium (Cr), manganese (Mn), zinc (Zn), lead (Pb), nickel (Ni) and copper (Cu) in air samples of solid waste management sites, a total of 16 times survey was made at solid waste disposal sites and transfer stations of Lahore, Pakistan. Four sites were selected for sampling during the period of 2017-2018 on the basis of wet and dry season.Portable air sampler was used for sucking the air on Whatmann 41 filter paper for the collection of air samples. Metrological parameters were also measured during sampling period. Samples were analyzed by acid digestion and flame atomic absorption spectrophotometer. The average concentration of Cr, Mn, Zn, Pb, Ni and Cu in ambient air ranged between 0.09-1.97 µg/m^3, 0.09-0.25 µg/m^3, 2.18-6.15 µg/m^3, 0.59-1.24 µg/m^3, 0.27-0.34 µg/m^3,0.25-0.47 µg/m^3 in wet season and 0.13-2.19 µg/m^3, 0.01-0.61 µg/m^3, 0.22-4.96 µg/m^3, 0.31-1.46 µg/m^3, 0.29-0.32 µg/m^3, 0.17-0.36 µg/m^3 in dry season respectively.Statistical analysis (ANOVA) showed that the concentration of metals Zn, Pb and Cu was significant at four sampling sites and in both season. The relationship between metrological parameters and heavy metals were also statistically evaluated. It was determined that the ambient air within services of solid waste management sites is unsafe for adjacent population. Though more information is required to suggest the extreme separation at which air from these localities go to the encompassing level.

* **Corresponding Author:** Sana Hafeez ✉ sanahafeeznaz@gmail.com

Introduction

With the increase of population and industrialization environmental quality is deteriorating in major cities of world. Domestic solid waste along with chemicals discharge from industries have increased rate of environmental effluence. Disposal of each waste type i.e. industrial, domestic or commercial is a problem and have negative impact not only on environment but also on public health and local economics. There is no completely safe method for the disposal of waste. Environmental impacts due to the poor waste management are: wind blow litter, insects and pest's attraction and discharge of leachate which can contaminate underground water and soil. Leachate contains toxic metals which persist in soil and enter into food chain by plants and animals (Abdus-Salam, 2009).

MSW consists of organic and inorganic materials with varying size and composition from ashes to furniture and household materials which contain insect sprays, batteries, paints, chemicals and plastic made products (Rashad and Shalaby, 2007).

These products have heavy metals including Cd, Cu, Cr, Pb, Mn, Hg, Ni, Zn (Prechthai*et al.,* 2008).Only a trace amount of these metals is required for living organisms. But their increased concentration causes serious illness (Srivastava and Majumder, 2008; Sat, 2008). Heavy metals may cause kidney failure, neurological damage, blood and bone disorders (Jaishankar *et al.,* 2014). Organic waste is degraded easily but heavy metals are not affected during degradation process. In composting process when manure is prepared from MSW, heavy metals are unaffected and subjected to bioaccumulation. As a result, transported to food chain and may become hazardous to human life (Smith, 2009). So, heavy metals require serious attention during treatment process of solid waste into compost (Esakku *et al.,* 2003).

Meteorological parameters including temperature, humidity, wind speed and direction also contribute to air pollution. Wind from the direction of waste causes emission of gases, odors, heavy metals and bioaerosols. So, the people living close to solid waste management sites are at great risk (Yongming *et al.,* 2006).Rashad and Shalaby, 2007 reported that MSW dumpsite is the main source of heavy metals. They observed highest concentrations of heavy metals close to dumpsite, lowest far off from dumpsite. Metals are suspended in aerosols by two means. Firstly, by transport of fine particles from MSW. Secondly, by incineration and ignition of materials from MSW. Dust particles and ash residues with heavy metals are suspended to aerosol and finally dispersed by wind. Moreover, deposition of compost from MSW is also a source to increase heavy metals concentration. During incineration of wastes i.e. plastics, batteries and paints, heavy metals are evaporated and remain unchanged into environment. Long *et al.,* 2011documented that plastic, kitchen waste, paper and ash are the main sources of heavy metals in MSW. A number of studies examined the levels of heavy metalsin air samples of solid waste management sites globally: Thailand (Muttamara and Leong, 1997), Colorado – USA (Darragh *et al.,* 1997), Croatia (Hrsak *et al.,* 2001), Pakistan (Aiman *et al.,* 2016), India (Karthikeyan *et al.,* 2011; Peter *et al.,* 2018), Japan (Ozaki *et al.,* 2019).

