

Determination of mercury in the wild plants with their soils along Indus, Gilgit and Hunza rivers

Arjumand Riaz^{1,2}, Anwarzeb Khan¹, Mohammad Tahir Shah², Islamud Din³, Sardar Khan^{1*} and Shuhab Danishwar Khan⁴

¹*Department of Environmental Sciences, University of Peshawar*

²*National Centre of Excellence of Geology, University of Peshawar*

³*Department of Environmental Sciences, FBAS, International Islamic University, Islamabad,*

⁴*Department of Earth and Atmospheric Sciences, University of Houston, USA*

**Corresponding authors email: sardar.khan2008@yahoo.com*

Submitted: 26/10/2016, Accepted: 13/01/2017, Published online: 30/03/2017

Abstract

This article emphasizes on mercury (Hg) and its negative effects on wild plants and soil of these plants. Hg is highly demanded element because of its multiple uses as the most dangerous element for both environment and human. Not only biotic but also nonliving things can be exposed to Hg contamination. This article investigated the concentrations of Hg in wild plants and their soil samples along the three rivers including Gilgit, Hunza and Indus of Northern areas of Pakistan. Natural and anthropogenic sources of Hg are present on the earth crust. Small-scale gold mining exists along these rivers and contribute in the emission of Hg in the environment through amalgamation and roasting process for gold separation from the sediments. This study based on terrestrial environment including wild plants with their soil. Almost 75-80 % samples in plants showed the higher Hg contamination, while 99% soil samples showed the higher Hg concentrations. The results indicated that the mean concentrations were 27.01 µg/kg and 214.31 µg/kg for plants and soil, respectively. These findings indicated the presence of Hg in the study area and contamination of soil and wild plant samples.

Keywords: Mercury; Contamination; Wild plants; Soil; Environment.

1. Introduction

Mercury (Hg) is a naturally occurring element but human activities are also major factor that contributes to its production in the environment (Biber et al., 2015). All forms of Hg are toxic in nature. In elemental form, Hg is dense, and silvery white liquid. Naturally its concentration in earth crust is very low (Gochfeld, 2003). It is estimated that its concentrations in the earth crust is 0.5mg/kg. Its natural emission estimates from 2000 to 6000 t/year, while anthropogenic activities also release Hg in atmosphere ranging from 2000 to 3000 t/year (Morita et al., 1998).

Hg is emitted from coal-burning, electricity generation and metal generation products. Due to its unique characteristics, it is widely utilized in thermometers, medicines, batteries, electrical switches and pesticides. All these sources ultimately release Hg in the environment in gas, liquid or solid form (Jin et al., 2008). Artisanal gold mining is one of the major sources of Hg all over the world

especially in developing countries (Boss-O' Reilly et al., 2010). In most cases, the miners used their traditional method for gold extraction and use Hg haphazardly. Approximately 1.3 kg of metallic Hg is used for the extraction of 1 kg gold (Barbosa, 1998). Gold and Hg make amalgam in which the gold particles are dissolve in Hg and by simple heating miners recover the gold while Hg evaporates and became a part of the environment (Biber et al., 2015). In this process 20-30 % is lost in soil, sediments and water present near the processing site (Straaten, 2000).

This study focused on level of Hg in the wild plants and soil and its adverse effect on the environment. The study area is very rich in mineral resources specially highlighted due to the presence of gold (Zain, 2010). Different articles reported the presence of gold in the stream sediments of rivers of northern areas of Pakistan. According to authors knowledge this is the first study conducted in these areas which cover the wild plants and field soil to see the

effects of Hg. Previously different works have been done in different parts of the world along Pakistan but less or no work has been done on exposure of wild plants to Hg in the vicinity of gold mines.

