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Original Article

Observational Study of the Relationship Between the Level of Lead and Hemoglobin in Women from Mining Centers in Huancavelica - Peru at More Than 3900 Mas L May, 2022

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Abstract *- The objective of this study was to determine the relationship between the level of lead in blood and the level of hemoglobin in women of childbearing age who live under the influence of mining centers in the Huancavelica region during the year 2022. Methodology: observational, prospective, cross-sectional, relational level research, in 132 women, with a minimum of three months of residence in Huachocolpa, Mimosa and Cochaccasa. Statistical analysis was done with Kendall's Tau b. Results: The majority were single (52.27%), young (60.61%), with a normal nutritional status (65.15%); 36.36%, the most frequent age (60.61%) was between 19 to 34 years, the average age was 28 years old, weight 55.65 kg and height 153 cm and 75% live in the area, more than 5 years old. Most of the houses were made of rustic material (82.56% adobe wall, 64.5% calamine or Eternit roof), 81% had basic sanitation and were located 1 km from the tailings, 75% of the families they had 3 or more members, 42.42% have children under 5 years old and 55.3% from 5 to 12 years old. None practice preventive measures and 94.70% want the information to avoid contamination by heavy metals. The lead level was 0.50 – 7.20 Ug/dL, the mean was 1.35 ± 1.11, and the Hb was 7.80 – 21.60 g/dL, and the mean was 11.85%, 3 out of 5 women had anemia; there a moderate negative relationship with a p-value from 0.000 to 99% confidence. Conclusions: low lead levels also affect hematopoiesis at higher blood lead levels and lower Hb levels.*

Keywords - *Blood lead, Lead, Anemia and lead, Hemoglobin and lead, Huancavelica blood.*

1. Introduction

Lead is a metal produced in cities and rural areas, which are highly polluted by gasoline combustion and mining, respectively. Its effects on humans are disastrous when it enters the blood. It can be stored in soft bones or excreted through the kidneys. In this way, lead affects the nervous, renal, reproductive, and hematopoietic systems.

In this sense, the concern arises to evaluate the relationship between the level of lead in the blood and the level of hemoglobin in women of childbearing age who live under the influence of the Huancavelica mining companies. Specifically, we worked with the population centers of Cochaccasa, Mimosa and Huachocolpa. In addition, the individual and socio-demographic aspects of women of childbearing age were characterized. In the same way, the age group was taken since investigations were found that indicated a greater risk in reproduction.

Lead (Pb) is a neurotoxic agent which is distributed in the environment, thus being a public health problem [1], [2]. The general population is exposed to this metal through the ingestion of contaminated food and the inhalation of lead in the air. According to the World Health Organization (WHO), the main source of environmental pollution is mining, followed by metallurgy [3].

Human exposure to lead can result in a wide range of biological effects, which can affect a person's health by damaging body systems and organs, such as the kidney, liver, and hematological and neurological systems [4], [5]; however, it also affects reproductive functions in women, birth outcomes, and child development [2]. Lead toxicity can reveal itself as an urgent surgical condition or a chronic illness, where the symptoms are usually broad and non-specific, ranging from mood and sleep disturbances, paresthesia and myalgias to abdominal pain, anemia, constipation, loss of appetite and irritability [6], [7].

Lead exposure causes approximately 0.6% of the global burden of disease, which occurs primarily in developing countries. Causing each year, 143 000 deaths and 600 000 new cases of intellectual disability due to exposure to lead [8].

Pregnancy is considered a critical time of lead exposure for the mother and fetus [9], [10]; since the placental barrier is permeable to free serum lead and the levels in the umbilical cord blood reach 5 to 10% of the level in the maternal blood. It is fetotoxic [11], [12]. In addition, lead can be released from the mother's bone stores during pregnancy; therefore, during this period, the demands for calcium increase, which leads to an increase in bone turnover, with the consequent release of lead from the bones, which also increases the reserve of biologically active lead [13], [14], and therefore, this can become a source important source of intoxication for the fetus [11].

High concentrations of lead in maternal blood can expose the fetus to its toxic effect; however, concentrations below 5 µg/dL have been associated with spontaneous abortion [15], [16], hypertension during pregnancy or preeclampsia [17]–[20], preterm delivery [21], premature rupture of membranes [22], low birth weight [23], [24] and mild malformations in the fetus [3]. Likewise, it has been related to decreased intellectual and academic performance and neurobehavioral alterations in infancy and early childhood [25,27,53]. Therefore, maternal exposure to lead plays an important role in adverse pregnancy outcomes.

The Center for Disease Control has recently lowered the threshold allowable lead level from 25 to 10 µg/dL [28], although this has been even lower in pregnant women. In this sense, the WHO has declared that the normal level of lead in pregnant women should be less than 5 µg/dL [29]; In the same way, it is developing a series of guidelines for the prevention and treatment of lead poisoning in order to offer policymakers, public health authorities and health professionals, guidance on the measures that can be adopted to protect the health of the population against exposure to lead [3], [30].

Studies on Peruvian pregnant women's blood lead levels in La Oroya revealed contamination. Further research is needed in areas with small-scale mines like Huancavelica to estimate risk and identify the link between lead and anemia. Human exposure to lead continues to be a public health problem; however, the production and use of lead continue to increase, despite mounting evidence of its health effects. The developing fetus and neonates are more vulnerable to lead in terms of exposure and health effects.

The main objective is to study observationally the relationship between lead level and hemoglobin in women near mining centers in the province of huancavelica in Peru. Therefore, it is important to investigate the socio-demographic characteristics of women of childbearing age, their knowledge of lead contamination, and how to prevent it. In addition, it was important to analyze the level of lead and hemoglobin in each of them first to see the behavior and if there is a relationship between them.

The present study is relational, observational, and prospective, cross-sectional. The research results will serve to develop regulatory measures aimed at reducing the risk of contamination, such as exposure to lead and generating preventive measures, which are little known by the population. Likewise, the results will serve as a basis for future research on the subject.

2. State of Art

Chen et al. [31] aimed to observe the main and interactive effects of cadmium and lead on the hemoglobin level in a Chinese population; its population was made up of 308 people, of whom 202 were women and 106 men. They found that the cadmium and lead level of the subjects living in the contaminated area was significantly higher compared to those living in the control area ($p < 0.05$). Likewise, they found that the level of hemoglobin in women was reduced with the increase of lead and cadmium ($p <0.05$); in addition, the hemoglobin of people with the highest level of cadmium and lead decreased by 8.3 g/L and 10.7 g/L compared to those with the lowest level of cadmium and lead. They concluded that cadmium and lead can influence the hemoglobin level.

