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ARTICLE

Does sulfuric acid have a 'protective' effect on battery recyclers exposed to lead?

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ABSTRACT
Culturally significant interventions to prevent lead exposure of battery recyclers are required. Sulfuric acid used in batteries causes skin lesions and could facilitate the recognition of hazards. This study explored whether joint exposure to lead and sulfuric acid can be used in interventions to manage hazardous work conditions. Data were collected from 120 informal workers, and the blood lead level was measured. Predictors of blood lead levels were explored using a tobit model. The median blood lead level was 9.45 μg/dL (Q_{75}-Q_{25}: 48.9 μg/dL); when lead and sulfuric acid exposure occurred, the level increased to 11.44 μg/dL, and when exposure to lead and other substances occurred, the level was 11.50 μg/dL. Workers are unaware of the risks of obvious and acute silent chronic exposure. Future preventive interventions could confront the economic benefits of battery recycling with the recognition of susceptibility and severity related to lead and sulfuric acid exposure.

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Skin lesions; intoxication; lead; industrial psychology; occupational health; toxicology

Introduction

Recycling of car batteries can have adverse effects on human health (Romieu et al. 1997), (Valdez 1997), (Tuakuila et al. 2013). In this process, batteries are dismantled, separating the lead components (terminals, plates, bridges and grids), sulfuric acid and plastic components. The lead components are melted to make moulds that can then be used to form other products or repair other batteries. This process may result in lead inhalation exposure, which is observed more frequently in the informal sector due to the lack of ventilation of most workshops. The health effects associated with occupational lead exposure are well known and include acute toxicity, chronic neurotoxicity, anaemia, reproductive disorders, kidney damage, reduction of infection resistance (immunotoxicity) and its possible action as a carcinogen and risk factor for hypertension (Gidlow 2015). In contact with skin, sulfuric acid causes irritation and chemical burns with edema, erythema and ulcers due to necrosis (Jelenko 1974). When exposure to sulfuric acid is chronic, as in the case of exposure in battery recycling, drying of the skin and ulcerations in the hands are observed. Sulfuric acid splashes

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in the eyes are particularly serious and can cause corneal ulcerations, keratoconjunctivitis and palpebral lesions with serious sequelaes (Palao et al. 2010).

Therefore, several educational interventions have been proposed to reduce blood lead levels among different groups of workers (Maples et al. 1982), (Porru et al. 1993), (Michaels et al. 1992). When evaluating these and other educational reports of occupational health, it is clear that the most successful interventions involve the active participation of workers (Burke et al. 2006). Thus, following the principles of meaningful learning (Ausubel et al. 1978), the first steps are to build on the prior knowledge of the trainees and then impart new knowledge. In the daily recycling of lead batteries, due to the highly toxicological effects of the metals involved, other hazardous substances are commonly ignored, such as sulfuric acid, which could modify the exposure levels to lead. In addition, health-related adverse effects, other than intoxication, may exist. This study sought to examine the working conditions of informal battery recyclers to identify indicators and develop interventions aimed at improving these risky working conditions.

This study sought to investigate the working conditions of informal battery recyclers. Among them the work time is not regularized, and daily labor demand determines changes in the activities. Battery recyclers do not usually receive training related to their work or in basic occupational health and industrial safety topics. In consequence, they increase the risk of adverse health effects related with their jobs (Cárdenas-Bustamante et al. 2001). Because sulfuric acid is a battery component with a high risk of skin lesions (given its low pH of ~2.5 at 1 mmol/L), this study explored whether exposure to sulfuric acid modifies lead exposure. This study should be understood as a first attempt to use a possible alarm signal to reduce lead exposure among a highly vulnerable group of workers.