2. Experimental

2.1. Study area description

Gilgit is the capital of Gilgit Baltistan (GB), located in northern areas of Pakistan. GB has total area of 72,496 km² and divided into seven districts: Gilgit, Ghezir, Hunza, Nagar, Diamar, Astore, Baltistan (Skardu) and Ghanhe (Fig. 1). The population density of GB is 14 persons/ km². It is rich in water resources with five rivers including Indus, Hunza and Gilgit and has potential of hydropower generation. Five peaks, including K⁻² having peaks above 8000 meters, and some largest glaciers are present in this region. Ninth wonder of the Karakoram highway also present in this area. This area specially popular as it is the meeting point of worlds three mountainous ranges including Karakorum, Hindu Kush and Himalayas. This region is rich in natural resources including rare plants and animals.

2.2. Sample extraction and chemical analysis

The plants and soil samples were collected along the rivers of the study area. The collected plants consist of different wild species which are as follow, True indigo (*Indigo feratinctoria*), Sugarcane (*Saccharum officinarum*), Greater plantain (*Plantago major*), Harmel (*Peganum harmala*), Kerda (*Capparis decidua*), Baker (*Sophromolli*), Common blue violet (*Viola sororia*), Basket flower (*Centaurea uniflora*), Bermude gran (*Cynodon dactylon*), Poa (*Poa annua*), Horse weed (*Conyza canadensis*), Sagebrush (*Artemisia tridintata*), Babylon willow (*Salix babylonica*), Indian heliotripi (*Heliotropium indicum*), London racket (*Sisymbrium Iris*) and Knot weed (*Polygonum coccineum*). Plant samples (n= 30) were collected in papers bags, washed with deionized water and separated in roots and shoot. The samples were dried to constant weight and powdered. The samples were digested with aqua regia and HClO₄. Briefly, 10 ml of aqua regia were added

and heated till no fumes appear then 2-4 ml of HClO₄ was added and heated again. The samples were filtered and the final volume was adjusted to 50 ml with deionized water. Soil samples (n=30) were taken in the polyethene bags and dried in shade to avoid Hg evaporation after sieving they were powdered in cup mill.

Soil samples (2g) were digested using standard procedure. Briefly, the samples were digested with 10 ml of HF for one hour, and with 20ml of aqua regia till dryness. The samples were collected and filtered and the final volume was adjusted to 30 ml with deionized water. Hg concentrations in plants and soil samples were determined using Atomic Absorption Spectrometer (AAS-Perkin Elmer-700) equipped with mercury hydride system (MHS-15), while sodium tetrahydrobromate (NaBH₄) with dilute HCl used as a reductant. To check the accuracy of the method, blank and standards were run before Hg analysis. Certified standard solution FlukaKamica (Bucha, Switzerland) of Hg with 15% concentrated HNO₃ and few drops of KMNO₄ were used as a standard.

3. Data analysis

3.1. Hg transfer factor

Hg concentration in the extract of soil and different parts of the wild plants including root, stem, and leaves were calculated based on dry weight. The plant concentration factor (PCF) was calculated as follow:

$$PCF = C_{(plant)} / C_{(soil)}$$

Where C_(plant) and C_(soil) represents the concentration of Hg in extract of wild plant and soil, respectively (Khan et al., 2008).

3.2. Pollution load index

Soil pollution was measured for Hg by using pollution load index (PLI) technique depending on Hg concentration. The following equation was used to determine the PLI.

$$PLI = C_{soil (sample)} / C_{reference}$$

C_{soil} represent the concentration of Hg in the

field soil while $C_{reference}$ represent the concentration of Hg in reference soil (Khan et al., 2008).

3.3. Statistical analysis

The data was statistically analyzed using statistical softwares. The mean and standard deviation was calculated using Microsoft office. The graphs were prepared on sigma plot.

4. Results and discussion

4.1. Hg concentration in wild plants and soil

The concentrations of Hg in wild plant and soil samples collected from the study area showed great variation (Fig. 2). The results indicated that higher concentrations of THg were observed in the selected soil and plant samples with the mean concentration of $27.01 \mu\text{g/kg}$. THg concentration in soil samples were ranged from 6.9 - $946 \mu\text{g/kg}$ with the mean concentration of $214 \mu\text{g/kg}$. Higher concentrations of THg were observed in soil samples.

