ORIGINAL ARTICLE

The Association of Reported Respiratory Symptoms among Children in Malaysia with Particulate Matter Exposure in Municipal Solid Waste Landfills

Dora Esphylin, Sharifah Norkhadijah Syed Ismail, Sarva Mangala Praveena, Zailina Hashim and Emilia Zainal Abidin

Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

ABSTRACT

Background: Prolonged exposure of heavy metals in the respirable particulate matter (PM10) from municipal solid waste (MSW) landfills may affect children health. Objective: To investigate the association of reported respiratory symptom with heavy metals in PM10, with heavy metals in fingernails among children residing close to MSW landfills. **Methods:** Two groups of children age 7 to 12 years old were involved in this cross-sectional study. Those residing within 3 km radius from a landfill were the exposed group and those residing more than 3 km radius as the unexposed group. Questionnaires adapted from American Thoracic Society were applied in the survey. Fingernails were used as biomarker. Ten heavy metals elements in PM and fingernail samples were analysed using inductively coupled plasma mass spectrometry (ICP-MS). **Results:** The cadmium, chromium, copper, manganese, nickel and lead concentrations in PM around the MSW landfills and residential areas exceeded the Canada and USEPA standard permissible limit. Heavy metals in fingernails ($p<0.001$) of exposed group were significantly higher than the unexposed group. Children with no pets have less reported respiratory symptoms. Elevated level of heavy metals in PM and fingernails were associated with high risk of reported respiratory symptoms. **Conclusion:** Heavy metals in PM10 and fingernails were associated with potential risk factor of respiratory health in children.

Keywords: Heavy metals, Children, Fingernails, Biomarker, Landfill

Corresponding Author:
Sharifah Norkhadijah Syed Ismail, PhD
Email: norkhadijah@upm.edu.my
Tel: + 603 8947 2643

INTRODUCTION

The health of children can easily be affected by various exposure pathways: through the air, soil, dust, drinking water and the food chain. Children between 7 and 12 years are the focus in this study as at this age they have a young and immature respiratory system and they are very active in indoor and outdoor activities (1).

Previous studies had reported the association of heavy metals and exposure to air pollution as the cause of reduced lung function and higher prevalence of respiratory symptoms and diseases in children and adults (2–5). Furthermore, Riedl (2008) had reported that higher symptoms of cough, bronchitis, asthma and chronic obstructive pulmonary disease had been associated with an elevated air pollutant levels. Past studies had also reported an association of air pollution with childhood hospital admission, school absenteeism, physician visits for upper and lower respiratory illnesses, deficits in lung-function growth rates, bronchitis, chronic cough, and increased infant mortality (7).

Malaysia currently has a total number of 158 operating landfills, yet only 12 percent of the landfills are of the modern sanitary type (2). The government has classified the landfills into different levels; non-sanitary landfill (Level 0 to 3) and sanitary (Level 4) in improvising the efficiency of deposited landfill sites (3).

The classification of landfill as different level was made based on the facility it has; Level 0 is an open dumping, Level 1 is a non-sanitary landfill with controlled tipping, Level 2 is a non sanitary landfill with daily soil covering and Level 3 is a non-sanitary landfill with a leachate recirculation system. Level 4 is a sanitary landfill with a leachate treatment system. Comprehensive written reports at present that define the health outcome of children living in the vicinity of landfills in Malaysia associated with heavy metals exposure are few and far between. A study in former landfill that produce landfill gas found a significant relationship between respiratory symptom with peak expiratory flow rate (L/min) reading among students in a school near a former landfill site (4). Previous study on health risk assessment at landfill sites on child scavengers showed non-carcinogenic risks, for heavy metals (i.e. As, and Se) were found to be exceeded the USEPA acceptable level (5).

The objective of this study is to assess the association between reported respiratory symptom in exposed children living close to MSW landfills with the heavy metals levels (i.e., Al, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn) in particulate matter (PM10) and accumulation of heavy metals in fingernails as biomarker.

MATERIALS AND METHODS

Description of the study area

A cross-sectional study was conducted in four different states in the western states (i.e. Melaka, Negeri Sembilan and Selangor) and east states (ie. Pahang) of Peninsular Malaysia. Krubong Landfill in Melaka is categorised as landfill type Level 1; Pajam Landfill (Negeri Sembilan) is under landfill type Level 2; Panchang Bedena (Selangor) and Jabor Jerangau (Pahang) are Level 3 (Table I).

A residential area less than a 3-km radius from the landfill were selected as the exposed area. A residential area situated more than 3-km radius from the landfill was referred as the unexposed area. This has been chosen for comparison purposes. Respondents from both areas have similar socioeconomic characteristics. Neither area was known to be exposed to any other source of environmental pollution. All selected areas are considered as urban, except for Panchang Bedena and Simpang Lima in Selangor, which are suburban.

Study Population

Name of the respondent from Grade 1 to Grade 6 (aged between 7 and 12 years old) was selected randomly from school attendance record list in 11 selected primary schools with permissions. Selected respondents were briefed on the purpose of this study. Parents Consent Form and Parent Information Sheet were given through the respondents to be completed by their parents. Questionnaires were then handed out to the selected respondents in school and filled out by their parents with their written consent. The socio-demographic data as well as medical history of the were obtained from the questionnaires.

