การประเมินความเสี่ยงทางสุขภาพจากการได้รับสัมผัสสารโลหะหนัก ในฝุ่นที่เข้าสู่ระบบทางเดินหายใจของพนักงานเก็บขยะมหาวิทยาลัยอุบลราชธานี

HEALTH RISK ASSESSMENT OF HEAVY METAL EXPOSURE IN RESPIRABLE DUST AMONG GARBAGE COLLECTORS IN UBON RATCHATHANI UNIVERSITY

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บทคัดย่อ

พนักงานเก็บขยะได้รับสัมผัสกับมลพิษต่าง ๆ อาทิ ฝุ่นที่เข้าสู่ระบบทางเดินหายใจ(1)และโลหะหนักที่อยู่ในฝุ่นที่เกิดขึ้นระหว่างกระบวนการเก็บขยะ งานวิจัยนี้ศึกษาความเข้มข้นของโลหะหนักในฝุ่นที่เข้าสู่ระบบทางเดินหายใจ(1) โดยการเก็บตัวอย่างระหว่างการทำงานของพนักงานเก็บขยะภายในบริเวณมหาวิทยาลัยอุบลราชธานี ในช่วงเดือนมิถุนายน โลหะหนักที่วิเคราะห์ ได้แก่ As, Pb, Cd, Hg, และ Cr โดยใช้ ICP-OES และประเมินความเสี่ยงต่อสุขภาพของพนักงานเก็บขยะ โดยพิจารณาจากค่า Hazard Quotient (HQ) สำหรับความเสี่ยงที่ไม่ก่อให้เกิดมะเร็ง และการประเมินความเสี่ยงต่อการเกิดมะเร็ง (CR) ตามมาตรฐานของ US.EPA การศึกษาพบว่าความเข้มข้นเฉลี่ยของโลหะหนักในฝุ่นที่เข้าสู่ระบบทางเดินหายใจ(1)ในขณะที่พนักงาน 3 คนปฏิบัติงานนั้น มีค่าเฉลี่ยของดัชนีความเสี่ยงต่อสุขภาพในกรณีไม่เกิดมะเร็ง (Hazard Index) เท่ากับ $3.72x10^{-5}$, $1.36x10^{-4}$ และ $2.5x10^{-4}$ โดยมีค่าเฉลี่ยรวมเท่ากับ $1.41x10^{-3}$ ส่วนค่าเฉลี่ยของความเสี่ยงต่อการเกิดมะเร็ง (Cancer Risk) อยู่ที่ $3.09x10^{-6}$, $1.12x10^{-5}$ และ $9.38x10^{-6}$ โดยมีค่าเฉลี่ยรวมเท่ากับ $7.91x10^{-6}$ ค่าเฉลี่ยปริมาณความเข้มข้นของโลหะหนักทั้งหมดมีค่าเกินมาตรฐานของ ACGIH จากผลการศึกษาพบว่าไม่มีความเสี่ยงที่มีนัยสำคัญต่อผลกระทบทางสุขภาพที่ไม่ก่อให้เกิดมะเร็ง (HI < 1) และการประเมินความเสี่ยงในการเกิดมะเร็งอยู่ในเกณฑ์ที่ยอมรับได้ อย่างไรก็ตามการสัมผัสกับโลหะหนักเป็นระยะเวลานานอาจมีผลกระทบต่อสุขภาพของพนักงานเก็บขยะ ควรดำเนินมาตรการควบคุมความเสี่ยงที่เหมาะสม จัดให้มีอุปกรณ์ป้องกันอันตรายส่วนบุคคลเพื่อช่วยลดและควบคุมระดับการสัมผัส

