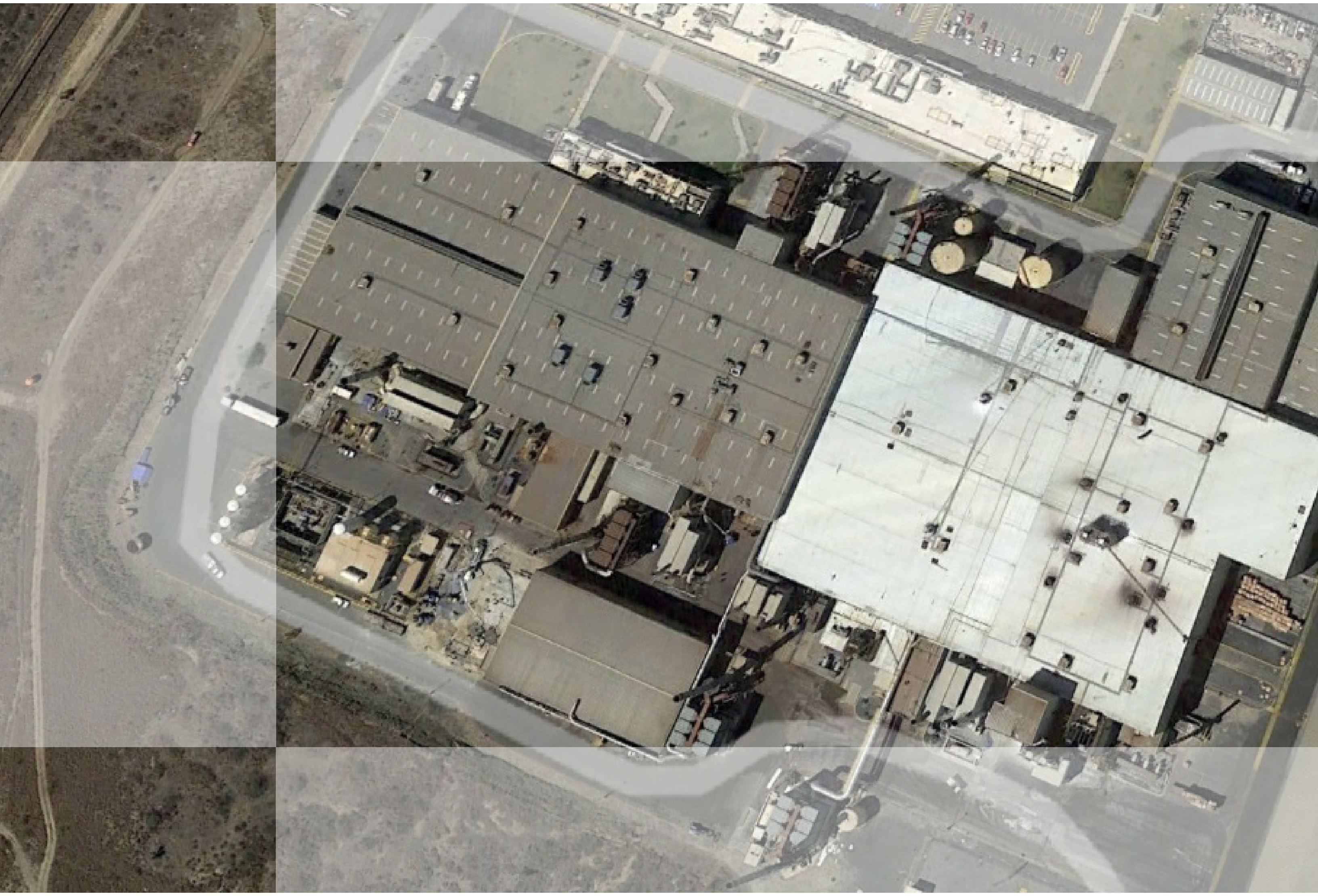
Hazardous Exports Contribute to Soil Contamination at Lead Battery Recycling Plants in Mexico



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Executive Summary

Mexico has less stringent environmental and occupational standards for the lead battery recycling industry than in the U.S. In addition, little investment is made in enforcing environmental regulations in Mexico. The lack of protective standards and weak enforcement have been cited as reasons for why Mexico is the destination of between 75-95% of used batteries exported annually from the U.S.