All of the selected exposed schools were located in the proximity of the four MSW landfill sites. All respondents were Malaysian with normal health status. Exposed children lived less than a 3-km radius away from a landfill as a benchmark as suggested by a study (6). The unexposed children lived more than a 3-km the landfill (6). Data were collected simultaneously in the areas from the four states from August to October in 2014.

Questionnaires

The health of the respondents was assessed using the modified version of the Children Health Questionnaires (CHQ) and the American Thoracic Society's: Recommended Respiratory Disease Questionnaire (2005). These questionnaires consisting of 139 items were translated into the Malay language. The questionnaires were divided into four parts - Part 1: Socio-demographic, Part 2: Respondent's Health Respiratory Status, Part 3: Parent's/Family Smoking Behaviour and Part 4: Daily food consumption and lifestyle. All questionnaires were answered by the respondents' parents. Cronbach's Alpha reliability test was carried out to measure their internal consistency and reliability and the value was 0.71, indicate good reliability.

Particulate matter (PM10) sampling

The PM10 samples were collected using Sensidyne Gilian GilAir-5 adapted method from EPA 201A (7). This instrument was an active personal air sampling/ air monitoring system which able to operate at a flow

Table I: Distribution of the study area

States	Landfill names, types & GPS coordinates	Total respondents (N=342)		Residential areas	
		Exposed (n=202)	Unexposed (n=140)	Exposed	Unexposed
Melaka	Krubong Landfill (Level 1)[a] 2°17′9.96″N; 102°15′5.04″	94	61	Krubong	Paya Rumput
Negeri Sembilan	Pajam Landfill (Level 2)[b] 2°50′10.55″N; 101°51′0.15″E	36	19	Pajam	Desa Cempaka, Taman Semarak
Selangor	Panchang Bedena Landfill (Level 3)[c] 3°41′26.36″N; 100°57′50.06″E	20	15	Panchang Bedena	Simpang Lima
Pahang	Jabor Jerangau (Level 3)[c] 2°50′10.55″N; 101°51′0.15″E	52	45	Balok, Balok Makmur	Sungai Talam, Indera Mahkota

[a]Level 1-non-sanitary with daily soil covering
[b]Level 2-non-sanitary with ban and daily soil covering
[c]Level 3-non-sanitary with leachate collection pond

rate of 1 to 5000 cc/min. The instruments were charged for 6 hours before used. After fully recharged, GilAir-5 samplers were calibrated at 2 L/min flow rate (8). To collect PM10 in landfill, cyclones were used with 37mm cassette size and filter papers. Filter papers were dried in an oven at the temperature of 60°C for 45 minutes before weighing. Pre-and post sample weighing was made 3 times before and after sampling. Sample weighing was measured using an analytical filter microbalance (Cahn C-35) with a resolution of 1 µg and ± 2 µg sensitivities.

Each GilAir-5 was mounted on a 70 mm diameter wooden rod which was fixed approximately 1 m from the ground using adapted method (9). The sampling pumps were placed in middle of open space in the field. Each instruments were placed starting at the boundary of the landfill and at various distances; <1 km, 1-2 km, 2-3 km and 3 km until to the respondent's residential area and school. Sampling time started at 7 am in the morning over duration of 7 hours. Samplings were made for 3 times, in a period 3 days in a week. Completed samples collected in cassette were sealed with a second transparent film, locked inside the zip lock plastic before transporting to the laboratory.

Fingernail Samplings

Standard method (10) was adapted for fingernails sample collection. Respondents were asked to clean their hands thoroughly with distilled water and medicated soap to avoid any potential trace metals contaminant. Fingernails were cut using stainless steel nail clippers. All fingernail samples of exposed and unexposed respondents (N=342) were kept in separate airtight plastic bags prior to treatment and analysis.

PM10 sample analysis

A standard method (11) was used using microwave digestion system (Multiwave 3000) with a rotor for sixteen Teflon digestion vessels for sample digestion (11). Filter paper from air sampling pump was weighted and inserted into a clean and dry Teflon digestion vessel. Nine millilitres (mL) of concentrated nitric acid (HNO3) was added, followed by 3 mL of hydrofluoric acid (HF) and 2 mL of hydrochloric acid (HCl). Finally, 1 mL hydrogen peroxide (H2O2) was added in the vessels and placed in the microwave. After digestion, the flasks were left to cool to remove excess acid and 5 mL of 0.1 M HNO3, were added to the residue and diluted with deionised water up to 10 mL in the volumetric flasks. For quality assurance/quality control (QA/QC) purposes, the standard reference materials and reagent blanks were digested and diluted in the same manner. Analysis for a range of metals was carried out by ICP-MS for metal content. In this study, ten elements (i.e., Al, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn) have been determined.