La Llave et al. [32] aimed to examine the relationship between blood lead levels and hematological indices in pregnant women, a cross-sectional study whose sample was made up of 292 pregnant women. They found that mean blood lead was 2.79 ± 2.16 µg/dL and detected lead levels ≥ 5 µg/dL in 25 women (8.6%). Likewise, they found that hemoglobin, hematocrit, and red blood cell counts were significantly higher in pregnant women with a blood lead concentration ≥ 5 µg/dL than in the group with lower blood lead levels ($p < .05$). They also found that mean corpuscular volume and mean corpuscular hemoglobin were not significantly related to lead levels. However, hemoglobin and hematocrit showed a non-significant positive correlation with blood lead. On the other hand, the correlation between red blood cell count and blood lead levels was statistically significant ($r = 0.185$, $p = 0.002$).

In addition to the concern of pregnant mothers in mining areas, we also have Xie et al. [33], which aimed to identify the effects of low-level prenatal exposure to lead on birth outcomes; its sample consisted of 252 mothers and children. They found that mean lead levels in maternal blood were 3.20 µg/dL and in the umbilical cord and 2.52 µg/dL. They also found that increased maternal blood lead exposure was associated with decreased birth weight (β = -148.99; 95% CI, -286.33 to -11.66); furthermore, they found a significant negative relationship between umbilical cord blood lead levels and length at birth (β = -0.84; 95%). %CI, -1.52 to -0.16). They concluded that low-level prenatal exposure to lead can negatively affect fetal growth.

Similarly, Hassanian et al. [34] conducted a descriptive cross-sectional study to detect blood lead levels in 100 pregnant women. They found that those living in contaminated areas had higher median blood lead levels (P=0.044), and substance exposure showed a significant correlation (P=0.02). Median blood lead levels were lower in those with no family history of lead toxicity (P=0.003). Living in non-industrial areas predicted blood lead levels below 3.2 and 5 µg/dL. All women gave birth to live babies at term. They concluded that a positive family history of lead toxicity and living in contaminated areas may lead to higher lead levels in pregnant women.

Ohtsu et al. [54] aimed to evaluate dietary exposure to lead, where its sample consisted of 86 pregnant women and 87 children. They found that lead concentrations in food, drinking water, and household dust were low; they also found that oral exposure to lead was higher in children (mean ± SEM; 5.21 ± 0.30 µg/kg body weight/week) than in pregnant women (1.47 ± 0.13 mg/kg of body weight/week). They also found that food and household dust were the main sources of lead contamination. On the other hand, the means ± SEM of peripheral and cord blood lead concentrations were 0.69 ± 0.04 µg/dL and 0.54 ± 0.05 µg/dL, respectively, for pregnant women and 1.30 ±0.07 µg/dL (peripheral only) in children. They concluded that the levels of oral lead exposure for Japanese children and pregnant women were low, with higher concentrations and exposures for children than for pregnant women.

Castro et al. [36] objective were to evaluate the concentration of lead in the blood of the umbilical cord and its impact on the level of hemoglobin, length, weight and APGAR at birth, a cross-sectional study where its sample consisted of 64 neonates from Huancayo and La Oroya. They found that neonates from Huancayo and La Oroya had average lead concentrations of 18.03 µg/dL and 22.96 µg/dL (p=0.016), these values being 1.8 and 2.3 times higher than the critical level suggested by the Center for Disease Prevention Control (CDC) and the WHO (10 µg/dL). They also found that the hemoglobin levels for the neonates from Huancayo and La Oroya were 18.3 and 16.9 g/dL (p=0.000), and anemia was only recorded in the neonates from La Oroya (9.38%). They concluded that an inverse association was evident between umbilical cord blood lead content and hemoglobin content, weight, length, and APGAR score at birth.

Castro et al. [37] objective was to determine the lead levels in pregnant women and newborns; in a cross-sectional study, its sample consisted of 40 pregnant women who gave normal birth. Within the demographic characteristics, they found that the average age of the mothers was 29 ± 6 years; the average number of years of residence was 16.5 ± 10.6, the average number of deliveries, without considering the last one, was two, and finally, the average gestational age at delivery was 39 weeks. Regarding lead levels, they found that the average lead levels in maternal blood were 27.4 ± 15.6 ug/dL, in umbilical cord 19.0 ± 12.6 ug/dL and in placenta 319.0 ± 215.9 ug/100g. Likewise, 67.5% of the neonates had more than 10 ug/dL of lead, and 10% had more than 40 ug/dL of lead. They concluded that pregnant women and newborns had high lead concentrations in their blood; likewise, lead concentrations in the placenta and umbilical cord were moderately correlated with maternal blood lead.

Castro et al. [38] objective was to estimate the quantitative relationship between the concentration of lead in the placenta and weight; the relationship between the weight of the placenta with gestational age, weight, length, and hemoglobin concentration of newborns; It was a descriptive, cross-sectional, and correlational study, where its sample consisted of 40 newborns of eutocic births. They found that the mean and standard deviation of gestational age was 39.20+1.18 weeks; lead content in the placenta was 319+215.86 ng/g; the placental weight was 504.25+83.53 g; the weight of the newborns was 3191.75+310.61 g, the length of the newborns was 49.72+1.26 cm, and the hemoglobin of the newborns was 16.76+1.88 g/dL. They concluded that high levels of lead in the placenta were negatively correlated with their own weight, and higher placental weights were positively correlated with the newborns' weight, length, and hemoglobin content.

Guillen et al. [39] objective were to determine the lead levels in breast milk in primiparous puerperal women; it was an observational cross-sectional study that included 100 breast milk samples. They found that the mean gestational age was 39.1 weeks; Likewise, they found that 37% of the samples had a detectable level of lead, six of them between 5.0 and 9.9 ng/g and five greater than 10 ng/g. On the other hand, they found no correlation of lead concentration with maternal age, educational level, or occupation. They concluded that a significant percentage of breast milk samples showed lead contamination, particularly in residents of the northern area of Lima.

Condori and Huamani [40], in their research "Lead concentration in blood and risk factors in children in the town of Huachocolpa, Huancavelica - 2017", aimed to determine the relationship between the concentration of lead in blood and risk factors in children; It was a cross-sectional study, where its sample consisted of 30 children. They found that 100% of children had low lead concentrations, and in relation to risk factors, 90% of children had high-risk factors while 10% had low-risk factors. They also found that 80% have a high epidemiological risk, 57% have a high environmental risk, 43% have a low environmental risk, and 20% have a low epidemiological risk.