Materials and methods

Design and participants

A cross-sectional study of battery recyclers who worked in the municipalities of Soacha and Bogotá, Colombia, was conducted. Study areas and informal companies were visited to identify workers, and participation was voluntary; thus, a convenience sample was obtained. The study was approved by the ethic committee of the Colombian National Health Institute *(Instituto Nacional de Salud).*

Variables and data collection

An instrument was designed to collect the sociodemographic and occupational data of the participants. The first group of variables consisted of age, sex (male/female), education level and type of health system affiliation (contributory/subsidised). Occupational variables included type of and seniority in the current occupation (months), training in lead management (yes/no), use of personal protective equipment (yes/no), hygiene and industrial safety measures (yes/no), amount of time worked in the sector (months), work habits and exposure to other toxic substances, including sulfuric acid. The use of tobacco and alcohol was also investigated.

Blood lead levels

Each worker provided a 5 mL blood sample, collected in heavy-metal-free tubes with heparin as an anticoagulant. Blood lead levels were determined with the Lead Care II ® portable analyser, which uses the Leadcare II Test kits, the company provider is ESA Biosciences, Inc (Massachusetts, USA). This system is based on electrochemistry and features a unique sensor to detect the presence of lead in whole blood. The active electrode in each sensor contains a small amount of gold particles in an inert matrix. The test sensors and treatment reagents are specific for the measurement of the presence of lead. Since most lead is transported by red blood cells, when the blood sample is added to the reagent (250 μL of diluted hydrochloric acid solution in water, 0.34 M), the erythrocytes are lysed, leaving the free lead, which is detected by the sensor and measured after 3 min. The Lead Care II system is sensitive to a range of blood lead concentrations of 3.3 to 65 μg/dL. A comparison of the results obtained with this device and those obtained by atomic absorption spectrometry using a graphite furnace resulted in a value of r^2= 0.96 (Bischoff et al. 2010), which validates the obtained concentrations.

Statistical methods

Categorical variables are described as percentages, and quantitative variables are presented as central tendency and dispersion measures, according to the distribution observed. Variables with a normal distribution were evaluated with the Shapiro–Wilk test. Additionally, the distribution of lead was explored using kernel density estimation, which is a non-parametric method to estimate the probability density function of a continuous variable (Parzen 2004). Lead concentrations were then compared for different categories of independent variables using χ^2, Fisher's exact, Mann-Whitney U or Kruskal–Wallis tests, according to the data distribution. Finally, the associations between independent variables and blood lead levels were explored by bivariate and multiple tobit regression because the minimum and maximum values were available, which allowed quantification of the laboratory technique. (McDonald and Moffitt 1980). All evaluations were performed using the statistical program Stata 14 (Stata Corporation, College Station).

Results

Table 1 shows the characteristics of the study participants, including age (all were adults who were nearly 40 years of age); most participants lived in urban areas and were affiliated with the contributory health system, although a small group had labour-risk insurance. Likewise, Table 1 shows that 79.41% of participants presented blood lead levels <30 μg/dL (Figure 1), without sex differences.

Table 2 shows the crude associations between several variables and blood lead levels. Note that as the age or time spent in the current activity increased, the lead levels decreased. The time spent manipulating batteries showed the opposite effect; lead levels increased with longer times. However, in cases of exclusive exposure to lead, lower lead concentrations were present than for participants exposed to lead and other substances, including sulfuric acid.

Table 3 presents a multiple tobit regression model that shows that the variables associated with an increase in lead levels include occupations related to lead exposure and exposure to other substances. It is striking that exposure to sulfuric acid is associated with higher lead levels, although the increase is not as great as the increase resulting from exposure to other substances. The education level shows a U-shaped association, where workers with an elementary education or higher than middle school education presents greater lead levels than those with a middle school education.

Discussion

This study found that the highest blood lead levels are observed in workers with direct exposure to lead, with lower or higher educational levels and who are exposed to additional hazardous substances. It is interesting to note that workers exposed to lead and sulfuric acid present higher lead concentrations than those with exclusive exposure to lead. Given the properties of sulfuric acid, this is contrary to expectations. Sulfuric acid is a recognised chemical agent associated with skin burns, especially in working environments (Sethi et al. 2012). In addition, recently in Colombia, sulfuric acid has been used to attack women (Restrepo-Bernal et al. 2014). On contact with the skin, sulfuric acid causes excessive heat and dehydration that can even result in microvascular necrotic coagulation (Jelenko 1974), (Palao et al. 2010). These injuries could result as a sign of occupational hazard, initiate an escape reflex mediated by the sympathetic nervous system (Jansen et al. 1995), that would avoid interfering with the personality traits of workers (Clarke and Robertson 2005) and could prevent injury.

