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Risk Assessment Due to Population Exposure to Lead Particles Emitted from Domestic Electrical Generators

Nabeel Hashim Ameen, Mohannad Kh. Mohammad and Takrid M. Nafae

Ministry of Science and Technology – Hazardous Materials and Environmental Researches Directorate

Abstract

Portable and stationary electrical generators became quite popular in Iraq soon after the shortage in national electrical energy after 2003. Multi step risk assessment process is used in this study in the assessment of risks caused by contamination of indoor air by lead particles emitted from domestic electrical generators. Two portable electrical generators are tested under controlled indoor conditions (Radial LG (0.9 keV) fueled with benzene and oil and TigMax (3 keV), fueled with benzene only). Lead particles in air were sampled by using portable dust sampler (Sniffer, L-30). The atmospheric particulate sampling process is carried out in a flat located in the first floor of a three stories building located in Baghdad city, Al-Zafarania region. The lead concentration in the digested filter papers is measured by using atomic absorption spectrophotometer (Buck, USA). Dose-to-risk conversion factor is applied in this study to estimate the potential cancer risk to Baghdad's population related to continuous inhalation of airborne lead at the mean observed concentrations. The results of toxicity analysis indicate that public exposure to airborne lead at the mean observed concentration of 4.991 μg/m3 can increase the risk of cancer at a rate of 12 extra cancer cases in a group of million exposed individuals. Males are found to be at greater risk than females because of higher inhalation rates. Children are found to be the most sensitive group due to low body weight (about 101 expected additional cancer cases in a group of million exposed child).

Keywords**:** lead, electrical generators

Introduction

Lead is the most abundant of the heavy metals in the Earth's crust. It has been used since prehistoric times, and has become widely distributed and mobilized in the environment. Exposure to and uptake of this non-essential element have consequently increased. Both occupational and environmental exposures to lead remain a serious problem in many developing and industrializing countries, as well as in some developed countries. In most developed countries, however, introduction of lead into the human environment has decreased in recent years, largely due to public health campaigns and a decline in its commercial usage, particularly in petrol. Acute lead poisoning has become rare in such countries, but chronic exposure to low levels of the metal is still a public health issue, especially among some minorities and socioeconomically disadvantaged groups. In developing countries, awareness of the public health impact of exposure to lead is growing but relatively few of these countries have introduced policies and regulations for significantly combating the problem [1].

Most lead emissions in the past have been from motor vehicles burning gasoline containing the antiknock additive, tetraethyl lead $(C_2H_5)_4Pb$. Lead is emitted to the atmosphere primarily in the form of inorganic particulates. Much of this is removed from the atmosphere by settling in the immediate vicinity of the source. Airborne lead may affect human populations by

direct inhalation, in which case people living nearest to highways are of greatest risk, or it can ingested after the lead is deposited onto food stuffs. Most of human exposure to airborne lead is the result of inhalation [2].
The aims of this study are:

(1) Estimation of the health risk to individuals in Baghdad's population as a result of inhalation of airborne lead emitted from domestic electrical generators. The associations between lead inhalation and the development of adverse health effects to the exposed individuals in Baghdad population are evaluated in this study by using linear, no threshold dose-response model.

(2) Investigation of the effect of the age, sex and activity level of the exposed individuals on the dose delivered and associated risk.

Experimental Work

Particulates in air are most commonly sampled by removal from the air by filtration through a cellulose filter, fiberglass, or molecular sieve (membrane) type media [3].
Portable dust sampler (Sniffer, L-30) (Fig.(1)) is used in collecting particulate matter by sucking air through the filter paper. The atmospheric particulate sampling process is carried out in Baghdad city, Al-Zafaraniya region, inside a flat located in the first floor of a three stories building. The sampler level is fixed at the human breathing zone (approximately 1.5 m). At the laboratory, the filter papers are dissolved in a solution containing 5 mL of HNO3 and several drops of HF. The lead concentration in the digested filter papers is measured by using atomic absorption spectrophotometer, model 210 VGP (Buck, USA) (Fig.(2)). The concentration of lead in air is calculated by using the following formula [4, 5]:

$$C_{Pb} = \frac{C * V_1}{V_t} \quad (1)$$

Where CPb is the lead concentration in the ambient air (μg/m3), C is the lead concentration in the solution in ppm, V1 is the volume of the sample solution in mL, and Vt is the volume of the sampled air (m3).
The air suction Vt (m3) is calculated from the following equation, based on the flow meter readings at the start and end of collection [6]:

$$\text{Air Suction} = \left[\frac{Q_S + Q_e}{2}\right] * T \quad (2)$$

Where Qs is the flow rate at the start of collection (m3/min), Qe the flow rate at the end of collection (m3/min), and T the collecting time (min). Data recorded include sampling place and date, time and flow rate readings at the start and end of sampling, useful meteorological data (weather condition, temperature, humidity, wind direction, wind velocity, etc.).

Fig.(1): Portable dust sampler (Sniffer, L-30)

Fig.(2): Atomic absorption spectrophotometer, model 210 VGP (Buck, USA)

Risk Assessment

Risk, may be defined as the chance of encountering the potential adverse effects of human or ecological exposures to environmental hazards. In general terms, risk is the probability of harm or loss, which may also be considered as a product of probability and the severity of consequences [7].
Risk assessment is the gathering of data that are used to relate response to dose. Such dose-response data can then be combined with estimates of likely human exposure to produce overall assessments of risk [2].
The National Academy of Sciences suggests that risk assessment be divided into the following four steps [8]:

Hazard IdentifIcation

The first step in a risk analysis is to determine whether the chemicals that a population has been exposed to are likely to have any adverse health effects.

Lead poisoning can cause aggressive, hostile, and destructive behavioral changes, as well as learning disabilities, seizures, severe and permanent brain damage, and even death. Children and pregnant women are at greatest risk. Lead is absorbed by the blood following inhalation. It has been estimated that about one-third of the lead particles inhaled are deposited in the respiratory system, and that about half of these are absorbed by the bloodstream [2]. Absorption also increases in children suffering from iron or calcium deficiencies. Deposition of lead particles in the respiratory tract of children is 1.6 - 2.7 times than that of adults [9]. Lead content in human blood varies according to age and sex, it tends to increase with age and males have more Pb in their blood than females. Mean Pb content in children is sometimes higher than adults [10]. Measurements made in actual communities suggest that an increase in airborne lead concentration of 1 μg/m3 results in an increase of about 1–2 μg/100 mL in blood lead level [2]. For European adults, values below 30 μg/100 mL are considered normal, whereas Pb concentration in blood above 70 μg/100 mL is poisonous [4], with possible severe brain damage or death, occurs at levels somewhat above 80 μg/100 mL [11].

Dose – response assessment

The fundamental goal of a dose–response assessment is to obtain a mathematical relationship between the amount of a toxicant to which a human is exposed and the risk that there will be an unhealthy response to that dose. For substances that induce a carcinogenic response, it is always conservatively assumed that exposure to any amount of the carcinogen will create some likelihood of cancer. For noncarcinogenic response, it is usually assumed that there is some threshold dose, below which there will be no response [2].

Human exposure assessment

Risk has two components: the toxicity of the substance involved, and the amount of exposure to that substance. A human exposure assessment is itself a two-part process. First, pathways that allow toxic agents to be transported from the source to the point of contact with people must be evaluated. And second, an estimate must be made of the amount of contact that is likely to occur between people and those contaminants [2].

The mean exposure concentration of contaminants is used with exposed population variables and the assessment-determined variables to estimate contaminant intake. The intake for inhalation of airborne contaminants is estimated from equation below [7]:

$$CDI = \frac{CA * IR * ET * EF * ED}{BW * AT} \qquad (3)$$

Where CDI = intake by inhalation (mg/kg.day),
CA = contaminant concentration in air (mg/m3),
IR = inhalation rate (m3/hr),
ET = exposure time (hr/day),
EF = exposure frequency (days/year),
ED = exposure duration (years),
BW = body weight (kg),
AT = averaging time (period over which the exposure is averaged, days).