In developing countries solid waste management system is not organized and causes potential risk for population and serious threats to environment. In such countries accessibility of sufficient grant and human resources is not attainable. Moreover, local administration is unable to provide basic facilities for the collection of solid waste (Mensah, 2006).

In Pakistan, waste production rate is 0.283 - 0.612 kg/capita/day (Mahmood *et al.,* 2018). While in Lahore it is estimated that waste production rate is almost 0.65 kg/capita/day (Ashraf *et al.,* 2016). Only 60% of solid waste is collected and a quantity of waste remain uncollected and lies along streets, roads, drains and vacant areas. There is no separate system for the treatment of recyclables as compared to developed countries (Batool and Nawaz, 2009).So, the data related to heavy metals in air samples of solid waste management sites is insufficient. It is necessary to monitor toxic heavy metals in and around solid waste management sites due to its strong effect on nearby communities by means of air, soil and ground water. Therefore, present research was designed to assess the levels of heavy metals (Cr, Mn, Zn, Pb, Ni, Cu) in air samples of solid waste management sites and to compare the change in concentration with respect to dry and wet season. Regression analysis was used to study the effect of metrological parameters on the concentration of heavy metals. Pearson Correlation was also used to find correlation between heavy metals and metrological parameters. The overall aim of these investigations is to create a premise for the improvement of policies in order to limit their exposure to ambient air.

Materials and methods

Study area

Lahore is the provincial capital of Punjab. According to 2017 census it has population of about 11.13 million with covering an area of about 1,772 km^2, of which 31% rural and 69% urban. The rate of population growth is 4.12%. Lahore is distributed into nine towns. These towns are further divided into 150 union councils. In Lahore solid waste management is the responsibility of Lahore Waste Management Company (LWMC), which was established on March 2010. LWMC is responsible to ensure waste collection, its transportation and disposal. The company contracted in March 2012, to two Turkish private organizations, M/s OzPak and M/s Albayrak, for the collection and transportation of waste to disposal site.

