REMEDIAL INVESTIGATION

Huancavelica Mercury Remediation Project

Huancavelica, Peru

Prepared By

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Executive Summary

Mercury (Hg) contamination from historic mercury processing in and near Huancavelica, Peru is above health-based screening levels in the walls, floors, and indoor air in 75% of the earthen homes studied, with the potential of 19,000 people being at risk of mercury exposure and adverse health effects. Despite the end of mercury processing in the 1970s, Huancavelica remains among the most mercury-contaminated urban areas in the world (Hagan 2014). Several investigations from 2009 to 2014 have been conducted to characterize the extent and magnitude of mercury contamination. Project-specific published studies based on the investigations provide peer-reviewed documentation of significant contamination and risk to residential occupants. The Environmental Health Council (EHC) has provided this Remedial Investigation (RI) which characterizes the site and contamination, summarizes the investigations, provides a risk-based evaluation, and recommendations in support of remedial action.

Over 400 years of mercury processing associated with the Santa Bárbara mercury mine several kilometers south of Huancavelica has resulted in contamination of earthen homes, surface soil, sediment, and food in and near Huancavelica. Historic furnace exhaust from roasting cinnabar at several furnace locations in Huancavelica, resulting in atmospheric fallout of mercury, has contaminated local surface soil within the city. The majority of the homes in the city are constructed from contaminated earthen materials and often interior walls and floors in these homes are unsealed and uncovered. Consequently, the walls and dirt floors of homes are contaminated with a variety of mercury compounds, some of which are bioaccessibile. In addition, elemental mercury in the walls and floors has the potential to be released in the indoor environment as a vapor, resulting in elevated mercury vapor levels in indoor air. Tailings (processed rock) may have also been used for construction of roads, and contaminated aggregate dredged from the Rio Ichu continues to be routinely used in construction projects.

The city of Huancavelica is located at about 12,000 feet above sea level in a dry moderate climate in the Andes. The department of Huancavelica, of which the city is the capital, is the poorest department in Peru. Most inhabitants speak Quechua, and those who have participated in this investigation are extremely poor, generally live on subsistence or near-subsistence diets, and usually have several children in the home. Many households are run by women as the as many men migrate in search of employment. About 75% of the homes in Huancavelica are constructed of locally-derived adobe bricks or rammed earth materials. Homes are generally under 1,000 square feet in size, have few rooms, tin/steel roofs, earthen walls and floors, and are generally in poor repair.

There are two main exposure pathways for humans to be exposed to mercury in homes, incidental ingestion of soil particles, and inhalation of contaminated air. Site-specific risk-based screening levels were developed using site-specific exposure factors for the ingestion pathway and established reference concentrations (RfCs) were used to evaluate the inhalation pathway. The site-specific screening level for total mercury in walls and floors, based on risk to children, and using site-specific bioaccessibility analysis, was determined to be 75 milligram per kilogram (mg/kg). The World Health Organization (WHO) screening level or RfC of 0.2 micrograms per meter cubed ($\mu g/m^3$) was used for inhalation of mercury in homes.

Extrapolating from results of residential sampling of 60 homes in the city, mercury in walls,

floors, and indoor air of approximately 4400 homes (with an average family size of six) is above exposure-specific screening values. About 20% of the homes may have mercury vapor above 1 $\mu g/m^3$, which is an action level for time-critical relocation of the residents, for several regional Removal Programs of the United States Environmental Protection Agency's USEPA. Contaminated sediment in the Ichu River has extremely elevated mercury and is likely a significant source of methyl mercury in local fish, and also the source of contamination in products utilizing aggregate drawn from the river. Other food stocks were assessed in a limited manner, and a preliminary evaluation suggests that local fish from the Ichu River, coastal fish brought from Lima, and alpaca are contaminated significantly above established tissue ingestion screening levels.