Fingernail analysis

In order to achieve a shorter digestion time, a standard microwave digestion method by EPA (11) was referred using Multiwave 3000 (11). Approximately, 0.5 to 1.0 g of fingernails sample was weighted and inserted into a clean and dry Teflon digestion vessel. Nine mL of concentrated HNO3 was added, followed by 2 mL of HCl and 1 mL of H2O2. The vessels were then closed, placed into the rotor and placed in the microwave. The vessels then heated to 180 °C over 5.5 minutes and then held at 180 °C for 9.5 minutes. After cooling for 30 min, the vessels were opened carefully. After digestion, the flasks were left to cool to remove excess acid. Five mL of 0.1 M HNO3, were added to the residue and diluted with deionised water up to 10 mL in volumetric flasks (11). The standard reference materials and reagent blanks were digested and diluted in the same manner. Analysis for a range of metals was carried out by ICP-MS for metal accumulation content in fingernails. In this study, ten elements (i.e., Al, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn) have been determined.

Statistical analysis

All the data were analyzed using the IBM SPSS Software, windows version 20.0. Descriptive statistics and the Chi-squared test were used to analyze the socio-demographic background of the respondents. Distribution of particulate matter on MSW landfills for the residential areas was analysed using the One-way ANOVA. The difference of heavy metals accumulation and reported respiratory symptoms between groups was performed using Mann-Whitney and Chi-Square test. Hierarchical multiple logistic regression analysis was performed to determine the association between heavy metals in airborne bound metals and heavy metals in fingernails with socio-demographic background and respiratory health symptoms.

RESULTS

Socio-demographic background

The socio-demographic characteristics of the study population are shown in Table II. The response rate of this study was 52%. Malays made up a majority of the respondents aged between 7 to 12 years. The highest education level was at secondary school (n=128) whereas most of the father in the unexposed group had a tertiary education level (n=74). Majority of the respondents was in the high income group. Almost half of the exposed respondents lived 1 to 2 km from the landfill. Respondents living in the vicinity of Level 1 landfill type accounted for the highest number.

Concentration of heavy metals in PM10

Table III shows the distribution of heavy metal concentrations in PM10 around the MSW landfill and residential areas. The highest mean concentration of heavy metals in the PM in the landfill was Al (117.25 ± 23.43 µg/m3 in landfill Level 1. In comparison between Level 1, Level 2 and Level 3-landfill types, only Al, Cd and Ni concentrations showed significant difference.. Similar trend was observed in the residential areas

Table II: Socio-demographic background

Variables		Category	Exposed N=202 (%)	Unexposed N=140 (%)
Gender		Boys	96 (47.5)	59 (42.1)
		Girls	106 (52.5)	81 (57.9)
Age (years)		7-10	68 (33.7)	55 (39.3)
		11-12	134 (66.3)	85 (60.7)
Ethnicity		Malay	187 (92.6)	136 (97.1)
		Non-Malay	4 (2.0)	1 (0.7)
Father's education level		Primary	3 (1.5)	0 (0.0)
		Secondary	128 (63.4)	63 (45.0)
		Tertiary	59 (29.2)	74 (52.9)
Socio economic status [a]		Poor	20 (9.9)	20 (14.3)
		Intermediate	59 (29.2)	31 (22.1)
		High	109 (54.0)	89 (63.6)
Number of siblings		<3	31 (15.3)	25 (17.9)
		3 to 5	141 (69.8)	99 (70.7)
		>5	29 (14.4)	16 (11.4)
Having a pet		Yes	57 (28.2)	31 (22.1)
		No	139 (68.8)	108 (77.1)
Canned food consumption[*,b]		Regular	87 (43.1)	43 (30.7)
		Irregular	105 (52.0)	96 (68.6)
Smoking habit	Father	Yes	61 (30.2)	42 (30.0)
	Mother	Yes	3 (1.5)	1 (0.7)
	Other family member	Yes	9 (4.5)	5 (3.6)
Length of residence (years)		<5 years	41 (20.3)	22 (15.7)
		> 5 years	161 (79.7)	118 (83.3)
Residential distance from landfill		<1 km	22 (10.3)	0 (0.0)
		1 km to 2 km	103 (48.1)	0 (0.0)
		>2 km to 3 km	77 (36.0)	0 (0.0)
		>3 km	0 (0.0)	140 (100.0)
Landfill types [c]		Level 1	94 (46.5)	0 (0.0)
		Level 2	33 (16.3)	0 (0.0)
		Level 3	75 (37.1)	0 (0.0)
		No landfill nearby	0 (0.0)	140 (100.0)

Chi square test

[a] Poor: income/month<RM 1,000; Intermediate: RM 1,000-RM 2,000; and High > RM 2,000, according to the Malaysia Poverty Line (Economic Planning Unit, 2009); [b] Regular: >3 times a week; Irregular: once a month; [c] Level 1: non-sanitary with daily soil covering; Level 2: non-sanitary with ban and daily soil covering; Level 3: non-sanitary with leachate collection pond

where the highest elements detected were Al (4.25 ± 3.17 μg/m3), Cr (2.83 ± 2.29 μg/m3) and Fe (2.96 ± 3.13 μg/m3) and most of the metals were significantly lower compared to the landfills. The metals concentrations were significantly higher in residential areas located less than 3 km from landfill.

