Health Risk Assessment of General Populations Exposed to Metals from an Aluminum Production Plant in Thailand

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Abstract

Background: General populations who live nearby aluminum foundry might have greater risk from exposure to metals from foundry. This study aimed to determine health risk assessment among general populations who lived nearby an aluminum foundry in Thailand.

Materials and methods: Quantitative health risk assessment method of U.S. National Academy of Sciences was used.

Results: Aluminum foundry emitted 6 types of metals. These metals could affect many kinds of health effects but had no carcinogenic effect. The most common pathway for general populations exposed to these metals was by inhalation. Calculated Reference Dose (RID) for inhalation of aluminum, manganese, copper, zinc, magnesium, iron used in this assessment were 1.2E-05, 2.0E-06, 2.2E-05, 6.4E-05, 7.3E-01, 8.25 mg/kg/day, respectively. Maximum Daily Doses (MDDs) for general populations measured in this foundry were 7.92E-06, 1.75E-08, 8.98E-09, 1.22E-05, 6.01E-08, and 9.98E-07 mg/kg/day for aluminum, manganese, copper, zinc, magnesium, and iron, respectively. Finally, risk characterization demonstrated that general populations exposed to metals had the similar risk compared to persons who were not exposed.

Conclusion: Exposure to metals from aluminum foundry did not increase chance of developing diseases from these metals. However, appropriate preventive measures should be maintained at all time to protect health of general populations.

Keywords: General populations; Risk assessment; Aluminum foundry

Introduction

General populations who live nearby aluminum foundry might have greater risk from exposure to metals from foundry. This study aimed to do quantitative health risk assessment among general populations who lived nearby an aluminum foundry.

Materials and Methods

An aluminum foundry in Thailand was selected into this health risk assessment. The National Academy of Sciences/National Research Council (NAS/NRC)’s four steps of risk assessment were performed. Hazard identification was performed by literature reviews for non-carcinogenic and carcinogenic effects of metals emitted from aluminum foundry. Dose-response assessment was performed by considering NOAEL/LOAEL data from epidemiological and animal studies for non-carcinogenic effects (to derive acceptable daily intake) and unit cancer risk for carcinogenic effect. Exposure assessment was performed by deriving air sampling data at into Maximum Daily Dose (MDD) for non-carcinogenic effect and Lifetime Average Daily Dose (LADD) for carcinogenic effect. Risk characterization was performed by using data from exposure and dose-response assessment. Non-carcinogenic risk was calculated by comparing maximum daily dose with acceptable daily intake. Carcinogenic risk was calculated by multiplying unit cancer risk to lifetime average daily dose.

Results

Hazard identification

There were aluminum, manganese, copper, zinc, magnesium, and iron used in this aluminum foundry. Aluminum could affect lung, brain, blood cells, heart, liver, kidney, bones, muscles, skin, eyes, body weight, and endocrine system. Copper could affect lung, intestines, immunity, and blood cells. Manganese could affect lung, brain, blood cell, immunity, heart, liver, kidney, development, reproduction, body weight, and endocrine system. Zinc could affect lung and blood cells. Magnesium could affect lung. Iron could affect lung, intestines, skin, and soft tissues. All of them were not carcinogens. The most common pathway for general populations exposed to these metals was by inhalation [1,2].

Dose-response assessment

Reference Concentration (RfC) calculation: RfC calculation for non-carcinogenic effects of metals emitted from aluminum foundry was done by dividing LOAEL or NOAEL by Uncertainty Factor (UF). Uncertainty factor was used upon study type and type of LOAEL or NOAEL as demonstrated in Table 1.

RfC for each metal was calculated by using the following formula:

\[ \text{RfC} = \frac{\text{NOAEL or LOAEL}}{\text{UF} \times \text{MF}} \]

Where NOAEL or LOAEL=value from animal or human study

UF (Uncertainty factor)=number from Table 1

MF (Modifying factor)=hypothetical number for quality of scientific data; 1 was used in this study for good quality of data

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Non-carcinogenic exposure assessment for non-carcinogenic effect was done because of populations lived nearby (Table 3).

The lowest RfC was selected in this study to protect health of the most sensitive general populations. The lowest RfCs for general population exposed to 6 metals from this aluminum foundry were demonstrated in Table 2.

The lowest RfD was used in this study to protect health of the most sensitive general populations. The lowest RfDs for general population exposed to 6 metals from this aluminum foundry were demonstrated in Table 4.

Non-carcinogenic risk for general populations exposed to each metal was calculated by dividing maximum daily dose with its reference dose. For all metals, general populations exposed to metals had the similar risk compared to persons who were not exposed (Table 5).


discussion and conclusion: Metal air samplings at the end of stack of this aluminum foundry were used to assess exposure among general populations lived nearby (Table 3).