Based on the results of the investigations, the evaluation of site-specific risk, and the conclusions of the RI, the EHC recommends several remedial actions. Primarily, homes with mercury above site-specific screening levels should be remediated or replaced. In support of remediation, the EHC proposes conducting a pilot project to evaluate the feasibility of covering the interior walls and floors to reduce exposure to mercury through incidental ingestion as well as reduction of mercury vapor. Additional assessment of sediment, common foods, and drinking water is also recommended.

Introduction

The EHC has prepared the following Remedial Investigation (RI) to summarize assessment work, to aid in identification of effective remedies, and to support cleanup efforts of Hg and other heavy metals in the highland Peruvian city of Huancavelica. Similar assessment work was conducted by the EHC in Potosí, Bolivia because of the historical similarities in emissions between the two cities. While the conclusions of this report can be adapted to guide cleanup of Potosí, this report is primarily focused on cleanup of Huancavelica.

The city of Huancavelica has been impacted by contamination from historic Hg refining processes since 1564 (Robins 2011) from the nearby Santa Bárbara Hg mine, the largest such mine in the Western Hemisphere. After extraction from the mine, most of the cinnabar was carried by llamas to one of several smelter sites in and around the city in order to extract elemental Hg. However some Hg was also retorted near the pit head at the mine. During the colonial period (1564-1820) approximately 68,000 metric tons of Hg were produced in the city, and transported to Andean silver mines, such as Oruro and Potosí, where it was used in the refining of silver through the amalgamation process. Approximately 17,000 metric tons of Hg vapor were released from the smelters between 1564 and 1810 (Robins, et al, 2012). Recent sampling throughout the city has revealed legacy Hg in various media and various species, significantly above background levels. Many of the homes in Huancavelica have been built with Hg-contaminated adobe material (rammed earth or bricks), and the majority of such homes also have earthen floors and unfinished walls. Elemental Hg in the adobe and floor material has resulted in elevated Hg concentrations in indoor air that are above residential health standards.

Recent assessment work has demonstrated that Hg levels in soil, indoor air, sediment, and some food stocks are above applicable human health action levels. This document has been prepared to summarize the data collected to date in and near the city of Huancavelica from the various media, to identify exposure pathways and applicable action levels, and to support the development of a focused feasibility to evaluate various cleanup options.

Because Hg concentrations in indoor air, alone, are significantly above The World Health Organization (WHO) and United States Environmental Protection Agency (USEPA) indoor air action levels in over 50% of the homes studied in Huancavelica, there is the need for a time-critical response. However, effective remedies and funding have not been identified. This document is intended to be comprehensive and include all aspects of the project (media, contaminants, routes of exposure, and remedial options), however it is not intended to preclude an interim removal action if an effective remedy and funding are identified. In addition, the risk assessment portion of the RI is focused on Hg. Future assessment work should include other contaminants of concern (COCs), such as other heavy metals, commonly associated with mining areas.

This RI was prepared following a common cleanup process consistent with US EPA's Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) format. This includes a Remedial Investigation phase that summarizes the assessment work conducted to date, and a Risk Assessment which looks at the different exposure routes, complete pathways, and a summary of current and future risk. It also provides a basis for conducting a Feasibility Study (FS). The FS looks at a variety of cleanup alternatives and compares the alternatives utilizing standard balancing factors (effectiveness, cost, long-term reliability, protectiveness, and implementability) to recommend the best and most efficient remedy. A proposed pilot study is presented in this report which provides a basis for the FS. Additional work is needed to fulfill the requirements of a thorough FS.

The lead author has 22 years of experience using the State of Oregon's Risk-Based Decision-Making (RBDM) approach to cleanup. Much of the risk assessment presentation uses the more detailed Oregon RBDM process for determining risk, yet it still generally follows the CERCLA process. Where reference values are different than Oregon's values, the difference will be presented and explained. Generally, the common approach in environmental cleanup is to use the more conservative screening values when there are competing values. This is important to consider, especially when there is limited exposure scenario information. If a less conservative value is used, there will be adequate explanation for the reasoning.

