

TOXICITY OF MERCURY IN DIFFERENT SAMPLES (WATER AND SOILS) AND ITS EXPOSURE IN PAKISTAN

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ABSTRACT: *The environmental impacts of Mercury and its compounds are globally wide spread and deep rooted due to its high toxicity. Four provinces of Pakistan have been inspected for first time during present study for mercury exposure to environment. A total of 108 solid (soils) and liquid (wastewater) samples were selected for identification and quantification of mercury contents using Cold Vapor Atomic Absorption Spectrometric method. The maximum mercury released in Kg/Year has been estimated as 1625.11 in extraction process, fuel and energy sources; 2500 in Cement production; 21120 in Chlor-alkali production; 1071.79 in Consumer products with intentional use of mercury; 5779 in other intentional products/process uses and 4637.55 in Waste deposition/land filling and waste water treatment indicating total cumulative release of 36898.77 Kg/year. The total minimum per year emission and transfer of mercury in Pakistan is 10842 Kg represents 637.76 mg per capita per year exposure of mercury which is highly alarming figure. Agricultural soils have very less values of mercury than permissible limit (i.e. within the maximum permissible limit of 0.3 mg/kg). The monitored figures indicated that maximum mercury concentration is limited to the solid waste disposal sites in all provinces of Pakistan. The exposure of mercury in other sources i.e. both land and water is only 2300 kg/year that represents a small segment of the overall annual exposure.*

KEY WORDS: Mercury, toxicity, Hair, Landfills, exposure, UNEP's Toolki

1.0 INTRODUCTION:

Determination of mercury toxicity and its exposure on human and its environment is of vital importance. Present study is first of its kind in Pakistan, deals with current practices of mercury and its compounds use and disposal. This study comprises; **i)** Selection of areas susceptible to mercury contamination, **ii)** Collection and analysis of waste water and soil for detection of mercury, **iii)** Preparation of mercury base line data in Pakistan. Mercury is proven toxic and persistent in the environment. It directly affects human beings and ecosystem. The control of mercury use and its release needs a clear picture of mercury route at national and global level. To cure and prevent the mercury toxicity to environment/humans, there must be a baseline information on the use, reuse and processing of mercury at national level. Such data would help policy makers prepare guidelines for stakeholders and to predict any alarming situations on mercury toxicity. Prior to this study, there was hardly any information on mercury and its products in Pakistan. The people are unaware of identification of potential mercury sources, the exposure risk, environmentally safe methods of disposal and reuse of mercury and its products. The workers of the industries/users are being exposed carelessly to mercury and mercury products. Assessment and quantification of mercury in Pakistan would play a critical role in saving human and wildlife from toxic mercury exposure. Different mercury and mercury products are being used in Pakistan. Unfortunately, there are no or insufficient regulations over the usage and safe disposal of mercury related products. Mercury using industries in other countries have made some developments in the reuse of mercury

wastes though they are still in the initial stages. The current practices of the disposal of mercury products within Pakistan have been studied with respect to their environmental and economic aspects. The following steps have been taken: **a)** selection of areas susceptible to mercury contamination, **b)** collection and analysis of waste water, solid and hair samples for detection of mercury, **c)** preparation of mercury base line data about the current situation, **d)** assessment of risk to general public based on the collected data, **e)** establishing a relationship between data collected/generated and point / area source locations, **f)** awareness on the health impacts of mercury exposed people, **g)** developing of mercury waste management plans for priority sectors. This study is aimed to provide baseline and awareness of environmentally safe reuse/disposal options of mercury products. The adoptions of these reuse options will provide the users some financial recovery thus also mitigating impacts on the products cost. The communities suffering from unsafe disposal of mercury products will be direct beneficiaries of the outcome of present attempt. The overall objectives of this study are given below;

1. To identify the sources of mercury exposure to the different sectors of society.
2. Quantify the mercury exposure sources.
3. To develop mercury waste management plans to reduce the risk of mercury exposure.

2.0 LITERATURE REVIEW: Mercury is a naturally occurring element found in air, water and soil, though it's ultimate source is the crust of the Earth. Its distribution in the environment is due to both natural processes as well as anthropogenic activities. Mercury is found in different