To assess the potential for airborne stack and fugitive emissions to contaminate areas around lead battery recycling plants, we collected 28 soil samples to test for lead contamination outside of select lead battery recycling plants. We found that 16 samples (57%) exceeded the Mexican standard for industrial areas (800 ppm). The average (arithmetic mean) lead concentration in the locations sampled was 4,897 parts per million (ppm) or more than six times the Mexican Standard and results ranged from 89 to 43,000 ppm. Our study points to the need for more protective standards and improved enforcement for lead battery recycling plants in Mexico.

Additional findings from this report include the following:

- From 2011 to 2021, exports of used lead batteries from the U.S. to Mexico increased by 18%;
- Approximately 75% percent of used lead batteries exported from the U.S. in 2021 were sent to Mexico for recycling;
- Clarios (formerly Johnson Controls) was responsible for 68% of all used lead battery exports sent from the U.S. to Mexico in 2021;
- Soil samples taken around lead battery recycling plants in Mexico had an average lead concentration of 4,897 ppm or more than six times the Mexican Standard;
- The average soil lead level outside of Clarios's Garcia plant, that took in the largest share of used lead batteries from the U.S. than any other facility, was 8,502 ppm or more than ten times the Mexican Standard;
- The Ambient Air Standard for airborne lead is more than three times greater in Mexico than in the U.S.

Introduction

Almost all lead batteries are recycled to recover lead for use in new batteries and other applications. However, the lead battery recycling industry has been known to emit high concentrations of lead and other metals resulting in air, soil and water contamination. The industry is also plagued by very high occupational exposures to lead. Even lead battery recycling plants in the U.S. have been major sources of soil contamination that contribute to lead exposures in surrounding communities. In California one older recycling plant that was shut in 2014 is responsible for contaminating an area housing approximately 100,000 people and spread contamination to more than 10,000 properties are a radius of approximately 2.7 km (California State Auditor, 2020).

Used lead batteries in the U.S. are recycled at eleven domestic secondary lead smelting facilities but a significant portion of used batteries are exported for processing in Canada, Mexico and South Korea. The U.S. is the world's largest exporter of used lead batteries (ILZSG, 2021). Data from the U.S. International Trade Commission shows that in recent years Mexico received between 75 and 95 percent of these exports (U.S. ITC, 2022). The reason that a large proportion of U.S. exports are shipped to Mexico is that environmental regulations and enforcement are less restrictive in Mexico than in the U.S. (ILZSG, 2021). Figure 1 shows the increase in used lead batteries shipped to Mexico after the U.S. National Ambient Air Quality Standard (NAAQS) for lead in ambient air was finalized and then enacted for the first time in 30 years.

