Assessment of human exposition to heavy metals pollution

Cerro de Pasco
Several recent studies carried out in Cerro de Pasco have shown the spatial and temporal extension of environmental contamination caused by mining activities and its effects on the community's health, especially on children.

The recent investigation made by SOURCE INTERNATIONAL has focused on an evaluation of exposure biomarkers as heavy metals concentration in hair and intelligence quotient (IQ) in children.

The investigation sites are the community of Paragsha, exposed to mining activities, and the town of Carhuamayo, located 43 kilometers far from Cerro de Pasco, in the neighboring province of Junín. Carhuamayo has been chosen as a control site for not having active mining activities.

The exposed population shown high concentrations of heavy metals like arsenic, lead, aluminum, and manganese above the German reference standard used as a reference. In addition, 12 heavy metals, of the 21 investigated were found in higher concentrations in the children of Paragsha than in the children from Carhuamayo. Trends measured between 2016 and 2021 were marked by an increase in heavy metal concentrations in Paragsha’s samples between 2016 and 2018, followed by a decrease of levels between 2018 and 2021.

The average value of the Total Intelligence Quotient (TIQ) in the exposed population of Paragsha obtained a score of 82.5, 12.3 points less than their peers in the unexposed population of Carhuamayo, whose average score was 94.8.
Hair analysis has been used as biomarker of heavy metal accumulation since years and it is considered as a reliable biomarkers. As an excretory system, human hair can accumulate and incorporate heavy metals into its structure during its growth process. Therefore, metal concentrations in hair may reflect the average level in the human body and therefore record population exposure to metals.\textsuperscript{1}

The cross-sectional study evaluated children between 6 and 16 years: a cohort of 81 exposed individuals living in Paragsha (39 boys and 42 girls) and a control group of 17 individuals in Carhuamayo (11 boys and 6 girls) where there are no active extractive activities.

The sampling respected a precise safety protocol using biosafety material. Staff cut one gram of hair with stainless steel scissors near the scalp in the occipital area, a section of hair representing exposure to metals in recent months.

For each sample, 21 metals have been analyzed. The hair samples were sent to a certified laboratory in Italy and analyzed with Inductively Coupled Plasma Mass Spectrometry using standard methods such as EPA 3051 A 2007\textsuperscript{2}+ EPA 6020 B 2014.\textsuperscript{3}

\textbf{HAIR ANALYSIS}

\textbf{Monitoring of heavy metals concentration of the exposed population}

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The mean value of hair heavy metals concentration results of the Paragsha children has been compared with the mean values of Carhuamayo samples. As a reference value, we also used the Maximum Acceptable Levels (MAL) for children (determined in a healthy population not exposed to contaminating sources) established by the German laboratory Micro Trace Minerals, a laboratory specialized in hair analysis. MALs are expressed as milligrams of metal per kilogram of hair (mg/Kg).

The population exposed to mining activities has higher metal values than the unexposed control group. In addition, the levels of metals in the exposed population exceed the maximum acceptable levels (MAL) set by the German laboratory.

The Paragsha samples show a higher concentration of almost all heavy metals compared to Carhuamayo sample. The average arsenic level (0.45 mg/Kg) is three times higher than the average value measured in Carhuamayo (0.15 mg/Kg), lead concentration (4.38 mg/Kg) is six times more than the unexposed group (0.15 mg/Kg), and cadmium (0.06 mg/Kg) is double.

Furthermore, the exposed population shows an average antimony concentration (0.11 mg/Kg) two and a half times the level of the control group (0.04 mg/Kg).

If we compare levels of Paragsha with MAL of the German laboratory, we observe that the average level of lead in the Paragsha’s sample is 43 times higher; iron is four times the MAL; manganese seven times; while aluminum is almost four times higher.
The general trend of heavy metals concentration in the population of Paragsha between the years 2016 and 2021 is marked by an increase between 2016 and 2018, followed by a reduction in levels between 2018-2021.