Objectives

The objectives of this report are:

- To prepare a comprehensive document that integrates the results of all studies on mercury contamination to date and to summarize the risks to human health in Huancavelica
- To demonstrate the need for remediation, based on a detailed and site-specific risk assessment
- To preliminarily identify effective remedial action alternatives
- To provide a summary and plan for a pilot study that supports completion of an FS and determine the most appropriate remedy

- To provide continued outreach to the people of Huancavelica about the risks of Hg exposure and engagement at the community level

Chronology of Studies

The following data sets and studies provide the basis for the RI and Risk Assessment:

- April, October, and November 2011 - Total Hg in Soil, dust wipes, adobe brick, and indoor air

- Robins N. Mercury, mining, and empire; *The human and ecological costs of silver mining in the Andes*; Indiana: Indiana University Press; 2011.

- Robins, N, N. Hagan, S. Halabi, H. Hsu-Kim, R. Dario Espinoza Gonzales, D. Richter, and J. Vandenberg; *Evaluation of residential exposure to historical mercury contamination in Huancavelica, Peru*; Oral presentation at the International Conference on Mercury as a Global Pollutant, July 2011.

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- Hagan, N, N. Robins, H. Hsu-Kim, J. Vandenberg and D. Leith. *Mercury speciation and bioaccessibility from adobe bricks and dirt floors in Huancavelica, Peru.* Poster presentation at the Society of Environmental Toxicology and Chemistry (SETAC) conference, November, 2012.

- Hagan N, Robins N, Espinoza Gonzales RD, Hsu-Kim H. "Speciation and bioaccessibility of mercury in adobe bricks and dirt floors in Huancavelica, Peru." *Environmental Geochemistry and Health* Vol. 36, No. 4 (August, 2014). DOI 10.1007/s10653-014-9644-1

Construction of Typical Home

There are several types of homes in Huancavelica, which are common throughout the Andes. The predominant form of construction is rammed earth "tapial" where local soil adjacent to the construction site is used. Walls are built in forms about 2 feet apart, 3 feet tall, and 4 feet wide which are held temporarily in place as soil is filled and compacted. The forms are raised as each lift is completed, setting forms around in succession until the exterior walls of the house are completed. Roof materials tend to be corrugated steel with no insulation. Because of the cost effectiveness of using local soil and because of the dry climate, rammed earth construction is the most common, especially for lower income families who are the focus of the supporting studies in this report. Approximately 75% of the homes included in assessment to date are of the rammed earth or tapial type. Generally, homes have walled courtyards. Many have kitchens and outhouses which are separate from the structure, and in this study the vast majority had earthen floors.

The remaining 20% of the homes included so far in the assessment work, are built with adobe bricks and clay mortar. Soil from the home site is used for the brick material which is packed into forms along with Ichu grass, used as a binder, and allowed to dry before placing in the wall. Local clay near the homesite is used as mortar. (personal comm., Espinoza 2014).

Other than minor differences in compaction, the porosity of the two wall types does not appear to vary much. The adobe brick wall may be more compact and less porous simply due to the ability to pack/form smaller bricks, compared with compacting larger volumes of material in one layer, such as with the tapial construction. The variability in porosity, which may affect the vapor intrusion rates, is most likely tied to the grain size and clay content of the site soils. In addition, wall coatings such as stucco or paint may significantly attenuate Hg vapor intrusion rates, however most adobe/rammed earth homes have uncovered walls. There is limited information available on porosity and permeability of the finished walls. Additional assessment of these parameters is warranted and should be addressed in the Feasibility Study.

Almost every home in the assessment have earthen floors. The construction of the floors is much the same as the walls, using site materials and compaction to make a smooth flat surface followed with very little treatment, if any. This is an important risk pathway for infants and young children who spend a lot of time on the floor and have higher ingestion rates.