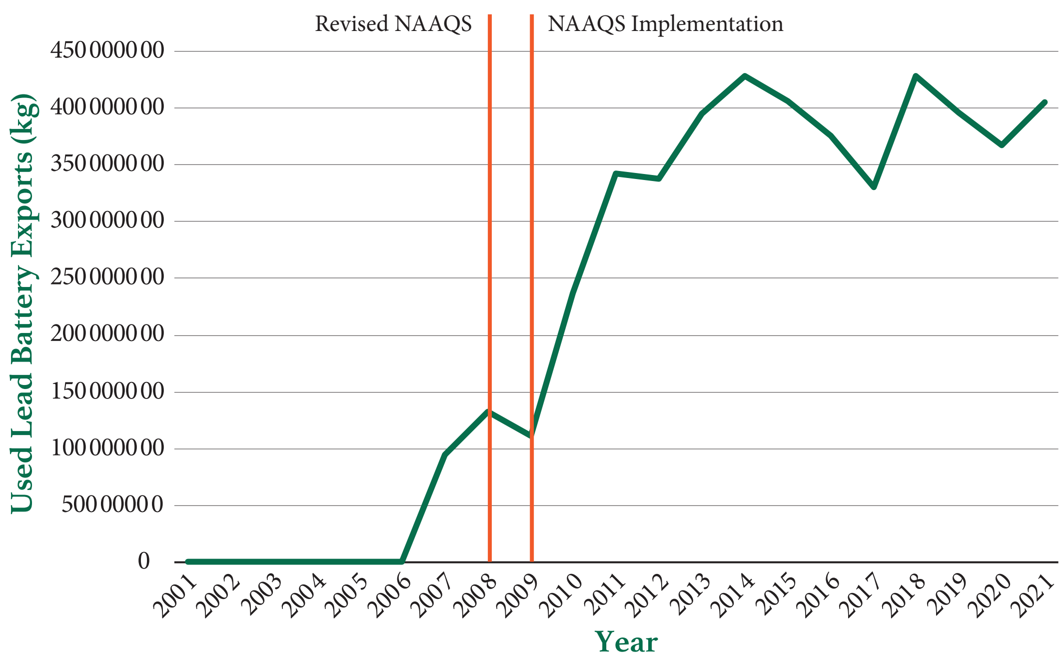

Figure 1: Used Lead Battery Exports from U.S. to Mexico

Source: U.S. International Trade Commission, (dataweb.usitc.gov) for tariff code 8548100540

Exports of used lead batteries from the U.S. to Mexico have grown substantially since 2008 following the reduction in the lead NAAQS and continued to increase by 18% from 2011 to 2021. Since 2017 exporters are required to track individual shipments and report to the U.S. Environmental Protection Agency (EPA) annually on the quantity and destinations of used lead batteries under the Universal Waste Export Rules (U.S. EPA 2016). From this information, we know that a single company, Clarios (formerly Johnson Controls) was responsible for 68% of U.S. used lead batteries shipped to Mexico in 2021 (unpublished data received from U.S. EPA via Freedom of Information Act request).

In 2021 Mexico imported more than 515,000 metric tons (MT) of used lead batteries from the U.S. to process at eight plants (unpublished data from U.S. EPA). Clarios's Garcia plant was the largest recipient taking in 43% of these exports from the company's U.S. operations.

Mexico has been the largest importer of used lead batteries from the U.S. for many years and was the subject of a 2013 report issued by the Commission on Environmental Cooperation (CEC) under the North America Free Trade Agreement (NAFTA) (CEC 2013). Since that report was released almost a decade ago, exports to Mexico have continued to increase. Note that the data available from the U.S. ITC appears to under report export quantities of used lead battery exports in comparison to U.S. EPA data (available since 2017) that comes from individual reports from all exporters.

Lead soil contamination reflects airborne lead from stack emissions and from fugitive emissions that has settled on surfaces. Over the past decade, the U.S. had lowered ambient air standards for lead which required existing recycling facilities to invest in improved pollution controls and resulted in reductions in lead concentrations around these facilities (Tanaka S, 2022). The ambient air standard in Mexico is more than three times higher than the U.S. standard, and unlike the U.S. standard only applies to lead particles less than 10 microns in diameter (PM10) (Mexico NOM-026-SSA1-2021).

Although Mexico updated the standard for lead stack emissions (NOM-166-SEMARNAT-2014) following the release of the CEC report, the regulation allowed for an eight-year phase in period to bring companies into compliance with a 0.2 mg/m^3 level with quarterly sampling required (Mexico Semarnat, 2014). The lower standard is scheduled to go into effect in January 2023, but Mexico lacks the enforcement capacity and a sufficient environmental monitoring program to ensure compliance.

Soil Sampling Procedures

We selected a total of seven recycling plants in two States in Mexico for testing. Five (71%) of the seven plants tested received used lead batteries imported from the U.S. in 2021.

