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Heavy metals screening model in primary care: Experience in the Sierra Minera de Cartagena (Spain)

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ABSTRACT

Introduction: Soils contaminated by heavy metals such as lead, cadmium, and arsenic represent a significant health risk. The Sierra Minera of Cartagena (Spain) is an area historically contaminated by mining activities. This study evaluates the exposure to heavy metals and proposes a clinical screening model for its management in primary care.

Method: Descriptive cross-sectional study conducted between 2017 and 2020 with volunteers from the Sierra Minera of Cartagena who provided blood and urine samples. Primary care health professionals were trained in sample collection and analysis, risk communication, and clinical protocols on heavy metals were implemented.

Results: 203 participants, 66.5% women and 38 (18.7%) under 16 years old. The majority resided in Zone 0 (contaminated area). Mean blood lead level was 1.78 µg/dl and 2.22 µg/dl in those under 16 years old, with. Metal concentrations, particularly lead, increased with age, male sex, Arab ethnicity, and proximity to contaminated areas. Tobacco smoke was identified as a main source of lead exposure in children under 16 years. The primary care clinical screening model identified 12 (7%) and 22 (11%) participants exceeding 5 µg/dl and 3.5 µg/dl respectively, particularly six children and one pregnant woman, with significant levels that normalized within 2–3 months following PEHSU's clinical guidelines.

Conclusions: The implementation of clinical and analytical screening for heavy metals in primary care, supported by pediatric environmental health units (PEHSU), proved effective in screening and reducing in children blood lead levels in a short period. Training health professionals is crucial to adequately address environmental risks and protect the health of affected populations.

Modelo de cribado de metales pesados en atención primaria: experiencia en la Sierra Minera de Cartagena (España)

Palabras clave:
Intoxicación por metales pesados
Contaminación ambiental
Contaminantes del suelo
Intoxicación por plomo
Atención primaria

RESUMEN

Introducción: Los suelos contaminados por metales pesados como plomo, cadmio y arsénico representan un riesgo significativo para la salud. La Sierra Minera de Cartagena (España) es un área históricamente contaminada por actividades mineras. Este estudio evalúa la exposición a metales pesados y propone un modelo de cribado clínico para su manejo en atención primaria.

Método: Estudio descriptivo transversal realizado entre 2017-2020 con voluntarios de la Sierra Minera de Cartagena que proporcionaron muestras de sangre y orina. Los profesionales de atención primaria fueron

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capacitados en la recolección y análisis de muestras, la comunicación de riesgos y se implementaron protocolos clínicos sobre metales pesados.

Resultados: Participaron 203 personas, de las cuales el 66,5% eran mujeres y 38 (18,7%) menores de 16 años. La mayoría residía en la Zona 0 (área contaminada). El nivel medio de plomo en sangre fue de 1,78 μg/dL y de 2,22 μg/dL en menores de 16 años. Las concentraciones de metales, especialmente de plomo, aumentaron con la edad, el sexo masculino, la etnia árabe y la proximidad a áreas contaminadas. El humo del tabaco fue identificado como una fuente principal de exposición al plomo en niños menores de 16 años. El modelo de cribado clínico en atención primaria identificó a 12 (7%) y 22 (11%) participantes que superaban los 5 μg/dL y 3,5 μg/dL, respectivamente, destacando seis niños y una mujer embarazada, cuyos niveles significativos se normalizaron en un periodo de dos a tres meses, siguiendo las pautas clínicas de las unidades de salud ambiental pediátrica (PEHSU).

Conclusiones: La implementación de cribado clínico y analítico para metales pesados en atención primaria, apoyada por PEHSU, resultó eficaz en la detección y reducción de los niveles de plomo en sangre en niños en un corto periodo. La formación de los profesionales de la salud es crucial para abordar adecuadamente los riesgos ambientales y proteger la salud de las poblaciones afectadas.