Table 1. Characteristics of Colombian battery recyclers exposed to lead (n = 120) .

		Pb in blood (µg/dL)						
Variable	n	median	mean	min	max	s.d.	Q_{75}-Q_{25}	P value
Occupational exposure								
Yes	60	50.55	48.68	10.70	76.60	14.75	14.95	<0.0001
No	60	1.65	2.27	1.65	8.20	1.48	0	
Age (years)								
20-31	33	1.65	17.44	1.65	71.20	23.17	32.85	0.647
32-42	28	45.45	36.54	1.65	68.90	25.20	53.00	
43-51	30	40.45	31.49	1.65	73.30	25.44	53.25	
52-75	29	3.40	17.72	1.65	76.60	23.99	37.95	
Site of residence (%)								
Rural	9	1.65	9.98	1.65	76.60	24.98	0	0.018
Urban	111	17.65	26.73	1.65	73.30	25.27	49.15	
Social security – health (%)								
Contributing	113	13.10	26.24	1.65	76.60	26.24	49.15	0.134
Subsidised	4	19.98	21.65	1.65	45.00	23.25	40.00	
No data	3	1.65	1.65	1.65	1.65	0	0	
Current occupation (%)								
No exposure to Pb	60	1.65	2.27	1.65	8.20	1.48	0	<0.0001
Grid handling	20	52.30	49.13	14.50	71.20	15.47	22.65	
Casting/Grid recycling	9	54.30	54.36	42.30	66.00	7.73	10.30	
Battery manufacturing	3	47.10	51.13	45.70	60.60	8.29	14.90	
Battery handling	5	47.40	48.92	44.30	54.90	4.13	4.20	
Administrative	14	44.95	42.24	10.70	73.30	18.80	27.70	
Unloading operations	1	51.40	51.40	51.40	51.40	- - -	- - -	
Welder	4	54.95	46.18	17.50	57.30	19.20	21.65	
Copper handling	1	58.30	58.30	58.30	58.30	- - -	- - -	
Other occupations	3	50.50	55.13	38.30	76.60	19.57	38.30	
Exposure to Pb and other substances								
None	74	3.30	10.31	3.30	60.00	15.54	1.40	<0.0001
Sulfuric acid	35	51.10	51.92	26.20	66.00	9.48	13.40	
Other substances	11	58.30	47.65	3.30	65.00	18.91	27.20	
Food consumption during work (%)								
Yes	15	45.70	40.82	1.65	76.60	21.42	37.40	<0.0001
No	46	51.25	50.22	10.70	73.30	12.99	14.60	
No data	59	1.65	2.28	1.65	8.20	1.49	0	
Hand washing before eating (%)								
Always	48	49.60	46.51	1.65	76.60	16.50	15.95	<0.0001
Sometimes	72	1.65	11.45	1.65	71.20	20.35	2.30	
Use of gloves (%)								
Yes	53	51.40	50.52	10.70	76.60	13.82	14.40	<0.0001
No	67	1.65	5.60	1.65	50.50	10.84	1.75	
Use of masks or respirators								
Yes	53	51.40	50.51	14.50	66.00	11.85	14.40	<0.0001
No	6	35.85	32.15	10.70	50.50	17.39	33.80	
No data	61	3.33	3.83	3.33	18.80	2.18	0	
Change of clothes after working								
Yes	52	50.95	49.17	10.70	66.00	13.61	14.25	<0.0001
No	7	28.60	33.69	3.30	65.00	20.31	28.10	
No data	61	3.30	5.10	3.30	56.20	8.42	0	

Mann-Whitney or Kruskal–Wallis equality-of-populations rank test.