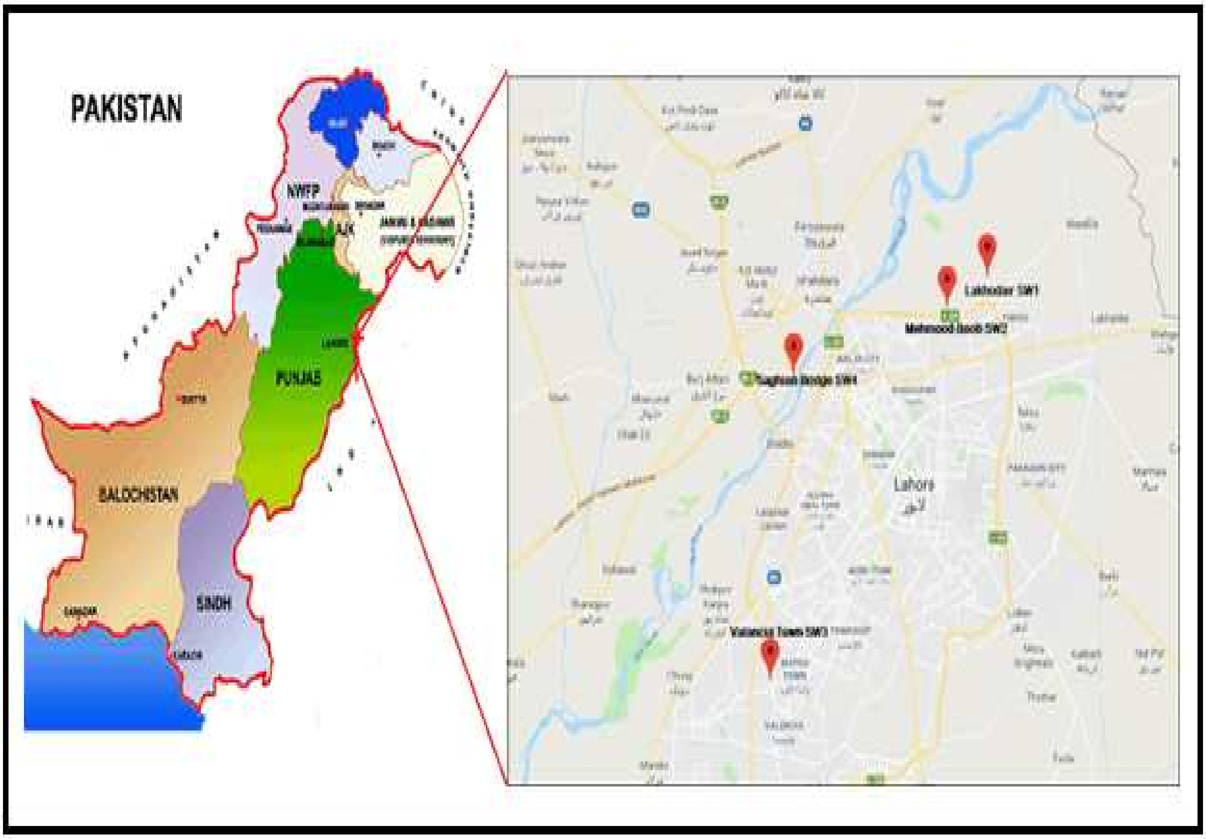

Fig. 1. Location of sampling sites Lahore, Pakistan.

Four sites of Lahore were selected including two waste disposal sites and two solid waste transfer stations. Sites including Lakhodair disposal site, MehmoodBooti disposal site, Valencia town transfer station and Saghian bridge transfer stationwere labelled as SW1, SW2, SW3 and SW4 respectively.The locations of selected sites are shown in (Fig. 1). These sites receive all type of waste materials except industrial and medical waste. Complete description of these sites are given in Table 1.

Sample collection

A total of sixteen samples were collected during 16 sampling periods between July 2017 to June 2018 on the basis of wet and dry season.Four samples from four sites were collected on each visit. Portable Dust Sampler (model, L30 MKIII by Rotheroe and Mitchell Ltd) with average air flow rate of 36.0 l/mwas used to suck the air on Whatmann 41 filter paper (20-25µm pore size and 47mm diameter) placed on suction chamber nozzle of dust sampler. Whatmann filter paper is composed of cotton linters and show retention of particles on its surface. Trace metals were collected on its surface.Samples were collected at a height of 1m above ground level and 200cm far away from source.

The sampling time at each site ranging 3-4 hours. During sampling, meteorological parameters including relative humidity, temperature and wind velocity were also measured by Aeroqual 500 series monitor probe andKestrel 4500 Pocket Weather Tracker.

Chemical analysis

Each of the Whatmann filter paper was placed in a round bottom flask and 3ml of HNO_3 and 1ml of $HClO_4$ was added into the flask. The process of acid digestion was completed at 150 °C for two hours. After complete digestion the solution was filtered and diluted with distilled water up to the volume of 15ml. The heavy metals in solution were analyzed by flame atomic absorption spectrophotometer. It is widely used method for the analysis of metals in air samples because of its low cost, wide dynamic range, sensitivity and reproducibility (Shevchenko *et al.,* 2003; Jimmy *et al.,* 2001).