Heavy metals concentration in fingernails

All heavy metals accumulated in fingernails were significantly higher in the exposed group than the unexposed (p<0.01) (Table IV). Fe accounted for the highest metal accumulation detected in the fingernails of the exposed respondents (171.06 ± 13.03 μg/g). Similar trend was observed for the unexposed children with Fe (79.37 ± 10.01 μg/g) as the highest metal found. Increase accumulated metal concentrations for the exposed children were in the following order; Fe > Cr > Al > Ni > Zn > Mn > Cu > Cd > Pb > Co.

Reported respiratory symptoms between exposed and unexposed children

Distribution and comparison of reported respiratory symptoms between exposed and unexposed children are in Table V. In the current study, exposed children were commonly afflicted to a higher degree with the symptoms: coughing with flu (N=79, 56.4%). On the other hand, unexposed children were afflicted to a lesser extent with coughing with flu (N=51, 25.2%). The results showed that numbers of respondents having running noses and sneezing were significantly different between the exposed and unexposed groups (p<0.05).

Table III: Distribution of heavy metal concentrations in airborne dust around MSW landfill and at the residential areas ($\mu g/m^3$)

Metals	Landfill types (N = 30)			F	P-value[a]	Residential areas by distances to landfill (N = 30)				F	P-value[b]	F	P-value[c]	Air quality standard permissible limit ($\mu g/m^3$)
	Level 1 (N=10)	Level 2 (N=10)	Level 3 (N=10)			<1 km (N=10)	1-2 km (N=10)	2-3 km (N=10)	>3 km (n=10)					
Al	117.25 ±23.43	4.61 ± 0.87	10.07 ± 7.22	88.64	<0.001**	4.25± 3.17	1.65± 1.46	3.35± 2.65	2.49± 1.46	174.22	<0.001**	25.66	0.208	-
Cd	0.34 ± 0.10	0.23± 0.13	0.14 ±0.03	10.07	0.005*	0.08± 0.07	0.05± 0.03	0.29± 0.71	0.14± 0.07	0.29	0.883	13.96	0.421	0.005 (WHO, Canada U.K & E.U)
Co	0.13 ± 0.01	0.15 ± 0.01	0.36 ± 0.38	0.89	0.445	0.05± 0.04	0.04± 0.03	0.06± 0.03	0.04± 0.02	55.15	<0.001**	11.30	0.001*	0.1 (Canada)
Cr	1.80 ± 0.59	3.27 ± 2.17	2.22 ± 0.64	1.30	0.319	2.43± 1.37	2.83± 2.29	2.26± 1.83	2.00± 1.22	1.96	0.100	40.32	0.006*	0.5 (Canada), 0.01(U.S.A)
Cu	0.61 ±0.39	1.48 ± 0.38	0.92 ±0.59	2.26	0.160	1.07± 1.32	0.41± 0.49	0.51± 0.42	0.06± 0.06	24.47	<0.001**	150.81	<0.001**	-
Fe	2.44 ±0.76	3.49 ± 2.77	3.46 ± 1.90	0.31	0.739	2.96± 3.13	2.13± 0.96	2.53± 1.21	0.67± 0.24	48.98	<0.001**	58.76	<0.001**	4.0 (Canada)
Mn	0.32 ± 0.06	0.50 ± 0.33	0.50 ± 0.31	0.45	0.654	0.32± 0.24	0.36± 0.12	0.36± 0.22	0.13± 0.07	49.41	<0.001**	22.30	<0.001**	0.02 (USEPA), 0.15 (WHO), 0.4 (Canada)
Ni	1.15 ± 0.18	0.76 ± 0.20	0.49 ± 0.26	8.10	0.010*	0.74± 0.41	0.40± 0.25	0.65± 0.55	0.67± 0.24	3.68	0.006*	25.70	0.003*	0.015 (U.S.A). 0.02 (U.K & E.U), 0.04 (Canada)
Pb	0.03 ± 0.02	0.07 ± 0.03	0.04 ± 0.03	2.19	0.168	0.04± 0.03	0.04± 0.02	0.03± 0.03	0.03± 0.01	4.70	0.001*	20.03	0.002*	0.5 (WHO, India, Canada, Australia, U.K & E.U), 1.0 (China),1.5 (Malaysia, Thailand, USEPA)
Zn	0.03 ± 0.04	0.12 ± 0.07	0.15 ± 0.06	3.88	0.061	0.11± 0.21	0.05± 0.03	0.08± 0.19	0.07± 0.06	0.973	0.422	1.24	0.882	-

[a]- comparison between landfill type (Level 1, 2 & 3); One-way ANOVA
[b] comparison between landfill and residential areas; One-way ANOVA
[c] comparison between residential areas by distance to landfill; T-test
metals that exceeded air quality standard permissible limit
*Significant at p <0.05 ** Significant at p <0.01

Table IV: Distribution of heavy metals in fingernails between exposed and unexposed children (N=342)