Most homes in the assessment are on average about 700 square feet in size, with one door, and one or two windows per room. Windows are metal framed, single pane, and un-insulated. There is little information on air exchange rates for these types of homes, but based on the type of construction and tightness of wall penetrations, the homes are probably leaky. Homes generally do not have heat, although a few have kerosene heaters. Cooking usually takes place over a fire made of charcoal or dung and is done in a separate building or lean-to adjacent to the home. Construction of the cooking area is also generally made with site soils using the tapial method or adobe brick method. The 2011 surveys have information on the use of wood stoves/fire places and cooking methods. Additional assessment of Hg vapor rates associated with increased temperature of adobe or tapial material as it relates to both daytime ambient temperature fluctuations as well as the significant increase in temperature associated with fire places and cooking, is warranted. An attempt should be made to address this in the Feasibility Study.

Results of Investigations

Nature and Extent

Soil

In 2009, samples were collected from 15 accessible public locations in the city as a means of determining the general distribution of total Hg in surface soil. Triplicate samples were collected from depths of 1 inch and 3 inches, resulting in six replicate samples from the same location. The 2009 sample nomenclature (ie H1-fn-1a) was used to identify the general area from which the sample was collected. The first letter and number (e.g., H1) represents Huancavelica and the transect number. The second two letters (e.g., fn) represents which location along the transect was sampled, using the following codes: fn=far north, nn=near north, c=center, ns=near south, and fs=far south). The last number and letter (e.g., 1a) represent the depth from which the sample was taken (1 inch or 3 inches) and the replicate (a, b, or c).

Total Hg concentrations ranged from 0.1 to 1201 milligrams per kilogram (mg/kg) in the surface soil samples, 2.5 to 688 mg/kg at the 1 inch depth, and 1.5 to 90 mg/kg at the 3 inch depth. There is a slight trend of decreasing concentration with depth, which may be related to the method of contamination. In this case the decreasing concentration with depth would indicate that the source was either from the air (i.e furnace exhaust fallout) or from tailings or dust from tailings being deposited on the native soil surface. However, there is usually a clear visible demarcation between tailings (reddish/pinkish gravel and sands) and native soils beneath. Contaminated dust would be more difficult to visually demarcate.

Fourteen of the surface samples, or 61% of the samples had concentrations greater than the USEPA Regional Screening Level (RSL) of 23 mg/kg. This RSL is based on the dermal, ingestion, and inhalation (particulate) exposure pathways for residential exposure. The screening value of 23 mg/kg is based on the reference dose for $HgCl_2$, a nearly 100% soluble form of Hg, which is likely not the predominant species in the soil in Huancavelica. However, for initial comparison of soil concentrations to an established screening value, 23 mg/kg will be used in this section. Additional discussion of site-specific screening levels is presented in the Risk Assessment section below.

There were two samples that appear to be in areas that were not excessively affected by furnace exhausts or tailings reuse. Samples H2-fn-1a and H3-ns-1a were collected from hillsides "overlooking town" and both had Hg at about 2.5 mg/kg. Further development of a background concentration with more data would be useful, but a background concentration range can be developed using these data along with information gained from crustal averages of Hg in mineralized and un-mineralized zones. Those concentrations can range from 0.1 mg/kg to 10 mg/kg. These two results fall in line with expected background concentrations based on other Hg mining districts in the world.

The 2009 ambient soil samples were analyzed for total Hg, and a subset of samples were subsequently analyzed for chemical species of Hg through sequential selective extraction and were analyzed for soil characteristics (Robins et al. 2012). In 2010, samples were collected from inside 60 typical tapial and adobe homes, including adobe brick, dirt floor, surface dust, and indoor air samples. Following the collection of residential samples in 2010, all 60 adobe brick and dirt floor samples underwent total Hg analysis and sequential selective extraction to characterize the species of Hg present in the samples, as well as a simulated gastric fluid extraction to estimate the percent of total Hg that was bioaccessible following ingestion (Hagan et al. 2014a). The results of the analyses are presented in the sections below.