Hg concentrations in different plant parts including roots, stems and leaves were ranged from 1.169 - $193.9 \mu\text{g/kg}$, 3.6 - $85.78 \mu\text{g/kg}$ and 2.6 - $98.2 \mu\text{g/kg}$, while their mean concentrations were $42.04 \mu\text{g/kg}$, $19.061 \mu\text{g/kg}$ and $32.55 \mu\text{g/kg}$, respectively. The results showed

that roots were highly contaminated then other parts of plants. The higher concentration in roots may be due to their direct contact with the soil. Generally, it is assumed that the soil to root transfer of heavy metals like Hg is higher than other parts. These results are consistent with previous studies (Tong et al., 2013). Our results are in agreement with the findings of Zheng et al. (2007). Many plants have a natural tendency to resist the toxic pollutant such as Hg and they detoxified the harmful effects of these pollutants (Tong et al., 2013). The detoxification effect of Hg in plants is also observed by its reduction (Tong et al., 2013).

Soil is an important sink for Hg deposition besides air and water. Those plants growing in Hg contaminated soil are more contaminated than other. Wild plants have a key role in the environment due to their diverse applications. Wild plants are used in medicines, as a source of food for wild animals, wood manufacturing industries and as fuel wood. So they contribute in the contamination of environment directly or indirectly. Morita (1998) reported that new sources of Hg causing pollution in developing countries are amalgamation in gold mining and its different forms in the environment. Hg circulates in the environment and changes its forms. In which form of Hg present in plants depends on its bioavailability. Its bioavailability related with solubility, stability and interaction with soil (Morita, 1998).