The inhalation rate varies with age, weight, sex, activity level, particulate size and other physical conditions; typical values are listed in Table (1). Typical body weights recommended by the EPA are listed in Table (2).

Table (1): Typical inhalation rates (m3/hr) [12]:

Types	Activity level			
	Resting	Light	Moderate	Heavy
Adult male	0.7	0.8	2.5	4.8
Adult female	0.3	0.5	1.6	2.9
Average adult	0.5	0.6	2.1	3.9
Child, age 6 y	0.4	0.8	2	2.4
Child, age 10 y	0.4	1	3.2	4.2

Table (2): EPA recommended values for average body weight [4]

Age (y)	Weight (kg)
0 – 1.5	10
1.5 – 5	14
5 – 12	26
Adult	70

Risk characterization

The final step in a risk assessment is to bring the various studies together into an overall risk characterization [2]. Carcinogenic risk is a function of the chronic daily intake and the slope factor [7]:

$$Risk = CDI * SF \qquad (4)$$

Where Risk = the probability of carcinogenic risk (dimensionless),
CDI = chronic daily intake (mg/kg.day),
SF = carcinogenic slope factor (kg.day/mg).

Results and Discussion

The mean observed airborne lead concentrations is measured to be 6.614 $\mu g/m^3$ for the 3 keV generator and 3.368 $\mu g/m^3$ for the 0.9 keV generator. The mean observed airborne lead concentration emitted from the two generators is estimated to be 4.991 $\mu g/m^3$, exceed the national standard established by the Ministry of Environment (Iraq) and the international standards established by the EPA (1.5 $\mu g/m^3$) and the World Health Organization WHO (1.5 $\mu g/m^3$ monthly, 0.5 $\mu g/m^3$ annual) [13]. This result indicates that there is some possible adverse health effects to the exposed individuals related to continuous inhalation of airborne lead particles at the mean observed concentration.

Multi-step risk assessment process is used in this study in estimation of the health risks to Baghdad population exposed to airborne lead emitted from domestic electrical generators. The first step is making quantitative measurements of airborne lead concentrations by using portable dust sampler and flammable atomic absorption spectrophotometer. The second step is estimation of the internal exposure by evaluation of the daily intake of lead by the local inhabitants living in the area of the study. The last step is making a correlation between the dose administered and the response or damage produced by using a linear, no threshold dose-response model (Eq.(4)). The chronic daily lead intake through inhalation pathway is estimated by substituting the appropriate values for the following parameters into Eq.(3):

CA = 6.614 $\mu g/m^3$ for 3 keV generator or 3.368 $\mu g/m^3$ for 0.9 keV generator = site-specific mean measured value,

IR = 20 m3/day (adult, average) [14], ranges from 7.2 to 115.2 m3/day as a function of age, sex and activity level,

ET = 24 hours/day = Pathway-specific values (dependent on the duration of exposure-related activities),

EF = 365 days/year = Pathway-specific value (dependent on the frequency of exposure-related activities),

ED = 70 years (lifetime, by convention) [7],

BW = 70 kg (adult, average) [15], 26 kg (child),

AT = 70 year = lifetime for carcinogenic effects (i.e., 70 years*365 days/years) [7].