Variables	Mean ± SD		P-value
	Exposed children (n=202)	Unexposed children (n=140)	
[a]Heavy metals (μg/g)			
Aluminium (Al)	48.34 ± 3.44	27.60 ± 4.42	<0.001**
Cadmium (Cd)	2.71 ± 0.37	1.44 ± 0.46	<0.001**
Cobalt (Co)	1.22 ± 0.18	0.31 ± 0.07	<0.001**
Chromium (Cr)	69.51 ± 7.42	18.10 ± 2.38	<0.001**
Copper (Cu)	5.82 ± 0.43	2.93 ± 0.40	<0.001**
Iron (Fe)	171.06 ± 13.03	79.37 ± 10.01	<0.001**
Manganese (Mn)	6.42 ± 0.79	2.24 ± 0.51	<0.001**
Nickel (Ni)	25.34 ± 3.61	8.17 ± 1.69	<0.001**
Lead (Pb)	2.70 ± 0.22	1.05 ± 0.17	<0.001**
Zinc (Zn)	11.46 ± 0.69	6.96 ± 0.87	<0.001**

[a]Mann-Whitney test was used as the data were not normally distributed
**Significant at p<0.001

Table V: Distribution of perceived respiratory symptoms between exposed and unexposed children (Parental report of respondents having the symptoms)

Symptoms	Total respondents N = 342 (%)	Exposed N = 202 (%)	Unexposed N = 140 (%)	P-value
Coughing with flu, n (%)	130 (38.0)	79 (56.4)	51 (25.2)	0.224
Chest tightness with phlegm and flu, n (%)	45 (13.2)	26 (18.6)	18 (8.9)	0.906
Chest tightness with phlegm only, n (%)	22 (6.43)	15 (10.7)	7 (3.5)	0.627
Wheezing with flu, n (%)	49 (14.3)	28 (20.0)	21 (10.4)	0.802
Wheezing during night, n (%)	23 (6.73)	13 (9.3)	10 (5.0)	0.819
Runny nose, n (%)	60 (17.54)	45 (32.1)	15 (7.4)	0.020*
Sneezing, n (%)	64 (18.71)	48 (34.3)	16 (7.9)	0.014*
Watery eyes, n (%)	18 (5.26)	16 (11.4)	2 (1.0)	0.062
Sore throat, n (%)	30 (8.77)	20 (14.3)	10 (5.0)	0.334

Chi squared test
*Significant at p<0.05

Association of reported respiratory symptoms in children with socio-demographic characteristics

Gender, age, parental education, family income and smoking habits were not associated with lower risk for reporting respiratory symptoms (Table VI). Not having pets at home had significantly reduced the risk of symptoms for coughing with flu (AOR 0.34, 95% CI 0.19-0.62), running nose (AOR 0.38, 95% CI 0.19-0.74) and sore throat (AOR 0.26, 95% CI 0.10-0.60). The length of residence in the area, distance to landfills and landfills type were not associated with the lower risk for reporting symptoms.

The current study showed high Co in fingernails was associated with high risk of coughing with flu (AOR 3.53, 95% CI 1.17-10.68), sneezing (AOR 14.24, 95% CI 1.19-170.23) and sore throat (AOR 44.12, 95% CI 1.14-1710.65). Similar to high Mn, was associated with chest tightness with phlegm (AOR 18.88, 95% CI 1.05-339.40).

Reported respiratory symptoms associated with heavy metals in PM10

The results (Table VII) show that an increase of 0.1 μg/m3 outdoor Co level was associated with doubling the reported symptoms of chest tightness with phlegm and flu (AOR 2.42, 95% CI 1.11 - 5.29) and reported wheezing at night (AOR 5.00, 95% CI 1.36-18.43). Meanwhile, the risk of reported running nose (AOR 10.66, 95% CI 2.75-41.41) and sneezing (AOR 5.54, 95% CI 1.45-321.13) were increased by 5 to 11% in association with an increase of 0.005 μg/m3 of Cd level outdoor.

DISCUSSION

In this study, five elements (Cr, Cd, Ni, Mn and Co) exceed the permissible limit of air quality standard (AQS) around MSW landfills and residential areas. Chromium exceeded the permissible limit of Canada and U.S.A air quality standard; Ni exceeded the permissible limit of U.S.A, U.K and E.U, and Canada AQS; Cd exceeded

Table VI: Hierarchical logistic regression on exposures (simultaneously) associated with respiratory symptoms [a](AOR[b] (95% CI[c]))