3. Conceptual Basis

3.1. The Lead

Lead, a bluish-gray metal, is naturally found in the earth's crust and is associated with other metals. It is soft, malleable, and resistant to corrosion. Lead contamination can occur in urban or rural areas near mining and from occupational exposure in various industries. Lead is absorbed by inhalation or ingestion, with children absorbing 30-50% and adults 10% circulating in the blood and excreted or deposited in tissues. [41], [42].

3.2. Lead in Blood

Blood lead is the main biomarker of lead exposure. The main biomarkers of effect are the inhibition of Delta-aminolevulinic acid dehydratase (ALAD) and the variation in some concentrations of metabolites, such as zinc protoporphyrin (ZP) in blood, delta-aminolevulinic acid in the urine (ALA-U), Delta-aminolevulinic acid in the blood (ALA-B), Delta-aminolevulinic acid in plasma (ALA-P) and coproporphyrin in urine (CP). However, not all the indicators mentioned equally reflect the dose and internal dose/effect relationship [55].

The average life of lead in blood is approximately 21 to 28 days, while lead accumulates in bone with an average life of 20 to 30 years [41], [44].

Research suggests that exposure to high and low lead concentrations negatively affects the hematopoietic, vascular, nervous, renal, and reproductive systems.

The WHO defines poisoning as when the value of lead in the blood is greater than 15µg/dL, called blood lead, and the CDC greater than or equal to 10µg/dL. Levels greater than 80 µg/dL correlate better with lead encephalopathy, with 50 µg/dL cognitive impairment, with 40 µg/dL nephropathy, with 20 µg/dL peripheral neuropathy, anemia being detectable from values of 10 µg/dL. Values of 40-60 µg/dL in adults have been correlated with renal failure and hypertension. In the child population, even with values below 10 µg/dL, intellectual deterioration and delayed puberty are reported in girls [41].

3.3. Effects of Lead on Pregnant Women and the Fetus

Lead, present in construction, batteries, and cosmetics, harms pregnancy outcomes. Women working in lead industries had higher chances of miscarriages, stillbirths, and neonatal deaths. Even lower blood lead levels increase the risk of fetal malformations [17], [44], [45].

Lead is known to freely cross the placenta, as evidenced by studies showing a strong correlation between maternal blood lead levels and umbilical cord blood lead levels; as a result, some evidence suggests neurodevelopmental impairment in children [46].

3.4. Hemoglobin Function

The main functions of Hb are to transport oxygen (O2) from the lungs to peripheral tissues and carbon dioxide (CO2) from the tissues to the lungs. The kinetics of Hb-O2 binding and release are tuned for this purpose and are adaptable depending on developmental ontogeny and metabolic perturbations.

In addition, the Hb molecule must limit potential problems caused by associated iron and free O2, which are reactive molecules capable of inflicting damage through the production of reactive oxygen species [47], [48].

3.5. Hemoglobin During Pregnancy

The blood volume in normal pregnancy increases by 40-45% at 32-34 weeks, mainly due to plasma and erythrocyte expansion.

Hemoglobin concentration and hematocrit decrease, with an average of 12.5 g/dL at term. Hemoglobin <11.0 g/dL, especially in late pregnancy, is abnormal due to iron deficiency, not hypervolemia. [49].

3.6. Lead and Hemoglobin

Lead inhibits enzymes, dehydratase, and ferrochelatase, that synthesize heme, leading to an increase in d-aminolaevulinic acid and free protoporphyrin.

Lead causes two types of anemia: acute exposure is associated with hemolytic anemia, while chronic exposure leads to hypochromic and normocytic or microcytic anemia. Lead also affects other biological processes. [50].

4. Methodology

The research type is observational, prospective, and cross-sectional; since the blood sample was taken from each participant, the lead and hemoglobin levels were analyzed.

It is of a relational level because it will be analyzed if there is a relationship between the level of lead and the level of hemoglobin, without neglecting to describe the socio-demographic characteristics and preventive measures.

The method is quantitative; specific methods used are inductive and deductive. The research design is relational.

Our test was made up of all women of childbearing age who live in the areas of influence of the mining centers of San Pedro de Mimosa, Ccochaccasa, and Huachocolpa.

Sample and sampling: they were for convenience. The women who agreed to participate in the study evidenced their informed consent, signed authorization, prior orientation, and counseling.

4.1. Data Collection Technique And Instruments

The interview was used to collect socio-demographic data on individual characteristics, housing, family, and preventive measures, through a structured survey.

For the quantification of lead, inductively coupled plasma mass spectrophotometry (ICP-Mass) was used, and the equipment used was of the Perkin Elmer brand. Model: ICP NexION 350D.

The technique used was the analysis of mean corpuscular volume, which was conducted using an MHC Microhematocrit Centrifuge with 24 Capillary Rotor HC-240 BOE 01801-13.

Information collection procedure:

- Women of childbearing age were interviewed to invite them to participate in the research
- It was informed about the research and asked to sign the informed consent
- The consent form was left for 72 hours so that a decision could be made without pressure, and the patient was returned to the home to obtain consent.
- In case of having given their consent, the sample was taken with the respective technique.

4.2. Data Collection and Sample Procedure

- The respective permits were requested from the local health institutions.
- Coordinated with health workers.
- Each woman of childbearing age who attended the health facility was informed about the project.
- The informed consent was read, and her signature was asked if she agreed to participate.
- The interview was conducted with each one during the waiting time.
- The procedure was explained to each participant of the test that was going to be performed again before taking the blood sample.
- 5 ml of venous blood was taken in heparinized test tubes with EDTA; the extraction was with a vacutainer.
- The samples were separated for the quantification of lead and hemoglobin.
- The sample was stored at -10°C in the laboratory of the Universidad de Huancavelica and the Hospital of Lircay.
- The samples were transferred to the UCH laboratory in the city of Lima with the pertinent protocols for lead quantification.
- Hemoglobin (Hb) quantification was processed in Huancavelica.

4.3. Data Processing and Analysis Techniques

Descriptive analysis was used in data processing.

For socio-demographic aspects, descriptive techniques involved the use of simple frequency distribution tables and percentages of one entry: as well as the use of box and area graphs for greater understanding.

