

## Original Article

# Occupational exposure to heavy metals in a metal-mechanical auto part manufacturing plant in Puebla, Mexico

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## ABSTRACT

**Aims:** The concentration of Cd, Cr, Al and Pb present in inhalable air and deposited dust in a metal-mechanical parts manufacturing plant in Puebla, México were determined in order to assess the occupational exposure of workers in this plant.

**Materials and Methods:** Fourteen air samples, six from the metal welding (MW) and eight from the metal forming (MF) areas, as well as metal dust accumulated on the floor of an auto part manufacturing plant, were collected. Sampling and analysis followed the National Institute for Occupational Safety and Health (NIOSH) recommended methods for metals in inhalable air.

**Results:** The average concentration of Al and Cd determined in a volume of inhalable air were adequate under NIOSH maximal exposure concentration limits in both sampled sites. Average concentrations of 0.001 (MF sampling site) and 0.105 µg/L (MW sampling site) for Al; 0.003 (MF) and 0.0005 (MW) µg/L for Cd, with respect to the NIOHS limits, 10 and 0.005 µg/L, for Al and Cd, respectively. However, Cr and Pb concentrations exceeded or were close to the limits recommended by NIOHS in both places (0.5 and 0.05 µg/L for Cr and Pb, respectively). Average concentrations of 0.345 (MF) and 0.77 (MW) µg/L for Cr and 0.153 (MF) and 0.649 (MW) µg/L for Pb, were determined. Levels of metal content (Cd, Cr and Pb) in powder samples collected in both sampling sites were also higher than the suggested limits.

**Conclusion:** The average concentration of Cr and Pb exceeded the limits recommended by the Occupational Safety and Health Administration and NIOSH for inhalable air in the workplace. Workers may be on risk of heavy metal occupational exposure. It is endorsed to implement safety measurements to avoid the breathing of contaminated air and also industrial level systems for dust and aerosol particle filtering or precipitation, altogether with stricter policies to regulate heavy metal exposure at these industries.

**Key words:** Air, Al, Cd, Cr, heavy metals, occupational exposure, Pb, workplace

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## INTRODUCTION

Heavy metals belong to a group of elements considered contaminants with toxic or ecotoxic effects commonly present in the environment or the human body at very low concentrations. Metals such as Pb, Hg, Cd, Va, Cr, Al

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or Cu, represent a high toxicity risk when reaching high concentrations in the environment.<sup>[1,2]</sup> Several events of occupational exposure to heavy metals have been registered, and their human health impacts were evaluated. For example, the urine levels of As, Pb, Hg and Cd in Mexican immigrant farmworkers were monitored in order to determine if they were originated by occupational exposition or by other sources, without finding any clear conclusion.<sup>[3]</sup> Children living near mineral industrial complexes (mining, smelting) in Mexico were found to have large As and Cd concentration in urine after continuous environmental exposure to those metals.<sup>[4,5]</sup> Traditional pottery may participate, in a daily use basis, on heavy metals exposure among Mexican workers. Heavy metals (particularly Pb, Cr and Cd) have been found in traditional pottery handcrafted in Puebla and other states of central Mexico, which also have been extensively used in different manufacturing process, including lead batteries, metal-mechanical and automotive industries.<sup>[6-9]</sup>

Metal welding (MW) is a common industrial process used for joining metallic based materials by fusion or coalescence of the interface. Welders are exposed to several airborne contaminants (metal aerosols) arising from the exothermic process in the workplace, which may induce lung abnormalities and airway irritation.<sup>[10]</sup> It has been proposed than simultaneous exposition of two or more heavy metals may increase the chances for DNA damage and cancer.<sup>[11,12]</sup> Metal forming (MF) or casting is another important process where finely-powdered metals are mixed and bound to be shaped into several components for different applications. Both, welding and casting are typical processes used in metal-mechanical plants (in particular, in the automotive industry) and where workers must follow very specific safety procedures for health protection. For example; aerosol removing respirators with appropriate filter and/or cartridges to eliminate particulates and fumes, as well as appropriate clothes and shoes, safety glasses, hearing protection and an strict following of indications such as do not eat or drink in the workplace.