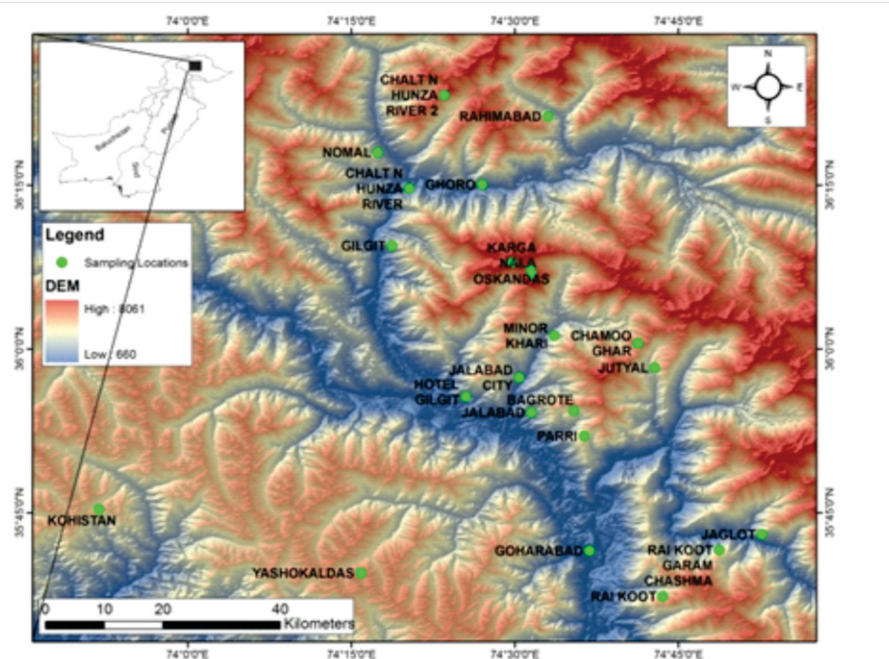


Fig. 1. Map of the study area showing the sampling sites

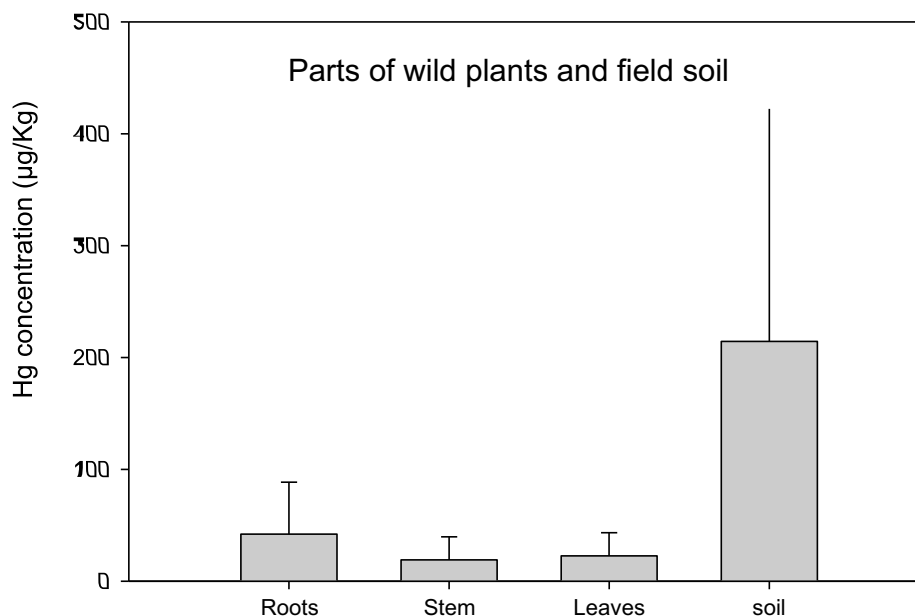


Fig.2. Mean concentration of Hg in soil, roots, stem and leaves samples

4.2. Hg transfer factor

The soil to plant transfer factor (PCF) of Hg is shown in Table-1. The results showed the uptake of Hg from soil to different parts of plant. Different plants and plant parts showed variable uptake, the uptake increased from root to stem then decrease in leaves. A decrease in stem to leaves translocation was observed in Kerde. Harmel showed the increase uptake of Hg from root to stem and then leaves. Similarly, in other plant species such as Common blue violet, Indian heliotrope, Bermuda grass, Poa and Horse weed an increase in PCF from root to stem and decreases in leaves was observed, while in Sagebrush, Baker, Babylonia willow, Sugar cane and True indigo PCF decreases from root to stem and increases from stem to leaves. An increase in PCF values from root to stem and then leaves was noted in the samples of London rocket, Mint, and True indigo. These findings showed that the soil to plant transfer of Hg showed great variation from specie to specie and within the same species at different plants parts.

4.3. Pollution load index

Table-1 showed the PLI values for different plant species. When compared with the reference value of $2.61 \mu\text{g/Kg}$, the PLI in all the samples were exceeded many folds than the reference value. Some plants showed least

increase while a significant increase was observed for other plant species. The highest increase of 210 times was observed for Indian heliotrop, while the least level exceeded in the Baker was 3.5 times than reference value. This increase in plants grown in contaminated soil revealed that the plant species of the area were highly contaminated with Hg. The results of these few plant species indicated that other plant species including vegetables may also contain high level of Hg which may be a great threat to the consuming population including human and animals.

5. Conclusion

The aim of this study was to find the effects of Hg on the environment and aware the local population to avoid the use of Hg and direct exposure. Hg is the hazardous element and its long term effects are dangerous for human as well as all other living organisms. In the present study high concentration of Hg has been reported in soil and plant samples and higher soil to plant transfer of Hg is the indication of food chain contamination. Higher Hg concentration in soil and plants may poses great threat to local population as they may directly or indirectly exposed to it. It is suggested that uses of mercury should be avoided in the area or specific precaution measures must be adopted to avoid environmental release of Hg.