Statistical analysis

Statistical analysis was accomplished by using SPSS VERSION 22. In order to study the effect of temperature, humidity and wind speed on the concentration of heavy metals Regression analysis was made. Moreover, Pearson Correlation analysis was conducted on dataset to confirm relationship between metrological parameters and heavy metals.

Results

Variations in the concentration of heavy metals such as Cr, Mn, Zn, Pb, Ni and Cu in air samples of solid waste transfer stations and disposal sites during wet and dry season are shown in Table 2.

Table 1. Sampling sites description.

Description of sites	Activities
Lakhodair disposal site (SW1)	
An area of total 52 Hectares with 28 Hectares covered area. Total six plots but only two plots are operational since April, 2016. These two operational plots receive 2000-2500 tons per day of waste.	Compacting of waste layers, transportation activities, sorting, unloading of waste and mechanical leveling of earth.
MehmoodBooti disposal site (SW2)	
An old disposal site in Lahore since 1995 and after receiving 6 million tons of waste it was saturated till 2010	No distinct activities except transportation
Valencia town transfer station (SW3)	
It is covering an area of about 15 kanal and is managing 1,000 tons of MSW every day.	Transportation activities, sorting, loading and unloading of waste material. Workshop activities for maintaining vehicles. In the absence of electricity generator works.
Saghian bridge transfer station (SW4)	
It consists of an area of 10 kanal and is capable of managing 1,400 tons of waste on daily basis. It is serving its operational waste management practices in forty six union councils of Lahore	Transportation activities, sorting, loading and unloading of waste material. Workshop activities for maintaining vehicles. In the absence of electricity generator works

The average heavy metal concentrations including Cr, Mn, Zn, Pb, Ni and Cu in ambient air of solid waste management sites showed maximum values as 2.19, 0.61, 6.15, 1.46, 0.34, 0.47 µg/m3 respectively and minimum values as 0.09, 0.01, 0.22, 0.31, 0.29, 0.17 µg/m3 respectively in all sampling sites of Lahore during wet and dry season.

Table 2. Heavy metal concentration (µg/m3) in the air of four sampling sites during wet (WS) and dry season (DS).

Sr No	Parameters	SW1		SW2		SW3		SW4	
		WS	DS	WS	DS	WS	DS	WS	DS
1	Cr	0.09	2.19	1.97	0.13	0.13	0.14	0.14	0.14
2	Mn	0.13	0.61	0.09	0.2	0.25	0.25	0.22	0.01
3	Zn	3.09	4.96	2.18	4.84	3.07	0.32	6.15	0.22
4	Pb	0.6	0.68	0.66	1.46	0.59	0.33	1.24	0.31
5	Ni	0.34	0.32	0.27	0.31	0.32	0.29	0.32	0.29
6	Cu	0.47	0.36	0.25	0.34	0.26	0.22	0.35	0.17

Results of Univariate Analysis of Variance showed that Cr, Mn and Ni concentration was not changed at four sampling sites during both seasons. Their mean concentration was parallel at four sampling sites. However, Zn metal showed significant difference ($p=0.032$) at 0.05 level of significancebetween wet and dry season in each of the four sampling sites. In dry season an increase in concentration of Zn ($p=0.009$) at 0.01 level of significance was observed than that of wet season. Pb also showed significant difference between seasons with $p=0.723$ at 0.01level of significance.Cu showed significant difference ($p=0.083$) at 0.1 level of significance on the average with respect to four sampling sites. In dry season the average concentration of Cu was higher ($p=0.031$ at 0.05 level of significance) as comparedto wet season.

Table 3. Existing meteorological parameters in the air of four sampling sites during wet (WS) and dry season (DS).