Due to the manufacturing processes, the automotive industry is a place with high risks for heavy metal exposition. Mexico is one of the main automobile producers (8<sup>th</sup> in the world); producing 2.68 million units in 2011 and exporting 2.14 million vehicles in the same period.<sup>[13]</sup> For the State of Puebla (located in the southeast of Mexico) this industrial activity is of particular importance as the Volkswagen (VW) plant is the bigger source of employment (with around 20,000 employees) and several automotive parts manufacturing suppliers of plastics, textiles and metal-mechanical components have been installed around (FINSA's Suppliers Park); this generates employment to >36,000 specialized workers, contributing with about the 25% of the gross income at the entity.

Some employers in developing countries do not pay attention to the exposure of workers to heavy metal. Official safety normativity related to metal exposure is usually soft or inappropriate in several states of México when compared

with international standards. Hence, the risks for heavy metals intoxication and the consequential health issues are the actual problem that requires attention, as chronic intoxication with those metals may show symptoms several years later in the life of over-exposed workers. In this work, an analysis of one manufacturing plant of automotive parts has been performed in order to evaluate whether or not their workers follow appropriate safety procedures and are exposed to a health risk for heavy metal intoxication.

## MATERIALS AND METHODS

Air samples were collected in the facilities of an automotive parts manufacturing company located in FINSA's automotive suppliers park at Puebla City [Figure 1]. The plant is located 100 km South-East of Mexico City. The industrial park agglomerates in the vicinity of the main Mexico's auto-maker plant, VW, nearly 25 suppliers, ranging from plastic auto parts to casting and other automotive parts. The specific supplier (whose name cannot be disclosed due to a confidentiality agreement) is a company devoted to the manufacturing of die casting, dies plates and metal tools. The metals analyzed in this work were Al, Cd, Cr, and Pb, as they are commonly present in the composition of several alloys used both in the MW and die forming/casting processes [Figure 2].

The manufacturing plant works in 24 h circles divided into three shifts of 8 h each one, keeping all areas (welding and casting) continuously working. In general, the employees must follow basic industrial safety norms, like the use of protective clothes, helmets, gloves, safety shoes, ear plugs and security glasses. However, it was not possible during the inspection visit, to find eyewash stations, first-aid kits or safety equipment distributed into the manufacturing area. Furthermore, only one person was using aerosol removing respirator with filters for fumes and particulated materials.

Fourteen points were selected for air sampling: Six in the MW area and eight in the metal casting area. No special criteria for the selection of the sampling sites was defined, except they should be taken in the specific spots where a typical worker station was located. Two types of samples were collected at



**Figure 1:** Aerial view of FINSA's suppliers park at Puebla City

each station: Inhalable air and dust accumulated on the floor. For inhalable air samples, an Airchek52 air pump previously calibrated to pull air at 2.5 L/min with a fluxometer (SKC, Cat No. 303) using static sampling was used. Sampling procedures were done according to the norms and protocols recommended by two occupational safety and health agencies in United States (National Institute for Occupational Safety and Health [NIOSH] and Occupational Safety and Health Administration [OSHA]).<sup>[14,15]</sup> A sampling time of 20 min in a site was enough to have a representative air volume (50 L) for the analysis of different metals. Table 1 shows the volume needed to analyze heavy metals according with the NIOSH Method 7300.<sup>[14]</sup> Conferring to that method, high purity cellulose cartridges with low content of metals (SKC Preloaded Caset mixed cellulose ester) were used. The cartridge was later chemically digested, and the metal content determined by flame atomic absorption spectroscopy (AAS) (atomic emission spectroscopy) analysis.