Dust

Samples of surface dust within the homes were collected within the same 60 homes as the wall, floor, and indoor air samples during the 2011 event. Dust is likely a mix of debris from decomposition of the walls and floors, but also from outside dusts that come in on clothes or other items that may have been contaminated from outside. Since much of the ambient environment within the urbanized area of Huancavelica is contaminated with Hg, dusts generated within the city are a potential source of contamination that comes into the home.

Total Hg in dust samples in Ascención homes ranged from 17.3 to 413 mg/kg, in San Cristobal from 9.6 to 153 mg/kg, in Yananaco from 12.2 to 256 mg/kg, and in Santa Ana from 2.4 to 21 mg/kg. Sample results are reported in mg/kg for simplicity, however the true analytical result is milligrams per dust wipe. Additional analysis of these data should be conducted before dust results are relied on for project decisions. Generally, the dust results correlate well with the co-located wall and floor samples. However, the dust results are overall slightly lower than the wall and floor sample results which could be due to dilution from outside dusts or debris that have less Hg than the wall and floor materials. Over half the samples had Hg concentrations over the generic EPA RSL of 23 mg/kg and about 23% of the samples had concentrations above 75 mg/kg, which is the site-specific screening level. The site-specific screening level is further explained in the Risk Assessment section. Sample results from Santa Ana were the lowest of the 4 neighborhoods.

Tapial and Adobe Walls

Samples were collected from earthen walls from the same set of 60 homes as the dust, floor, and indoor air samples collected during the 2011 study. Collection methods for wall samples collected from walls and floors are described in Hagan et al (2013) and Hagan et al (2014). Total Hg in wall samples in Ascensión ranged from 9.9 to 763 mg/kg, in San Cristóbal from 21.6 to 944 mg/kg, in Yananaco from 26.3 to 1072 mg/kg, and in Santa Ana from 8 to 243 mg/kg. Walls in homes in Ascención, San Cristobal, and Yananaco have a similar distribution of Hg concentrations within 73% of the homes were over the generic EPA RSL of 23 mg/kg and about 55% of the homes were above 75 mg/kg. Walls in homes in Santa Ana are less contaminated and tend to have Hg less than the 23 mg/kg RSL.

Earthen Floors

Samples were collected from earthen floors from the same set of 60 homes as the dust, wall, and indoor air samples collected during the 2011 study. Total Hg in floors in Ascensión homes ranged from 16 to 833 mg/kg, in San Cristóbal from 16.7 to 839 mg/kg, in Yananaco from 19.2 to 926 mg/kg, and in Santa Ana from 3.1 to 66.4 mg/kg. Results from wall samples from individual homes correlate moderately well with results from earthen floors within the same home. This is to be expected since the walls and floors were likely made from the same material in the vicinity of the home, which is the common construction method. Hg concentrations within 76% of the homes were above the generic EPA RSL of 23 mg/kg and about 47% were above 75 mg/kg. Also, similar to wall sample results, the floor sample results were lowest in the Santa Ana neighborhood.

Vapor (Indoor Air)

Indoor air samples were collected in triplicate from the same homes as the wall, floor, and dust samples using a Jerome 405 Hg vapor analyzer which has a detection limit of 0.5 micrograms per meter cubed ($\mu g/m^3$). Hg vapor results in Ascención ranged from the detection limit (0.5 $\mu g/m^3$) to 5.1 $\mu g/m^3$, in San Cristóbal from the detection limit to 1.8 ug/m3, in Santa Ana from the detection limit to 2.7 $\mu g/m^3$ and in Yananaco results were mostly below detection limits. About 40% of the homes had vapor results above the detection limit which is above the screening level of 0.2$\mu g/m^3$. The vapor results do not correlate well with the wall, floor, and dust samples results. For example, indoor air results in Yananaco had only 3 homes out of the 15 with barely measurable Hg vapor, yet generally Yananaco had the highest Hg concentrations in wall, floor, and dust samples. Also the home with the highest Hg concentration in walls and floors and second highest Hg concentration in dust (out of the 60 homes), did not have detection of Hg in indoor air. This likely has to do with the variety of Hg species in the wall, floor, and dust samples. This may also have to do with variations in ventilation, or wall and floor porosity or permeability.