SrNo	Parameters (4 hrave.)	SW1		SW2		SW3		SW4	
		WS	DS	WS	DS	WS	DS	WS	DS
1	Temperature(˚C)	38.39	35.49	32.09	27.64	36.14	38.86	29.83	35.34
2	Humidity (%)	36.63	24.42	48.59	50.33	32.8	37.28	50.38	46.37
3	Wind speed(m/s)	2.2	1.34	2.44	1.01	1.65	0.8	0.56	0.87

During sampling periodmetrological measurements such as temperature, humidity and wind speed ranged between 27.64 - 36.5˚C, 24.42 to 50.38 % and 0.56 to 2.44 m/s as shown in Table 3. In order to study the effect of weather parameters on the concentration of metals regression modelling for each metal was applied. Wind speed was significantly effecting the Cr concentration. Cr concentration was increased with the increase of wind speed.Cr and Zn concentration was decreased with the increase of temperature and humidity. Temperature was also significantly related to the concentration of Pb and

Cu. With the increaseof temperature their concentration was decreased.Pearson correlation between meteorological parameters and heavy metals in air samples showed that temperature was negatively correlated with Zn and Pb at p= 0.05 (2-tailed) and p= 0.01 (2-tailed) respectively. While the other parameters were positively correlated with each other as shown in Table 4.

Discussions

Pb concentration was higher than that of permissible WHO value (0.5 µg/m3) at all sampling sites except in dry season at SW3 and SW4 sites. According to WHO (WHO, 2002) and USEPA (Yoshida, 1988) guidelines Mn concentration is 0.15 µg/m3. In this study its concentration was higher during dry season of all sampling sites except SW4, where it showed higher level in wet season. Cr concentration was below the permissible standards (1.1 µg/m3) for ambient air metals except only one of the two seasons at SW1 and SW2 sites (dry and wet respectively). The comparison of heavy metal concentration with European Commission guidelines showed that Ni was in higher concentration than permissible levels (0.01-0.05 µg/m3) at all sites (European Commission, 2000).

Table 4. Pearson Correlation between meteorological parameters and heavy metals.

Parameters	Temp °C	Humidity %	Wind speed m/s	Cr	Mn	Zn	Pb	Ni	Cu
Temp °C	1								
Humidity %	-.590*	1							
Wind speed m/s	.188	-.028	1						
Cr	-.194	.086	.566*	1					
Mn	.179	-.204	-.290	-.267	1				
Zn	-.609*	.047	-.095	.224	.060	1			
Pb	-.780**	.490	-.199	.053	.128	.658**	1		
Ni	.020	-.228	-.038	-.184	.302	.334	.435	1	
Cu	-.313	-.108	.034	-.168	.346	.601*	.518*	.682**	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

The present results revealed that Cr, Ni and Cu levels were lower while Zn concentration was higher as compared to a study made by Rashad and Shalaby, 2007 at two dumpsites in Alexandria, Egypt for the ambient air, vegetation and soil. They measured levels of heavy metals in different directions and distances. They observed maximum levels of Cd, Cu, Ni, Cr and Zn as 1.35, 3.17, 2.85, 3.05 and 2.40 µg/m3 and minimum levels as 0.20, 0.35, 0.31, 0.35 and 2.10 µg/m3 respectively.

Meteorological conditions including temperature, relative humidity and wind speed also influence the concentration of heavy metals suspended into particulate matter (PM). In this study, overall increased level of heavy metals were observed in wet season than in dry season and are comparable to the results of Ambade, 2014 who studied increased concentration of heavy metals related to the particulate matter in winter as compared to other seasons. Kulshrestha *et al.,* 2009 reported an increased concentration of PM in winter season than that of summer season. This increase in concentration was associated with meteorological parameters (low temperature and moderate humidity) which contributes poor dilution of chemicals in winter. Melaku *et al.*, 2008 observed strong relationship between heavy metals and meteorological measurements in ambient air.

In another study Lee *et al.,* 2007 reported seasonal differences of heavy metals in ambient air of two cities of china. Hong Kong city showed an increase level of heavy metals during winter than summer whereas Guangzhou showed no seasonal variation. A single study made in Kolkata, India showed characterization and identification of pollutants in industrial and residential areas, where Cd, Fe, Mn, Ni, Pb and Zn levels were higher in winter as compared to summer due to the inversion of low temperature (Karar and Gupta, 2006).Along with that of meteorological parameters other activities like combustion process and firework festivals globally also have impact on PM and heavy metals in ambient air: China (Wang*et al.*,2007), India (Barman*et al.*,2008; Sarkar*et al.*,2010), Girona – Spain (Moreno*et al.*,2010), Taiwan (Tsai*et al.*,2012).