Introduction

Environmental pollution is a growing global concern with significant implications for human health, particularly due to exposure to heavy metals such as lead, cadmium, and arsenic.[1] These metals, which have no biological function in the human body, can cause permanent damage, severely affecting vulnerable populations such as children and pregnant women.[2] No safe level of lead has been observed, and in April 2021, the Environmental Health Committee of the Spanish Association of Pediatrics proposed lowering the action levels to 3–3.5 μg/dl based on nephrotoxic and neurodevelopmental evidence.[3]

In Spain, contaminated soil is considered as such when its characteristics have been negatively altered by the presence of hazardous chemical components resulting from human activity in concentrations that pose an unacceptable risk to human health or the environment.[4] The European Environment Agency reports approximately 2.8 million contaminated sites in Europe, with heavy metals being the most common contaminants.[5] These metals interact with cellular components such as membranes, mitochondria, and DNA, causing significant cellular damage.[6] The International Agency for Research on Cancer (IARC) classifies cadmium and arsenic as human carcinogens.[7] Prolonged exposure to these metals is linked to cardiovascular, renal, and neurological diseases; lead, for example, is responsible for 4.6% of cardiovascular diseases, 3% of chronic kidney diseases, and 30% of idiopathic intellectual disability globally.[8] Cadmium exposure has been linked to renal dysfunction and osteoporosis in older adults.[9] In individuals who smoke, cadmium levels are typically elevated, thereby increasing the risk of developing lung cancer.[10] Arsenic, particularly in its inorganic form, is a well-documented carcinogen that affects the skin, lungs and bladder. Chronic exposure to arsenic has been associated with an increased risk of developing cancer and cardiovascular disease.[11]

Children are particularly vulnerable to environmental contamination due to the biological immaturity of their systems, high metabolic rate, longer life expectancy, and limited decision-making capacity.[3] Children absorb 70% of ingested lead compared to 20% in adults. Additionally, the inhalation of dust contaminated with lead and other metals is a primary source of childhood exposure in areas with contaminated soils.[12] Lead accumulated in the bone can be mobilized during periods of high calcium demand such as pregnancy or illnesses, increasing the risk in children, the elderly, and pregnant women.[3]

Despite its importance, experiences integrating environmental health into clinical practice are scarce. In the Region of Murcia, the first pediatric environmental health unit (PEHSU) in Spain was established in 2005, developing new models and professional profiles in this field. Pediatric environmental health units (PEHSUs) integrate pediatricians, internist and other specialists to address these issues in a multidisciplinary manner based on a set of standards. These units exist in numerous countries and serve as an international reference for training and clinical management in environmental health.[13]

The Sierra Minera de Cartagena-La Unión, located in the southeast of Spain, is a region with over 2500 years of mining activity.[14] This activity has left a legacy of contaminating residues, including heavy metals, which have spread to inhabited areas, posing a significant risk to the health of the local population.[15] Previous studies have documented high concentrations of metals in these areas, especially in soils of schools and residential areas,[16] highlighting the need to recover and restore these degraded areas.[17]

This study aims to evaluate the exposure to heavy metals in the population of the Sierra Minera and describe the levels found in blood and urine. Additionally, it seeks to implement and disseminate a clinical and analytical screening model for the early detection and management of exposure to these contaminants in primary care (PC) clinical practice. This integrated approach includes the training of health professionals, sample collection, and risk communication, with the purpose of protecting the health of the affected population.

Materials and methods

A descriptive cross-sectional study was conducted between 2017 and 2019, reviewing medical records to assess exposure to heavy metals in volunteers residing or working in the Sierra Minera de Cartagena area, ranging from 2 to 76 years old. The study also aimed to evaluate levels of lead, cadmium, and arsenic in blood and urine and their distribution across various demographic factors.

Protocol development and training of health professionals

The experience of PEHSU-Murcia in managing metal contamination and health was utilized to implement a community-based clinical and analytical screening model for early detection and management of exposure to these contaminants in primary care (PC) practice. This included training PC health professionals. The process involved several stages:

Strategic and operational planning

Collaborative alliances and procedures were established among different healthcare levels and the Public Health and Clinical Toxicology laboratories, supported by the Health Council.