inorganic and organic forms and is persistent in the environment. Mercury occurs in three valence states: elemental mercury (also known as metallic mercury, Hg^0), mono-valent mercurous (Hg^+), and the divalent mercuric (Hg^{++}). Elemental mercury is the most stable form and does not react readily with oxygen or water. Mercuric and mercurous mercury are normally thermally unstable. They decompose readily to elemental mercury when subjected to heat, exposed to light and treated with reducing agents. Hg^0 is only slightly soluble in water. However its solubility, compared to water, is more in non-polar organic solvents. Vapours of elemental mercury can occur at room temperature posing hazard during spillages [1]. Mercury is proven toxic and persistent in the environment. It directly affects human beings and ecosystem. The activities of human beings have increased the level of mercury in the atmosphere by roughly a factor of 3. Most of the mercury found in the contemporary environment is the outcome of many years of relentless release due to human activities. The anthropogenic and natural components of the total atmospheric mercury load are difficult to estimate [2]. According to Lacerda, 1997 [3], "the worldwide annual mercury releases into environment of 460 metric tons from gold extraction in the late 1980's/early 1990's which constituted about 10 percent of the total global anthropogenic releases". According to Lamborg et al., 2002 [4], "the global average level of mercury in the atmosphere at present is 1.6 ng/m^3 ". The total mercury levels range between 1-50 ng/L [5], [6], [7]. Accordance to Lawrence, [8] "on a worldwide basis, the amount of by-product mercury was estimated at about 400 metric tons per year". The main form of mercury found in soil is Hg^{+2} . Complexing of Hg^{+2} with soil organic phases is the dominant process by which mercury is fixed in soil. The most toxic form of mercury i.e. methyl mercury occurs in very small proportion (at 0.01- 2% of the total mercury) [5], [9], [10]. The dimethyl mercury compared to methyl mercury occurs in very low concentration. The dimethyl mercury is less than 1/1000 times of methyl mercury [9]. Because of strong complexing of Hg with soil organic matter, its retention time is long. The mercury thus accumulated is likely to continue to be released to other media possibly for hundreds or perhaps thousands of years [11], [12]. Notwithstanding the fact that a significant range of mercury contents have been reported from soils, most agricultural soils and the vegetation they support have very low values of mercury. According to Archer and Hodgson, [14], "an average range was 0.02 to 0.40 mg/kg". Contents of mercury is excess is to be considered contaminated. [15]. According to Schlüter [16], Tack et al., 2005 [17], Rodrigues et al., 2006 [18], "urban soils contain quite variable but generally higher levels of mercury compared to rural/agricultural soils. However, soils within the influence of natural or anthropogenic emission sources are likely to contain very high levels of mercury". In USA, Friedli et al., 2001 [19] estimated the mercury contents of garbage and green vegetation from seven locations which ranged from 0.01–0.07 mg Hg/kg dry weight. The aquatic environment contains mercury in different physical and chemical forms. The chemical species that matter are various complexes of the mercuric ion with different organic and inorganic ligands, methyl mercury, dimethyl mercury and elemental

mercury. Uncontaminated freshwaters may contain generally <5 ng/L total mercury. Median values of 3.1 to 6.2 ng/L of mercury were reported in 25 Swedish lakes [5]. Higher values of up to 10 or 20 ng/L could be detected in humic lakes or rivers which are rich in particulate mercury [20]. Contaminated waters may contain mercury in $\mu\text{g/L}$ range [20]. Total mercury concentrations in the marine environment are much lower and range between 0.1 to 1 ng/L [21,22, 23, 24, 25]. Methylation of mercury occurs in aquatic systems. Due to this reason, aquatic biota and fish eating birds and animals generally contain much higher levels of mercury compared to terrestrial animals. No wonder the concentration of ethyl mercury increase with trophic level and age. According to Dehn et al., 2006 [26], "arctic zooplanktons contain between 1 to 10 $\mu\text{g/kg}$ wet weight while top predators like beluga whale (toothed whale, *Delphinapterus leucas*), polar bears (*Ursus maritimus*) and ringed seals (*Phoca hispida*) may contain >10,000 $\mu\text{g/kg}$ in their livers". Livers and kidney of marine mammals contain more methyl mercury than other body parts. In muscle tissue, the main form of mercury is methyl mercury. However due to a process of demethylation, the livers of many marine mammals and seabirds show a decrease in methyl mercury with increase in total concentration of mercury [27], [28], [29], [30], [31], [32]. Inorganic mercury compounds are used in a number of manufacturing processes. These compounds have been extensively used in batteries and products such as fungicides, antiseptics or disinfectants. There are a number of mercury compounds; however, methyl mercury is the most common compound in the foodstuff and atmosphere. Organic mercury compounds have been used as fungicides and pharmaceutical agents like mercurochrome in topical antiseptics, thiomersal as a preservative in vaccines. The salts of phenyl mercury have been used as pharmaceutical, fungicides and cosmetic preparations to control growth of microbial organisms. Phenyl mercury acetate had been used in paint as a preservative. Ethyl mercury, methyl mercury and phenyl mercury occur mostly as acetates and chlorides. According to ATSDR, 1999 [33], "the inhalation of mercury vapor, intake of mercury contaminated drinking water and exposure to mercury through medical treatments may impact animals and humans. Intake through food is the main source of unintentional and non professional exposures to mercury".