Variables		Coughing with flu (N =130)	Chest tightness with phlegm and flu (N = 45)	Chest tightness with phlegm only (N = 22)	Wheezing with flu (N =49)	Wheezing during night (N = 23)	Runny nose (N = 60)	Sneezing (N = 64)	Watery eyes (N =18)	Sore throat (N = 30)
Gender [d](Boy)	Girl	0.60 (0.35-1.01)	0.73 (0.37-1.44)	0.77 (0.31-1.95)	1.01 (0.52-1.98)	0.85 (0.32-2.25)	0.51 (0.27-0.97)	0.51 (0.27-0.96)	0.90 (0.31-2.62)	0.96 (0.39-2.36)
Age in years [d](11-12)	7-10	0.69 (0.38-1.23)	0.75 (0.34-1.63)	0.46 (0.16-1.46)	1.06 (0.51-2.17)	0.49 (0.16-1.53)	0.47 (0.23-0.97)	0.51 (0.25-1.05)	0.20 (0.04-1.04)	0.28 (0.09-0.82)
Parental education [d](High)	Low	0.54 (0.29-1.01)	1.23 (0.55-2.76)	1.23 (0.40-3.82)	1.39 (0.64-3.00)	2.81 (0.85-9.28)	1.10 (0.51-2.41)	1.04 (0.48-2.24)	0.56 (0.11-2.75)	1.43 (0.48-4.26)
Household income [d](High income)	Low	1.58 (0.82-3.05)	1.28 (0.54-3.04)	0.63 (0.19-2.55)	1.23 (0.53-2.87)	0.46 (0.14-1.55)	1.47 (0.63-3.40)	0.83 (0.38-1.83)	0.61 (0.15-2.56)	1.43 (0.43-4.72)
Family smoking [d](No)	Yes	0.93 (0.52-1.57)	0.40 (0.19-0.84)	0.45 (0.16-1.33)	0.69 (0.33-1.46)	0.32 (0.12-0.88)	0.97 (0.44-2.12)	0.81 (0.41-1.62)	0.58 (0.16-2.15)	1.17 (0.41-3.37)
Having furry pet [d](Yes)	No	0.34 (0.19-0.62)*	0.49 (0.23-1.03)	0.57 (0.21-1.56)	0.98 (0.46-2.09)	0.35 (0.13-0.95)	0.38 (0.19-0.74)*	0.51 (0.26-1.00)	0.28 (0.08-0.95)	0.26 (0.10-0.60)*
Canned food consumption [d](Irregular)	Regular	0.96 (0.57-1.62)	0.71 (0.34-1.46)	0.64 (0.23-1.84)	0.62 (0.30-1.28)	0.85 (0.32-2.24)	1.61 (0.81-3.19)	1.29 (0.68-2.43)	2.90 (0.80-10.50)	2.27 (0.87-5.93)
Length of residence in years [d](<5)	>5	1.29 (0.65-2.53)	1.16 (0.49-2.76)	1.54 (0.53-4.51)	0.98 (0.40-2.39)	1.22 (0.38-3.99)	1.04 (0.44-2.42)	1.46 (0.67-3.15)	0.89 (0.21-3.85)	1.16 (0.38-3.57)
Distance from landfill [d](> 1 km)	< 1 km	2.39 (0.99-5.76)	1.25 (0.43-3.66)	1.15 (0.29-4.63)	0.34 (0.12-0.96)	0.51 (0.13-1.96)	0.37 (0.14-1.02)	0.86 (0.33-2.25)	0.83 (0.16-4.39)	0.15 (0.04-0.59)
Types of landfill [d](No nearby landfill)	Level 1	1.43 (0.45-4.56)	3.44 (0.57-20.82)	0.56 (0.03-1.26)	0.46 (0.10-2.23)	1.30 (0.10-16.68)	1.06 (0.16-7.31)	0.12 (0.01-1.60)	0.24 (0.01-6.87)	0.08 (0.00-3.40)
Al [d](Low)	High	0.73 (0.39-1.52)	1.25 (0.49-3.21)	1.06 (0.31-3.68)	1.10 (0.44-2.74)	3.13 (0.85-11.45)	2.15 (0.90 -5.15)	1.54 (0.69-3.43)	1.41 (0.36-5.53)	1.69 (0.48-5.99)
Cd [d](Low)	High	0.58 (0.23-1.50)	1.81 (0.50-6.48)	0.34 (0.06-1.85)	1.02 (0.34-3.10)	1.16 (0.21-6.30)	0.77 (0.23-2.58)	1.42 (0.42-4.80)	0.28 (0.03-2.79)	0.50 (0.09-2.86)
Co [d](Low)	High	3.53 (1.17-10.68)*	2.83 (0.54-14.79)	7.91 (0.59-62.62)	4.04 (0.96-17.00)	4.49 (0.43-47.32)	5.11 (0.84-31.10)	14.24 (1.19-170.23)*	9.17 (0.28-302.18)	44.12 (1.14-1710.65)*
Cr [d](Low)	High	0.37 (0.17-0.80)	0.54 (0.21-1.44)	0.75 (0.19-3.00)	0.41 (0.16-1.03)	0.27 (0.08-0.95)	0.75 (0.27-2.04)	1.73 (0.61-4.92)	3.51 (0.17-71.57)	0.42 (0.11-1.62)
Cu [d](Low)	High	0.87 (0.36-2.12)	0.31 (0.09-1.10)	0.09 (0.01-0.71)	0.18 (0.06-0.56)	0.37 (0.06-2.13)	1.33 (0.42-4.27)	0.62 (0.22-1.80)	0.59 (0.10-3.33)	2.29 (0.05-1.62)
Fe [d](Low)	High	2.56 (0.01-6.49)	1.80 (0.50-6.52)	0.68 (0.12-4.07)	1.89 (0.60-6.02)	1.85 (0.33-10.22)	3.37 (0.86-13.22)	0.31 (0.08-1.19)	3.05 (0.24-38.58)	0.66 (0.11-3.88)
Mn [d](Low)	High	0.25 (0.08-0.82)	3.77 (0.54-26.50)	18.88 (1.05-339.40)*	1.41 (0.31-6.53)	1.05 (0.13-8.72)	0.33 (0.08-1.36)	0.15 (0.39-5.96)	2.64 (0.24-28.98)	2.61 (0.34-20.19)
Ni [d](Low)	High	2.07 (0.58-7.39)	0.08 (0.01-0.72)	0.06 (0.00-1.12)	3.12 (0.54-18.06)	1.32 (0.11-16.21)	1.40 (0.28-7.08)	0.88 (0.20-3.96)	0.53 (0.04-7.68)	1.61 (0.18-14.85)
Pb [d](Low)	High	1.54 (0.55-4.36)	0.25 (0.06-1.00)	0.38 (0.06-2.33)	0.54 (0.14-2.12)	1.18 (0.17-8.22)	0.52 (0.13-1.98)	1.86 (0.44-7.82)	0.58 (0.06-5.91)	0.81 (0.11-5.69)
Zn [d](Low)	High	1.04 (0.37-2.93)	2.60 (0.62-10.95)	7.67 (0.84-70.27)	-	0.36 (0.05-2.66)	0.47 (0.14-1.64)	0.52 (0.15-1.84)	0.14 (0.12-1.31)	1.63 (0.22-12.00)
Cox & Snell R Square-Nagelkerke R Square [e]		0.18-0.24	0.48-0.64	0.61-0.82	0.45-0.60	0.59-0.79	0.44-0.58	0.39-0.51	0.65-0.87	0.59-0.79