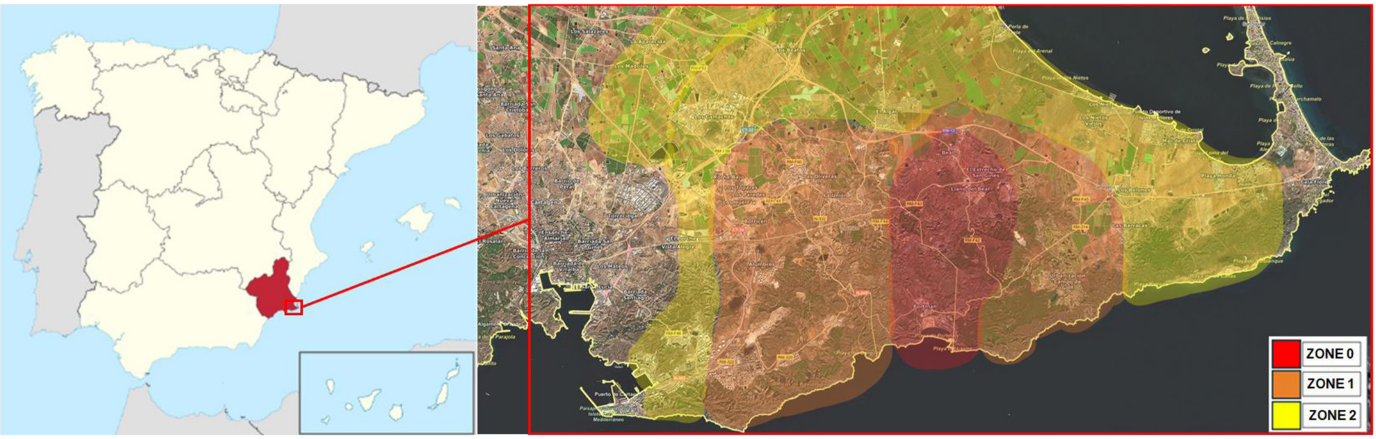

Fig. 1. Map of the division of zones to which the study participants belong (usual place of residence) based on their proximity to the most contaminated areas. *Note*: Zone 0: Population centers directly on highly contaminated soils (El Beal, El Llano del Beal, El Estrecho, and Portmán). Zone 1: Localities with a long history of mining activity but with mining deposits farther from urban centers (La Unión, Roche). Zone 2: Localities farther from the Sierra Minera, not directly belonging to it, but with possible contamination concerns.

Training and education

Training workshops were held at the Health Centers of El Algar and La Unión, as well as the Llano del Beal clinic. Additionally, a Postgraduate University Course was organized in 2018 for pediatricians, family doctors, nurses, and students. The materials included clinical guidelines, protocols, and informational documents on heavy metal exposure (Appendix A).

Implementation of clinical and analytical screening

Detailed protocols were provided to Health Centers for the collection, handling, and sending of samples to the responsible laboratories. Screening was conducted on individuals who voluntarily consulted their family doctor or pediatrician, expressing concern about heavy metal exposure (Appendix B). The results were reviewed by environmental medicine specialists at PEHSU.

Awareness and knowledge transfer

Community meetings and outreach activities were organized to inform the population about the risks associated with heavy metal contamination and recommended preventive measures. Specifically, regular meetings were organized with the Neighborhood and School Parent Associations throughout the process. Seminars were also conducted with affected communities, involving members of PEHSU and lead toxicity experts from the US Centers Disease Control (Atlanta). The progress was presented publicly at the Regional Assembly of Murcia.[18]

Study area

The Sierra Minera de Cartagena-La Unión is a mountainous region located in the southeast of Spain, in the province of Murcia, near the Mediterranean coast-Mar Menor. With an approximate area of 50 km^2, is situated within the municipalities of Cartagena-La Unión. For the study, the population was divided into three zones based on their residential proximity to the most contaminated areas (Fig. 1).

Data collection

During the PC consultation visit, a clinical evaluation was carried using a screening tool or an environmental anamnesis including general data, leisure and occupational exposures (Green Page) (Appendix C), in order to design an individual and personalized description of environmental exposures. In addition, blood and urine samples were collected from the participants, following these specific procedures. The samples were analyzed at the Clinical Toxicology laboratories of the Virgen de la Arrixaca University Hospital and the General Directorate of Public Health of the Region of Murcia. All results were reviewed at the Pediatric Environmental Health Unit.

A 200 μl sample of venous blood was obtained in an EDTA tube for blood lead levels (BLL). In children, capillary puncture was preferred. Analysis was performed by graphite furnace atomic absorption spectrometry.

A standard 24-h urine collection was performed, discarding the first urine of day 1 and including the first of the following day. Spontaneous collection was performed in young children. Levels of cadmium, total arsenic, creatinine, and cotinine were measured in urine. Additional recommendations were given for arsenic to avoid seafood or fish consumption 3–5 days before collection to prevent artificially elevated arsenic levels. Analyses were conducted by inductively coupled plasma mass spectrometry (ICP-MS). When blood lead levels exceeded 3.5 μg/dl, clinical evaluation was shared between PEHSU-PC.