Sample locations were selected to be representative of bare soil areas in the vicinity of the recycling plants. An attempt was made to access public areas around all four cardinal directions (North, South, East and West) where possible to account for variable prevailing winds and dispersion patterns. We recorded the approximate distance from the property line, wall or fence line to the sample locations. In some cases, public access was limited due to fencing or other barriers. Sample locations varied from within 1 to 385 meters from the recycling plant boundaries depending on access and site conditions.

A standard sampling protocol was used to collect surface soil from the top 0-3 cm at representative locations at the fence line or factory wall that represented the closest public access to each facility. Individual sample locations were selected by convenience to be representative of bare soil conditions. At each sample location, we collected 5 to 8 sub-samples from bare soil within a one square meter area as a composite that was placed in a labeled and sealed 25 ml plastic sampling tube.

Each facility address was recorded along with location coordinates from a handheld GPS unit. Information on land use in the surrounding area around the plants was recorded from direct observation and from reviewing aerial satellite images. Photographs were also taken to document land usage in representative sample locations. Figures 2-5 show representative soil sampling locations at four of the facilities tested.

A total of 28 soil samples were collected from areas outside of the facility boundaries. Samples were transported via air freight carrier to EMSL Laboratories (Cinnaminson, N.J. USA) for analysis. Samples were imported into the U.S. under U.S. Department of Agriculture permit number P330-20-00038. Total lead concentrations were analyzed by flame Atomic Absorption Spectroscopy (AAS) with EPA method SW 846 3050B/7000B.

Results and Discussion

The arithmetic mean soil lead concentration for the 28 samples was 4,897 parts per million (ppm) and ranged from 89 to 43,000 ppm (see Table 1). The median level from the locations tested around these plants was 1,035 ppm. Six of the seven facilities had at least one sample location that exceeded 800 ppm, or the

Figure 2: RECMAT de Mexico: East Wall Soil Lead Level of 1,800 ppm

Figure 3: Clarios Garcia: Facility North Wall Soil Lead Level of 13,000 ppm

Figure 4: RIASA Grupo Gonher: South Fence Soil Lead Level of 1,600 ppm

Figure 5: Corporación Pipsa: South Fence Soil Lead Level of 43,000 ppm

Mexican soil lead standard for industrial areas (NOM-147-SEMARNAT/SSA1-2004).

U.S. EPA uses 800 ppm for lead in soil as a screening level for non-residential sites. California uses 320 ppm as the screening level for commercial or industrial properties. However, cleanup goals are generally set based on specific site conditions and vary based on the results of a human health risk assessment considering the exposed population, exposure duration, bioaccessibility and other factors.

It is important to note that lower lead soil contamination standards apply to residential areas. In both the U.S. and Mexico, the trigger level is 400 ppm for residential soil lead levels (Mexico NOM-147-SEMARNAT/SSA1-2004). In California, the State Government has a residential screening level of 80 ppm.

The facilities that imported used lead batteries from the U.S. in 2021 had extensive lead soil contamination in the surrounding areas tested. Table 2 lists the facilities, average soil lead levels, and the quantity (in metric tons) of imported used lead batteries delivered to each in 2021. According to Mexican government data, our survey