Some theoretical models used in public health to understand why individuals did or did not engage in an specific behavior could explain this contradictory findings. For instance, according to the health belief model, perceived susceptibility, severity, benefits and barriers are key elements (Janz and Becker 1984). Perhaps in this study, battery recyclers do not percived sulfuric acid as an hazard agent, because for them its presence and contact is usual in the work environment, and the occurrence of severe skin injuries are not frequent. It is also possible that battery recyclers have a very high perception of economic benefits, which exceeds the perception of susceptibility and severity. Currently, lead obtained of batteries is sold to industries that require it as an input of their production process.

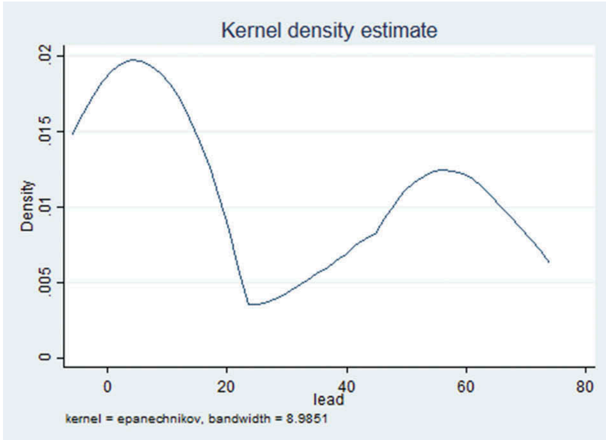

Figure 1. Kernel density estimate

Table 2. Crude associations between exposure-related variables and blood lead concentrations (µg/dL) among Colombian battery recyclers (n = 120).[¥]

Variables	β	95% CI	P value
Sex (female)	−11.41	−25.08; 1.85	0.090
Age (years)			
20-31	Ref		
32-42	21.71	8.17; 35.24	0.002
43-51	15.97	2.68; 29.26	0.019
52-75	0.04	−13.37; 13.45	0.995
Education			
Elementary (complete or incomplete)	Ref		
Secondary (complete or incomplete)	−5.60	−9.05; −2.15	0.002
Technical or professional	−53.33	−56.78; −49.88	<0.001
Tobacco smoking	3.40	−17.08; 23.89	0.743
Occupation			
No exposure to Pb	Ref		
Grid or plate handling	53.13	51.28; 54.98	<0.001
Battery recycling (casting)	53.85	51.29; 56.41	<0.001
Administrative (with Pb exposure)	44.69	42.56; 46.81	<0.001
Other occupations (with Pb exposure)	49.18	47.21; 51.15	<0.001
Exposure to Pb and other substances			
None	Ref		
Sulfuric acid	48.67	47.53; 49.81	<0.001
Other substances	57.16	55.35; 58.96	<0.001

[¥]estimates obtained with tobit regression.

For this reason, possible interventions should include educative elements to increase the perception of susceptibility and severity related with the exposure to lead and sulfuric acid. Evidence useful for these interventions include matters of classical toxicology of lead (acute toxicity, anaemia, reproductive disorders, kidney damage, immunotoxicity), and more specific topics related with dermal exposure to sulfuric acid or lead and related-skin damage. In this category are lower skin hydration and elasticity associated with lead exposure, the increased occurrence of skin lesions as dermatitis, urticaria, hyperkeratosis, gingival brown pigmentation, gingivitis and lead line (Rerknimitr et al. 2019) (Wani and Usmanib 2016), and burns related with sulfuric acid exposure (Bond et al. 1998; Matshes et al. 2008). Succesful interventions with informal workers are difficult because economic benefits are seen as larger than the risks associated with work (López-Ruiz et al. 2015), thus more emphasis in to increase susceptibility and severity is required.