Statistical analysis

SPSS version 28.0.1.1 for Mac was used. Descriptive analyses, normality studies with parametric and non-parametric tests where necessary were conducted. The Mann–Whitney *U* test was used to compare groups by sex, and the Kruskal–Wallis test was used for other demographic comparisons. A *p*-value of less than 0.05 was considered significant. Pearson and Spearman correlations and multiple regression analysis for BLL, cadmiumuria, and arsinuria were performed.

Results communication and follow-up

Personalized models and reports were provided to participants, including recommendations based on analytical results (Appendix D). These were sent from PEHSU to PC, and the final interlocutors were the PC professionals. Cases exceeding reference levels were also evaluated at PEHSU Murcia and communicated to the General Directorate of Public Health to contribute to the creation of environmental health surveillance network and improve population-level intervention strategies. This collaborative approach enabled a swift and effective response to address the identified risks.

Table 1
General characteristics of the sample ($n = 203$) and concentrations of heavy metals in blood and urine.

Variable	Total (n)	%	AM ± SD	GM	P95	Max.	Heavy metals details
Gender							
Female	135	66.5					
Male	68	33.5					
Race							
Caucasian	195	96.1					
Árabic	8	3.9					
Age (years)			38.12 ± 19.13				
<16 years	38	18.7					
16–35 years	50	24.6					
35.01–59.9 years	84	41.4					
≥60 years	31	15.3					
Usual residence							
Zone 0	106	52.2					
Zone 1	50	24.6					
Zone 2	47	23.2					
Cotinine (ng/ml)	172		121.36 ± 248.37				
<10	91	52.9					
10–40	42	24.4					
41–250	9	5.2					
>250	30	17.4					
Heavy metals							
Pb (μg/dl)[a]	194		1.78 ± 1.54	1.31	5.15	9	*p*25: 0.80 Median: 1.35 *p*75: 2.15
Cd (μg/L)[b]	176		0.21 ± 0.19	0.15	0.58	1.21	*p*25: 0.08 Median: 0.15 *p*75: 0.3
Cd (μg/gCr)[b]	110		0.24 ± 0.22	0.17	0.72	1.23	*p*25: 0.09 Median: 0.18 *p*75: 0.31
As (μg/L)[b]	186		27.1 ± 38.57	15	104.2	247	*p*25: 6.6 Median: 15.2 *p*75: 29.6
As (μg/gCr)[b]	115		31.2 ± 49.26	17.5	101.2	428.04	*p*25: 8 Median: 15 *p*75: 38.4

n = number of participants with results. AM: arithmetic mean. SD: standard deviation. GM: geometric mean. p: percentile. Max: maximum.

[a] Measured in blood by graphite furnace atomic absorption spectrometry.

[b] Measured in urine by inductively coupled plasma mass spectrometry (ICP-MS).

Ethics committee

This study received favorable evaluation from the Research Ethics Committee of the University of Murcia (M10/2024/039R, 28/02/2024).

Results

Sample characteristics

The study included 203 participants with a mean age of 38 years; two-thirds were women (66.5%). Additionally, 38 participants were under 16 years of age (18.7%). 52% of the participants resided in Zone 0, 28% in Zone 1, and 20% in Zone 2 (Table 1).

Heavy metal levels

Table 1 also includes the levels of exposure to heavy metals. Table 2 shows the quantified levels of heavy metals for Zones 0, 1, and 2. Blood lead levels (BLL) ($n = 194$) had an arithmetic mean (AM) of 1.78 ± 1.54 μg/dl and a geometric mean (GM) of 1.31 μg/dl. The number of people with BLL ≥ 5 μg/dl was 12 (6.2%), and those with BLL ≥ 3.5 μg/dl was 22 (11.3%), including six under 16 years old and one pregnant woman.

For urinary cadmium, the AM was 0.21 ± 0.19 μg/L, and the GM was 0.17 μg/L. None of the individuals exceeded the reference levels (2 and 4 μg/L). For arsenic, the technique used measured total arsenic, without differentiating between organic and inorganic species. The AM was 27.1 ± 38.57 μg/L, and the GM was 15 μg/L. Reference levels for total arsenic (>50 μg/L) were exceeded by 26 individuals (13.98%), three of whom were under 16 years old from Zone 0. Table 2 details the cases that exceed the action levels for lead and arsenic by residence zone.