คำสำคัญ: การประเมินความเสี่ยงทางสุขภาพ / โลหะหนัก / พนักงานเก็บขยะ

Abstract

Garbage collectors were exposed to various pollutants such as respirable dust and heavy metals in the dust generated during the waste collection processes. This research studied the concentration of heavy metals in this found respirable dust by collecting samples during the collectors' work. The heavy metals analyzed included As, Pb, Cd, Hg, and Cr by ICP-OES to evaluate the health risks for the collectors in terms of hazard quotient (HQ) for non-carcinogenic risks and cancer risk for carcinogenic risk assessment following US.EPA. The study found that the average concentration of heavy metals in fine dust particles within the area of Ubon Ratchathani University while three garbage collections had a hazard index average of $3.72x10^{-5}$, $1.36x10^{-4}$ and $2.5x10^{-4}$ with a combined average of $1.41x10^{-3}$. The cancer risk average was $3.09x10^{-6}$, $1.12x10^{-5}$ and $9.38x10^{-6}$ with a combined average of 7.91×10^{-6}. The average concentration of total heavy metals exceeded the standard limits set by ACGIH. The results found no significant risk of non-carcinogenic health effects (HI < 1) and the cancer risk assessment was within the acceptable risk criteria. However, long-term exposure to heavy metals can impact the health of garbage collectors. Appropriate risk control measures should be implemented; personal protective equipment should be provided to employees to reduce exposure levels.

Keyword: Health Risk Assessment / Heavy Metal / Garbage Collector

Introduction

Currently, in various manufacturing industries, heavy metals have been used as raw materials or ingredients in various products such as batteries, printer ink, fluorescent light bulbs, and insecticides. When it is used and discarded, it creates waste and effects on the environment and human health, both directly and indirectly.

Heavy metals have slow decomposition properties that are stable and accumulate in the environment. Heavy metals were specific in causing effects on the health such as causing lung inflammation hepatic cell destruction if exposed to heavy metals have both acute and chronic effects. The most common heavy metals in Thailand were lead cadmium arsenic and manganese and found that 50 patients with the highest age range 45-50 years old[2] have heavy metals enter the body through many channels including breathing eating and contact through the skin which can also accumulate in the air and bind to respirable dust. A study on health risk assessment of heavy metals in workers exposed to waste recycling facilities in a municipal area of Iran detected various heavy metals in the work environment of waste sorting staff. The identified heavy metals included cadmium (Cd), lead (Pb), arsenic (As), cobalt (Co), chromium (Cr), nickel (Ni), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn), with average concentrations of 0.022 mg/m³, 0.165 mg/m³, 0.044 mg/m³, 0.018 mg/m³, 0.167 mg/m³, 0.514 mg/m³, 3.746 mg/m³, 2.844 mg/m³, 0.927 mg/m³, and 0.418 mg/m³, respectively.[3]

The inhalation pathway is a notable means of exposing humans to metals in the atmosphere. A worker at a landfill site in Indonesia was exposed to heavy metals, resulting in a non-carcinogenic risk with an HI value of 25 and a carcinogenic risk level ranging from ($10^{-3} \leq CR < 10^{-1}$). And the workers within the landfill exhibited symptoms such as cough and breathlessness. The health complaints of workers can be a warning sign regarding their health, especially in the workplace. Therefore, immediate action is required to determine the causes of these symptoms[4]. Since the initial issues primarily affect the respiratory system, the assessment of inhalation exposure is a potential approach for conducting studies on human health.

Garbage collectors were occupations that must come into contact with garbage within heavy metals when comparing the concentration of heavy metals with reference health values, it was found that some metals exceed the reference values, namely chromium, cadmium and manganese. which assesses the risk from inhalation exposure[5]. From the study of exposure to heavy metals found in waste particles in the community it was shown that there is a high risk that heavy metals are dangerous to workers and pose a health risk both non-carcinogenic and cancer-causing, which is inhalation exposure[3]. Therefore, it may cause health problems for employees because heavy metals are dangerous substances and are toxic to the health. There is exposure to the health in excessive amounts. Therefore, a survey to assess the health risks of garbage collectors is great importance.