Mn is discharged into air by the process of ignition and manufacturing of alloys and steel (Sharma and Patil, 1992). Solid waste including paper, ash, kitchen waste and plastic contributed to 55 – 96% of MSW and are main components of Cu (76%) and Zn (82%) (Long *et al.,* 2011). Discarded batteries and electrical equipment, fabrics, alloys and tanned leather are sources of heavy metals like Cr, Ni and Cd into dumpsites (Ihedioha*et al.,* 2017). MSW can account a role for the emission of lead into atmosphere after incineration. Moreover, in Lahore city rapid industrialization also increased the emission of lead by use of coal as fuel (Ali and Athar, 2010). This study showed that Zn and Pb are positively correlated and are comparable to the result of Sakata *et al.,* 2000who examined a positive correlation between Pb and Zn, Cd and As in Japan to study the role of MSW incineration to the concentration of heavy metals. Zn and Pb showed a positive correlation with Cu. This study also exhibited a positive relationship between Ni and Cu. Such positive or direct relationships are comparable to a study made in north china for the assessment of heavy metals in the vicinity of MSW incinerator, where Zn was significantly correlated with Cu and Pb. Moreover, metals such as Cr, Pb, Ni and Cu were also positively correlated with one another (Ma *et al.,* 2018).

Conclusion

This study analyzed the concentration of heavy metals during wet and dry season in the vicinity of solid waste management sites of Lahore. Such sites are serious source of heavy metals. Some of the metals concentration was higher than that of permissible level which can pose health risks. Cr, Mn and Ni concentration was not changed while Zn, Pb and Cu showed significant difference in their concentration between seasons.Metrological conditions play key role with respect to heavy metals. In Pakistan incomplete data is available regarding the levels of heavy metal in and around solid waste disposal sites and transfer stations. More studies are required to access the levels of heavy metals from such sites. However, this study provide basis for the concentration of heavy metals in and around solid waste management sites.In orderto reduce pollutant levelscontinuous air monitoring should be considered by regulation authoritiesandgood management approach should be implemented at such sites to prevent poor air quality.

References

Abdus-Salam N. 2009. Assessment of heavy metals pollution in dumpsites in Ilorin Metropolis. Ethiopian Journal of Environmental Studies and Management **2,** http://dx.doi.org/10.4314/ejesm.v2i2.45926

Aiman U, Mahmood A, Waheed S, Malik RN. 2016. Enrichment, geo-accumulation and risk surveillance of toxic metals for different environmental compartments from MehmoodBooti dumping site, Lahore city, Pakistan. Chemosphere **144,** 2229-2237. https://doi.org/10.1016/j.chemosphere.2015.10.077

Ali M, Athar M. 2010. Impact of transport and industrial emissions on the ambient air quality of Lahore City, Pakistan. Environmental monitoring and assessment **171,** 353-363. http://doi.org/10.1007/s10661-009-1283-0

Ambade B. (2014). Seasonal variation and sources of heavy metals in hilltop of Dongargarh, Central India. Urban climate **9,** 155-165. https://doi.org/10.1016/j.uclim.2014.08.001

Ashraf U, Hameed I, Chaudhary MN. 2016. Solid waste management practices under public and private sector in Lahore, Pakistan. Bulletin of Environmental Studies **1,** 98-105.