Hg vapor detections lower than 0.5 $\mu g/m^3$ have been adjusted to a value of 0.35 $\mu g/m^3$, which is one half the limit of detection divided by the square root of two. Regardless, any detection on the Jerome 405 is above the screening level of 0.2 $\mu g/m^3$. The WHO reference concentration (RfC) of 0.2 $\mu g/m^3$ is used as the screening level. This is further discussed in the Risk Assessment Section. Approximately 40% of the homes had Hg vapor concentrations in indoor air above the screening level.

Walls, floors, and to some extent dust may have more or less elemental Hg in the media and resulting vapor in indoor air. This depends on a number of factors such as proximity to former furnaces, temperature of the home, vapor attenuation due to wall or floor coverings, ventilation of the home, and porosity and permeability of the walls and floors. Further discussion of speciation results and total Hg in walls and floors is presented below.

Risk Assessment Summary

The Hg vapor (indoor air) concentrations in the residential scenario alone presents a risk at least one order of magnitude above the USEPA and WHO standards. The soil concentrations range one to two orders of magnitude above the site-specific RBCs in the residential scenario and a few samples of outdoor soil had total Hg above the site-specific occupational screening levels. Additional evaluation of the soil ingestion pathway, such as more detailed speciation or *in vitro* biaccessibility analysis, or *in vivo* bioaccessibility analysis could be conducted. However, based on the risk from inhalation of Hg vapor, regardless of additional analysis, remedial action is warranted. Remediating the vapor risk will also remediate the soil ingestion risk within the homes, assuming that a low to non-permeable wall and floor covering will also decrease residential exposure to particles from the walls and floors.

Another level of action or priority could be set at 1.0 $\mu g/m^3$ which is used as an action level for time-critical relocation of residents by several USEPA regional Removal Programs. Additionally, the several USEPA regional Removal Programs recommend immediate relocation of the resident if Hg vapor exceeds 10 $\mu g/m^3$.

When comparing site data to the site-specific screening values, significant risk is estimated for the residential child receptor category, moderate to significant risk is estimated for the residential adult receptor category, and limited risk is presented for the occupational receptor category. Individual risk can vary based on varying exposure factors such as time indoors, body weight, hygiene, fish consumption or many other factors. Conservancy is built into the screening levels to account for the varying exposure factors.

Conclusions and Recommendations

Outdoor soil, earthen homes, indoor air, sediment, and food in and near Huancavelica are contaminated with Hg from historic Hg processing associated with colonial era mining operations at the nearby Santa Barbara Hg mine. Total Hg in soil and homes made of soil in Huancavelica is above risk-based concentrations for residential use in approximately 50% of the homes. Hg vapor in homes made of contaminated soil is above the screening level or RfC for residential use in 40% of the homes. Overall, 45 of the 60 homes or 75% have at least one media result over the respective screening value. Many of the 45 homes have more than one of the media results above respective screening values. Approximately 1.2% of the earthen homes in Huancavelica were assessed. However, the sample set of 60 homes is a representative group of the larger population of people and homes.

Assuming Huancavelica's population in 2014 was 47,000 (INEI, 2014) with 1.6% annual population growth (INEI, 2014), the 2015 population would be approximately 48,000 people. Assuming an average of 5 people per family or household, there should be about 9600 homes. Approximately 52% or about 5000 homes are constructed of locally-derived earthen materials. Based on the results presented in the RI, approximately 75% of all the earthen homes, or about 3700 homes, have the potential to be contaminated at levels above screening levels and pose a risk to human health. In other words, approximately 19000 people may be exposed to levels of Hg in soil and/or vapor above international health-based screening levels and are potentially at risk for developing adverse health effects.