This study is interested in conducting that analyzed the concentration of heavy metals in respirable dust to assess health risks from exposure including arsenic (As), lead (Pb), mercury (Hg), cadmium (Cd) and chromium (Cr) because these 5 heavy metals were rated as heavy metal substances that harmful to health (ATSDR, 2019)[6] Which are primarily inhaled into the respiratory system[5]

Methods

1. Study area description

This study focuses on studying the respirable dust samples to analyze for heavy metals. The samples were collected while garbage collectors within the area of Ubon Ratchathani University which conducted in June 2024. Total of three workers in twelve samples which the collected form 3 worker within 4 days of operation.

The garbage collector of Ubon Ratchathani University works an average of 4 hours per day. They collect waste from a total of 40 points within the university **(Figure. 1),** The collection of respirable dust will be conducted continuously each worker 4 hours

per day, from Monday to Friday. The sampling will be conducted during the period when the employees are working in the waste collection area within the university.

Figure 1. Waste collection points map[7]

2. Sample collection

The respirable dust and personal dust sampling were conducted by collecting ambient air samples throughout the working period for 4 hours from garbage collectors. A total of 12 samples were collected within the Ubon Ratchathani University area during June, 2024. The CA-tech zone PCV filter with a size of 5 μm and diameter of 37 mm. and Aluminum cyclone, utilizing the TSI 4100 series calibrator with a flow rate of 2.5 liters per minute according to the guidelines of NIOSH method 0600[8].

Sample digestion prior to analysis follows the guidelines of EPA Method Number 3051A[9]. The filter was cut into small pieces, placed into a vessel and 10 ml of concentrated nitric acid [conc. HNO_3] was added. The sample was digested use a microwave digester at a temperature of 180 °C for 1 hour. After cooling, it was diluted with deionized water (DI) in a 25 ml volumetric flask. The sample underwent filtration use a 0.45-micron syringe filter and a 10 ml syringe into a 30 ml plastic bottle to separate suspended solids from the solution before analysis with an Inductively Coupled Plasma - Optical Emission Spectrometer (ICP-OES). Analyze heavy metals in the sample using the Perkin Elmer ICP-OES instrument, model Optima 8000, with a specified pump rate of 1 ml/min. Focus on analyzing five heavy metals, Such as Arsenic (As), Lead (Pb), Mercury (Hg), Cadmium (Cd) and Chromium (Cr)

3. Data analysis

3.1 Assessment of exposure dose.

Process of analyzing the possibility of adverse health effects caused by human exposure to environmental pollutants. Which was a quantitative technique related to measuring and assessing human exposure to environmental pollutants, as well as predicting future impacts that may occur. This study evaluated potential non-carcinogenic health effects and cancer risk related to inhalation exposure to heavy metal in respirable dust on garbage collector in Ubon Ratchathani University. The evaluation followed the guidelines of the United States Environmental Protection Agency[10]. The five heavy metals evaluated for health risks among the workers including As, Pb, Hg, Cd, and Cr. The study explores the relationship between Inhalation Rate (InhR; m^3/day) and exposure to hazardous air pollutants, particularly airborne heavy metals. The concentration of heavy metals (Conc., mg/m^3) per Body Weight (BW) of the workers was calculated according to the following:

$$\text{Total Dose} = \frac{\text{Conc.} \times \text{InhR}}{\text{BW}} \qquad (1)$$

The inhalation rate is referenced from the guideline manual for monitoring areas at risk from air pollution[11] which cites the ATSDA agency. Additionally, the researchers collected personal information including age, weight, years of service and working hours, as shown in **Table 1.**

3.2 Health risk assessment

Use the total dose, which is the inhalation exposure from (1)[5], 1 with the Averaging Time (AT), to calculate the Chronic Daily Intake (CDI).

$$\text{CDI} = \frac{\text{Total Dose}}{(\text{BW} \times \text{AT})} \qquad (2)$$

Averaging time was over the potential exposure lifetime, calculated based on the average life expectancy of the population, as referenced from the Thailand Board of Investment 2023[12]. The average life expectancy of the male population is used because all the sample subjects were male.