3.0 MATERIALS & METHODS:

In Pakistan, mercury is being released into the environment through extensive use of mercury compounds as well as through use of certain high volume materials with traces of mercury. The calculations of mercury releases were made on the basis of guidelines, methods, sources and factors contained in the United Nations Environment Programme (UNEP)'s Toolkit (UNEP, 2005) for identification and quantification of mercury releases. Potential sources i.e. Chlor-alkali plants, Health sectors (hospitals, health care units, and clinics) for both mercury contained in products (thermometers and amalgam fillings) and mercury released from medical waste incineration, Landfills (municipal waste

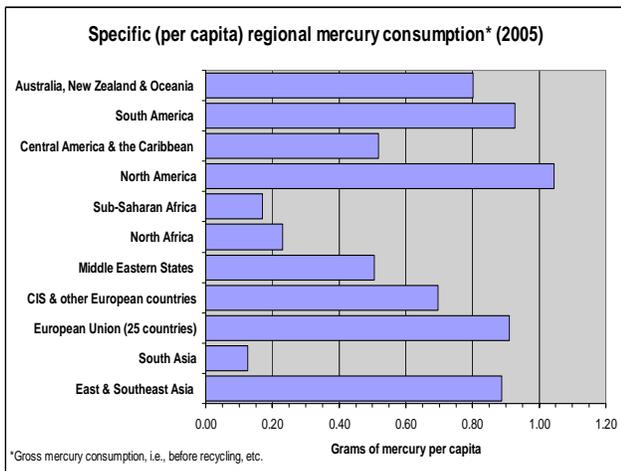


Fig.1.: Regional Mercury Consumption (2005)

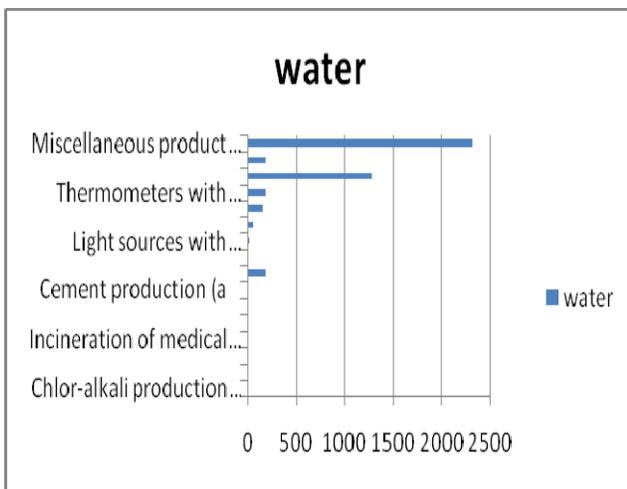


Fig.2: Mercury Releases in Water (Kg per year)

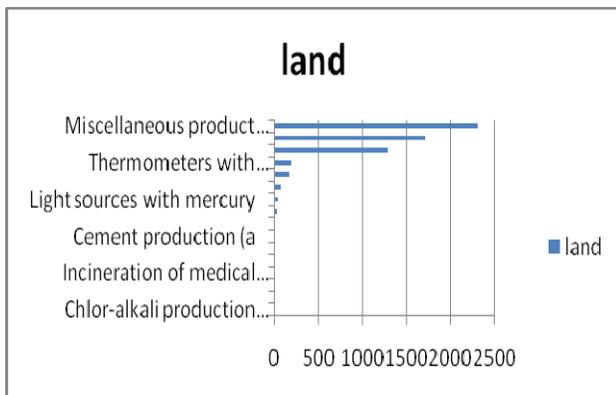


Fig.3: Mercury releases in land (Kg per year)

dumping)were focused. A total of 181 samples of solids and waste water for the analysis of mercury were collected from all four provinces of Pakistan.

3.1 Identification And Quantification Methodology: A pragmatic and viable methodology was formulated to identify and quantify mercury release sources in Pakistan to make an assessment of total volume of mercury available in the country. This exercise included the followings steps:

1. Selection of areas susceptible to / effected by mercury contamination in the country.

2. Collection of waste water and solid samples from the country.
3. Analysis of the samples in the laboratories of the Institute of Chemistry, University of the Punjab, Lahore and University of Aberdeen, Scotland, UK.
4. Data collection of mercury and mercury
5. products from mercury usage markets/industries in the country
6. Preparation of baseline data/inventory of mercury and mercury products about the current situation in the country

To accomplish the objectives of mercury data, UNEP’s Toolkit [34] was used for preparing the inventory throughout the country. Emission factor is a parameter that plays a fundamental role in the calculation of the release of mercury into the environment. If emission factors are not assigned values, it is complicated to effectively calculate the mercury releases. In this regard, the UNEP’s Toolkit clearly identifies emission factor values according to specific source categories/sub-categories. Although the UNEP’s Toolkit is a very useful document for the development of a mercury release inventory report, even though it mostly seems to be designed for use in developed countries rather than developing countries. This may create some confusion for developing countries with limited experience [34].

Determining release sources for Pakistan mainly depended on the UNEP’s Toolkit. However, in a few cases, it poses some difficulty and complexity. Based on available knowledge and information, the following sources were focused;

1. Chlor-alkali plants.
2. Health sector (hospitals, health care units, and clinics) for both mercury contained in products (thermometers and amalgam fillings) and mercury released from waste incineration.