Central tendency and dispersion statistics were also used. The normality of the data was evaluated with the Kolmogorov-Smirnov normality test.

The correlation coefficient was estimated using Kendall's Tau-b rank correlation coefficient significance test to evaluate the hypothesis, corresponding to a non-parametric correlation test.

Correlational techniques were based on using double-entry tables and scatter plots to visualize the relationship.

4.4. Description of the Hypothesis Test

The hypothesis test was performed with Kendall's Tau b significance test, considering that the distribution of the hemoglobin and blood lead level data did not correspond to a normal distribution, according to the Kolmogorov-Smirnov test (p-value < 0.05) and the distribution of the crossing of variables was square.

A significance level of 1% was used, with a confidence of 99%.

It should be noted that Kendall's Tau b test is the non-parametric correlation test that most closely approximates a normal distribution.

5. Results

The results are presented, responding in the first instance to the specific objectives; and then to the general objective.

It should be noted that the study sample consisted of 132 women of childbearing age (15 to 49 years old) from the area of influence of three mining centers in the Huancavelica region.

First, the socio-demographic characteristics of the women who participated in the study are described, including individual data, data on family members, housing characteristics, and access to basic sanitation services.

The table 1 shows the Operationalization of variable of this observational study, which compares the independent variable, conceptual definition, opercional definition, dimensions, indicators, item amd type of variable.

Table 1. Operationalization of variable

Independent Variable	Conceptual Definition	Operacional Definition	Dimensions	Indicators	Item	Type of variable
Lead level in women of childbearing age	Lead is a metal that can be quantified in the blood and tissues of living beings, in this case, in women of childbearing age. Between 15 and 49 years old. Amount of lead identified in the blood of women aged 15 to 49 years.	Amount of lead identified in the blood of women aged 15 to 49 years.	Individual characteristics	Marital status at the time of the survey.	Marital status	Nominal categorical
				Age at the time of sampling.	Age in years.	Numeric
				Nutritional status	BMI: Weight, height	Numeric
				Number of births	Parity.	Nominal categorical
			Housing	Distance in km from the contamination area	Distance from your home to the mining center or mining tailings of your locality	Numeric
				Residence time	How long do you live?	Nominal categorical
				Housing tenure	Rented, owned	Nominal categorical
				Type of material	Of the walls Of the roof Floor Material	Nominal categorical
				Basic sanitation service	Water, water supply source, drain, electricity.	Nominal categorical
			Family	Number of family members by age group.	Total number of members, number of children under 5 years of age, number of members between 5 and 12 years old	Nominal categorical
			Preventive measures		Wish to be informed application of preventive measures previous lead	Categorical ordinal
			The lead level in peripheral blood.	µg of lead/dL of peripheral blood.	Lead quantification	Numeric
Hemoglobin of women of childbearing age exposed to lead	Hemoglobin quantified in women living in the area of influence of the Huancavelica mining companies.	It is the evaluation of hemoglobin, around two months, in which the level of lead is evaluated.	Acceleration	Hemoglobin accelerations in women exposed to lead.	Hb in mg/dL	Numeric
			Decelerations	% Of women with anemia Without anemia	Without anemia mild anemia moderate anemia Severe anemia	Categorical ordinal

Table 2. Individual characteristics of women of reproductive age living in the area of influence of the mining centers of the huancabvelica region, 2022

Individual Characteristics	Values	
	Frequency	%
Marital status		
Single	69	52.27
married	59	44.70
Widow	3	2.27
Divorcee	1	0.76
Total	132	100.00
Age group		
Adolescent (<19 years)	24	18.18
Young (19 to 34 years old)	80	60.61
Adult (35 to 49 years old)	28	21.21
Total	132	100.00
Nutritional status according to body mass index (BMI)		
Thinness	1	0.76
Normal	86	65.15
Overweight	44	33.33
Grade I obesity	1	0.76
Total	132	100.00
Parity		
nulliparous	48	36.36
Primipara	33	25.00
Secondary	22	16.67
Third to more	29	21.97
Total	132	100.00

Table 2 shows the individual characteristics of the 132 women of childbearing age included in the study. It was found that they were single (52.27%), young (60.61%), with a normal nutritional status (65.15%), and did not have children (36.36%) or only had one (25.00%).

Table 3 shows the measures of central tendency and dispersion of the age, weight, and height of the women of childbearing age who participated in the study. Women aged 15 to 49 years were included, whose average age was 28 ± 8.68 years; half of them were under 27 years old, and it was more common to find women 17 years old.

Table 3. Individual quantitative data of women of reproductive age livin in the area of influence of the mining centers of huancavelica region, 2022

Statistical Tools	Variables		
	Age (years)	Weight (kg)	Height (cm)
n	132	132	132
Minimum	15	45	143
Maximum	49	72	178
Range	34	27	35
Interquartile range	14	6	4
Average	28	55.65	153
Median	27	55.25	153
Mode	17	54	150
Standard deviation	8.68	4.92	4.40

Table 4. Data on the dwelling of women of children's age living in the area of influence of the mining centers of the huancavelica region, 2022

Housing Data	Values	
	Frequency	%
Distance to the tailings of the mining center (km)		
0.1	5	3.79
0.3	47	35.61
1	65	49.24
2	15	11.36
Total	132	100.00
Residence time		
From 3 months to less than 1 year	21	15.91
From 1 to less than 3 years	3	2.27
From 3 to less than 5 years	9	6.82
From 5 years to more	99	75.00
Total	132	100.00
Home tenure		
Rented	51	38.64
own	81	61.36
Total	132	100.00
Material of the walls		
Adobe	71	82.56
Wood	15	17.44
Brick	46	53.49
Total	86	100.00
Roof material		
Calamine	78	59.09
eternal	8	6.06
Concrete	44	33.33
Wood	2	1.52
Total	132	100.00
Floor material		
Cement	78	59.09
Wood	19	14.39
Land	35	26.52
Total	132	100.00

In addition, women of childbearing age weighted 45 to 72 kg, with an average weight of 56.65 ± 4.92 kg; the median of them had less than 55.25 kg, and a weight of 54 kg was more frequent. Height was between 143 to 178 cm, with an average of 153 ± 4.40 cm; half of the women of childbearing age had a height less than 153 cm, and a height of 150 cm was more frequent.

Table 4 shows the housing data of the 132 women of childbearing age included in the study. It was found that their homes are located 1 km (49.24%) and 0.3 km (35.61%) from the tailings of the mining center. Likewise, they have resided in that area for 5 years or more (75.00%). The dwelling is most often owned (61.36%).