Distribution of heavy metal levels by gender, ethnicity, age, and residence

Higher levels of heavy metals were observed in men (Appendix E – table E.1) and increased with age. BLL were significantly higher in Arabs compared to Caucasians (5.07 ± 1.11 μg/dl vs. 1.64 ± 1.39 μg/dl, $p < 0.01$, Mann–Whitney U test). BLL were higher in the elderly and young, forming an open U-shaped graph (Fig. 2). Cadmium values also significantly increased with age (Fig. 2). Fig. 3 shows that BLL were higher in Zone 0 and decreased with distance from this zone.

Work background, leisure and lifestyles

None of the people included in the study or their immediate family members were currently working in the mining industry. The mining industry closed down more than 30 years ago. Of the 22 people with more than 3.5 ppm BLL, 6 were children and 1 woman was pregnant. After investigation of dietary sources, home visits, parental occupation and lifestyle studies, frequent daily out-

Table 2
Heavy metal values (Pb, Cd, As) as a function of the area of residence and % of exceedances of action levels.

	n	GM	AM	CI95%	*p*	Reference exceedances *n* (%)
Lead[a] *(μg/dl)*						
Zone 0	106	1.68	2.17	1.84–2.49	**<0.01**[*]	18 (16.98)[d]
Zone 1	47	1.14	1.54	1.12–1.96		4 (7.4)[d]
Zone 2	41	0.8	1.05	0.82–1.28		0 (0)[d]
Cadmium[b] *(μg/L)*						
Zone 0	99	0.17	0.24	0.20–0.28	0.06	0 (0)
Zone 1	43	0.14	0.18	0.14–0.23		0 (0)
Zone 2	34	0.12	0.17	0.11–0.24		0 (0)
Cadmium[b] *(μg/gCr)*						
Zone 0	61	0.21	0.3	0.23–0.37	**<0.01**[*]	
Zone 1	21	0.13	0.16	0.11–0.22		
Zone 2	28	0.14	0.18	0.12–0.23		
Arsenic[b] *(μg/L)*						
Zone 0	102	15.92	30.17	22.37–37.97	0.65	20 (19.60)[c]
Zone 1	45	14.64	23.93	13.39–34.46		3 (5.88)[c]
Zone 2	39	13.14	22.67	9.84–35.50		3 (9)[c]
Arsenic[b] *(μg/gCr)*						
Zone 0	61	19.92	39.33	23–55.67	0.41	
Zone 1	23	17.15	26.43	15–37.86		
Zone 2	31	13.74	18.88	12.95–24.8		

n = number of participants with results. AM: arithmetic mean. GM: geometric mean. CI95%: 95% confidence interval. *p*: percentile.

[a] Measured in blood by graphite furnace atomic absorption spectrometry.

[b] Measured in urine by inductively coupled plasma mass spectrometry (ICP-MS).

[c] Number of individuals exceeding > 50 μg/L urine arsenic.

[d] Number of individuals exceeding > 3.5 μg/dl blood lead.

[*] Kruskal–Wallis test for independent samples.