Table.1 PLI and PCF for field soil and wild plants

Sample	PLI	PCF		
		Soil to root	Root to Stem	Stem to leaves
Greater plantain	54.5	0.22	3.79	0.17
Kerde	30.1	0.01	0.49	0.39
Harmel	75.2	0.16	0.22	5.65
Basket flower	29.9	0.45	1.98	0.37
Common blue violet	49.1	0.01	84.0	0.46
Indian heliotrope	206.0	0.47	84.0	0.36
Bermude grass	11.5	0.35	12.4	0.21
Poa	20.9	0.26	3.74	1.28
Horse weed	32.8	0.18	1.29	1.07
Sage brush	17.5	1.64	0.02	8.62
Baker	3.43	1.52	0.20	25.7
Babylon willow	30.0	1.22	0.11	0.52
London rocket	24.8	0.25	0.89	0.93
Knot weed	8.60	2.25	0.38	0.18
Sugar cane	11.5	12.1	0.66	4.66
Mint	28.9	0.44	0.45	4.01
True indigo	27.7	0.64	0.49	1.06

Acknowledgment

This study was financially supported by the funding under PAK-US Science and Technology cooperation program Phase IV and HEC.

Authors' contribution

Mrs. Arjumand Riaz has done the analytical work including preparation, extraction and analysis. Mr. Anwarzeb khan helped in tabulation of data and graphs presented in the paper. Mr. Muhammad Tahir shah was the co supervisor and helped in field work, samples collection and provided guidance for analysis of samples. Mr. Islamud din helped in data analysis and polishing of the paper. Mr. Sardar khan is the supervisor and helped in field work, samples collection and provided guidance for analysis of samples and final drafting of paper. Mr. Shuhab Danishwar khan helped in reviewing the manuscript and improved its readability.

References

- Barbosa, A. C., Silva, S. R., L., Do'rea, L. G., 1998. Concentration of Mercury in Hair of Indigenous Mothers and Infants from the Amazon Basin. Archives of Environmental Contamination and Toxicology, 34, 100-105.
- Biber, K., Khan, S. D., Shah, M. T., 2015. The source and fate of sediments and mercury in Hunza river basin, Northern area, Pakistan. Hydrological Processes, 29, 579-587.
- Gochfeld, M., 2003. Cases of mercury exposure, bioavailability, and absorption. Ecotoxicology and Environmental Safety, 56, 174-179.
- Jin, Y., Wang, x., Lu, J., Zhang, C., Duan, Q., 2008. Effects of modern and ancient human activities on mercury in the environment in Xi'an area, Shannxi Province, China. Environmental Pollution, 153, 342-350.
- Khan, S., Cao, Q., Zheng, Y. M., Huang, Y. Z., Zhu, Y. G., 2008. Health risks of heavy

- metals in contaminated soils and food crops irrigated with waste water in Beijing, China. *Environmental Pollution*, 152, 686-692.
- Morita, M., Yoshinaga, J., Edmondst, J, S., 1998. The determination of mercury species in environmental and biological samples. *Pure and Applied Chemistry*, 70 (8), 1585-1615.
- Straaten, P. V., 2000. Mercury contamination associated with small-scale gold mining in Tanzania and Zimbabwe. *Science of the Total Environment*, 259, 105-113.
- Tong, Y., Zhang, W., Hu, D., Ou, L., Hu, X., Yang, Y., Wei, W., Li, J., Wang, X., 2013. Behavior of mercury in an urban river and its accumulation in aquatic plants. *Environmental Earth Sciences*, 68, 1089-1097.
- Zain, O, F., 2010. A socio-political study of Gilgit Baltistan province. *Pakistan Journal of Commerce and Social Sciences*, 30, 181-190.
- Zheng, L., Liu, G., Chou, C., 2007. The distribution, occurrence and environmental effect of mercury in Chinese coals. *Science of the Total Environment*, 384, 374-383.