Table 1. Soil Lead Concentrations

Recycling Facility	Lead ppm (mg/kg)
DIAN Procesos Metalúrgicos, S.A. de C.V.	580
DIAN Procesos Metalúrgicos, S.A. de C.V.	280
DIAN Procesos Metalúrgicos, S.A. de C.V.	89
DIAN Procesos Metalúrgicos, S.A. de C.V.	590
Eléctrica Automotriz Omega, S.A. de C.V.	3,100
Eléctrica Automotriz Omega, S.A. de C.V.	8,200
Clarios: Cienega de Flores facility	120
Clarios: Cienega de Flores facility	1,200
Clarios: Cienega de Flores facility	640
Clarios: Cienega de Flores facility	3,400
Clarios: Cienega de Flores facility	230
RECMAT de Mexico	590
RECMAT de Mexico	1,800
RECMAT de Mexico	1,100
Clarios: Garcia facility	9,400
Clarios: Garcia facility	12,000
Clarios: Garcia facility	15,000
Clarios: Garcia facility	13,000
Clarios: Garcia facility	960
Clarios: Garcia facility	650
Corporación Pipsa	240
Corporación Pipsa	1,500
Corporación Pipsa	43,000
Corporación Pipsa	16,000
Corporación Pipsa	740
RIASA Grupo Gonher	150
RIASA Grupo Gonher	970
RIASA Grupo Gonher	1,600
Average (Mean)	**4,897**
Median	**1,035**

Table 2. Quantity of Lead Batteries Imported from the U.S. at Select Mexican Recycling Plants (2021)

Importing Facility	Quantity of Used Lead Batteries Imported from U.S. (MT)[i]	Number of Shipments[i]	Capacity (tons)[ii]	Mean Soil Lead Level (ppm)
DIAN Procesos Metalúrgicos	–	–	4,320	385
Eléctrica Automotriz Omega	–	–	94,000	5,650
RECMAT de Mexico	4,634	240	24,000	1,163
Corporación Pipsa	30,224	1,579	104,760	12,296
RIASA Grupo Gonher	59,244	3,256	121,804	907
Clarios: Cienega de Flores facility	130,049	6,547	254,085	1,118
Clarios: Garcia facility	220,070	9,974	252,000	8,502
Total	**444,220**	**21,596**		

Sources: (i) Obtained through a Freedom of Information Request from the U.S. Environmental Protection Agency (EPA) for annual reports on the quantity and destinations of used lead batteries exported as required under the Universal Waste Export Rules. (ii) Facility capacities reported by the Mexico Ministry of Environment and Natural Resources, 2022.

included four of the five largest lead battery recycling plants in Mexico with a capacity greater than 100,000 tons/year (Mexico Ministry of Environment and Natural Resources, 2022). The results suggest that some of the largest plants tested have the highest mean lead levels in soil surrounding these facilities. These larger plants also import the greatest quantities of used lead batteries from the U.S. The data shows substantial contamination around that the two Clarios facilities that are importing the majority of all used lead battery exports from the U.S. to Mexico (EPA unpublished data).

In 2021, Clarios shut down its only U.S. recycling plant impacting 360 jobs in South Carolina and increased shipments of used lead batteries going to its plants in Mexico (WPDE). As production at the plant did not cease until the end of the first quarter of 2021, it is likely that this closure will result in an even larger quantity of exports shipped to Mexico in 2022. A report from the International Lead Zinc Study Group (ILZSG) says that the reason that these waste batteries are exported is because Mexico has more lenient standards and less strict enforcement for the lead battery recycling industry than the U.S. (ILZSG, 2021). The report explains that the growth in used lead battery exports in recent years is a reflection of the strict environmental controls and related administrative costs in the U.S. It also notes that the U.S. is the destination for more than 80% of Mexico's refined lead exports.

Some of the recycling plants included in this study shared properties with lead battery production facilities or other lead chemical plants. The Clarios facility in Cienega de Flores also has a lead battery manufacturing plant. The RIASA Grupo Gonher site also houses a lead battery manufacturing facility. The Omega recycling plant appears to share the site with Penox which produces lead oxide and perhaps other lead-containing chemicals. The available information indicates that at least in 2012 OMEGA was the lessor and PENOX the lessee of the property where it is located (Penox report 2012).

Mexican lead battery recycling plants operate with less stringent regulatory requirements than facilities in the U.S. The Commission on Environmental Cooperation (CEC) report "Toxic Trade?" released in 2013 highlighted some of these deficiencies including the difference in ambient air standards and in air concentrations allowed from stack emissions. Table 3 summarizes the key Mexican and U.S. environmental and occupational standards that relate to lead battery recycling facilities.