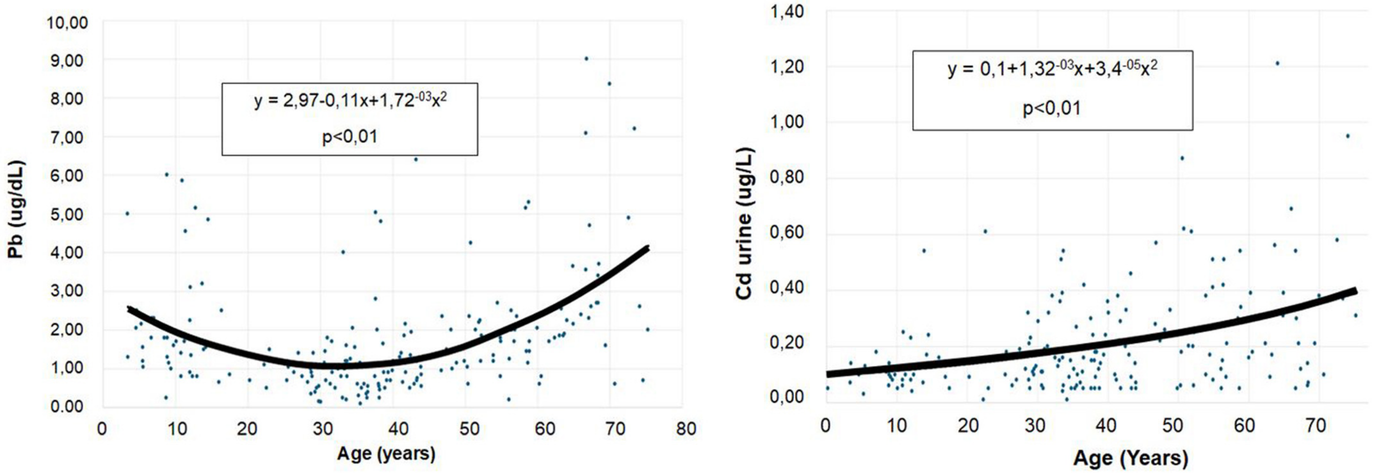

Fig. 2. Distribution of lead (blood) and cadmium (urine) values according to age in years. *Note*: Data (mg/L) are used for comparison with international studies. Standardized figures by creatinine are provided in Appendix E. Although not shown, the analyses did not change the results.

door activities in areas with contaminated soil were found to be the main source of exposure. Among the other 15 adults with BLL above 3.5 ppm, one was a street sweeper, and 4 others reported a history of occupational exposure from work in mining, transport and removal of contaminated soil many years ago. Of the remainder, they had no occupation that could lead to heavy metal exposure.

Cotinine and heavy metal levels

52.9% of the sample had ≤10 ng/ml of urinary cotinine (non-exposed or non-smokers). The correlation between cotinine and heavy metals in the population was positive for cadmium ($p < 0.05$) (Appendix F – Fig. F.1) in Pearson and Spearman's Rho. In those under 16 years old, a significant correlation was observed between BLL and urinary cotinine levels ($R^2 = 0.286$; $b = 0.13$), $p < 0.05$ (Appendix E – Fig. E.1).

Multivariable analysis of lead, cadmium, and arsenic levels

The results are presented in Table 3. Lead levels increased with age (β: 0.03, $p < 0.01$), Arab ethnicity (β: 3.924, $p < 0.01$), and proximity to Zone 0, and decreased in females (β: −0.81, $p < 0.01$).

For cadmium, the significant factors were age (β: 0.0054, $p < 0.01$) and cotinine (β: 0.0002, $p < 0.01$). The only significant factor for arsenic was age (β: 0.67, $p = 0.01$). In those under 16 years old, a sub-analysis for BLL showed that cotinine (ng/ml) was the predictive factor (β: 0.079, $p = 0.02$) (Table 3).

Discussion

This is the first study in Europe with a clinical approach to integrate and adapt health programs to the local realities of communities living on contaminated soils. The collaboration between a PEHSU and primary care (PC) was key to establishing commu-

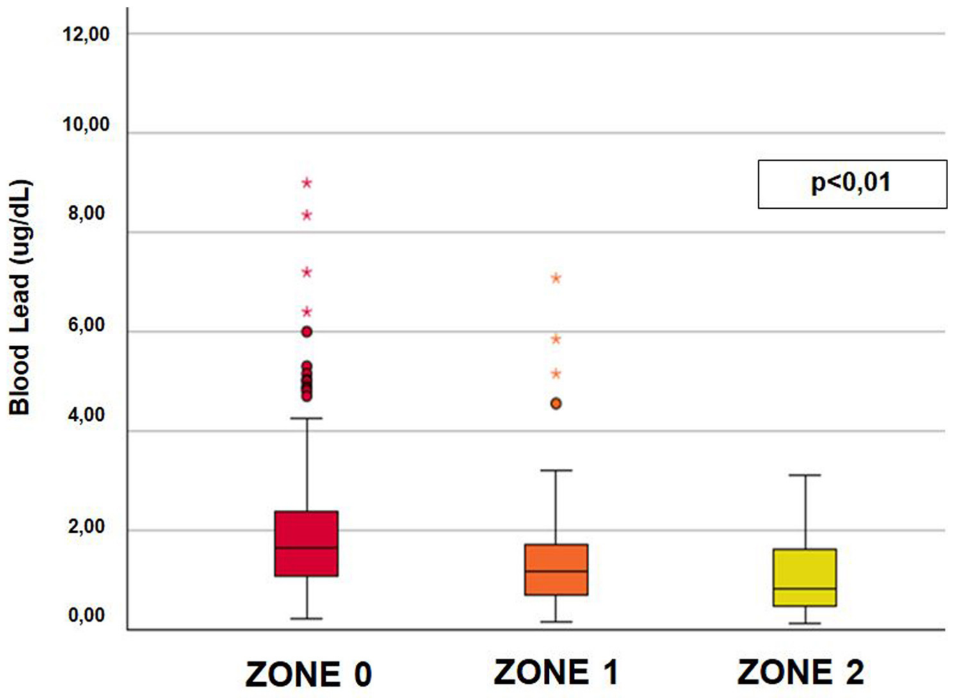

Fig. 3. Proximity to the source. Distribution of blood lead levels by residential zone. Kruskal–Wallis method for independent samples ($p < 0.01$).