3. Landfill (municipal waste dumping).

3.2 Collection of samples:The quantitative data was analyzed to figure out the mercury usage and release hotspots. After the quantification of mercury releases in the country, the samples were prioritized, based on mercury releases as well as on hotspots like chlor-alkali industries. Hotspots represent 57 % of the mercury releases in the country.All the 109 identified and prioritized samples of soil and water were collected from four provinces by the author with the help of provincial Environmental Protection Agencies and UNEP’s team.

3.2.1. Waste water and soil samples:The wastewater and soil samples were obtained from selected mercury affected sites in all the four provinces of Pakistan to assess the mercury pollution level and water contamination. For this purpose, 109 samples were collected and analyzed for mercury at the Laboratories of the Institute of Chemistry, University of the Punjab, Lahore, Pakistan. The Cold Vapour Atomic Absorption Spectrometry method was used for mercury analysis.

3.3. Preparation of samples

3.3.1. Waste water sampling

a) Flowing streams/ waste drain channels: One liter liquid samples were taken from 3 meter depth levels, well mixed in a polyethylene container and filled in 120 ml sample bottles containing 20 drops of 5% HNO₃.

b) Stagnant liquid reservoirs: One liter liquid samples were taken from four points at least 10 meter apart along the vertices of a hypothetical rectangle, mixed in polyethylene containers and immediately transferred in 120 ml sample bottles of polyethylene, already containing 20 drops of 5% HNO_3 . The remaining liquid was discarded into the same reservoir.

3.3.2. Sampling of soil matrices

a) Soil samples: For sampling of soil, typically an area of 100 m² was sampled. The sampling areas were open space land / different types of soil were sampled such as agricultural fields, forests and from vicinity of potential hot spots. Samples were taken with a clean spoon. Each soil sample consisted of at least five individual pick-ups, each of them approximately 50 g. All 50 g samples were placed into a bowl in the field, small twigs and other organic material was removed; the sample was mixed and placed into a zip-lock bag. Total samples size was approximately 200 g. The samples were transported to the analytical laboratory and stored in brown bags until analysis. Before analysis, samples were air-dried in the laboratory and sieved through a 300 mesh sieve.

b) Sludge: In case of sludge underneath a water channel, a plastic cup attached to a long stick was used to collect 200 gm samples. The samples were stored in dual zipper bags or filled in 120 ml polyethylene bottles using a funnel. 20 drops of 5% HNO_3 were added to the sample.

3.4 Techniques used for determining of mercury: Two sets of instrumentation/ techniques were used for the determination of mercury:

- Cold Vapour Atomic Absorption Spectrometry (CV-AAS)
- Cold Vapour Atomic Fluorescence Spectrometry (CV-AFS)

3.4.1 Method of Cold Vapour Atomic Absorption Spectroscopy (CV-AAS): Mercury was analyzed by Cold Vapour Atomic Absorption technique. The HNO_3 digested sample solution was treated with a reducing agent (20% SnCl_2) to convert the ionic mercury into mercury atoms in the form of fine vapours. Nitrogen gas was purged through the solution at a constant rate of 1 L/min and then the atomic vapour of mercury was swept into the 10 cm glass cell. The cell consists of a quartz window, transparent to radiation at 253.7nm of the mercury line that was used for detection. A mercury hollow cathode lamp was used as source. A series of standards ranging from 0.1 to 0.9 $\mu\text{g Hg/L}$ and in another range from 1 to 10 $\mu\text{g Hg/L}$ were analyzed to establish the 10-point calibration curve. In a similar way, different samples were analyzed and concentration of Hg was determined.

3.4.1.1. Chemical reagents: The following chemical reagents were used for the said work:

- i) Mercuric sulphate (Hg_2SO_4)
- ii) Stannous chloride (SnCl_2) 20%
- iii) Sulphuric acid (H_2SO_4) ACS reagent.
- iv) Conductivity water?
- v) Hg Standard stock solutions (1000 $\mu\text{g/L}$), Hg Calibration Standards (1-10 $\mu\text{g/L}$), (0.1-0.9 $\mu\text{g/L}$)

3.4.2 Cold Vapor Atomic Fluorescence Spectrometry (CV-AFS): Cold Vapor Atomic Fluorescence Spectrometry (CV-AFS) is the commonly used method to analyze very low concentration of mercury (Hg) due to its high

sensitivity, selectivity and relatively low cost. CV AFS model [Millennium Merlin- satellite spur (PSA 10.125), PSA instrumentation, England] was used to determine the concentration of total mercury (Hg) in hair certified reference materials (CRM IAEA 085, NIES-13) and human hair samples. The first requirement to perform this analysis is to convert all organic forms of mercury (Hg) by various digestion and oxidation procedures (seven procedures) to inorganic mercury.

3.4.2.1. Chemical reagents

- i. Stannous chloride (SnCl_2) 3.0%
- ii. Nitric acid (HNO_3) 5.0 %
- iii. Hydrochloric acid (HCl) 10%
- iv. Deionized water

3.4.2.2. General operation procedure: The bore size of the pump tubing and the rotational speed of the pump head determine the flow rate of each stream. In addition, the sample and blank/ acid flow rates are approximately twice that of the reducing agent (SnCl_2). This design helps to control the chemical reaction and stabilizes the flow patterns thus minimizing the inherent noise within the system.

