MERCURY FATE AND TRANSPORT IN HUNZA AND GILGIT RIVERS, NORTHERN AREAS, PAKISTAN – A NUMERICAL MODELING APPROACH

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Abstract

Due to the highly mobile nature of mercury, it is considered to be a global environmental pollutant that is being distributed in the atmosphere, lithosphere and hydrosphere. Its biogeochemical transfer between different compartments in the environment is complex and not known thoroughly. However, the importance of fate and transport of mercury in surface waters must be recognized for the well-being of people who drink or consume fish from contaminated waters. Using mercury in pan amalgamation for the extraction of gold from stream deposits along Indus and Gilgit Rivers in Pakistan is being practiced for many decades. Pan amalgamation in the small-scale gold panning and extraction (GPE) activities are considered to be releasing considerable amount of mercury to the environment due to inappropriate smelting practices.1372 stream sediments along Indus, Gilgit and Hunza Rivers were analyzed. Results showed that riverbank sediments upstream of Hunza and Gilgit Rivers are highly contaminated with mercury. From a data range of 4 to 2200 ppb, a total of 24 anomalous sites (having a concentration of more than 100 ppb) have been identified. An adaptive sampling of surface waters from Hunza and Gilgit Rivers was performed in June 2011. A total of 37 samples were collected. Sampling was done as per EPA Method 1631. Samples are being analyzed in terms of dissolved and suspended mercury content in the water column. During the field trip, many GPE sites were observed. Panning, amalgamation and roasting processes are being done at workers huts where large amount of mercury is released to environment particularly due to no mercury recycling in the smelting process. The goal of this research study is to understand the source, fate and transport of mercury by creating a hydrologic model and develop scenarios by using this model to decrease mercury concentrations to allowable limits.

Introduction

Using mercury in pan amalgamation for the extraction of gold from stream deposits along Indus and Gilgit Rivers in Pakistan is being practiced for many decades. Pan amalgamation in the small-scale gold panning and extraction (GPE) activities are considered to be releasing considerable amount of mercury to the environment due to inappropriate smelting practices. It has been suggested that workers who involved in GPE activities in the Gilgit, Hunza and Indus rivers have high Hg concentrations in their blood (**Figure 1**). After being released to the environment, inorganic mercury undergoes biotransformation into methyl mercury species by the action of anaerobic bacteria that live in aquatic environments. This organic mercury species then bio-accumulate in the tissue of fish and other organisms (Adimado and Baah, 2001). This suggests that people having high organic mercury concentration in their blood might have been exposed to the mercury through ingestion of fish from contaminated rivers.

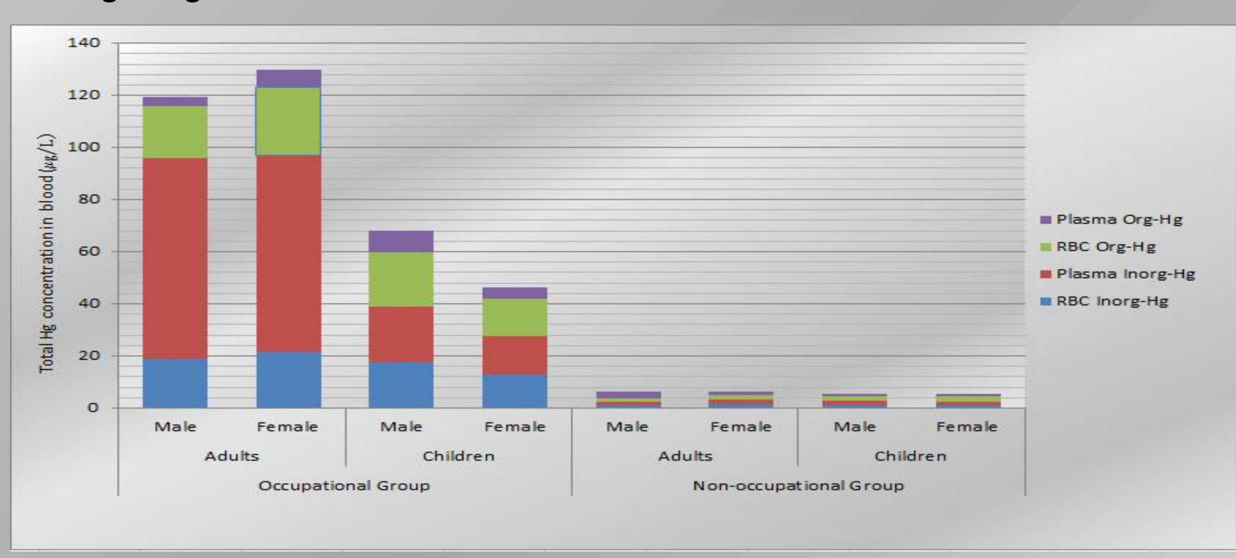

Figure 1. Mean concentrations (µg/L) of Hg species in red blood cell (RBC) and plasma samples. Table shows that blood samples from GPE workers are significantly higher in Hg concentration than non-occupational control group (people who are not involved in GPE). Organic-Hg concentrations in the blood samples suggest food and/or drinking water may be contaminated (After Khan et al., in review).