nication mechanisms with society. The clinical program enabled the detection of individuals with significant blood lead levels (BLL), with 12 participants having BLL ≥ 5 μg/dl and 22 with BLL ≥ 3.5 μg/dl (11.3% of the participants). Our results show a gradient of lead exposure that decreases as we move away from Zone 0, reinforcing the hypothesis that proximity to contaminated soils is a primary cause of exposure.

Our findings also highlight the importance of considering multiple demographic and lifestyle factors when assessing heavy metal exposure in vulnerable populations. International initiatives like the National Health and Nutrition Examination Survey (NHANES) in the United States and the German Environmental Survey (GerES) in Germany have provided valuable biomonitoring data.[19,20] In addition, other communities, such as Port Colborne in Canada,[21] Broken Hill in Australia [22] and Torreón in Mexico [23] have implemented effective local programs to manage heavy metal exposure. In Spain, studies like BIOAMBIENT in 2007 reported a geometric mean BLL of 2.4 μg/dl in adults aged 18–65,[24] higher than our sample's GM (1.31 μg/dl). This decline can be attributed to the reduction in lead use in gasoline and housing construction, as well as industrial emission controls.[25]

For cadmium, the levels found in our sample are similar to those in the United States (0.256 μg/L).[26] Regarding arsenic, without differentiating between organic and inorganic species, 26 individuals had total urinary arsenic levels above 50 μg/L, with only three under 16 years old. The variability in daily exposure, urinary excretion, and adherence to seafood-free diets suggests that arsenic monitoring has limited clinical utility in the absence of exposure symptoms. Unlike arsenic, lead presents more stable levels making it highly relevant for clinical biomonitoring particularly in asymptomatic individuals, as it allows for the prevention of neurotoxic damage and the evaluation of therapeutic interventions.

Lead exerts significant neurotoxic effects, causing irreversible brain damage, especially in children and adolescents. In our study, BLLs below 10 μg/dl were observed, and it is in these small increments where a greater decline in IQ is recorded in exposed children.[27] This message underscores the critical importance of early pediatric intervention in communities with contaminated soils, where lead's effects can be more devastating and long-lasting.

It was observed that BLL and cadmium levels vary significantly with age, following a U-shaped distribution for lead. Children and the elderly showed higher levels, similar to previous studies indicating greater vulnerability in childhood and accumulation in old age.[28,29] BLLs in those under 16 years in our study (2.2 ± 1.5 μg/dl, GM: 1.8 μg/dl) are higher than those reported in other Spanish studies.[30] Arab participants had significantly higher BLLs compared to Caucasians, though the small sample size limits definitive conclusions about potential causes.[31] Men also showed higher heavy metal levels, related to higher smoking rates and occupational exposure, consistent with previous studies.[32] These findings emphasize the need to continue prevention and control measures in these vulnerable populations.

Similar to other initiatives,[33] training primary care professionals was crucial for ongoing prevention and reduction of heavy metal exposure. Importantly, the control measures implemented helped normalize BLLs within 2–3 months, underscoring the importance of early detection and appropriate intervention. All affected children were asymptomatic. Other community participation and environmental risk education initiatives have shown effectiveness in reducing BLLs in other regions.[34,35]

This study has several limitations that could affect the generalizability of the results. One major limitation is the potential selection bias as a voluntary study, likely involving mainly those most motivated or aware of the issue. Variability in lead exposure across demographic groups and the potential underreporting of lead poisoning cases are also significant limitations. The small sample size of some subpopulations, such as the Arab group (3.9%), and the potential underreporting of lead poisoning cases, limit the generalizability of the findings. These factors may have influenced the results, and future studies should consider the inclusion of random samples and longitudinal follow-up to assess the real impact of exposure. Although we have considered some confounding factors, in the future other socioeconomic and environmental variables should be considered. The use of total arsenic in urine in our study

Table 3
Multiple linear regression model with blood lead and urinary cadmium and arsenic as dependent variables.