4.0 Results and Discussion: Several products containing mercury or mercury compounds have been used in commercial and domestic sectors in Pakistan for long time, with the product lifecycle ultimately ending up as waste, adding up to the environment. Regarding the management of mercury release into the environment, sound management and use of products/equipment containing mercury or its compounds, there is no specific guideline, exact inventory or any legislation in Pakistan. This study was focused on the preliminary field survey on mercury uses and releases during the period of January to August, 2008 throughout Pakistan. The specific aim was the establishment of true inventory of mercury and its products in the environment of Pakistan.

4.1 Waste water and solid samples from Pakistan: To identify the mercury contamination level in the country, 109 samples of different solid and liquid wastes of chlor-alkali industries, waste water treatment plants, sugar & paper mills, tanneries, municipal & industrial drains, residues of hospital waste incinerators, match factories, etc were collected. The results of these samples are given in the following tables and figures; Results of 108 samples collected from waste water and land are shown in figures below..

The potential source of Mercury discharge in the water was found controlled landfills followed by thermometers and batteries with mercury in Pakistan Fig 2.

The penitential source of Mercury discharge in the land was found controlled landfills followed by thermometers and batteries with mercury in Pakistan Fig 3. The results indicate that all the sectors of society and industry have exposure to mercury at least to some extent as revealed by the data in above tables. This is an alarming situation as no sector of the society is safe from the effects of mercury exposure. It has become more of concern because this study touches the narrowly selected windows of samples which are, but meager representative of real image. The results also indicate that the maximum mercury concentration is limited to the solid waste disposal sites in all areas of provinces of Pakistan. The sources contributing to the higher mercury concentration in municipal solid waste is apparently due to the waste batteries cells, fluorescent lamps, some switching devices and Compact Fluorescent Lamps (CFL) (widely in

use these days due to energy crises). No doubt, this figure of the finding is disturbing but on the other hand, the solid waste can be managed more easily and it spreads much less as compared to liquid waste. The proper disposal or removal of mercury from the solid waste could be reliable mitigation measure for the toxicity of mercury. The need is to identify sources adding the maximum mercury in the solid waste, be it some industry or occupation.

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5.0 Conclusions and Recommendations: The overall aim of this study was to identify and quantify mercury releases in Pakistan. Mercury waste management will improve the quality of life of people and conserve aquatic resources by reducing mercury releases to environment through ensuring provision for mercury alternatives at all levels at an affordable cost and in an equitable, efficient and sustainable manner. The recommendations of this study are;

1. Coordinate with advanced research laboratories to study the health impacts of mercury.
2. Replace mercury products with mercury alternatives in future.
3. Conduct a study for most economical and environmental friendly mercury alternatives.
4. Conduct a study for the recovery/recycling of mercury from mercury waste and mercury products.
5. Conduct a study on the determination of methyl mercury in rivers, sea and all types of fish.
6. Ensure protection and safety of all people working/using mercury for different purposes.
7. Encourage community participation and empowerment in planning, implementation, monitoring and operation for safe disposal of mercury.

Table 1: Results of Samples From Sindh (Karachi etc)

Sr. No.	Sampling Point	Hg (ppb)
1	Civil hospital, korangi, Karachi	0
2	Haji Naimat Ullah Tannery,Karachi	0
3	Hasan square drain ,Karachi	0.05
4	Inlet of treatment plant effluent, Karachi	2.41
5	Korangi dumping waste "D", Karachi	3.48
6	Korangi dumping waste "A", Karachi	8.84
7	Korangi dumping waste "B", Karachi	0.02
8	Korangi dumping waste "C", Karachi	1.49
9	Korangi waste drain (Left),Karachi	0
10	Korangi waste drain (Right),Karachi	0
11	Leachate of solid waste, Karachi	2.73
12	Malir river wet land sludge, Karachi	0
13	Malir river wet land water, Karachi	2.06
14	Modern Tannery, Karachi	0.32
15	Municipal effluent, Karachi	0
16	Municipal sludge ,Karachi	0
17	Permanent Sludge Lagoon(PSL) Sludge, Karachi	0.85
18	Shaheen Tannery, Karachi	0
20	Subhanullah Tannery, Karachi	0
21	Zubair Afzal Tannery, Karachi	9.26
22	Faran Sugar Mill ,Badin	0.59
23	Digri Sugar Mill ,Digri	0
24	Mehran Sugar Mill, Talhar	0
25	Serri Sugar Mill,Tando Mohammad Khan	0
26	Tando Muhammad Khan Sugar Mill ,Tando Mohammad Khan	0

Table 2: Results of Samples From Punjab (Lahore, Sheikhpura, Faisalabad Etc)