Table 3: Comparison of key regulatory standards between the U.S. and Mexico

Air Emissions	U.S.	Mexico
End of stack (facility wide)	0.2 mg/dscm[a]	0.2 mg/m^3[a]
End of stack (each stack)	1.0 mg/dscm[a]	1.0 mg/m^3[d]
Ambient air	0.15 µg/m^3 over 3-month rolling average (total suspended particulate matter)[b]	0.5 µg/m^3 averaged annually (for PM10 only)[e]
Occupational	**U.S.**	**Mexico**
Permissible Exposure Limit (PEL)	50 µg/m^3 averaged over 8 hours[c]	50 µg/m^3 averaged over 8 hours[f]
Blood lead level for medical removal	50 µg/dl[c]	No standard

References:

a. US EPA 40 CFR Part 63, National Emissions Standards for Hazardous Air Pollutants Secondary Lead Smelting; Final Rules (January 5, 2020)

b. US EPA 40 CFR Parts 50, 51, 53, and 58 National Ambient Air Quality Standards for Lead; Final Rule November 12, 2008

c. U.S. OSHA, Occupational Lead Standard (general industry) 1910.1025.

d. NORMA Oficial Mexicana NOM-166-SEMARNAT-2014, Control de emisiones atmosféricas en la fundición secundaria de plomo.

e. NORMA Oficial Mexicana NOM-026-SSA1-2021, Salud ambiental. Criterio para evaluar la calidad del aire ambiente, con respecto al plomo (Pb). Valor normado para la concentración de plomo (Pb) en el aire ambiente, como medida de protección a la salud de la población.

f. NORMA Oficial Mexicana NOM-010-STPS-2014, Agentes químicos contaminantes del ambiente laboral-Reconocimiento, evaluación y control.

Since the CEC pointed out the Mexican regulatory deficiencies in their 2013 report, both countries updated their ambient air standards but Mexico still allows more than three times greater airborne lead levels than in the U.S. Occupational health controls in Mexico are also far more lenient than in the U.S. under Occupational Safety and Health Administration (OSHA) regulations. However, given the lack of enforcement for environmental regulations in Mexico, many companies are unlikely to invest in pollution control equipment needed to meet the revised emission standard.

Comparative Levels of Contamination Reported in Other Studies

Background lead levels in Mexico have been assessed by others. Hernández-Mendiola reported mean background lead levels of 16.6 ppm from samples at 12 locations (Hernández-Mendiola, E., et al. 2022). Similarly, background lead levels globally have been estimated to be 16 ppm (Hooda, P; 2010).

A Mexican study tested soil contamination at a shuttered lead battery recycling facility in Tepetlaoxtoc and reported average levels of 41,893 ppm with a maximum reported of 122,404 ppm. (González-Chávez, M; et al. 2019). An earlier study of soil lead levels in a residential area near a lead refinery and lead crystal factory reported a median concentration of 467 mg/kg (Benin, A; et al. 1999). Another study conducted in San Luis Potosi, Mexico within 1.5 km of a primary smelter, reported the mean lead level was 1,450 mg/kg with a maximum 12,600 mg/kg (Carrizales, L; et al. 2006).

In other countries similar soil contamination from lead battery recycling and manufacturing plants have been reported. For example, samples collected near a secondary lead smelter in northern France showed soil lead values ranging from 880 to 9,030 mg/kg (Schneider, Arnaud R., et al. 2016). Samples collected within one kilometer of a lead battery recycling plant in China included 25 soil samples collected from the top 1-2 cm of the surface. Although median soil lead levels were relatively low at 100 mg/kg, the data showed a statistically significant relationship with the direction and distance from the facility (Zhang, et al. 2016). Testing of surface soil lead concentrations in an area outside of a formal sector lead battery recycling plant in Banten Indonesia ranged from 240 to 1,780 mg/kg at distances from 300 to 600 meters from the plant (Adventini, N, et al. 2017). In addition, lead concentrations in surface soil were inversely proportional to the distance from the smelter.