Eq.(3) is put into the following more convenient form for continuous exposure to airborne contaminants:

$$CDI = \frac{CA * IR}{BW} \quad (5)$$

An individual is assumed to weigh 70 kg (adult) or 26 kg (child) and breathe air at the inhalation rates listed in Table (1), so the mean chronic daily intake is estimated by Eq.(5). The lead dosage administered is correlated with the response or damage produced by using linear, no-threshold (LNT) dose-response model. The slope factor for inhalation of lead is taken to be 8.5*10-3 kg.day/mg [15]. Using Eq.(4), the results of risk assessment to Baghdad's population for different sexes, ages, and activity levels related to continuous inhalation of airborne lead at the mean observed concentrations are listed in Table (3). The data listed in Table (3) indicate that domestic electrical generators provide a potential for internal lead exposure to nearby individuals and result in detrimental health effects including increased incidence of cancer. Children group is found to be at greatest risk.

Table (3): Results of risk assessment:

Population group	Activity level			
	Resting	Light	Moderate	Heavy
3 keV generator				
Adult male	13 per 1000000	15 per 1000000	48 per 1000000	92 per 1000000
Adult female	5 per 1000000	9 per 1000000	30 per 1000000	55 per 1000000
Average adult	9 per 1000000	11 per 1000000	40 per 1000000	75 per 1000000
Child, age 6 y	20 per 1000000	41 per 1000000	103 per 1000000	125 per 1000000
Child, age 10 y	20 per 1000000	51 per 1000000	166 per 1000000	218 per 1000000
0.9 keV generator				
Adult male	6 per 1000000	7 per 1000000	24 per 1000000	47 per 1000000
Adult female	2 per 1000000	4 per 1000000	15 per 1000000	28 per 1000000
Average adult	4 per 1000000	5 per 1000000	20 per 1000000	38 per 1000000
Child, age 6 y	10 per 1000000	21 per 1000000	52 per 1000000	63 per 1000000
Child, age 10 y	10 per 1000000	26 per 1000000	84 per 1000000	111 per 1000000

Conclusions

1. The mean observed lead concentrations emitted from the 0.9 keV generator (3.368 $\mu g/m^3$) and the 3 keV generator (6.614 $\mu g/m^3$) are found to be higher than the national ambient air quality standard (1.5 $\mu g/m^3$) [Masters, 1991]. These results indicate that there is some probable risk to the human health related to continuous inhalation of contaminated air at the observed concentrations.

2. The health impact of the 3 keV electrical generator is found to be greater than that for the 0.9 keV generator under the same exposure conditions.

3. The predicted mean lead concentration in blood (7.48 μg/100 mL) is found to be less than the poisonous concentration (70 μg/100 mL) [4]. This result indicates that acute health effects related to blood poisoning by lead are excluded, but latent effects (such as cancer incidence) are expected.

4. The results of risk assessment listed in Table (3) indicate that males are at greater risk than females because of higher inhalation rates. Children are found to be the most sensitive group due to low body weight.

5. The exposure of the Baghdad population to the airborne lead emitted from electrical generators causes possible long term adverse health effects including increased incidence of cancer and blood poisoning by lead. The results of toxicity analysis indicate that one extra cancer risk incident is expected for every 82501 persons living in Baghdad dwellings related to continuous inhalation of airborne lead at mean observed concentration of 4.991 μg/m3, or there is 12 extra cancer cases in a group of a million exposed individuals if they would all inhale lead at a rate of 36.43 mg per year instantaneously.

Nomenclature

C_{Pb}	Lead concentration in the ambient air	($\mu g/m^3$)
C	Lead concentration in the solution	ppm
V_1	The volume of the sample solution	mL
V_t	The volume of the sampled air	(m^3)
Q_s	The flow rate at the start of collection	(m^3/min)
Q_e	The flow rate at the end of collection	(m^3/min)
T	The collecting time	(min)
CDI	Intake by inhalation	(mg/kg.day)
CA	Contaminant concentration in air	(mg/m^3)
IR	Inhalation rate	(m^3/hr)
ET	Exposure time	(hr/day)
EF	Exposure frequency	(days/year)
ED	Exposure duration	(years)
BW	Body weight	(kg)
AT	Averaging time	days
Risk	The probability of carcinogenic risk	dimensionless
CDI	Chronic daily intake	(mg/kg.day)

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