Three different air samples were taken at every sampling point at time intervals of 8 days. Each sample was taken at a height of 1.5 m over the working zone floor, at a distance between 1.0 and 1.5 m to the nearest worker. Dust samples (10 mg) were collected in only one sampling point at each area in a unique time. Each cartridge was opened in the laboratory and the cellulose filter removed and digested in a 50 mL beaker containing 10 mL of concentrated HNO<sub>3</sub> during 2 h. After that, the solution was recovered in a volumetric flask and filled to 250 mL with distilled water. All glassware was previously cleaned with HCl 10 N overnight to eliminate any metal trace and rinsed with distilled and deionized water (18 ohms of conductivity). Then, the samples were dissolved in 10 mL of concentrated HNO<sub>3</sub> and processed as previously described.

Standard solutions (1000 ppm) for each metal were prepared from commercially available AlCl<sub>3</sub>, Cd(NO<sub>3</sub>)<sub>2</sub>, Cr(NO<sub>3</sub>)<sub>3</sub>, and Pb(NO<sub>3</sub>)<sub>2</sub>. All reagents were purchased from Aldrich and were analytical grade and used as delivered. All salts were predissolved in 10 mL of HNO<sub>3</sub> and then diluted to 1 L with distilled water. These solutions were used to prepare a calibration curve according with the maximum limit concentrations recommended by NIOSH for heavy metal exposure in work places and environment.<sup>[14]</sup> Heavy metal content was determined by AAS, using a Varian SpectrAA 220FS spectrophotometer, with a flame of air/acetylene for Cd, Pb, and Cr and a flame of N<sub>2</sub>O/air for Al.

To consider the risk of heavy metals exposure, NIOSH and OSHA permitted maximum air occupational exposure metal concentration limits were used as a reference [Table 2].<sup>[14,15]</sup>

## RESULTS

The auto parts manufacturing plant had a 24 h work cycle, with three shifts every 8 h. There were 102 people working at the time, 17 were administrative or supervisors and 85 were

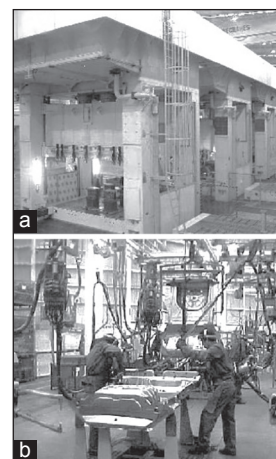
**Table 1: Minimum and maximum air volume needed to detect different heavy metals**

| Metal         | Minimal air volume required (L) | Maximal air volume required (L) |
|---------------|---------------------------------|---------------------------------|
| Aluminum (Al) | 5                               | 100                             |
| Cadmium (Cd)  | 13                              | 2000                            |
| Chrome (Cr)   | 5                               | 1000                            |
| Lead (Pb)     | 50                              | 2000                            |

**Table 2: Maximum levels of different heavy metals in work places according to NIOSH and OSHA**

| Metal | NIOSH/MCP* (µg/L) | OSHA/MCP* (µg/L) |
|-------|-------------------|------------------|
| Al    | 10                | 15               |
| Cd    | 0.005             | 0.005            |
| Cr    | 0.5               | 1                |
| Pb    | 0.05              | 0.05             |

\*MCP: Maximum concentration permitted, NIOSH: National institute for occupational safety and health, OSHA: Occupational safety and health administration



**Figure 2:** (a) High technology presses used in casting processes; (b) metal welding area, at the suppliers manufacturing site

operators in the manufacturing area. Of these, 47 were female and 38 male (55% and 48% respectively). Three persons were working simultaneously at the MW area and 24 at the MF area every shift. Safety regulations mandate the use of basic security equipment, both in the welding as in the forming area, such as helmets, security glasses, gloves, welding apron, cotton overalls, ear plugs and industrial shoes; and minimally security glasses, cotton overalls, ear plugs and industrial shoes for supervisors and administrative personal. However, only one person among all was using the proper security equipment (at the welding area). None of the workers used aerosol removing respirators as recommended by OSHA regulations.<sup>[16]</sup>