The average concentration of most heavy metals is higher in 2021 compared to 2016: the exceptions are beryllium and boron, which reduced their concentration between 2016 and 2021.

The analysis showed a 70% reduction in the level of cadmium and manganese in the hair of the children in 2021 compared to 2018.
The neurobehavioral study aimed to examine a potential cause-effect relationship between heavy metals human exposure and its effect on psychophysical human health. Two population samples took part to the study: children and adolescents from Paragsha, directly exposed to mining contamination, and the control sample from Carhuamayo.

**Methodology**

The Intelligence Quotient (IQ) is a measurement of general intelligence, the result of standardized tests designed for this purpose.

IQ studies are particularly applicable in mining pollution contexts to qualify and quantify the risk and damage to the psychophysical health of the exposed population since many pollutants, especially heavy metals, released by mining activities have impacts on normal neurological development.\(^5\)

The IQ neurobehavioral study cohort is made up of boys and girls between the age of 6 and 16: the exposed group consists of 81 individuals (39 boys and 42 girls) and the non-exposed group of 17 individuals (11 boys and 6 girls).

The Wechsler Intelligence Scale for Children IV (WISC-IV) was applied. WISC is internationally recognized as the most reliable and widely applicable diagnostic intelligence test.\(^6\) Children and adolescents has performed various activities grouped into verbal comprehension scales, working memory, perceptual analysis and information processing speed.
Results

IQ level measured in the two populations is consistently different: the average value of the total IQ of the Paragsha sample (CIT 82.5) turns out to be **12.3 points less** with respect to Carhuamayo (CIT 94.8).

Only 59% of the children of Paragsha have an IQ higher than the national average value set at 82, compared to 94% of the Carhuamayo.

The children of Paragsha, exposed to mining activities, present a higher percentage of boys, girls and adolescents with a “Low” and “Very low” Total Intelligence Quotient (TIQ) (range 24.7% and 12.3%, respectively) than peers in Carhuamayo (0% and 5.9%, respectively).

The Carhuamayo population presents a higher percentage of children and adolescents with the “Normal-high” range represented by 17.6% of the population against 1.2% of the Paragsha sample. The “Normal-low” range is equally represented with approximately 35% in the two surveyed populations.
Throughout various epidemiological investigations, it has been observed that children exposed to metal contamination obtain lower scores in IQ tests.\(^7\)

Exposure to pollutants during the first three years of life can affect the development of the growing brain. A young child’s brain is especially vulnerable because it can be damaged by a lower dose of toxic chemicals than an adult brain.\(^8\)

The exposure to environmental toxins in the growing age causes alteration of neurodevelopmental processes and disorders, with profound and permanent consequences, and lasting disabilities for life with great family, social and economic costs.\(^9\)

Heavy metals that cause neurological toxicity, such as lead, mercury, cadmium, copper, zinc, arsenic, iron, and cadmium, considered the most neurotoxic agents for humans, are of particular concern due to the long-lasting and possibly irreversible nature of their effects.

On the interaction of various metals, it is evident that neurotoxic substances such as arsenic, cadmium, mercury, manganese and lead negatively affect the areas of the brain associated with language, memory and executive function, and psychosocial behavior.\(^10\)

Disorders such as autism, attention deficit disorder, mental retardation, and cerebral palsy are common in children exposed to high levels of neurotoxic substances.\(^11\)

The statistical analysis, carried out by SOURCE INTERNATIONAL, has investigated the association between the values of the Intelligence Quotients and the respective concentrations of heavy metals in the hair of the population exposed to mining pollution.

The results reveal a correlation (<0.33) between heavy metals in the hair and IQ.

However, most of the coefficients are negative, indicating an inverse linear relationship between heavy metal concentrations and IQ, with a greater correlation with lead, arsenic, cadmium, manganese and antimony.