The methodology outlined in assessing non-carcinogenic health risk associated with hazardous materials via inhalation was utilized for calculating the pertinent hazard quotient (HQ) and the United States

Environmental Protection Agency investigated cancer risk related to exposure to harmful air pollution[10]. The estimation of the risk indicated as CR (Cancer risk) is calculated using equation (3)[5] and (4)[5]

$$HQ = \frac{\text{Exposure or CDI}}{\text{RfD}} \quad (3)$$

$$CR = CDI \times CSF \quad (4)$$

The inhalation reference dose (RfD) for the specific metal component, show in **Table 1**, is measured in milligrams per cubic meter (mg/m^3). Based on the finding of the United States Environmental Protection Agency[11], it has been established HQ values <1 have no significant risk. In contrast, HQ levels >1 potential negative health impact. The hazard index (HI = ΣHQ) was used to calculate the non-carcinogenic risk associated with the heavy metal under study. Which uses the same interpretation method as the HQ value. The CR value serves as a quantitative measure of the possibility that an individual would get cancer as a result of long exposure to metal with cancer causing effect in their lifetime. The interpretation of CR ≤ 1x10^{-6} indicates that it may not cause health effects in terms of carcinogenicity. Conversely, CR > 1x10^{-6} suggests there is a potential for health effects in terms of carcinogenicity. If the CR value falls between 10^{-6} and 10^{-4}, it is considered to have an acceptable or tolerable threshold limit value for potential health effects in terms of carcinogenicity.

Table 1. Parameters for non-carcinogenic and carcinogenic health risk assessment

Definition	Parameter	Unit	Values	Reference
Average concentration of heavy metals	Conc.	mg/m^3	**Table 2**	primary data study
Inhalation rate	InhR	m^3/day	0.83 (InhRx24)	(Department of Health and Department of Disease Control, Ministry of Public Health, 2015)
Body weight	BW	kg	70 (Sample 1,2) 67 (Sample 3)	primary data study
Averaging Time	AT	day	14570.9 (Sample 1) 13840.8 (Sample 2) 9095 (Sample 3) (Life Expectancy of Thai male = 74.92)	primary data study, (BOI: the Board of Investment of Thailand, 2023)
Chronic daily in-take	CDI	mg/kg.day	-	-

Parameter	**RfD (mg/kg.day)**	**CSF (mg/Kg.day)**	**Reference**
AS	-	12	(Prayad Kenyota, 2021)
Cd	0.001	6.1	(Thanaporn Maneerat, 2017; Prayad Kenyota, 2021)
Cr	0.003	52	(Thanaporn Maneerat, 2017; Prayad Kenyota, 2021)

Parameter	RfD (mg/kg.day)	CSF (mg/Kg.day)	Reference
Pb	0.0035	4.2x10-2	(Thanaporn Maneerat, 2017; Prayad Kenyota, 2021)
Hg	0.0003	-	(Thanaporn Maneerat, 2017)

Result

1. Concentration of heavy metals in respirable dust

The analysis of heavy metals in respirable dust samples while garbage collectors were working, five heavy metals of concern including As, Cd, Pb, Cr and Hg. The analysis revealed that sample 1 detected four types of heavy metals: As, Cd, Pb and Cr, the average concentration of 2.35, 0.7, 0.1, 0.3 mg/m^3 respectively. The sample 2 detected five types of heavy metals: As, Cd, Pb, Hg and Cr, the average concentration of 2.3, 1.7, 0.1, 2.3 and 2.4 mg/m^3 respectively. The last sample detected two types of heavy metals: As and Pb, the average concentration of 3.2 and 1.8 mg/m^3 respectively shown in **Table 2** and **Figure 2**. Most of the concentrations of heavy metals (HMs) found in the fine dust samples exceed the Threshold Limit Value (TLV) for concentration during an 8-hour workday and a 40-hour workweek, according to the recommendations set by the American Conference of Governmental Industrial Hygienists (ACGIH). The TLV for the chemicals As, Cd, Cr, Pb, and Hg were set at 0.01, 0.002, 0.5, 0.15, and 0.01 mg/m³, respectively. Accept the concentration of Pb in sample 1 isn't exceeding the standard value.