Sr.No.	Sampling Point	Hg (ppb)
1.	ARC sock near Kahna, Hudiarah drain, Lahore	0
2.	Badian road, Hudiarah drain , Lahore	1.59
3.	Main Ferozepur road, Hudiarah drain, Lahore	0
4.	Near Shafi Reso Chem, Hudiarah drain, Lahore	0
5.	Azadi chowk, Ravi road,River Ravi, Lahore	0
6.	Near Taj company, Ravi road, River Ravi, Lahore	1.26
7.	Shahdra village bridge, Ravi road,River Ravi,Lahore	0
8.	Town ship municipal waste drain, Lahore	0.60
9.	Mehmood Booti Drain, Lahore	3.9
10.	Dharam pura canal , Lahore	0
11.	Kot Lakhpat industrial Estate drain, Lahore	0
12.	Leachate Mehmood Booti Dumping Site Bund Road 1,Lahore	4.1
13.	Leachate Mehmood Booti Dumping Site Bund Road 2, Lahore	3.7
14.	Leachate Mehmood Booti Dumping Site Bund Road 3, Lahore	2.8
15.	Mehmood Booti Dumping Site 1, Lahore	1.2
16.	Mehmood Booti Dumping Site 2, Lahore	0.6
17.	Residual waste of incinerated hospital waste, Children Hospital ,Lahore	1.52
18.	Supra Tannery, Lahore	0
19.	Ittehad chemicals Outlet 4, Kala Shah Kaku, Sheikhpura	2.7
20.	Ittehad chemicals Solid Waste 1, Kala Shah Kaku, Sheikhpura	0.77
21.	Ittehad chemicals Solid Waste 2, Kala Shah Kaku, Sheikhpura	0.4
22.	Ittehad chemicals Solid Waste 3, Kala Shah Kaku, Sheikhpura	0
23.	Ittehad chemicals Outlet 1,Kala Shah Kaku, Sheikhpura	2.3
24.	Ittehad chemicals Outlet 2, Kala Shah Kaku, Sheikhpura	0.4
25.	Ittehad chemicals Outlet 3, Kala Shah Kaku, Sheikhpura	3.1
26.	Sheikhpura Municipal Drain, Sheikhpura	2.1
27.	Drain near Sitara chemicals, Faisalabad	2.4
28.	Sitara chemicals effluent1, Faisalabad	1.1
29.	Sitara chemicals effluent 2, Faisalabad	1.3
30.	Sitara chemicals effluent 3, Faisalabad	0.89
31.	Sitara chemicals effluent 4, Faisalabad	1.34
32.	Sitara chemicals effluent 5, Faisalabad	2.7
33.	Sitara chemicals Solid Waste 1, Faisalabad	0.4
34.	Sitara chemicals Solid Waste 2, Faisalabad	0.5
35.	Sitara chemicals Solid Waste 3, Faisalabad	1.2
36.	Nimir chemicals effluent 1,Sheikhpura-Faisalabad Road	0
37.	Nimir chemicals effluent 2, Sheikhpura-Faisalabad Road	0
38.	Nimir chemicals effluent 3, Sheikhpura-Faisalabad Road	0
39.	Municipal sewerage, Okara	0
40.	Yousaf Sugar mill, Shahpur	0

Table 3: Results Of Samples From Baluchistan (Quetta Etc)

Sr.No.	Sampling Point	Hg (ppb)
1.	Informal dumping site solid waste	3.48
2.	Informal dumping site solid waste	7.16
3.	Lime as product , Quetta	0
4.	Lime fuel source (coal) , Quetta	5.26
5.	Lime stone as raw material , Quetta	2.96
6.	Quetta city municipal waste sludge,	0
7.	Quetta city municipal waste water,	0.03
8.	Residue of hospital waste incinerator,	1.81

Table 4: Results of Samples From N.W.F.P (Peshawar Etc)