Table 3. Adjusted associations between independent variables and blood lead concentrations (µg/dL) among Colombian battery recyclers (n = 120).[¥]

Variables	Adj. β	95% CI	P value
Sex (female)	−7.27	−14.90; 0.37	0.062
Age (years)	0.17	−0.05; 0.39	0.123
Education			
Elementary (complete or incomplete)	Ref		
Secondary (complete or incomplete)	−2.54	−4.29; −0.79	0.005
Technical or professional	−1.28	−3.38; 0.83	0.233
Tobacco smoking	1.51	−0.28; 3.30	0.098
Occupation			
No exposure to Pb	Ref		
Grid or plate handling	45.25	34.72; 55.78	<0.001
Battery recycling (casting)	49.81	38.34; 61.27	<0.001
Administrative (with Pb exposure)	45.00	35.07; 54.93	<0.001
Other occupations (with Pb exposure)	46.57	37.08; 56.06	<0.001
Exposure to Pb and other substances			
None	Ref		
Sulfuric acid	11.44	4.58; 9.17	<0.001
Other substances	11.50	11.40; 16.87	0.014

[¥]estimates obtained with tobit regression.

An interpretation our findings should take into account the limitations of the study design. Given the type of design, it is not possible to ensure the temporal relationships between the variables. It is possible that lead exposure induces neurotoxicity that facilitate the exposure to sulfuric acid. In addition, using worker reports as the main data source may generate measurement errors, which, in the case of the self-report of exposure to skin-irritating substances, we do not think it was differential. All variables that were found to be associated with blood lead concentrations were self-reported, which could have led to an underestimation of the results.

Conclusion

The present study suggested that exposure to sulfuric acid is not a sufficient warning signal to take actions to prevent lead exposure; however, lead exposure can promote exposure to sulfuric acid skin lesions. For some workers may be very difficult to separate exposure to lead and sulfuric acid due to the recycling practices. It is very important because in low and middle-income countries there are not good experiences in occupational interventions for control chemical agents (Verbeek and Ivanov 2013). Thus, a possibility exists of developing creative and innovative educational interventions for workers exposed to lead in batteries using skin lesions as a warning sign without increase economic costs. This mechanism is still a valuable element for developing effective interventions to prevent diseases and accidents of occupational origin. Further prospective studies are required to explore this possibility.

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References

Ausubel DP, Novak JD, Hanesian H. 1978. Educational psychology: A cognitive view. 2nd ed. New York: Rinehart & Winston.

Bischoff K, Gaskill C, Erb HN, Ebel JG, Hillebrandt J. 2010. Comparison of two methods for blood lead analysis in cattle: graphite-furnace atomic absorption spectrometry and LeadCare(R) II system. J Vet Diagn Invest. 22:729–733. doi:10.1177/104063871002200510.

Bond SJ, Schnier GC, Sundine MJ, Maniscalco SP, Groff DB. 1998. Cutaneous burns caused by sulfuric acid drain cleaner. J Trauma. 44:523–526. doi:10.1097/00005373-199803000-00019.

Burke MJ, Sarpy SA, Smith-Crowe K, Chan-Serafin S, Salvador RO, Islam G. 2006. Relative effectiveness of worker safety and health training methods. Am J Public Health. 96:315–324. doi:10.2105/AJPH.2004.059840.

Cárdenas-Bustamante O, Varona-Uribe ME, Núñez-Trujillo SM, Ortiz-Varón JE, Peña-Parra GE. 2001. Correlación de protoporfirina zinc y plomo en sangre en trabajadores de fábricas de baterías, de Bogotá, Colombia. Salud Publica Mex. 43:203–210. doi:10.1590/S0036-36342001000300005.

Clarke S, Robertson IT. 2005. A meta-analytic review of the Big Five personality factors and accident involvement in occupational and non-occupational settings. J Occup Organ Psychol. 78(3):355–376. doi:10.1348/096317905X26183.

Gidlow DA. 2015. Lead toxicity. Occup Med Lond. 65:348–356. doi:10.1093/occmed/kqv018.

Jansen AS, Nguyen XV, Karpitskiy V, Mettenleiter TC, Loewy AD. 1995. Central command neurons of the sympathetic nervous system: basis of the fight-or-flight response. Science. 270:644–646. doi:10.1126/science.270.5236.644.