Data in Table 3 shows the concentrations of Al, Cd, Cr and Pb as determined from the air samples collected during 3 days at the selected sites. The average concentrations in air of Al, Cd, Cr and Pb at the MF area were 0.105, 0.001, 0.770 and 0.649 µg/L, respectively while the average values for the same metals at the MW area were 0.0, 0.003, 0.345 and 0.153 µg/L,

respectively. For the two samples of 10 mg of metal powder collected at the floor of each sampling site, the concentrations of Al, Cd, Cr and Pb were 1.885, 0.014, 0.338, 0.390 µg/L (volume of inhalable air) respectively for the MW zone and 7.664, 0.085, 0.516 and 0.450 µg/L for the MF zone.

The average concentrations determined by AAS for Al, Cd, Cr and Pb in the MF and welding areas, and the metal concentration, both in air and in powders collected in those sites, respectively are shown in Figures 3 and 4.

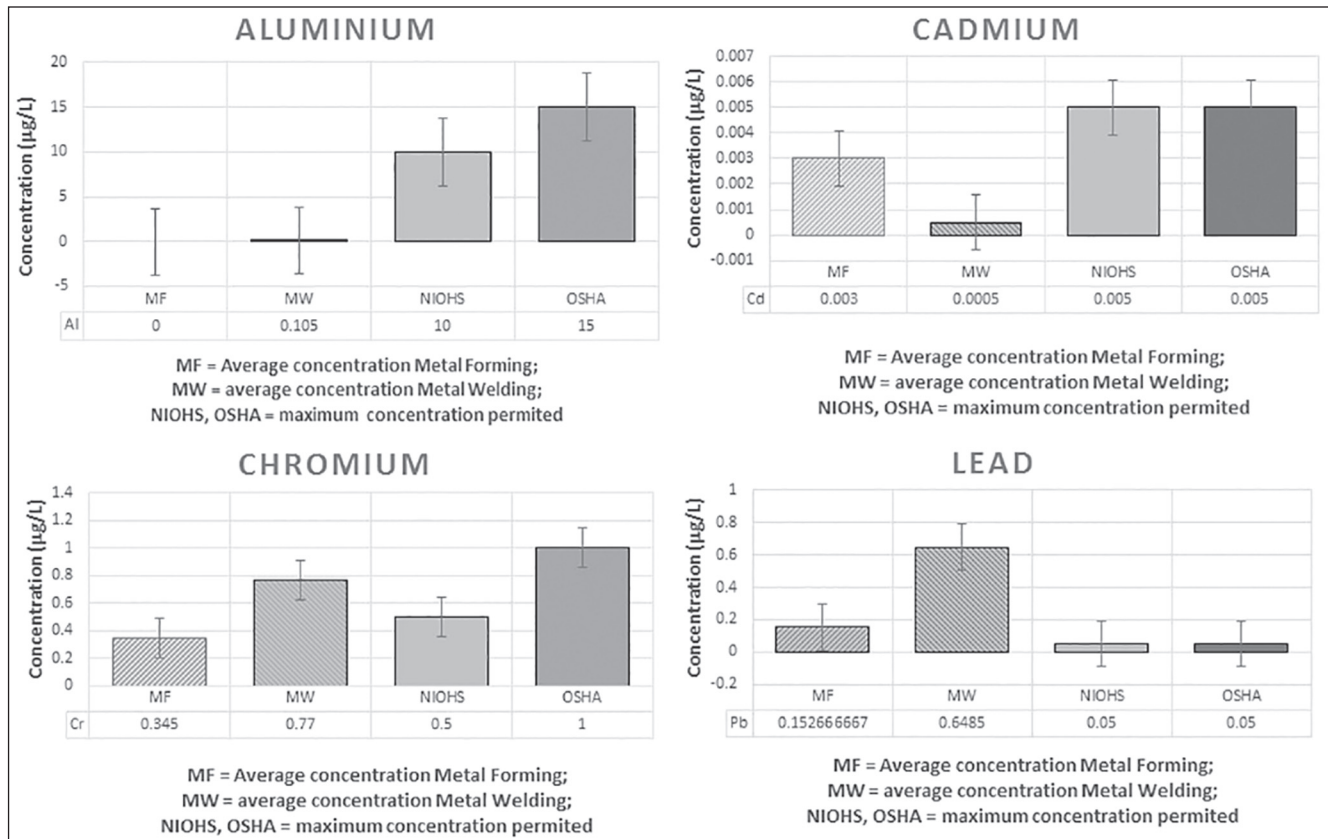
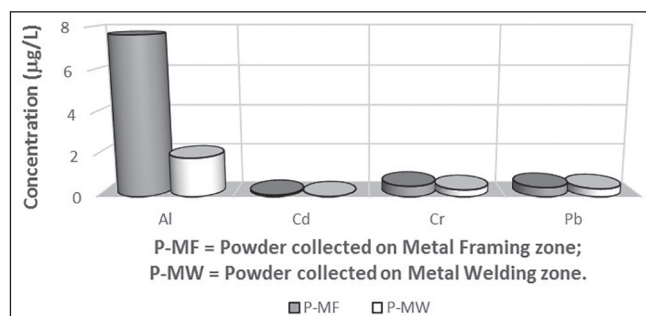