Regarding the material of the house, the walls are adobe (82.56%), the roof is corrugated iron (59.09%), and the floor is cement (59.09%).

Table 5. Basic sanitation services in the homes of women of reproductive age living in the area of influence of the mining centers of the huancavelica region, 2022

Basic sanitation services	Values	
	Frequency	%
Water		
Yes	130	98.48
No	2	1.52
Total	132	100.00
Main source of water supply		
home public service	123	93.18
public pool	2	1.52
Spring	7	5.30
Total	132	100.00
Drain		
Yes	108	81.82
No	24	18.18
Total	132	100.00
Electric light		
Yes	114	86.36
No	18	13.64
Total	132	100.00

Table 5 shows the basic sanitation services accessed by the study sample's 132 women of childbearing age. At the time of the survey, there was a water service (98.48%), having supply from a public source at home (93.18%) and a community pool (1.52%). In addition, 81.82% of women access the drainage service; and 86.36% have access to electricity service at home.

Table 6. Members of the family of women of reproductive age living in the area of influence of the mining centers of the huancavelica region, 2022

Family members	Values	
	Frequency	%
Number of family members		
From 1 to 2	31	23.48
From 3 to 5	78	59.09
From 6 to 9	21	15.91
More than 10	2	1.52
Total	132	100.00
Number of children under 5 years		
None	76	57.58
1	45	34.09
2	10	7.58
3	1	0.76
Total	132	100.00
Number of children from 5 to 12 years old		
None	59	44.70
1	50	37.88
2	15	11.36
3	7	5.30
4	1	0.76
Total	132	100.00

Table 7. Preventive measures for lead contamination in women of reproductive age living in the area of influence of the mining centers of the huancavelica region, 2022

Preventive Measure	Values	
	Frequency	%
Want to know about heavy metal contamination.		
Yes	125	94.70
No	7	5.30
Total	132	100.00
Application of measures to control contamination by heavy metals		
Yes	0	0.00
No	132	100.00
Total	132	100.00
Pre-study blood lead screening		
Yes	4	3.03
No	128	96.97
Total	132	100.00
Application of preventive measures		
Yes	4	3.03
No	128	96.97
Total	132	100.00

Table 6 shows the family members' data of the total sample of 132 women of childbearing age. It is observed that, with greater frequency, the number of family members for each woman was between 3 and 5 members. 57.58% of women reported not having children under 5 years old, and 34.09% registered a child under 5 years old in their family. Likewise, 44.70% of women did not have any children between 5 and 12 years old, while 37.88% had a child in that age range at the time of the survey. The level of knowledge about lead contamination is described below.

Table 7 shows the preventive measures for lead contamination applied by the 132 women of childbearing age who participated in the study. It is observed that 94.70% are interested in learning about the issue of heavy metal contamination, including lead. None of the respondents has applied measures to control contamination by heavy metals. Only 3.03% of them have been screened for lead in their blood as a preventive measure for contamination. In general, 96.97% of the women of childbearing age surveyed have not applied any preventive measure against lead contamination.

Next, the results of the analysis of the blood lead level of the women of childbearing age included in the study are presented. Table 8 shows the statistics of central tendency and dispersion of the lead level in the analyzed blood of 132 women of childbearing age. The minimum level of lead in blood was 0.50 ug/dL, and the maximum level was 7.20 ug/dL, with a range of 6.70 ug/dL and an interquartile range of 1.20 ug/dL (low dispersion). On average, the blood lead level was 1.35 ± 1.11 ug/dL; median of the women, the value was less than 1.10 ug/dL, with a value of 0.50 ug/dL being more frequent.

Table 8. Level of lead in the blood of women of reproductive age living in the area of influence of the mining centers of huancavelica region, 2022

Statisticians	Values
	Blood lead (ug/dL)
n	132.00
Minimum	0.50
Maximum	7.20
Range	6.70
Interquartile range	1.20
Average	1.35
Median	1.10
Mode	0.50
Standard deviation	1.11

Table 9. Categorization of the level of lead in the blood of women of reproductive age living in the area of influence of the mining centers of the huancavelica region, 2022

Blood lead level Values	Values	
	Frequency	%
Low (<5ug/dL)	130	98.48
Elevated with quarterly monitoring (5- 9.9 ug/dL)	2	1.52
Total	132	100.00

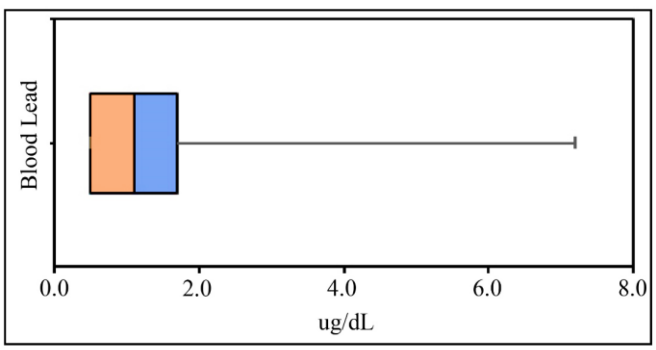

Fig. 1 Box Diagram of the distribution of the level of lead in the blood of women of reproductive age living in the area of influence of the mining centers of the huancavelica region, 2022

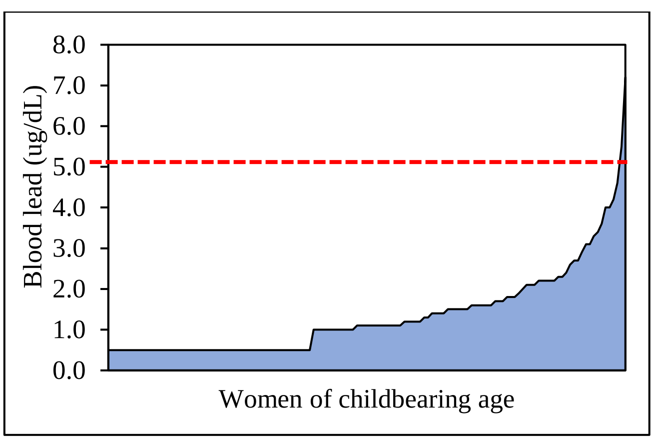

Fig. 2 Area diagram of the upward distribution of the level of lead in the blood of women of reproductive age living in the area of influence of the mining centers of the Huancavelica region, 2022

Table 10. Hemoglobin levels of women of reproductive age living in the area of influence of the mining centers of the huancavelica region, 2022

Statisticians	Values
	Hemoglobin (g/dL)
n	132.00
Minimum	7.80
Maximum	21.60
Range	13.80
Interquartile range	3.03
Average	11.85
Median	10.70
Mode	10.60
Standard deviation	2.84

Figure 1 shows the blood lead level data distribution through a box plot. The data distribution is not close enough to normal, even though the median is in the center of the distribution, and this is due to the presence of extreme values, represented by the extensive upper whisker and the absent lower whisker.