Concentrations of metals which general populations exposed to were estimated by using SCREEN 3 dispersion model of US EPA. Only exposure assessment for non-carcinogenic effect was done because of no carcinogenic effect of all metals. Maximum Daily Dose (MDD) was calculated for non-carcinogenic exposure assessment. Calculation of MDD was performed by the following formula:

$$MDD = \frac{C \times I}{BW}$$

Where C=estimated concentration of metals which general populations exposed to (mg/m³)

I=air volume general populations inhaled during 24 hours=10.8 m³/day

BW=Body Weight=60 kg

Calculated maximum daily doses for all metals general populations exposed to were shown in Table 3.

Table 1: Uncertainty Factor (UF) used to estimate RfC of metals in this study.

| Metals       | Exposure type     | RfC (mg/m³) | RfD (mg/kg/day) | References |
|--------------|-------------------|-------------|-----------------|------------|
| Aluminum     | Acute and subacute| 6.1E-04     | 1.1E-04         | [3]        |
| Aluminum     | Chronic           | 6.5E-05     | 1.2E-05         | [4]        |
| Manganese    | Acute and subacute| 9.0E-06     | 2.0E-06         | [5]        |
| Manganese    | Chronic           | 3.2E-04     | 5.8E-05         | [6]        |
| Copper       | Acute and subacute| 1.2E-04     | 2.2E-05         | [7]        |
| Copper       | Chronic           | 6.4E-03     | 1.15E-03        | [8]        |
| Zinc         | Acute and subacute| 3.6E-04     | 6.5E-05         | [9]        |
| Magnesium    | Acute and subacute| 4.1         | 7.38E-01        | [10]       |
| Iron         | Chronic           | 45.85       | 8.25            |            |

Table 2: RfC values and Estimated RfD for general populations exposed to metals by inhalation from the aluminum production plant.

| Metals        | Concentration at the end of stack (mg/m³) | Date of Air sampling | Estimated concentration general populations exposed to (mg/m³) | Calculated Maximum Daily Dose (MDD) (mg/kg/day) |
|---------------|--------------------------------------------|----------------------|---------------------------------------------------------------|-------------------------------------------------|
| Aluminum      | 6.184                                      | Jul 14, 2009         | 4.4E-05                                                      | 7.92E-06                                         |
| Manganese     | 0.013                                      | June 18, 2009        | 9.7E-08                                                      | 1.75E-08                                         |
| Copper        | 0.006                                      | Aug 20, 2009         | 4.9E-08                                                      | 8.98E-09                                         |
| Zinc          | 9.043                                      | June 18, 2009        | 8.7E-05                                                      | 1.22E-05                                         |
| Magnesium     | 0.043                                      | Jul 23, 2009         | 1.3E-07                                                      | 6.01E-08                                         |
| Iron          | 0.778                                      | Jul 14, 2009         | 1.5E-06                                                      | 9.98E-07                                         |

Table 3: Concentration of metals sampling at the end of stack, estimated concentration of metals which general populations exposed to, and calculated Maximum Daily Dose (MDD) for general populations exposed to metals.

Table 4: Selected RfD for general populations exposed to metals by inhalation from the aluminum production plant.

| Metals       | RfD (mg/kg/day) | References |
|--------------|-----------------|------------|
| Aluminum     | 1.2E-05         | [4]        |
| Manganese    | 2.0E-06         | [5]        |
| Copper       | 2.2E-05         | [7]        |
| Zinc         | 6.5E-05         | [9]        |
| Magnesium    | 7.38E-01        | [10]       |
| Iron         | 8.25            |            |

Table 5: Non-cancer risk estimated for general populations exposed to metals from the aluminum production plant.
this foundry were 7.92E-06, 1.75E-08, 8.98E-09, 1.22E-05, 6.01E-08, and 9.98E-07 mg/kg/day for aluminum, manganese, copper, zinc, magnesium, and iron, respectively. General populations exposed to metals from this aluminum foundry had the similar risk compared to persons who were not exposed.

There were 2 quantitative risk assessments of metals from foundry. The first one was done in a Polish abandoned metal smelter site. There were cadmium, copper, iron, manganese, lead, and zinc contaminated at this site. Cadmium was only carcinogens and calculated carcinogenic risks from cadmium were 1.6E-06 and 2.6E-07 for future industrial and recreational use, respectively [12]. The second one was the assessment of emissions from copper smelters and refineries and from zinc plants in Canada. Airborne levels nearby these metal-processing operations overlapped those associated with cardiorespiratory effects for PM$_{10}$ and exceeded health-based guidelines for SO$_2$ and, near some facilities, lead [13].

Limitation of this study was upon assumption used in this model of assessment. This study aimed to protect the most sensitive populations; therefore, conservative data were used. Calculated risk data were the highest one general populations would have from exposure to metals emitted from this aluminum foundry. Exposure to metals from aluminum foundry did not increase chance of developing diseases from these metals. However, appropriate preventive measures should be maintained at all time to protect health of general populations.

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