A study examining soil contamination outside 15 lead battery recycling plants in seven African countries identified soil lead levels ranging up to 48,000 mg/kg. The mean level was 2,600 mg/kg (Gottesfeld, P; et al. 2018).

Several studies have noted that lead levels in topsoil around lead battery recycling plants decreases with depth. A French study near a lead recycling plant found lead concentrations in topsoil of 1,930 mg/kg that rapidly decreased to background levels at a depth of 60 cm below ground surface (Cecchi, et al. 2008). A review article summarizing 160 studies reporting on soil contamination from nonferrous smelters showed that lead is less mobile in soils than cadmium and zinc (Ettler, Vojtěch. 2016). The same study also confirmed that prevailing wind direction is a key factor in dispersion and soil deposition patterns.

Several studies have demonstrated that soil contamination near lead battery recycling plants can lead to significant lead exposures in surrounding communities (Daniell, William E., et al. 2015; Levallois, P., et al. 1991; Wang, Jung-Der, et al. 1992). A review summarizing ten published studies showed that average blood lead levels among children living in the proximity of lead battery recycling plants in developing countries averaged 29 µg/dl (Gottesfeld, P; 2011). In areas of Los Angeles surrounding the Exide lead battery recycling facility that was closed in 2015, elevated blood lead levels were reported among children residing within a mile of the facility. An analysis conducted by the State of California showed that 3.5% of children within this zone had blood lead level greater than 4.5 µg/dl compared with 1.95% for all of Los Angeles County (California Department of Public Health, 2016).

In the case of the Mexican lead battery recycling plants included in this survey, several sites were within a 2 KM radius of residential areas. There is no information available on blood lead levels in these communities.

Conclusions and Recommendations

Communities in the vicinity of the facilities tested may have soil and dust contamination from airborne lead emissions at these sites. Soil testing should be conducted at residential properties and public parks in these areas to determine the extent of the contamination. In addition, children residing in these areas can be impacted without even being aware of this risk. There is a need to conduct blood lead testing among children in these high-risk communities near lead battery manufacturing and recycling plants. Mexico had conducted a national blood lead surveillance in recent years, but additional targeted testing should be focused in communities around lead-using industries.

The lead soil contamination identified in areas around these lead battery recycling plants suggest that there are serious deficiencies in regulating and controlling emissions from secondary lead smelters in Mexico. More enforcement is needed to determine if these facilities are meeting current regulatory standards. Additional transparency is also needed so that local communities can be aware of lead emissions from these facilities. Many of these facilities do not report annual lead releases as required under the Mexican under the Registro de Emisiones y Transferencia de Contaminantes (RETC) system which requires annual report of airborne releases, waste disposal and other releases similar to the U.S. Toxic Release Inventory (TRI). However, to further compound the lack of reporting, Mexico changed the reporting requirements for lead in 2013 (NOM-165-SEMARNAT-2013) that appears to have limited the reporting to releases of respirable lead. Given that health based concerns are generally with total airborne lead and that is the way it is regulated in other countries, it is difficult to assess the limited data provided after the regulatory change in Mexico.

Soil contamination often varies considerably over short distances and can be impacted by soil disturbances due to landscaping and previous construction in the immediate area. Given our small sample size, it is not possible to rank the sites by hazard level or make conclusions regarding the extent of the contamination noted in Table 2. Corporación Pipsa plant had the highest level of lead contamination (12,296 ppm) and was the fourth largest importer of used lead batteries from the U.S. in 2021. The RIASA Grupo Gonher plant was the third largest importer but had a somewhat lower mean soil lead level (907 ppm).

Perhaps one of the most polluting facilities is the Clarios site in Cienega de Flores near Monterrey, Mexico which had a mean soil lead concentration of 1,118 ppm. In 2013 the CEC indicated that this facility had the highest airborne lead emissions among all of the recycling plants that reported to the RETC. The CEC estimated that emissions from Mexican lead battery recycling plants were about 20 times higher than similar plants in the U.S.