[a] Three-level hierarchical logistic model was applied with all factors related to gender, socio-demographic, lifestyle, distance and type of landfill and biomarker level were included in the model simultaneously.
[b] OR value indication of association between an exposure and an outcome. The OR represents the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure.
[c] 95% CI indication a range of values that can be 95% certain contains the true mean of the population.
[d] Reference for low/high heavy metals accumulation in fingernails (µg/g) were based on previous studies

Al: High > 37.5; Low < 37.5 (12)
Cd: High > 0.9; Low < 0.9 (14)
Co: High > 0.3; Low < 0.3 (15) fingernails and toenails of healthy volunteers (normal concentration
Cr: High > 13.3; Low < 13.3 (10)
Cu: High > 8.1; Low < 8.1 (14)
Fe: High > 99.1; Low < 99.1 (13)
Mn: High > 5.0; Low < 5.0 (10)
Ni: High > 25.3; Low < 25.3 (this study)
Pb: High > 1.0; Low < 1.0 (16)
Zn: High > 11.4; Low < 11.4 (this study)

[e] indication of good model fit the residuals are unit exponentially distributed.
*Bonferroni correction, significant at p<0.0056

Table VII: Regression on respiratory symptom associated with outdoor PM_{10} ([a]AOR [b](95% CI))

Variables[c]	Coughing with flu (N =130)	Chest tightness with phlegm and flu (N = 45)	Chest tightness with phlegm only (N = 22)	Wheezing with flu (N =49)	Wheezing during night (N = 23)	Runny nose (N = 60)	Sneezing (N = 64)	Watery eyes (N =18)	Sore throat (N = 30)
Al	0.64 (0.31-1.31)	0.32 (0.09-1.09)	0.88 (0.19-4.11)	0.70 (0.25-1.92)	1.35 (0.27-6.63)	0.55 (0.18-1.63)	0.99 (0.37-2.62)	-	0.95 (0.23-3.88)
Cd	1.37 (0.46-4.12)	3.75 (0.88-15.96)	1.80 (0.25-13.13)	1.26 (0.29-5.40)	1.11 (0.12-10.35)	10.66 (2.75-41.41)*	5.54 (1.45-321.13)*	6.29(0.58-68.50)	4.39 (0.93-20.72)
Co	1.08 (0.66-1.78)	2.42 (1.11-5.29)*	1.34 (0.53-3.42)	0.94 (0.47-1.88)	5.00 (1.36-18.43)*	0.65 (0.86-3.18)	1.62 (0.87-3.05)	2.02 (0.71-5.77)	1.26 (0.55-2.90)
Cr	1.05 (0.36-3.02)	0.79 (0.19-3.32)	0.46 (0.05-4.19)	0.71 (0.17-2.98)	0.22 (0.02-3.07)	0.41 (0.11-1.56)	0.39 (0.10-1.54)	0.26 (0.02-4.29)	0.15 (0.02-1.08)
Cu	0.87 (0.45-1.68)	0.70 (0.28-1.75)	0.46 (0.15-1.46)	0.75 (0.32-1.76)	0.44 (0.14-1.43)	0.23 (0.10-0.52)	0.33 (0.15-0.73)	0.10 (0.02-0.42)	0.34 (0.12-0.95)
Fe	1.89 (0.90-3.98)	1.19 (0.43-3.31)	1.51 (0.45-5.04)	2.42 (0.87-6.73)	1.87 (0.51-6.78)	1.57 (0.67-3.71)	1.26 (0.54-2.94)	1.19 (0.36-3.90)	1.61 (0.56-4.62)
Mn	0.81 (0.47-1.38)	1.17 (0.55-2.51)	0.64 (0.22-1.81)	0.79 (0.38-1.65)	0.49 (0.16-1.47)	1.10 (0.53-2.27)	1.06 (0.53-2.94)	0.84 (0.25-2.76)	0.62 (0.24-1.59)
Pb	0.20 (0.05-0.85)	0.21 (0.04-1.19)	0.08 (0.03-0.22)	0.19 (0.04-0.90)	0.34 (0.06-1.94)	0.90 (0.19-4.32)	0.81 (0.18-3.78)	0.10 (0.04-0.28)	0.17 (0.02-1.63)
Zn	2.38 (0.59-9.56)	0.40 (0.07-2.21)	-	0.66 (0.15-2.86)	0.09 (0.01-0.58)	0.25 (0.05-1.21)	0.32 (0.07-1.47)	-	0.84 (0.09-7.94)
Cox & Snell R Square-Nagelkerke R Square [d]									
	0.058-0.078	0.461-0.615	0.588-0.784	0.420-0.560	0.584-0.779	0.370-0.494	0.326-0.435	0.624-0.832	0.530-0.706