Barman SC, Singh R, Negi MPS, Bhargava SK. 2008. Ambient air quality of Lucknow City (India) during use of fireworks on Diwali Festival. Environmental monitoring and assessment **137(1-3),** 495-504. https://doi.org/10.1007/s10661-007-9784-1

Batool SA, Ch MN. 2009. Municipal solid waste management in Lahore city district, Pakistan. Waste management **29,** 1971-1981. https://doi.org/10.1016/j.wasman.2008.12.016

Darragh AH, Buchan RM, Sandfort DR, Coleman RO. 1997. Quantification of air contaminants at a municipal sewage sludge composting facility. Applied occupational and environmental hygiene**12,** 190-194. https://doi.org/10.1080/1047322X.1997.10389487

Esakku S, Palanivelu K, Joseph K. 2003. Assessment of heavy metals in a municipal solid waste dumpsite. In Workshop on sustainable landfill management**35,** 139-145.

European Commission. 2000. Ambient air pollution by AS, Cd and Ni compounds. Position Paper. Office for official publications of the European Communities. Luxembourg. ISBN 92-894-2054- 5.

Hrsak J, Sisovic A, Skrbec A, Sega K. 2001. Seasonal differences in the levels of suspended particulate matter and heavy metals in the vicinity of a waste dump. Atmospheric environment **35,** 3543-3546. https://doi.org/10.1016/S1352-2310(01)00083-8

Ihedioha JN, Ukoha PO, Ekere NR. 2017. Ecological and human health risk assessment of heavy metal contamination in soil of a municipal solid waste dump in Uyo, Nigeria. Environmental geochemistry and health **39,** 497-515. https://doi.org/10.1007/s10653-016-9830-4

Jaishankar M, Tseten T, Anbalagan N, Mathew BB, Beeregowda KN. 2014. Toxicity, mechanism and health effects of some heavy metals. Interdisciplinary toxicology **7,** 60-72. https://doi.org/10.2478/intox-2014-0009

Jimmy CY, Ho KF, Lee SC. 2001. Determination of lead in fine particulates by slurry sampling electrothermal atomic absorption spectrometry. Fresenius journal of analytical chemistry **369,** 170-175.

Karar K, Gupta AK. 2006. Seasonal variations and chemical characterization of ambient PM10 at residential and industrial sites of an urban region of Kolkata (Calcutta), India. Atmospheric research **81,** 36-53. https://doi.org/10.1016/j.atmosres.2005.11.003

Karthikeyan OP, Murugesan S, Joseph K, Philip L. 2011. Characterization of Particulate Matters and Volatile Organic Compounds in the Ambient Environment of Open Dump Sites. Universal Journal of Environmental Research and Technology **1,**

Kulshrestha A, Satsangi PG, Masih J, Taneja A. 2009. Metal concentration of PM2. 5 and PM10 particles and seasonal variations in urban and rural environment of Agra, India. Science of the Total Environment **407,** 6196-6204. https://doi.org/10.1016/j.scitotenv.2009.08.050

Lee CS, Li XD, Zhang G, Li J, Ding AJ, Wang T. 2007. Heavy metals and Pb isotopic composition of aerosols in urban and suburban areas of Hong Kong and Guangzhou, South China—evidence of the long-range transport of air contaminants. Atmospheric Environment **41,** 432-447. https://doi.org/10.1016/j.atmosenv.2006.07.035

Long YY, Shen DS, Wang HT, Lu WJ, Zhao Y.

2011. Heavy metal source analysis in municipal solid waste (MSW): case study on Cu and Zn. Journal of hazardous materials **186,** 1082-1087. https://doi.org/10.1016/j.jhazmat.2010.11.106

Ma W, Tai L, Qiao Z, Zhong L, Wang Z, Fu K, Chen G. 2018. Contamination source apportionment and health risk assessment of heavy metals in soil around municipal solid waste incinerator: a case study in North China. Science of the Total Environment **631,** 348-357. https://doi.org/10.1016/j.scitotenv.2018.03.011

Mahmood S, Sharif F, Rahman AU, Khan AU. 2018. Analysis and forecasting of municipal solid waste in Nankana City using geo-spatial techniques. Environmental monitoring and assessment **190,** 275. https://doi.org/10.1007/s10661-018-6631-5

Melaku S, Morris V, Raghavan D, Hosten C. 2008. Seasonal variation of heavy metals in ambient air and precipitation at a single site in Washington, DC. Environmental pollution **155,** 88-98.