For a better understanding, blood lead levels are categorized according to the reference values of the Center for Disease Control and Prevention (CDC) of the United States, proposed in the year 2021, which are applied nationally and internationally.

Table 9 shows the categorization of the lead level according to normal and intoxication limits. 98.48% of women of childbearing age have a low blood lead level, and 1.52% have a high level requiring quarterly monitoring.

Figure 2 shows that the entire data distribution area is made up of women of childbearing age with blood lead values below 5 ug/dL.

The results of the analysis of the hemoglobin level of the women of childbearing age who participated in the study are detailed above.

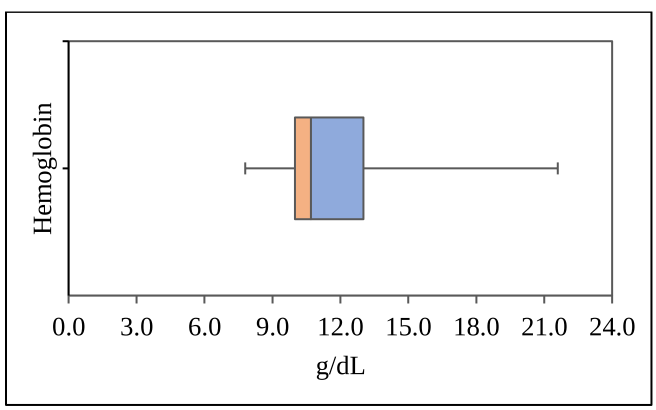

Fig. 3 Box diagram of the distribution of the hemoglobin level of women of reproductive age living in the area of influence of the mining centers of the Huancavelica region, 2022

Table 11. Categorization of the hemoglobin level of women of reproductive age living in the area of influence of the mining centers of the huancavelica region, 202

Hemoglobin level	Values	
	Frequency	%
No anemia (12 g/dL or more)	47	35.61
Mild anemia (11 - 11.9 g/dL)	7	5.30
Moderate anemia (8 - 10.9 g/dL)	76	57.58
Severe anemia (> 8 g/dL)	2	1.52
Total	132	100.00

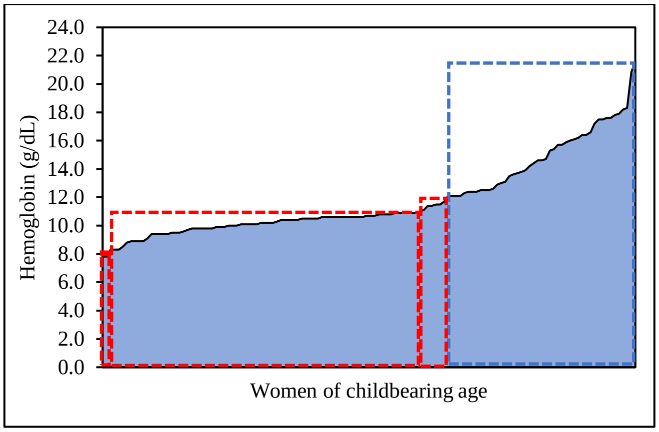

Fig. 4 Area diagram of the upward distribution of the hemoglobin level of women of reproductive age living in the area of influence of the mining centers of the Huancavelica region, 2022 2022

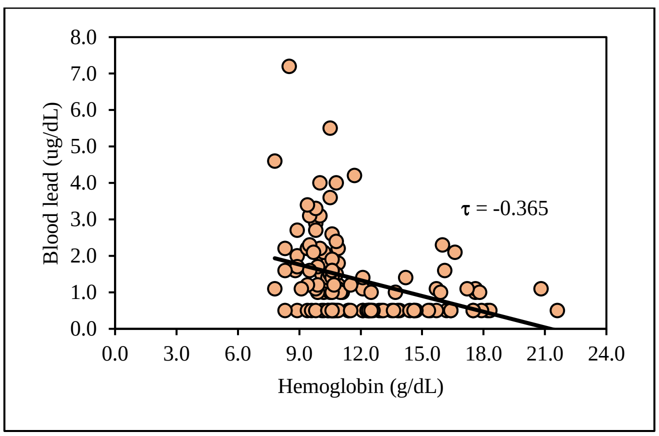

Fig. 5 Dispersion diagram of the level of lead in the blood with respect to the level of hemoglobin of women of childhood age living in the area of influence of the mining centers of the Huancavelica region, 2022

Table 10 shows the statistics of central tendency and dispersion of the hemoglobin level of the blood analyzed from the sample of 132 women of childbearing age. The minimum hemoglobin level found was 7.80 g/dL, and the maximum level was 21.60 g/dL, with a range of 13.80 g/dL and an interquartile range of 3.03 g/dL (low dispersion). On average, hemoglobin was 11.85 g/dL with standard deviation of 2.84 g/dL; median women had a value less than 10.70 g/dL. A value of 10.60 g/dL of hemoglobin was more frequent.

Figure 3 represents the distribution of hemoglobin data through a box plot. The data distribution was not normal; since the line corresponding to the median was not located in the center of the box but was closer to the lower values; therefore, there was a positive asymmetry, which was also corroborated by the greater extension of the upper whisker of the box.

For a better understanding, hemoglobin levels are categorized in degrees of anemia according to the technical guide called: Procedure for determining hemoglobin using a portable hemoglobinometer, approved by Resolution No. 363-2022/MINSA.

Table 11 shows the categorization of the hemoglobin level of the 132 women of childbearing age. Moderate anemia (57.58%) and not suffering from anemia (35.61%) were more frequent. Figure IV shows a greater area of distribution of the hemoglobin level between 8 and 11 g/dL (moderate anemia) and from 12 to more g/dL (no anemia).

To respond to the general objective, the relationship between the level of lead in blood and the level of hemoglobin is determined based on a double categorical entry table and a dispersion diagram of the values obtained.

Table 12 shows the cross table of the categorization between the blood lead level and the hemoglobin level categorization of the 132 women of childbearing age.