About 20% of the homes or about 700 homes potentially have Hg vapor in indoor air above a relocation action level. That is approximately 3500 people that may be living in conditions that pose a significant risk from exposure to Hg vapor, and that may need their homes remediated or replaced as soon as possible. The screening levels and development of site specific screening levels in this RI are based on well established toxicological studies and supported by USEPA, ATSDR, the WHO, and UN Environment Programme.

In addition, several areas in Huancavelica have surface soil contamination above risk-based concentrations for occupational use. Hg in sediment in the Ichu River is significantly elevated above methylation screening levels. Based on limited sampling, fish and alpaca may be significantly contaminated above risk-based consumption levels. These additional Hg loads to human health are most likely cumulative to the residential loads presented above.

Exposure factors affect individual exposures to Hg. This RI attempts to determine appropriate risk-based concentrations based on site-specific exposure factors. Where there was uncertainty in the determination of an exposure factor, conservative estimates were used.

Based on the information presented in the Remedial Investigation, the EHC provides the following recommendations:

In residential settings –

- Homes with Hg in dust, walls, and floors above the soil ingestion screening level or RBC of 75 mg/kg should be considered for remediation or replacement to reduce the risk to current and future residents.

- Homes with Hg in air above the WHO screening level of 0.2 $\mu g/m^3$ should be considered for remediation or replacement to reduce the risk to current and future residents.

- Homes should be assessed for other heavy metals associated with gangue mineralization of cinnabar. Arsenic and lead are the metals of most concern and are likely elevated where Hg is elevated or where mine tailings are visible.

- Outreach should continue to be conducted to the general public and local, regional, and national civil authorities presenting the risks and providing recommendations on ways for individuals to reduce their risk to Hg and other heavy metals.

- If possible, all earthen homes in Huancavelica should be assessed for total Hg in walls and floors and Hg vapor in indoor air, and appropriate actions taken.

Occupational Settings and General Recommendations –

- Occupational settings where Hg in soil is above 770 mg/kg, or where Hg vapor is above 50 $\mu g/m^3$ for an 8-hr period, or where elemental Hg is visible, should have warning signs and worker safety protocols should be developed and employed.

- Local groundwater used for drinking, both for springs and wells, should be assessed for total arsenic. City water should be prioritized for assessment.

- Fish that reside in the Ichu River near Huancavelica that are commonly consumed by humans, as well as locally farmed fish, should be assessed for Hg.

- Further Hg assessment should be conducted on other food stocks such as alpaca, llama, cuy, chicken, potatoes, or other livestock that graze near Huancavelica and that are commonly eaten.

To support development of a FS, a pilot project is being developed by the EHC, which aims to reduce exposure to both particulate Hg and Hg vapor in prioritized homes. The pilot project is planned for the June/July 2015 timeframe. The goal is to exercise several preliminary remedial actions and to evaluate and present the results to the stakeholders, civil authorities, and potential funders. The hope is that an inexpensive, locally available, simple, and protective remedy will be developed.

Disclaimer and Limitations

The lead author of this document works for the Oregon DEQ, yet this report is not endorsed by Oregon DEQ or Oregon Health Authority, nor were State of Oregon funds used in the preparation of this report or the assessment activities associated with this project. The lead author is a registered geologist in the State of Oregon (United States) and as such, this document was prepared following professional standards and ethics associated with the professional certification under the Oregon State Board of Geologist Examiners. There is no religious or political bias in the recommendations and conclusions of this report. The lead author's motivation for developing this report is solely for promoting human welfare.

The information presented in this report was collected, analyzed, and interpreted following the standards of care, skill, and diligence ordinarily provided by a professional in the performance of similar activities as of the time the activities were performed. This report and the conclusions and/or recommendations contained in it are based solely upon research and/or observations, and physical sampling and analytical activities that were conducted. The quality of information, conclusions, and estimates contained herein is based on: i) information available at the time of preparation, ii) data supplied by outside sources, and iii) the assumptions, conditions, and qualifications set forth in this report.

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