The proportion of heavy metal concentrations (mg/m^3) in respirable dust that can be classified into 3 samples which ordered from lowest to highest as follows: sample 1 Cd < Cr < Pb < As and sample 2 Cd < Pb < Hg, As < Cr final sample Pb < As respectively

Table 2. The average concentration in respirable dust of garbage collectors.

Samples	Heavy metals	Concentration Avg. (mg/m^3)	Std.
Sample 1	As	2.35	0.65
	Pb	0.7	0
	Cd	0.1	0
	Hg	ND	-
	Cr	0.3	0
Sample 2	As	2.3	0.8
	Pb	1.7	1.3
	Cd	0.1	0
	Hg	2.3	0.80
	Cr	2.4	0
Sample 3	As	3.2	0
	Pb	1.8	1.3
	Cd	ND	-
	Hg	ND	-
	Cr	ND	-

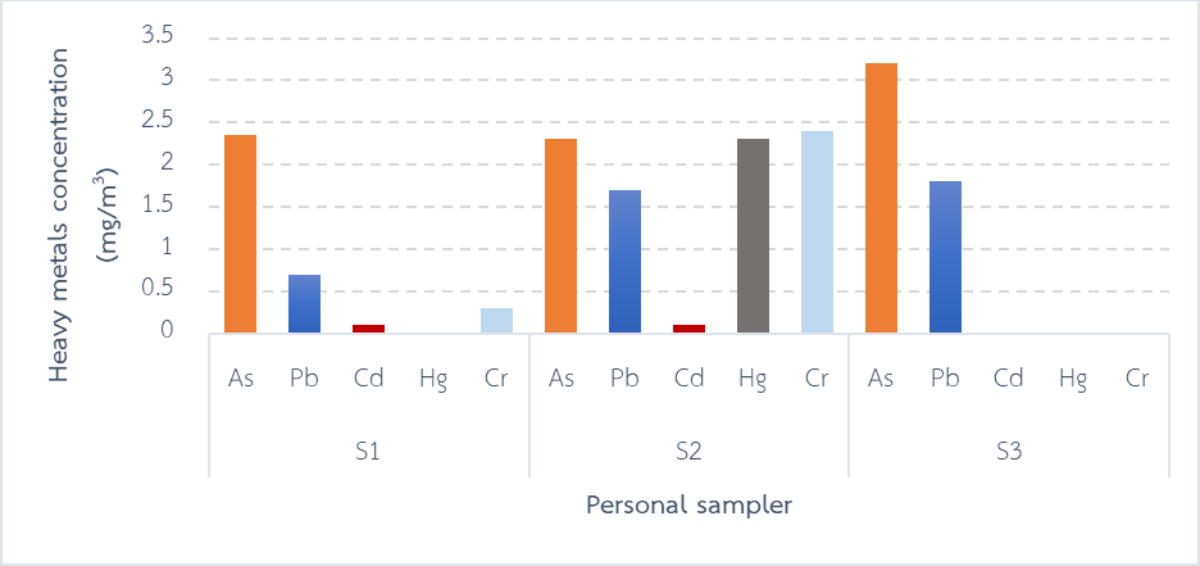

Figure 2. The proportion of the average heavy metals content in the personal dust sampler