Figure 3: Al, Cd, Cr and Pb average concentrations in air as determined at the metal forming and metal welding areas

Table 3: Metal concentrations of Al, Cd, Cr and Pb at the sampling sites

| Metal/day of collection | Metal forming 1 (µg/L) | Metal forming 2 (µg/L) | Metal forming 3 (µg/L) | Metal welding 1 (µg/L) | Metal welding 2 (µg/L) |
|-------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| Day 1                   |                        |                        |                        |                        |                        |
| Al                      | < MDL *                | < MDL *                | < MDL *                | < MDL *                | 0.020                  |
| Cd                      | 0.008                  | < MDL *                | < MDL *                | < MDL *                | 0.003                  |
| Cr                      | 0.412                  | 0.447                  | < MDL *                | 0.453                  | 0.464                  |
| Pb                      | 0.155                  | 0.180                  | 0.150                  | 0.165                  | 0.165                  |
| Day 9                   |                        |                        |                        |                        |                        |
| Al                      | < MDL *                | < MDL *                | < MDL *                | 0.495                  | 0.115                  |
| Cd                      | 0.02                   | 0.014                  | < MDL *                | < MDL *                | 0.001                  |
| Cr                      | 0.458                  | 0.442                  | 0.496                  | 0.659                  | 2.074                  |
| Pb                      | 0.399                  | 0.175                  | 0.210                  | 0.325                  | 2.874                  |
| Day 17                  |                        |                        |                        |                        |                        |
| Al                      | < MDL *                | < MDL *                | < MDL *                | < MDL *                | < MDL *                |
| Cd                      | 0.002                  | < MDL *                | < MDL *                | < MDL *                | < MDL *                |
| Cr                      | 0.399                  | 0.448                  | < MDL *                | 0.455                  | 0.517                  |
| Pb                      | 0.165                  | 0.170                  | < MDL *                | 0.175                  | 0.185                  |
| Metal powder            |                        |                        |                        |                        |                        |
| Al                      |                        |                        | 7.664                  |                        | 1.885                  |
| Cd                      |                        |                        | 0.085                  |                        | 0.014                  |
| Cr                      |                        |                        | 0.516                  |                        | 0.338                  |
| Pb                      |                        |                        | 0.450                  |                        | 0.390                  |

\* < MDL: Lower than the method detection limit. Al: 0.01, Cd: 0.0009, Cr: 0.04, Pb: 0.05 µg/L



**Figure 4:** Heavy metal concentration in collected powder at the metal forming and metal welding areas

## DISCUSSION

With those considerations, it is possible to say that >90% of the personnel including administrative were not using proper safety protection and were exposed to risk of chronic heavy metal intoxication. The lunch room and a small coffee room close to the administrative office were located in a place where air currents may carry metal powders containing heavy metals, with the consequential risk of inhalation/ingestion by the workers.