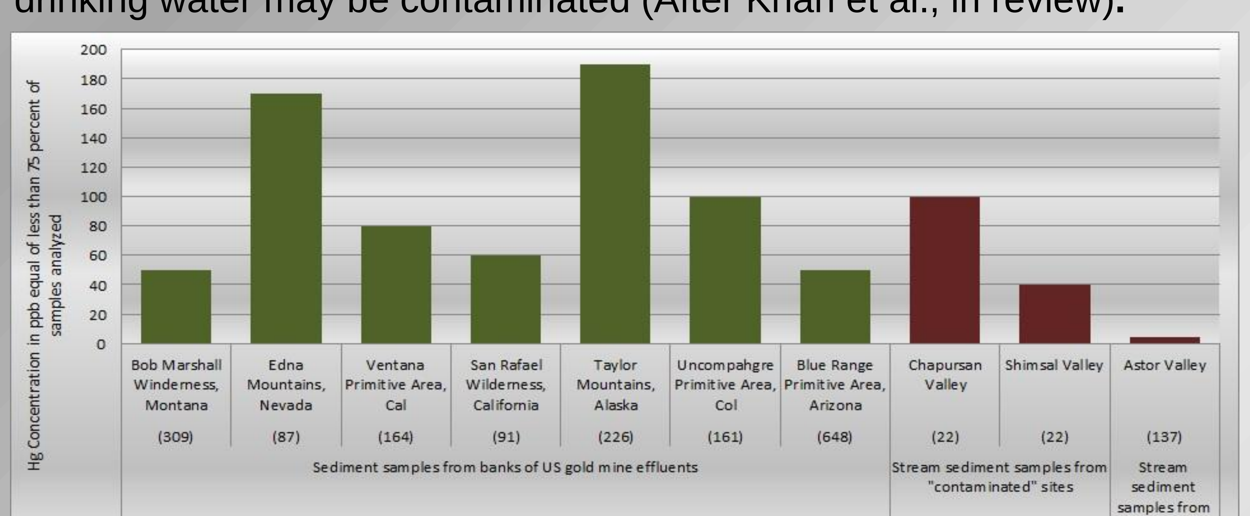

Figure 2. Comparing US mine dump samples with sediments from study area. Numbers in parenthesis are number of samples investigated. 75 percent of the samples in each dataset have mercury content equal or less than the listed value (Data source: USGS, 1970)

Hypothesis and Objective

Having elevated org-Hg concentrations in their blood system, GPE workers may be exposed to contaminated food or drinking water sources. By the completion of this project we will be able to determine (by numerical methods) the fate and transport of the mercury in Hunza River, where we suspect mercury release is greatest.