Janz NK, Becker MH. 1984. The health belief model: a decade later. Health Educ Quart. 11(1):1–47. doi:10.1177/109019818401100101.

Jelenko C. 1974. Chemicals that "burn". J Trauma. 14:65–72. doi:10.1097/00005373-197401000-00009.

López-Ruiz M, Artazcoz L, Martínez JM, Rojas M, Benavides FG. 2015. Informal employment and health status in Central America. BMC Public Health. 15:698. doi:10.1186/s12889-015-2030-9.

Maples TW, Jacoby JA, Johnson DE, Ter Har GL, Buckingham FM. 1982. Effectiveness of employee training and motivation programs in reducing exposure to inorganic lead and lead alkyls. Am Ind Hyg Assoc J. 43:692–694. doi:10.1080/15298668291410431.

Matshes EW, Taylor KA, Rao VJ. 2008. Sulfuric acid injury. Am J Forensic Med Pathol. 29:340–345. doi:10.1097/PAF.0b013e3181847e3d.

McDonald JF, Moffitt RA. 1980. The uses of tobit analysis. Rev Econ Stat. 62:318–321. doi:10.2307/1924766.

Michaels D, Zoloth S, Bernstein N, Kass D, Schrier K. 1992. Workshops are not enough: making right-to-know training lead to workplace change. Am J Ind Med. 22:637–649. doi:10.1002/(ISSN)1097-0274.

Palao R, Monge I, Ruiz M, Barret JP. 2010. Chemical burns: pathophysiology and treatment. Burns. 36(3):295–304. doi:10.1016/j.burns.2009.07.009.

Parzen E. 2004. Quantile probability and statistical data modeling. Stat Sci. 19(4):652–662. doi:10.1214/088342304000000387.

Porru S, Donato F, Apostoli P, Coniglio L, Duca P, Allision L. 1993. The utility of health education among lead workers: the experience of one program. Am J Ind Med. 22:473–481. doi:10.1002/ajim.4700230310.

Rerknimitr P, Kantikosum K, Chottawornsak N, Tangkijngamvong N, Kerr SJ, Prueksapanich P, Sithisarankul P, Kumtornrut C, Asawanonda P, Sutheparuk S, et al. 2019. Chronic occupational exposure to lead leads to significant mucocutaneous changes in lead factory workers. J Eur Acad Dermatol Venereol. 33:1993–2000. [Epub ahead of print]. doi:10.1111/jdv.v33.10.

Restrepo-Bernal D, Gómez-González A, Gaviria SL. 2014. Intentional burns with acid. New expressions of violence against women in Medellín, Colombia. Vertex. 25(115):179–185.

Romieu I, Lacasana M, McConnell R. 1997. Lead exposure in Latin America and the Caribbean. Lead research group of the Pan-American health organization. Environ Health Perspect. 105:398–405.

Sethi G, Belum VR, Maibach H. 2012. Kanerva's occupational dermatology. Sulfuric acid burns. Rustemeyer T, Elsner P, Swen-Malte J, Mai H, editors. Heidelberg: Springer Berlin Heidelberg.

Tuakuila J, Lison D, Mbuyi F, Haufroid V, Hoet P. 2013. Elevated blood lead levels and sources of exposure in the population of Kinshasa, the capital of the Democratic Republic of Congo. J Exposure Sci Environ Epidemiol. 23:81–87. doi:10.1038/jes.2012.49.

Valdez H. 1997. Lead battery markets and recycling in Mexico and South America. J Power Sources. 67:219–223. doi:10.1016/S0378-7753(97)02553-6.

Verbeek J, Ivanov I. 2013. Essential occupational safety and health interventions for low- and middle-income countries: an overview of the evidence. Saf Health Work. 4:77–83. doi:10.1016/j.shaw.2013.04.004.

Wani L, Usmanib JA. 2016. Occupational stress among workers having exposure to lead. Clin Epidemiol Global Health. 4:163–170. doi:10.1016/j.cegh.2015.12.004.