2. Human risk assessment of inhalation exposure to heavy metals

2.1 non-carcinogenic risk of heavy metals via inhalation

The potential risk to human health in the waste collection area was assessed by garbage collectors by inhalation. By collecting samples of personal dust particles and digesting heavy metal samples in the ICP-OES machine, the risk assessment was conducted according to the U.S.EPA guidelines. with standard concentrations of As, Pb, Cd, Hg, and Cr as 0.50, 0.05, 0.005, 0.10, 1 mg/m^3 respectively. The HQ value is greater than 1 indicating that the body is exposed to a risk factor that exceeds the standard and is unsafe for health. The CR value is between 10^{-6} and 10^{-4} indicating that it is possible to have an impact on health but acceptable. It may not cause cancer or may cause cancer. **Table 3** shows the values. Health risk assessment results from three sample groups showed that: sample 1 heavy metals with HQ values were Pb Cd and Cr, with values of $5.58x10^{-5}$, $2.79x10^{-5}$ and $2.79x10^{-5}$ respectively and HI with values $3.72x10^{-5}$. Sample 2 heavy metals with HQ values were Pb Cd and Cr with values of $1.43x10^{-4}$, $2.94x10^{-5}$ and $2.3x10^{-5}$ respectively and HI with values $1.36x10^{-4}$. Sample 3 heavy metals with HQ values were Pb with values of $2.51x10^{-4}$ and HI with values $2.51x10^{-4}$. The hazard index of three samples is a value of $1.41x10^{-4}$.

The non-cancer risk assessment from heavy metals in respirable dust samples collected from garbage collectors at Ubon Ratchathani University found that HI < 1 for all three sample groups. This indicates that there was no significant health risk from exposure to heavy metals in fine particulate dust at levels considered hazardous to health.

Table 3. Non-carcinogenic assessment of heavy metals on human health via inhalation of respirable dust

Samples	Heavy metals	The average daily dose	The Hazard Quotient (HQ)	HI	HI $_{Average}$
Sample 1	As	0.67	-	$3.72x10^{-5}$	$1.41x10^{-4}$
	Pb	0.20	$5.58x10^{-5}$		
	Cd	0.03	$2.79x10^{-5}$		
	Hg	-	-		
	Cr	0.09	$2.79x10^{-5}$		
Sample 2	As	0.65	-	$1.36x10^{-4}$	
	Pb	0.48	$1.43x10^{-4}$		

Samples	Heavy metals	The average daily dose	The Hazard Quotient (HQ)	HI	HI Average
	Cd	0.03	$2.94x10^{-5}$		
Sample 2	Hg	0.65	-	$1.36x10^{-4}$	$1.41x10^{-4}$
	Cr	0.68	$2.3x10^{-4}$		
	As	0.95	-		
	Pb	0.54	$2.51x10^{-4}$		
Sample 3	Cd	-	-	$2.51x10^{-4}$	
	Hg	-	-		
	Cr	-	-		

2.2 Carcinogenic risk of heavy metals via inhalation

This study on cancer risk assessment found that heavy metals in respirable dust samples collected during the work of garbage collectors posed a risk of cancer. The identified metals include Pb, Cd and Cr with the following values: Sample 1 heavy metals were found Pb, Cd and Cr with values $5.58x10^{-5}$, $2.79x10^{-5}$ and $2.79x10^{-5}$. Sample 2 heavy metals were found Pb, Cd and Cr with values $1.43x10^{-4}$, $2.94x10^{-5}$ and $2.3x10^{-4}$. Sample 2 heavy metals were found Pb with values $2.51x10^{-4}$ shown in **Table 4.**

assessing health risks related to potential carcinogenic effects, the acceptable range for CR is recommended to be within $<10^{-6}$ to 10^{-4} (less than 10^{-6} but not exceeding 10^{-4}) according to US.EPA guidelines. From **Table 4.** The cancer risk associated with inhalation of the metals present in a sample of individuals. It consists of 3 examples as follows: Examples 1, 2 and 3 were $3.09x10^{-6}$,$1.12x10^{-5}$, $9.38x10^{-6}$. There is a chance of have health effects in the case of causing cancer, that is still acceptable.