Of the total number of women of childbearing age with low blood lead levels, 56.92% had moderate anemia. In addition, the 2 women with elevated blood lead levels had moderate anemia. In the categorized data, there is no evidence of a relationship between the variables. For this reason, categorical data are left out, and continuous data on blood lead and hemoglobin levels are analyzed through a scatter diagram.

Table 12. Comparison of blood lead levels and hemoglobin level in women of childbearing age who live in the area of influence of the mining centers of the huancavelica region, 2022

Hemoglobin level	Blood Lead Level					
	Low		High with quarterly monitoring		Total	
	Frequency	%	Frequency	%	Frequency	%
no anemia	47	36.15	0	0.00	47	35.61
mild anemia	7	5.38	0	0.00	7	5.30
moderate anemia	74	56.92	2	100.00	76	57.58
severe anemia	2	1.54	0	0.00	2	1.52
Total	130	100.00	2	100.00	132	100.00

Figure 5 shows the scatter diagram of the blood lead level data and the hemoglobin level data of the 132 women of childbearing age who participated in the study. The scatter points have been grouped from top to bottom, left to right, with a trend line that implied a negative relationship. It is observed that the higher the level of lead in the blood, the lower the level of hemoglobin. In addition, the estimated Kendall Tau-b coefficient was -0.365, which implies an inverse or negative relationship, in which the blood lead level explains 13.32% of the variation in the hemoglobin level (coefficient of determination).

5.1. Hypothesis Testing Process

The test of the central hypothesis is conducted on the relationship between the level of lead in blood and the level of hemoglobin.

5.2. Formulation of Statistical Hypotheses

H0: The blood lead level does not have a significant relationship with the hemoglobin level of women of childbearing age who live in the area of influence of mining centers in the Huancavelica region during the year 2022.

$$H_0: p=0$$

H1: The blood lead level has a significant relationship with the hemoglobin level of women of childbearing age who live in the area of influence of mining centers in the Huancavelica region during the year 2022.

$$H_1: p\neq 0$$

The significance level was 1% (ρ = 0.01), and the confidence level was 99%. The selected statistic was Kendall's Tau-b rank correlation coefficient test for significance, which corresponds to a non-parametric correlation test since the following assumptions are met: The data were paired. Variables were measured on a continuous scale. The estimate of a correlation coefficient closest to the normal distribution was sought. The distribution of laboratory data was not normal in any of the variables. This was verified with the Kolmogorov-Smirnov normality test because the sample was greater than 50, as seen in the following table.

Table 13. Kolmogorov-Smirnov test of data distribution of blood lead level and hemoglobin level of women of childbearing age living in the area of influence of mining centers of the huancavelica region, 2022

Statistician	Values	
	Blood lead (ug/dL)	**Hemoglobin (g/dL)**
n	132	132
gl	132	132
Statistic	0.222	0.221
Bilateral asymptotic significance	0.000	0.000

Table 13 shows that the p-value of the Kolmogorov-Smirnov statistic is 0.000 for the data of the blood lead level and the hemoglobin level. This value was less than 0.05; therefore, the null hypothesis of normality was rejected; the distribution of both data groups was not normal.

On the other hand, Kendall's test is estimated with the following formula.

$$\tau_b = \frac{2\,(C-D)}{\sqrt{n(n-1) - \sum(tx_i^2 - tx_i)} \cdot \sqrt{n(n-1) - \sum(ty_i^2 - ty_i)}}$$

Where:

- τ_b = Kendall's Tau-b rank coefficient.
- C = n number of concordant pairs.
- D = n number of discordant pairs.
- n = Sample size.
- Tx_I = Length of the i-th tie for the variable x.
- Ty_I = Length of the i-th tie for the variable y.

The significance is estimated from the Gaussian z distribution, for samples greater than 10, with the following formula.

$$z = \frac{3\tau_b\sqrt{n(n-1)}}{\sqrt{2(2n+5)}}$$

Where:

τ_b = Kendall's Tau-b rank coefficient.
n = Sample size.

For a bilateral test and a significance level of 1%, the null hypothesis was rejected if the calculated z-value was greater than the tabular z-value of 2.576 or less than the tabular z-value of -2.576, as can be seen in the following figure.

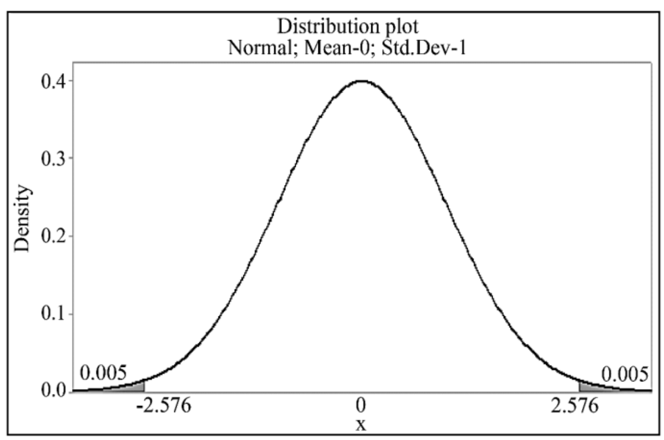

Fig. 6 Zone of rejection of the null hypothesis for the bilateral z distribution and a significance of 1%.

The test statistics were estimated with the help of the statistical program IBM SPSS 25.0; the results are presented in the following table.

Table 14. Significance test of the kendall tau-b rank correlation coefficient for the blood lead level and the hemolglobin level of women of childbearing age living in the area of influence of the mining centers of the huancavelica region, 2022

Statistician	Values
n	132
Kendall's Tau-b coefficient	-0.365
Asymptotic standardized error at	0.053
Z approximate b	-6.208
Approximate p-value	0.000
n	132

Table XIV shows that Kendall's Tau-b correlation coefficient was -0.365, which implies a moderate negative relationship (it is between 0.35 and 0.39), which is equivalent to an approximate z value of -6.208, which turns out to be less than the tabular z value of -2.576, falling in the region of rejection of the null hypothesis. Therefore, the null hypothesis was rejected under a p-value of 0.000, less than the significance level of 0.01.

6. Discussion

Lead is a harmful metal; whether exposure is in high or low concentrations, it affects health, the vascular, hematopoietic, renal, and reproductive systems. Clinically, it is difficult to identify the risk or intoxication by this metal, which is why it is necessary to evaluate the blood level to see the contamination, and it is possible to use faneras to evaluate the exposure [41]. In our study, it was evaluated in blood.