In 2011, Johnson Controls had acknowledged deficiencies in the Cienega plant and had indicated that the facility required an investment of $70 million dollars to upgrade its furnaces and environmental controls. In 2013, the company said it required two more years to complete the upgrade but no information or announcement was found indicating if the planned improvements were ever conducted. (CEC, 2013, p. 46 and Johnson Controls, August, 30 2011)

Significantly higher concentrations of lead averaging 8,502 ppm were found in soil samples adjacent to the Clarios Garcia plant that has only been operational since 2011. Unlike some of the smaller plants we included or the older plant that Clarios had purchased in La Cienega, the Garcia plant was built by Johnson Controls at the same time that they invested in the large recycling facility in Florence, South Carolina. In the case of the U.S. plant, regulators insisted as a condition of obtaining an air permit to operate the plant that the company disclose air monitoring data to the State regulators which promptly posted this information on their website. As a result, the U.S. plant operated with perhaps the most transparency of any lead battery recycling plant.

It is well known that the costs of installing, operating, maintaining and testing pollution control equipment can be substantial and is the reason that such investments are only cost effective in large plants operating near capacity. These additional costs in the U.S. may explain why Clarios decided to close their plant in South Carolina and instead ship the used batteries collected from their U.S. operations to their facilities in Mexico. However, the contamination found around their Mexican plants and their self-reported air emissions data under the RETC suggest that the company operates these facilities with inferior pollution control equipment than would be allowed for comparable plants in the U.S.

Given the limited samples collected near these lead battery recycling facilities, it is recommended that additional testing be conducted in areas surrounding all lead battery recycling plants in Mexico and appropriate action be taken if contamination is found in agricultural land or residential areas.

It is imperative that Mexico take immediate steps to update the ambient air standard for lead. Investments in greater levels of enforcement are also needed. Mexico should increase transparency and reporting requirements for all lead battery manufacturing and recycling plants to include data on stack emissions, ambient air testing and annual lead releases (under the RETC system). In addition, Mexico must adopt comprehensive occupational health and safety standards to protect workers in these facilities account for airborne exposures and require regular blood lead level testing and medical removal protection for workers over-exposed to lead.

Mexico must also improve the transparency of this extremely hazardous industry. As noted, the RETC system is broken and allows companies to stop reporting their emissions in a consistent manner. Given the lack of enforcement capacity, Mexico should implement comprehensive reporting requirements similar to what the Clarios lead battery recycling facility in South Carolina was subject to by State authorities. All such plants should be providing daily ambient and quarterly stack air monitoring results to be posted online. Summary data at each lead battery recycling facility for employee blood lead levels should also be reported annually. Without identifying individual reports, this data should include the number of tests, the mean and median levels, and the range.

At the same time, the U.S. must recognize that allowing used lead batteries that are classified as hazardous waste to be exported to Mexico and other countries is contributing to environmental injustice abroad. It is time for the U.S. to prohibit the export of this type of hazardous waste to facilities operating with weaker environmental standards and little enforcement. Efforts in the U.S. under the Biden Administration to highlight environmental justice must not stop at the U.S. border but should involve working with other countries to improve standards in extremely hazardous industries.

As the value of lead is set globally on the London Metal Exchange it equalizes the economic benefits of extracting and refining lead from used lead batteries anywhere in the world. Lead battery recycling is a profitable enterprise even when conducted with regulatory oversight, advanced pollution controls and occupational health provisions. There is no economic reason for Mexico to delay regulating this hazardous industry to significantly reduce exposures to workers and environmental emissions.

Mexico and the U.S. should cooperate on improving industry-specific standards to better protect public health and the environment. Investments in controlling lead exposure are extremely cost effective given the alternative of paying for environmental remediation of contaminated soil. There are also substantial costs associated with children's loss of learning potential and the resulting loss of life-time income and from healthcare costs for adults linked to cardiovascular disease and other health endpoints.

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