Table 4. Carcinogenic assessment of heavy metals on human health via inhalation of respirable dust

Sample	Heavy metal	The average daily dose	The Cancer risk (CR)	$CR_{Average}$	$CR_{Average}$ (all samples)
	As	0.67	$7.87x10^{-6}$		
	Pb	0.20	$8.20x10^{-9}$	$3.09x10^{-6}$	
Sample 1	Cd	0.03	$1.70x10^{-7}$		
	Hg	-	-		
	Cr	0.09	$4.35x10^{-6}$		
	As	0.65	$8.11x10^{-6}$		
	Pb	0.48	$2.09x10^{-8}$	$1.12x10^{-5}$	
Sample 2	Cd	0.03	$1.79x10^{-7}$		$7.91x10^{-6}$
	Hg	0.65			
	Cr	0.68	$3.67x10^{-5}$		
Sample 3	As	0.95	-	$9.38x10^{-4}$	
	Pb	0.54	$3.69x10^{-8}$		
	Cd	-	-		
	Hg	-	-		
	Cr	-	-		

Discussion

Heavy metals are substances that impact the health of those exposed to them, both in terms of carcinogenic effects and other non-carcinogenic impacts. In modern industrial production, heavy metals are often used as raw materials or components in various everyday products. Once these products are used and discarded, heavy metals can spread into the environment. They can also accumulate in the air and attach to fine particulate matter. Fine particulate matter, or respirable dust, is particulate matter small enough to easily enter the respiratory system. Thus, heavy metals can enter the body through inhalation, posing health hazards. Garbage collectors were a profession at risk of exposure to these heavy metals. Samples of fine particulate matter were collected personally while garbage collectors were working. The average concentration of heavy metals was found in three samples, ordered from lowest to highest as follows: Sample 1: Cd < Cr < Pb < As, with values of 0.1, 0.3, 0.7, and 2.35 mg/m³, respectively. Sample 2: Cd < Pb < Hg < As < Cr, with values of 0.1, 1.7, 2.3, 2.3, and 2.4 mg/m³, respectively. Sample 3: Pb < As, with values of 1.8 and 3.2 mg/m³ respectively. Heavy metal concentrations were exceeding the limit values provided by the American Conference of Governmental Industrial Hygienists (ACGIH). It indicates that workers exposed to these conditions for a long time could be exposed to a potential health hazard, which is associated with the CR value, which indicates a cancer risk but is within an acceptable range.

Health risk assessments from inhalation exposure indicated that garbage collectors at Ubon Ratchathani University have non-carcinogenic health risks from exposure to the five heavy metals in respirable dust (HI < 1). The carcinogenic health risk from heavy metals was found to be within acceptable limits (CR value less than 10^{-6} but not exceeding 10^{-4}). Similar to the research of Azham Umar Abidin et al[1]. there was high-risk level of cancer. Work activities that could affect workers or have the potential to impact health, possibly leading to diseases in at-risk groups, such as cardiovascular diseases; CVD, respiratory dysfunctions and cancer-causing diseases. However, long-term exposure could impact health due to the accumulation of small amounts over a prolonged period. From observations of the behavior of garbage collectors, it was revealed that some workers used improper types of personal protective equipment (PPE), while others did not wear any PPE during their tasks. Therefore, providing standard personal protective equipment (Personal Protective Equipment - PPE) as recommended by (The National Institute for Occupational Safety and Health - NIOSH), which has suggested implementing personal control measures. to workers during their tasks, may help prevent and reduce risk levels.

Conclusion

This study found that the concentrations of heavy metals have been shown to exceed the concentration limits set by the TLV. The HI values for the target metals, which indicate non-carcinogenic risk, were found to be $3.72x10^{-5}$, $1.36x10^{-4}$ and $2.5x10^{-4}$ with a combined average of $1.41x10^{-3}$. The cancer risk average was $3.09x10^{-6}$, $1.12x10^{-5}$ and $9.38x10^{-6}$ with a combined average of 7.91×10^{-6}. The results found that there is no significant risk of non-carcinogenic health effects (HI < 1) according to the U.S. EPA guidelines, and the cancer risk assessment was within the acceptable risk assessment criteria outlined by the U.S. EPA guidelines, with cancer risk (CR) values ranging from $10^{-6} \leq CR < 10^{-4}$, which are considered acceptable. Which is associated with the concentration of heavy metals exceeding the TLV. However, long-term exposure to heavy metals can impact the health of garbage collectors. Appropriate risk control measures should be implemented, and personal protective equipment should be provided to employees to reduce and control the level of exposure.

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