Variable	Lead				Cadmium				Arsenic				Lead < 16 years			
	β	*t*	*p*	CI 95%	*β*	*t*	*p*	CI 95%	*β*	*t*	*p*	CI 95%	*β*	*t*	*p*	CI 95%
Age	0.03	5.60	<0.01*	0.02–0.04	0.01	4.35	<0.01*	0.01–0.02	0.67	2.53	0.013*	0.14–1.19	−0.00	−0.04	0.97	−0.17–0.17
Gender	−0.81	−4.13	<0.01*	−1.20–0.42	0.00	0.03	0.98	−0.07–0.08	−15.21	−1.64	0.103	−33.56–3.14	0.08	0.14	0.89	−1.08–1.24
Race	3.92	7.88	<0.01*	2.94–4.90	0.14	1.04	0.30	−0.13–0.41	−25.02	−0.74	0.461	−91.95–41.90	–	–	–	–
Zone 0 vs 1	−0.41	−1.82	0.071	−0.85–0.04	−0.08	−1.5	0.14	−0.18–0.03	−4.29	−0.36	0.721	−28–19.42	−0.00	−0.02	0.98	−1.15–1.13
Zone 0 vs 2	−0.79	−3.50	<0.01*	−1.24–−0.35	−0.04	−1.00	0.32	−0.13–0.04	−12.64	−1.25	0.213	−32.63–7.36				
Cotinine	-9×10^{-6}	−0.03	0.98	−0.00–0.00	0.00	3.21	<0.01*	0.00–0.00	−0.01	−0.61	0.55	−0.04–0.02	0.07	2.38	0.02*	0.01–0.15

This table summarizes the results of the multiple regression analyses for lead, cadmium, arsenic and lead in children under 16 years of age, presenting the coefficients (*β*), *t*-values, *p*-values and confidence intervals for each variable considered.

* Statistically significant ($p<0.05$).

is a low-cost test but requires dietary compliance from the participants. Despite these limitations, the study included 10% of the population in Zone 0—the most contaminated area—and identified 22 individuals with BLLs above the action level (>3.5 μg/dl) for international agencies, including six children and one pregnant woman.[2,3] Our findings advocate for expanding screening while conducting larger studies to obtain a more accurate picture of lead's health impact on the community. To maximize the impact, it's recommended the implementation of systematic screening programs in primary care, particularly in areas affected by environmental contamination. These programs should be multidisciplinary, involving specialized Pediatric Environmental Health Units (PEHSUs), as demonstrated in our intervention in the Sierra Minera, which normalized blood lead levels within 2–3 months. For future research, it is suggested conducting longitudinal studies that assess the long-term health effects of heavy metal exposure, as well as the effectiveness of the interventions implemented. These studies are crucial for quantifying the impacts on neurological development and other affected systems, and for optimizing public policies and intervention programs.

While most individuals had blood lead levels (BLLs) below the action level, the primary care screening model supported by PEHSU identified 22 individuals with elevated levels, including six children and one pregnant woman. Following PEHSU's guidelines, levels normalized within 2–3 months, demonstrating the intervention's effectiveness.

Conclusions

Including BLL screening in primary health programs for communities with contaminated soil is essential for achieving environmental justice, as there is no safe level of lead in the blood, particularly for children.

It is crucial to establish at least one Pediatric Environmental Health Specialty Unit (PEHSU) in each autonomous community in Spain to reduce neurotoxic exposure in affected areas. Additionally, public policies should prioritize the implementation of comprehensive soil remediation programs in areas with high contamination levels. This approach, combined with systematic BLL screenings, will help mitigate long-term health risks and ensure healthier living environments.

Ongoing and detailed educational programs must also be implemented to inform communities about the risks associated with heavy metal exposure and promote practices that minimize contact with contaminated soil. Such programs should engage local residents, schools, and healthcare providers to increase awareness and adoption of preventive measures. The collaboration between PEHSU-Murcia, primary care, and laboratories highlights the importance of knowledge-sharing in environmental health, which could be replicated in other European regions. Expanding research on lead exposure, particularly its effects on children's neurological development, is also necessary.

Routine BLL screening in contaminated areas would improve public health and adapt programs to environmental challenges. Training healthcare professionals in environmental health is key to identify and manage these risks, ensuring the protection of vulnerable populations through education and soil decontamination efforts.

Ethics considerations

The research committee of our center approved the work. The data have been processed in an anonymised form, so no specific consent has been signed by the patients.

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Conflicts of interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.medcli.2024.10.025.

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