Methods

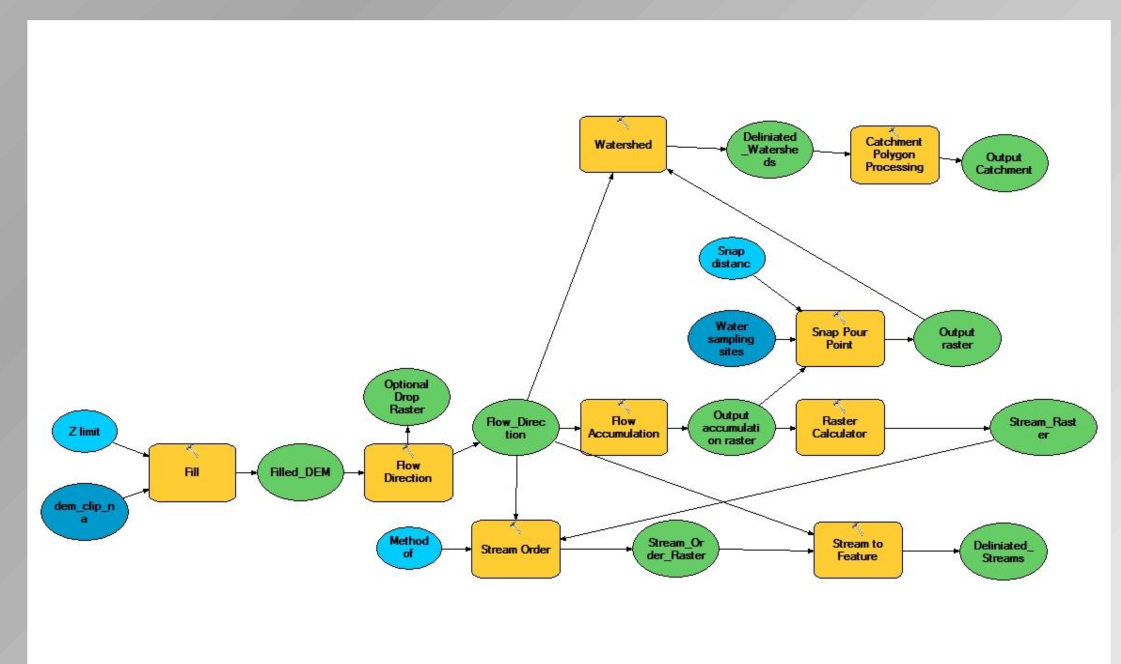

Figure 2. Model developed in ArcGIS to delineate drainage network and watersheds as water sampling sites being the outlet points. Blue, cyan, yellow and green boxes represent inputs, applied parameters, tools and outputs, respectively.

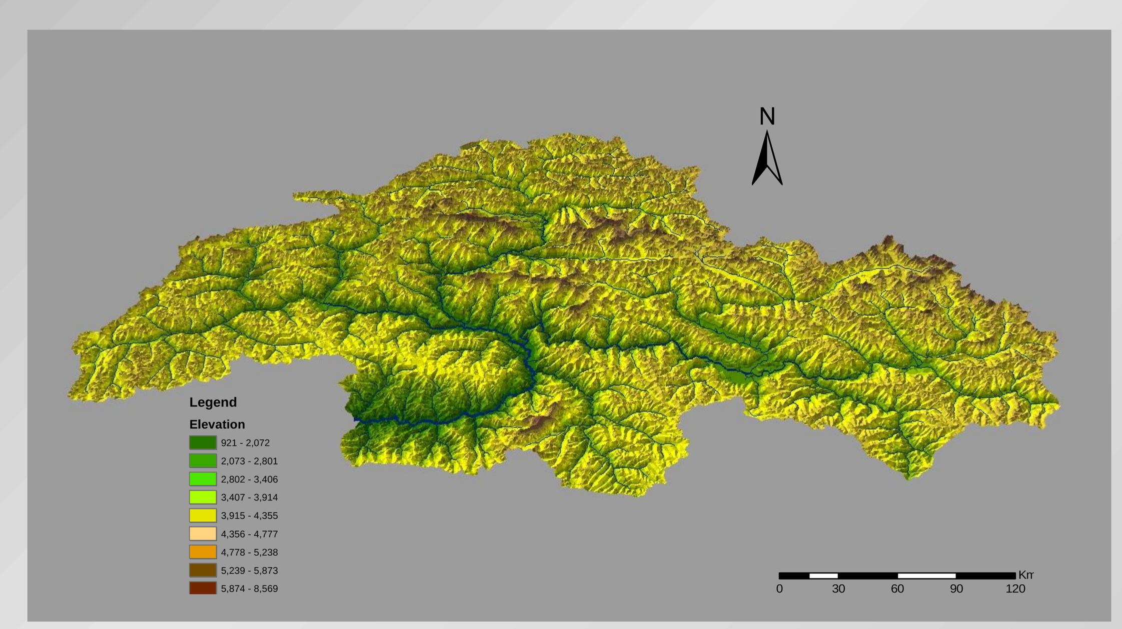

Figure 3. 2-D perspective scene of the study area using SRTM elevation data with delineated stream channels draped on triangulated irregular network (TIN) elevation surface.