From a socio-demographic perspective, women of childbearing age have an average age of 28±8 years, are single, young, nulliparous, and have a normal nutritional status. What was observed is that their homes are located 1 km from the tailings of the mining center, and they have reported living there for more than 5 years. Most of them also have their own house made of rustic material, corrugated iron roofs and cemented floors, with water services, drainage, and electricity in their homes. Their families have 3 to 5 members; 3 out of 10 women have a child under 5 years old, and 4 out of 10 have a child between 5 and 12 years old. On the other hand, Hassanian et al. [34], in Tehran - Iran, when evaluating 100 pregnant women, found the mean age of the participants to be 29 ± 5 years and reported higher lead contamination in women living in a contaminated residential highly industrialized area.

In contrast, our population lives in rural areas near the mine tailings. Likewise, Castro et al. [37] in La Oroya found a mean age of 29 ± 6 years and an average residence time of 16.5 years: both studies present a similar age to ours; in our study population, the area of residence and the pollution sources differ. Considering that lead is found on surfaces attached to dust, rustic construction favours exposure to the metal, which can be inhaled or ingested, with children under 5 and between 5 and 12 years old at greater risk [35], [41]. Therefore, the population studied is exposed to lead contamination.

It is found that in women of childbearing age, the majority (94.70%) do not apply preventive measures to reduce lead contamination; likewise, a need for information has been found in 9 out of 10, and only 3% conducted a control lead level above. This makes us notice that it is a population that requires intervention with preventive measures to reduce the risk of contamination.

The level of lead in the blood of women of childbearing age was from 0.50 to 7.20 μg/dL, on average 1.35± 1.11 μg/dL, in the majority, it was found within the normal range if these were stored at the marrow level bone, critical manifestations of the effect could be seen [43], in this regard, La Llave et al. [32], in Mexico, found in pregnant women at 2.79±2.16 μg / dL, while Xie et al. [33] in Shanghai – China, also in pregnant women found 3.20 μg / dL, higher levels (27.4 ± 15.6 ug/dL) was reported by Castro et al. [37], in a study conducted in Oroya – Peru.

As we can see at the level of lead, we find that it is lower than those reported by national studies and other countries, even though tailings can be observed very close to the dwelling of the inhabitants. The application of preventive factors is scarce. On the other hand, Condori et al. [40] found low lead levels in children from the Huachocolpa mining center, despite the fact that 90% had risk factors, a study developed in 2017 here in Huancavelica.

Hemoglobin level was from 7.80 to 21.60 g/dL, with an average of 11.85±2.84 g/dL, 3 out of 5 women had anemia, mostly moderate level. A study in the region of Madre de Dios, located in the Peruvian jungle and carried out in 2013, reports a mean hemoglobin of 10.75 g/dL [51], lower than our finding, a situation that may be because, in addition to informal mining in the region do not have basic sanitation, which leads to a greater risk of anemia. Despite its importance, few studies have been conducted on women of childbearing age since preventive actions and lead detoxification must be conducted in them so that, if they have a pregnancy, it does not occur. The complications indicated in studies developed in pregnant women have been widely described. On the other hand, it is important that the lead level be evaluated in pregnant women with anemia due to the relationship found. In this sense, 1 out of 3 women presented anemia, showing more moderate anemia (57.58%) and less proportion of mild and severe in 1.52%.

A moderate and significant negative relationship has been found between the level of hemoglobin and the level of lead in the blood. This relationship is explained by the fact that lead can be stored in the bone marrow, and the main effect is to reduce the production of red blood cells. The relationship was found in response to the fact that low amounts, such as the one in our study, can also affect hematopoiesis [41]. Likewise, Chen et al. [31] discovered that the increase in lead levels reduces the amount of hemoglobin, as in our study. On the other hand, La Llave et al. [32] found a positive relationship, where found that hemoglobin and hematocrit counts were higher in women with higher lead levels. Faced with this, more studies are required, although the literature widely finds the effect of lead on hematopoiesis. In this sense, it is essential to conduct preventive interventions in populations with areas of influence of mining companies in Huancavelica to avoid the risks that lead contamination brings to the reproduction and development of the human being.

7. Conclusion and Future Work

In the zone of influence of the mining centers of the Huancavelica region, during the year 2022, from a socio-demographic perspective, women of childbearing age are mainly single, young, nulliparous, with normal nutritional status, live 1 km from the tailings of the mining center, with a residence time of 5 or more years old, in their own homes, of rustic material, with corrugated iron roof and cemented or dirt floor; with water, drainage and electricity services in their homes. Their families have 3 to 5 members; 3 out of 10 women have a child under 5 years old, and 4 out of 10 have a child between 5 and 12 years old.

Preventive measures against lead contamination are not applied by almost any women of childbearing age who live under the influence of the mining centers. 9 out of 10 of them want to be informed on the subject. It is also found that none has ever applied preventive measures, and only 4 of them have undergone a prior blood lead screening. It is concluded that the level of lead in blood has a negative, moderate, and significant relationship with respect to the hemoglobin level of women of childbearing age who live in the area of influence of mining centers in the Huancavelica region during the year 2022.

The blood lead level ranged from 0.50 a 7.20 μg/dL, with an average of 1.35± 1.11 μg/dL in women of childbearing age who live under the influence of the mining centers. This implies that only 2 out of 100 women had elevated lead levels (5 or more μg/dL).

The hemoglobin level was from 7.80 a 21.60 g/dL, with an average of 11.85±2.84 g/dL in women of childbearing age who lived under the influence of the mining centers during the year 2022. From this, 3 out of 5 women were classified as moderately anemic, and 2 out of 5 were not anemic. The level of lead in blood was related in a negative, moderate, and significant way ($\tau = -0.365$; p-value < 0.01) with respect to the hemoglobin level of women of childbearing age who live in the influence of mining centers of the Huancavelica region, during the year 2022. This implies that the higher the level of lead in the blood, the lower the level of hemoglobin in women of childbearing age.

As future work, we wish to increase health promotion to prevent heavy metal contamination in mining-affected areas, conduct lead screening in women with chronic anemia, deepen heavy metal research, and reduce contamination risk through social outreach in Mimosa, Buenaventura, and Huachocolpa.

Ethical Considerations

The present study has the approval of the ethics committee of the University of Sciences and Humanities and the National University of Huancavelica, each participant agreed to their participation by means of an informed consent and each participant was given a copy of it.

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