Sr.No.	Sampling Point	Hg (ppb)
1.	Buddhni Nala, Bacha Khan Chowk, Peshawar	6.8
2.	Ferrous Waste Product, Peshawar	<0.5
3.	Ferrous Waste Un-reacted, Peshawar	<0.5
4.	Hayatabad Dumping solid waste site 1 (Labor	6.4
5.	Hayatabad Dumping solid waste site 2,Peshawar	5.7
6.	Hayatabad treatment plant ,Peshawar	3.5
7.	Sludge, industrial estate , Hyatabad, Peshawar	4
8.	Treatment Plant Gulbahar, Peshawar	3.1
9.	Waste water , Afghan Match , Hyatabad, Peshawar	2.7
10.	Waste water , Khyber Match, Peshawar	2.1
11.	Waste water ,Ashraf Match, Peshawar	2
12.	Waste water ,Ganda Nala, Peshawar	5.4
13.	Waste water ,Hasan Pharma, Hayatabad , Peshawar	3.4
14.	Waste water ,Hayatabad Labour colony, Peshawar	0
15.	Waste water ,Khyber Teaching Hospital, Peshawar	2.4
16.	Waste water ,Midway Hotel, Peshawar	0
17.	Waste water ,Mohsin Match, Hayatabad , Peshawar	2.4
18.	Waste water ,Neelam Paper, Peshawar	2.6
19.	Waste water ,PCSIR Environmental Lab, Peshawar	<0.8
20.	Waste water ,Rapid Car Wash, Peshawar	0
21.	Waste water ,Royal PVC raw material ,Hayatabad ,	1.3
22.	Waste water ,Sardar Begum Dental College,	0
23.	Waste water ,Sarhad Board, Hayatabad, Peshawar	1.5
24.	Waste water ,Sufi Foods, Peshawar	0
25.	Waster water, industrial estate, Hyatabad, Peshawar	3.1
26.	Waste water ,Taj Ghee, Hattar, Haripur	1
27.	Waste water ,Volta Battery, Hattar, Haripur	3.7
28.	Waste water , Chinoti Gul Ghee ,Hattar, Haripur	1
29.	Waste water ,Hattar Rending,Hattar,Haripur	2.1
30.	Waste water ,Khyber Lamps, Hattar, Haripur	3.6
31.	Waste water ,Lateef Ghee, Hattar,Haripur	1.5
32.	Waste water ,Permanent Paper, Hattar,Haripur	3.6
33.	Waste water ,Chashma sugar mill, D.I. Khan	0
34.	Waste water ,Fouji Corn Complex, Swabi	3.4
35.	Waste water ,Musarat Shaukat Hospital Complex,	2

36.	Waste water ,Pakistan Tobacco Company ,Akora	1.9
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8. Promote cost effective and appropriate technological options for proper handling of mercury.
9. Mercury containing batteries should be handled with care.
10. Waste reduction and proper waste management of products containing mercury should be considered in households, business, industry and mercury spills.
11. In order to regulate mercury at consumer level, all purchasers of mercury containing products should be registered and proper mercury/chemical regulation unit should be established in all provincial EPA's.
12. Replacement of mercury products with mercury alternatives must begin at the production level in industrial processes and also for making of products for direct use by consumers.
13. Disposal of dry mercury cells of all types having high concentration of mercury should be high priority. In addition, pressure measuring devices, new and old (come with scrap e.g. ship breaking) should be carefully managed.
14. Mercury poisoning should be included in environmental awareness campaigns. It should be a part of pollution plus poisoning campaigns.