The level of lead in the children’s hair was significantly related to the IQ \((r = -0.32; R^2 = 11\%, \ p = 0.0011)\), that is, the level of lead can explain 11% the IQ value in a highly significant way \((p < 0.01)\).

In general, the lowest hair lead levels and highest CIT scores have been measured in Carhuamayo, while the highest hair lead levels and lowest CIT have been measured in Paragsha. This finding is consistent with many previous studies that have reported an association between even "low" blood lead levels and reduced intellectual functioning.\(^12,13,14\)

Other weaker but also statistically significant inverse relationships with TIC were observed with respect to cadmium, arsenic, manganese and antimony. The relationships of lead and these metals were similar with respect to verbal ability (CLI) and working memory (IMT) scores. These results are consistent with previous studies indicating the relationship of lead, cadmium and antimony with susceptibility to attention deficit hyperactivity disorder (ADHD) in children.\(^15\)
Once again, **biomonitoring of hair** shows higher levels of heavy metals in the population exposed to mining activities than in the control population of Carhuamayo. The average arsenic level of 0.45 mg/Kg is three times higher than the average value of Carhuamayo (0.15 mg/Kg), lead (4.38 mg/Kg) is six times more than the average level of the unexposed group (0.7 mg/Kg), and cadmium (0.06 mg/Kg) is double compared to Carhuamayo (0.03 mg/Kg).

Hair heavy metal concentrations increased between 2016-2018 for the Paragsha samples; to following a reduction in levels between 2018-2021. The average concentration of the majority of heavy metals in 2021 is greater than in 2016. This indicates that sources of pollution are still active and organisms are still exposed to toxic pollutants.

The **IQ study**, the first to be carried out in the territory of Cerro de Pasco, shows a great difference between the two populations. The average IQ value of the Paragsha sample (CI = 82.5) is 12.3 points lower than the average value of the sample from Carhuamayo (CI = 94.8).

In Carhuamayo, 94% of the children have a higher IQ than the national average value set at 82, compared to 59% of Paragsha’s sample. In the Paragsha sample, 37% of children and adolescents obtained an IQ in a low or very low category, compared to international standards.

The statistical analysis has shown an inverse linear relationship between heavy metal concentrations and IQ with a greater correlation with arsenic, cadmium, manganese, antimony and even greater with lead. Higher hair lead concentrations and lower IQ levels have been measured in Paragsha, lowest hair lead concentration and highest IQ scores have been measured in Carhuamayo. This finding is consistent with many previous studies that have reported an association between even low blood lead levels and reduced intellectual functioning.
RECOMMENDATIONS

LOCAL AUTHORITIES

>> Carry out information campaigns on environmental and health studies.

>> Promote ecosystem recovery campaigns.

>> Promote community support networks.

>> Promote educational programs with mental exercises to strengthen the brain potential of children and adolescents.

CENSOPAS

>> Provide the results of biomonitoring transparently and timely to DIRESA Pasco to carry out the intervention plans within the established deadlines and budgets.

>> Carry out or promote the development of representative studies.

>> Carry out epidemiological studies that include blood lead data and additional explanatory variables that make it possible to adjust the associations between lead levels and IQ/ADHD in a statistically significant way.

OEFA

>> Guarantee proper monitoring of pollution in all aspects of the area of the study.

DIRESA PASCO

>> Establish a long-term environmental epidemiological surveillance plan in the district of Simón Bolívar.

>> Intervene in the population identified as high risk. Promote comprehensive health care protocols and health education.

>> Implement free assistance to all those children whose IQ is low to support their development and cognitive abilities.

>> Implement cognitive, psychomotor and early childhood development stimulation programs for early intervention plans.

MINSA

>> Ensure that DIRESA Pasco has the necessary resources to provide follow-up care to children with high levels of heavy metals in their hair and with low levels of intelligence quotient.

>> Provide evaluation services for the neurological and intellectual development of the most exposed children.
Bibliography


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Cerro de Pasco, Peru

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Edited by: Source International

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Contact: info@source-international.org