Mensah A. 2006. People and their waste in an emergency context: the case of Monrovia, Liberia. Habitat international **30,** 754-768.

Moreno T, Querol X, Alastuey A, Amato F, Pey J, Pandolfi M, Gibbons W. 2010. Effect of fireworks events on urban background trace metal aerosol concentrations: is the cocktail worth the show. Journal of Hazardous Materials**183,** 945-949.

Muttamara S, Leong ST. 1997. Environmental monitoring and impact assessment of a solid waste disposal site. Environmental Monitoring and Assessment **48,** 1-24.

Ozaki H, Ichise H, Kitaura E, Yaginuma Y, Yoda M, Kuno K, Watanabe I. 2019. Immutable heavy metal pollution before and after change in industrial waste treatment procedure. Scientific reports **9,** 1-12.

Peter AE, Nagendra SS, Nambi IM. 2018. Comprehensive analysis of inhalable toxic particulate emissions from an old municipal solid waste dumpsite and neighborhood health risks. Atmospheric Pollution Research **9,** 1021-1031.

Prechthai T, Parkpian P, Visvanathan C. 2008. Assessment of heavy metal contamination and its mobilization from municipal solid waste open dumping site. Journal of Hazardous Materials **156,** 86-94.

Rashad M, Shalaby EA. 2007. Dispersion and deposition of heavy metals around two municipal solid waste (MSW) dumpsites, Alexandria, Egypt. American-Eurasian Journal Agricultural and Environmental Science **2,** 204-212.

Sakata M, Kurata M, Tanaka N. 2000. Estimating contribution from municipal solid waste incineration to trace metal concentrations in Japanese urban atmosphere using lead as a marker element. Geochemical Journal **34,** 23-32.

Sarkar S, Khillare PS, Jyethi DS, Hasan A, Parween M. 2010. Chemical speciation of respirable suspended particulate matter during a major firework festival in India. Journal of Hazardous Materials **184,** 321-330.

Sat IG. 2008. The effect of heavy metals on peroxidase from Jerusalem artichoke (Helianthus tuberosus L.) tubers. African Journal of Biotechnology **7(13),**

Sharma VK, Patil RS. 1992. Chemical composition and source identification of Bombay aerosol. Environmental Technology **13,** 1043-1052.

Shevchenko V, Lisitzin A, Vinogradova A, Stein R. 2003. Heavy metals in aerosols over the seas of the Russian Arctic. Science of the total environment **306,** 11-25.

Smith SR. 2009. A critical review of the bioavailability and impacts of heavy metals in municipal solid waste composts compared to sewage sludge. Environment international **35,** 142-156.

Srivastava NK, Majumder CB. 2008. Novel biofiltration methods for the treatment of heavy metals from industrial wastewater. Journal of hazardous materials **151,** 1-8.

Tsai HH, Chien LH, Yuan CS, Lin YC, Jen YH, Ie IR. 2012. Influences of fireworks on chemical characteristics of atmospheric fine and coarse particles during Taiwan's Lantern Festival. Atmospheric environment **62,** 256-264.

Wang Y, Zhuang G, Xu C, An Z. 2007. The air pollution caused by the burning of fireworks during the lantern festival in Beijing. Atmospheric Environment **41,** 417-431.

WHO. 2002. Air quality guidelines for Europe. Second edition. WHO regional publications. European series; No. 91. Regional Office for Europe Scherfigsvej 8, DK-2100 Copenhagen O, Denmark.

Yongming H, Peixuan D, Junji C, Posmentier ES. 2006. Multivariate analysis of heavy metal contamination in urban dusts of Xian, Central China. Science of the total environment **355,** 176-186.

Yoshida K. 1988. Ambient air quality standards. Journal of Toxicological Sciences**13,** 262–264.