6.0 REFERENCES

- 1- Cotton, F.A. and Wilkinson, G. 1988. Advanced Inorganic Chemistry, 5th edition. Wiley-Interscience (John Wiley & Sons), New York, Toronto.
- 2- Munthe, J., Kindbom, K., Kruger, O., Petersen, G., Pacyna, J., and Iverfeldt, A. Examining source-receptor relationships for mercury in Scandinavia. Modelled and empirical evidence, *Water Air Soil Pollution.*, **6**(II), 270:279, (2001).
- 3- Lacerda, L.D. (1997a): Global mercury emissions from gold and silver mining. *Water, Air and Soil Pollution*, **2**(I), 209-221, (1997).
- 4- Lamborg, C.H., Fitzgerald, W.F., O'Donnell, J., and Torgersen, T. A non-steady-state compartmental model of global-scale mercury biogeochemistry with interhemispheric atmospheric gradients. *Geochim. Cosmochim. Acta.*, **66**: 1105-1118, (2002).
- 5- Lindqvist, O., Johansson, K., Aastrup, M., Andersson, A., Bringmark, L., Hovsenius, G., Håkansson, L., Iverfeldt, Å., Meili, M., and Timm, B. Mercury in the Swedish environment – recent research on causes, consequences and corrective actions. *Water Air Soil Pollut.*, **55**: 1-261. (1991)
- 6- Hall, B. The gas phase oxidation of elemental mercury by ozone. *Water Air Soil Pollut.* **80**: 301-315. (1995)
- 7- Lawrence, B. The Mercury Marketplace: Sources, Demand, Price, and the Impacts of Environmental Regulation. Presentation at USEPA's *Workshop on Mercury in Products, Processes, Waste, and the Environment. Baltimore, Maryland (USA)*, March 22-23, (2000).
- 8- Downs, S.G., Macloed, C.L. and Lester, J.N. Mercury in precipitation and its relation to bioaccumulation in fish: a literature review. *Water Air Soil Pollut.*, **108**: 149-187 (2010).
- 9- Davis, A., Bloom, N.S. and Hee, S.S.Q.. The environmental geochemistry and bioaccessibility of mercury in soils and sediments: a review. *Risk Anal.*, **17**: 557-569 (1997).
- 10- Grigal, Mercury sequestration in forests and peatlands: a review. *J. Environ. Qual.* **32**:393-405 (2003).
- 11- United Nation Environment Programme: Global Mercury Assessment, UNEP Chemicals, Geneva, Switzerland., (2002).
- 12- Hissler, C. and Probst, J.L. Impact of mercury atmospheric deposition on soils and streams in a mountainous catchment (Vosges, France) polluted by chlor-alkali industrial activity: the important trapping role of organic matter. *Sci. Tot. Env.* **361**: 163-178 (2006).
- 13- Archer, F.C. and Hodgson, J.H. Total and extractable trace element contents of soils in England and Wales. *J. Soil Sci.* **38**: 421-431 (1987).
- 14- Kabata, Pendias, A. Mercury In Trace Elements in Soils and Plants. CRC Press London, 157-168 , (2001).
- 15- Schlüter, K. Evaporation of mercury from soils. An integration and synthesis of current knowledge. *Environ. Geol.* **39**: 249-271 (2000).
- 16- Tack, F.M.G., Vanhaesebroeck, T., Verloo, M.G., Rompaey, K.V. and Ranst, E.V. Mercury baseline levels in Flemish soils (Belgium). *Environ. Poll.* **134**: 173-179 (2005).
- 17- Rodrigues, S., Pereira, M.E., Duarte, A.C., Ajmone-Marsan, F., Davidson, C.M., Grčman, H., Hossack, I., Hursthouse, A.S., Ljung, K., Martini, C., Otabong, E., Reinoso, R., Ruiz- Cortés, E., Urquhart, G.J., and Vrščaj, B. Mercury in urban soils: a comparison of local spatial variability in six European cities. *Sci. Tot. Env.*, **368**: 926-936 (2006).
- 18- Friedli, H.R., Radke, L.F. and Lu, J.Y. Mercury in Smoke from Biomass Fires. *Geophysical Research Letter.*, **28**:3223-3226 (2001).
- 19- Ulrich, R., Raszyk, J. and Napravnik, A. Variations in contamination by mercury, cadmium and lead on swine farms in the district of Hodonin in 1994 to 1999. *Veterinarni Medicina.*, **46**:132-139 (2001).
- 20- Leermarkers, M. Galletti, S. De Galan, S. Brion, N. and Baeyens, W. Mercury in Southern North Sea and Scheldt Estuary. *Mar. Chem.*, **75**: 229-248 (2001).
- 21- Kotnik, J., Horvat, M., Tessier, E., Ogrinic, N., Monperrus, M., Amouroux, D., Fajon, V., Gibicar, D., Zizek, S., Sprovieri, F., and Pirrone, N. Mercury speciation in surface and deep waters of the Mediterranean Sea. *Mar. Chem.*, **107**: 13-30 (2007).
- 22- Horvat, M. Kotnik, J. Logar, M. Fajon, V. Zvonaric, T. and Pirrone, N. Speciation of mercury in surface and deep-sea waters in the *Mediterranean Sea. Atmos. Env.* **37** (1): 93-108 (2003).
- 23- Mason, R.P. and Sullivan, K.A. The distribution and speciation of mercury in the South and Equatorial Atlantic. *Deep-Sea Res II* **46**: 937-956 (1999).
- 24- Mason, R.P., Rolffhus, K.R. and Fitzgerald, W.F. Mercury in the North Atlantic. *Mar.Chem.*, **61**: 37-53 (1998)

- 25- Dehn, L.-A., Follmann, E.H., Thomas, D.L., Sheffield, G.G., Rosa, C., Duffy, L.K., and O'Hara, T.M. Trophic relationship in an Arctic food web and implications for trace metal transfer. *Sci. Tot. Env.*, **362**: 103-123 (2006)
- 26- Gaskin, D.E. Stonefield, K.I. Suda, P. and Frank, R. Changes in mercury levels in harbor porpoises (*Phocena phocena*) from the Bay of Fundy (Canada) and adjacent waters during 1969-1977. *Arch Environ. Contam. Toxicol.*, **8**: 733-762 (1979).
- 27- Falconer, R.C., Davies, I.M. and Topping, G. Trace metals in the common porpoise *Phocena phocena*. *Mar. Environ. Res.* **8**: 119-127 (1983).
- 28- Chen, M.-H., Shih, C.-C., Chou, C.L. and Chou, L. S. Mercury, organic-mercury and selenium in small cetaceans in Taiwanese waters. *Marine Pol. Bul.*, **45**(1-12): 237-245 (2002).
- 29- Endo, T., Haraguchi, K., Cipriano, F., Simmonds, M.P., Hotta, Y. and Sakata, M. Contamination by mercury and cadmium in the cetacean products from the Japanese market. *Chemosphere*, **54**: 1653-1662 (2004).
- 30- Thompson, D.R. and Furness, R.W. The chemical form of mercury stored in South Atlantic seabirds. *Environ. Poll.*, **60**: 305-317 (1989).
- 31- Wagemann, R., Trebacz, E., Boila, G. and Lockhart W.L. Methyl mercury and total mercury in tissues of arctic marine mammals. *Sci. Tot. Env.*, **218**: 19-31 (1998).
- 32- Wagemann, R., Trebacz, E., Boila, G. and Lockhart, W.L. Mercury species in the liver of ringed seals. *Sci. Tot. Env.*, **261**: 21-32 (2000).
- 33- UNEP-Toolkit for identification and quantification of mercury releases – Pilot draft, November (2005)