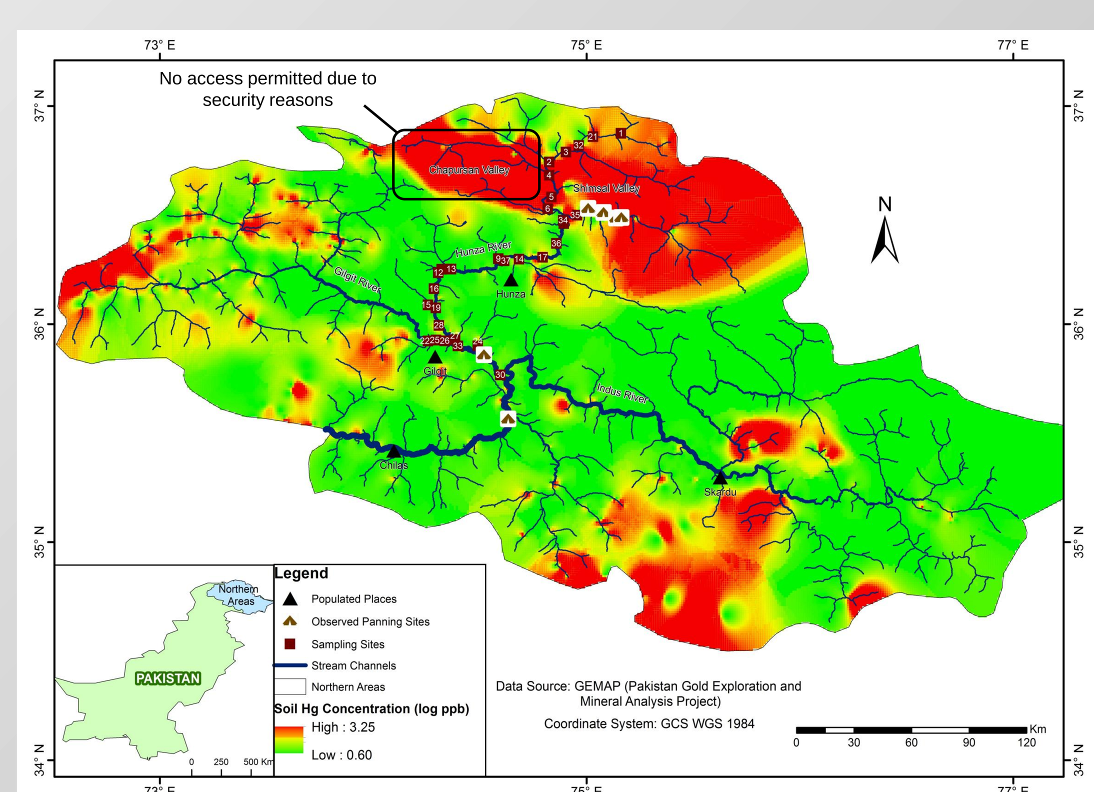

Figure 5. A photo taken during field trip. The lady in the picture is putting some drops of liquid mercury to amalgamate panned sediments from Hunza River. After being mixed with the sediment, mercury is let to evaporate by heating in the stoves it their tents (seen on right side) to recover gold. Notice that no health risks are considered in the amalgamation and roasting processes.

Figure 6. Photo showing the recovered gold after evaporation /roasting process. The raw gold is further refined by gold-dealers and goldsmiths in shops and refinement places. This small-scale GPE process is similar in all selected sites of the study area.

Figure 4. Map showing mercury concentration distribution in stream sediments, field sampling sites and observed GPE sites. Background is an interpolation map based on 1372 sampling sites along river banks. 3rd order IDW (inverse distance weighted) interpolation method was used. Concentration values are represented in log ppb. Mercury was reported with 10 ppb detection limit. Background concentration was assumed to have a value of 5 ppb. Observed GPE sites confirm that panning activities increase upstream of Hunza River. 37 water and sediment samples collected along Hunza and Gilgit Rivers. Due to security reasons access to Chapursan Valley was prohibited.

Analysis

Field Samples

Dissolved Hg (Water)	Suspended Hg (Solids)
• Filtration: through 0.45- µm filters in the field to separate dissolved from suspended • Preservation: by BrCl to stabilize and oxidize all Hg species to Hg^{2+}. • Storage: 125 ml glass and HDPE bottles • Analysis: Cold Vapor Atomic Fluorescence Spectrometry at the University of Houston	• Filtration: A fixed volume of water was pushed though a glass fiber membrane with a field syringe. • Analysis: sediments on the membranes will be analyzed for mercury directly on a mercury analyzer (thermal decomposition) • Filters will be weighted to get TSS (Total suspended solids) • Storage: HDPE vials for the filters

Figure 7. Field sampling and analysis methodology were adapted from EPA Method 1631, Revision E (EPA, 1999). Collected water and solid samples will be analyzed for dissolved and suspended (sediment bound) mercury concentration. Water samples are filtered through 0.45-µm filters to separate dissolved from suspended mercury. Preservation by BrCl was done in the field to stabilize Hg species. Water samples are stored in glass and HDPE bottles. A fixed volume of water was pushed though a glass fiber membrane with a field syringe. Membrane and retained sediments were collected. Filter and the sediments will be analyzed directly on a thermal decomposition mercury analyzer. Filters will be weighted to estimate TSS in the water column. This parameter will be used to calibrate the transport model that will be developed later.

Work in progress

- Field samples are being analyzed for dissolved and suspended Hg concentration as per EPA Methods 1631 and 7473.
- A 15-m resolution DEM is being created with ASTER 3N and 3B stereo bands. Stream channel geometries will be extracted from this surface.
- HSPF (Hydrologic Simulation Program – Fortran) numerical model will be used to simulate the transport of water, sediments and contaminant.

Conclusions

- High organic Hg species concentration in GPE workers suggest water and/or food sources are contaminated.
- High Hg content in stream sediments from Chapursan and Shimshal Valleys is comparable with Hg gold amalgamation mine sites existed in 1960s in the US.
- Field observations confirm the usage of Hg in gold panning and extraction activities.

Acknowledgements

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