Multiple logistic regressions; *Bonferroni correction, significant at $p<0.0056$

the permissible limit of WHO, U.K and E.U, and Canada AQS; Mn exceeded the permissible limit of USEPA, WHO and Canada AQS and Co exceeded the permissible limit of Canada AQS.

Existing studies reported that airborne Cr element had been released into the environment in larger amounts as a result of human activities, which accounted for 60–70% of the total emissions of atmospheric chromium (17,18). As for Ni, exceeding concentration level cause an estimated 8.5 million kg of nickel being emitted into the atmosphere from natural sources each year (19). On-road mobile sources accounted for only 10 tons per year of Ni released to the air, whereas airplanes and boats accounted for a release of 66 tons of Ni compounds per year (19). Exceeding concentration level of Ni and Cd either from natural sources or from anthropogenic activity into the atmosphere had affected the air quality standard globally. Cadmium was estimated at about 150-2,600 tonnes per year, accounting for the emission to the environment globally (20). The World Health Organisation in 2007 reported the airborne Cd being able to travel for long boundary distances from the source of emission through atmospheric transport (20). Manganese is able to be spread widely from Mn-containing soils, airborne dusts and drinking water (ATSDR, 2012). Airborne emission of Mn also arises from anthropogenic activity, commonly associated with industrial emissions, landfill sites and vehicle exhaust (23).

The results of this study showed that the concentrations of all accumulated heavy metals in fingernails were significantly higher among the exposed children as compared to those of the unexposed children. Comparison with other studies, showed that the levels of Fe observed in Kenya (13) were below from those of the exposed group in this study. Cr concentration levels observed in this investigation for the exposed group were excessively higher than previous studies observed in Jordan (10), Taiwan (24) and Poland (15). Aluminium (Al) accumulation in the fingernails of the exposed group from the current study was also higher than previous studies in Turkey (12) and Saudi Arabia (25). These differences can be explained by the influence of heavy metal exposures to different environmental settings and nutritional factors. Difference family lifestyles could also probably be the cause for higher levels of Fe concentrations in fingernails (13). Cr exposure in children might be due to ingestion of chromium-containing food and water (26).

Previous studies reported the association of heavy metals and exposure to air pollution as the cause of reduced lung function and higher prevalence of respiratory symptoms and diseases in children and adults (27,28). Higher Cd and Cr concentration in PM from MSW landfill may cause respiratory inflammation to the exposed children. High Co levels in ambient air showed significant association with respiratory symptoms. These findings were in line with those of previous studies which reported an association of nose and throat irritations, coughs, wheezing and dyspnea or severe asthma in children who were exposed to high levels of some heavy metals such as Pb, Cd, Cr, Mn, Ni, As, Hg, Co or Va (29).

Several factors had been proven to be associated with the prevalence of asthma and wheezing in children. These included their age, sex, atopic history of their parents, parental education, genetics, nutritional status, number of siblings, lifestyle, allergy status, family history, and parents' occupations. Environmental factors would include house dust, animal pollen, moulds, cockroach infestation, indoor/outdoor air pollution, cooking fumes, aeroallergens, and the climate (30). A previous study had also shown that children who were exposed to these factors in their early life would show an increased risk of developing respiratory diseases at later ages (31).

CONCLUSION

Findings from this study indicated that residing near landfill sites and the increasing levels of certain metal accumulations in the fingernails were the risk factors that had caused numerous reports of reported respiratory symptoms among children. Studies with a larger population size, and with a mix of major ethnic groups, will have to be undertaken in order to identify the precise and actual reasons for the observed differences between these groups in terms of heavy metal levels detected in the fingernails samples. Various ranges of age for toddlers and kindergarten children need to be undertaken with the aim of understanding the effects of particulate matter (PM2.5 and PM10) in MSW landfills. Other option of biomarkers such as blood, hair and serum will also help in the understanding of the relationship between PM pollution and the health of children.

ACKNOWLEDGEMENT

This study had received an ethical approval from the ethical committee of the Faculty of Medicine and Health Sciences, Universiti Putra Malaysia. This research was funded by Universiti Putra Malaysia. We would like to address our utmost gratitude to the respondents who participated in this research.

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