Aluminum was under the mandatory limits (10 µg/L NIOSH, 15 µg/L OSHA) in both sampling places. The Cd concentration was also under the recommended limits (0.05 µg/L, NIOSH and OSHA) in both sampling sites, although it was high enough at the welding zone to become a risk for chronic intoxication for an operator under long time (years) exposure.<sup>[17]</sup> The average Cr concentration was found higher than the recommended limits (0.5 µg/L) in the welding area by NIOSH. It was found that the average Pb concentration was higher than the maximum amount permitted in air by OSHA and NIOSH (0.05 µg/L) in both the MF and welding areas.

10 mg of metal powders deposited in the floor at the forming manufacturing site were collected and analyzed by AAS; 77% were aluminum, with near 10% composed by the other metals (0.8% Cd, 5% Cr and 4% Pb). Although these are nonvolatile solids, they can deposit on several substrates (clothes, food, and skin) and become a health issue if ingested or internalized by other ways just as transdermal absorption, inhalation, or wounds.

From the concentration values determined, there was no special safety recommendation for Al exposure at the factory. Also, Al seems to have a low air mobility as deduced from the high concentration of the metal in the powders deposited on the floor. Cadmium, in the other hand, is a heavy metal of considerable occupational concern as it is classified as a human carcinogen by several regulatory agencies.<sup>[18]</sup> It was present at significant amounts at every sampling place, which requires the consideration of implementing appropriate measures to avoid large exposure time periods and, as a result, decrease the probability for

chronic intoxication. Chromium was in nonsignificant concentrations around the sampling sites, but as it may become toxic depending of its speciation and oxidation state, because of that it is recommended to consider the application of safety measures in order to avoid occupational exposure for long times. Finally, lead concentration was a big concern, as it was present in concentrations higher than the limits allowed by both OSHA and NIOSH. The use of auxiliary aerosol removing equipment with appropriate filters is mandatory for all operators at the manufacturing plant. Installation of an industrial air purification system, with capabilities for particle trapping under 2.5 µ (µm) such as electrostatic precipitators, industrial size filters or electroacoustic agglomeration is highly recommendable.

The problem of occupational exposure to heavy metals is of interest as it may become a complex and expensive health issue. In Mexico no strict policies to regulate exposition to heavy metals at workplaces exist, so several national and foreign industries have choice to establish at our territory due to the flexible or nonexistent safety norms. That of course represents a danger for people working at those places. Lack of information on the use and types of safety equipment to avoid heavy metal exposition at the work area are supposedly being part of the responsibilities of the company. Also, safety courses on the potential dangers to human health derived from heavy metal exposition may be of great help to decrease incidental exposure and other risky situations.

In summary, in this work the manufacturing plant was recommended to strength their safety policies in order to reduce or eliminate the risk for heavy metal occupational exposure to the working personnel, including administrators and especially for women which, if pregnant, are the most sensitive to potential teratogenic damage to the embryos.<sup>[19,20]</sup> However, independently from the gender type, it was noted that all workers were in risk to develop different acute or chronic diseases. There are several reports on heavy metal exposition among automobile and electronics related employees and the potential negative impacts into their health.<sup>[17,21-23]</sup> Although the levels of Al, Cd and Cr in the sampled areas were lower than the limits recommended by NIOSH and OSHA norms, they should take in count that workers may be exposed for long time and may develop chronic intoxication by bioaccumulation. Another feature that was not considered is the metal particle size, a parameter that may become very important to understand the physical and chemical interaction of the particles with a biological system. Periodical clinical analysis (blood, urine) for all workers are also recommended to check their health status and to take preventive actions with the purpose of avoiding future complications associated with heavy metal intoxication. Even though the company has taken in consideration all the endorsements, these type of studies should continue to be done in the future to follow the air quality at this and other metal-mechanical manufacturing plants at the region and in the rest of the country.

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