MERCURY RISING

Mercury Pollution in Lebanon and Morocco

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1 Executive summary

Mercury is emitted into the atmosphere through both naturally occurring and anthropogenic processes. Natural processes include volatilization of mercury in marine and aquatic environments, volatilization from vegetation, soils and volcanic emissions. Anthropogenic sources of mercury include its use in chlor-alkali plants, in paints as preservatives or pigments, in electrical switching equipment and batteries, in measuring and control equipment (thermometers, medical equipment), in tooth-filling materials (amalgams), and many other sources. Globally, the major sources of anthropogenic mercury air emissions are fossil fuels combustion, artisanal and small-scale gold production, metal production, cement production, waste incineration, land filling, steel scrap, release by breaking and waste recycling.

Mercury is highly toxic and may be fatal if inhaled and harmful if absorbed through the skin. When inhaled, it may cause harmful effects to the nervous, digestive, respiratory, immune systems and the kidneys. Adverse health effects from mercury exposure can be tremors, impaired vision and hearing, paralysis, insomnia, emotional instability, development deficits during fetal growth, attention deficit, and development delays during childhood. Recent studies suggest that mercury may have no threshold below which some adverse effects don't occur.

Mercury has become an increasingly popular chemical of concern over the last several years. The United Nations Environment Program (UNEP) released its Global Mercury Assessment in 2002 (UNEP Report), citing information and comments submitted by 81 countries. Several important findings have shown that mercury pollution is a problem of global concern. This has led the UNEP Governing Council to initiate in 2009 a historic new process of governmental negotiations for the development of a comprehensive global treaty on the reduction of mercury releases to protect human health and the environment. 140 countries have agreed to establish an Intergovernmental Negotiating Committee (INC) for this purpose. At the time this report was produced two sessions of the INC have been concluded, and the third session will be held in Nairobi, Kenya, in October/November 2011. UNEP aims to have the treaty adopted in 2013, after five more global negotiating sessions.

Lebanon and Morocco still lack a comprehensive national survey that presents an objective assessment of mercury risks in the two countries. Initial literature review has shown that there is no data on the level of mercury pollution in the air in both Lebanon and Morocco. Therefore, IndyACT initiated a sampling operation of mercury pollution levels in the air in several areas in Lebanon and Morocco as a preliminary step to fill the existing gap. The operation covered the medical sector (hospitals, medical labs, and dental clinics), various industrial zones, waste dumps, and other potentially contaminated sites. This preliminary sampling operation aims at starting the debate around mercury pollution and elimination in the Arab region. The operation serves as a sneak preview on the existing situation of air mercury pollution, and the following information was found.

Baseline concentration levels for mercury in the atmosphere in rural areas of Lebanon was identified, and was found to range between 1.6 - 2.7 ng/m^3. In urban areas, the concentration levels of mercury in Lebanese and Moroccan cities were in the range of 5.7 - 20.2 ng/m^3, which is comparable to mercury concentrations in the air in European cities.

All measured mercury concentration levels in the air in proximity of cement industry in Lebanon and Morocco have been found to be higher than those found in rural areas. This indicates that the cement industry has an effect on the air quality in terms of mercury pollution.

Mercury levels were measured in the proximity of chlor-alkali factory called Coelma in the region of Tetouane, Morocco. This plant is of particular importance regarding mercury pollution, since it produces caustic soda, chlorine and other products using an old technology called mercury cell. This process uses mercury as a catalyst in its processes. Measurements were also taken along the river that passes by Coelma factory and continues across the city of Tetouane to Madiaq. This river receives industrial effluents from Coelma. The measurement results clearly show a higher concentration of mercury in the atmosphere of the entire region around the plant. What is more interesting is that mercury concentrations in the air along the river are also higher than background levels even at a long distance from the plant, which confirms the assumption that the river has become a secondary source of mercury emissions**.**

Mercury measurements taken next to electrical power plants in Jieh, Lebanon, and in Mohammedia, Morocco, have shown that the dispersion of mercury follows the plume direction. Therefore mercury concentration following the prominent wind direction is higher than in other directions.

Mercury measurements in the proximity of waste dumps, such as the ones taken in Lebanon next to the Nabatieh, Kfar Tibnit dump, and the Tyr, RasElAin dump, have reached 10 ng/m^3. Nevertheless, in other waste dump areas, such as next to Saida dump in Lebanon and Casablanca - Mediouna dump in Morocco, concentrations of mercury in the air have only slightly exceeded baseline levels. The reason for the differences depends a lot on the content of waste, which varies from place to place and time to time, as well as what happens in these dumps during time. For example, just after a dump catches fire, concentration levels of mercury in the atmosphere are expected to rise. This indicates that waste dumps could also be an important secondary source of mercury emissions.

Maybe the most interesting finding was the mercury concentrations in indoor air of the dentistry sector in Lebanon and Morocco. The use of mercury containing amalgam in the dentistry sector leads to high concentrations of mercury inside the closed spaces of dental care clinics. This leaves dentists and personnel of dental care clinics exposed to high concentrations of mercury vapor, which poses risk of chronic mercury intoxication. A number of clinics visited have reported that they have completely stopped the use of mercury amalgam. Nevertheless, a substantial number of dental care clinics still use it, but most of those use the amalgam in a packaged form and through a mechanical closed mixer. Given the wide variation in the type of dental care clinics and their locations, four categories of clinics have been identified:

A- The first category of dental care clinics use mercury amalgam without any specific control or precaution. In such clinics the level of mercury samples exceeds 3000 ng/m^3. The dentists and staff in this category of dental care clinics are highly exposed to mercury, which could lead to chronic intoxication.

B- The second category of dental care clinics are those that still use mercury amalgam, but in a packaged form and utilize a mechanical closed mixer. The level of mercury concentrations measured in these clinics varied between 214 - 797.1 ng/m^3. These levels of mercury concentration are significant and can pose real risks to the health of those exposed.

C- The third category of dental care clinics has in general stopped the use of mercury amalgam. However, they still use them in rare and special cases, when the alternative is out of stock or is too expensive for the customer. Measurements of mercury concentrations this category of clinics was found to be between 62 - 170.4 ng/m^3. This concentration level is medium. This shows that mercury could be persistent in closed spaces, and decontaminating the air from mercury will require a substantial amount of time. Long-term exposure to mercury in this category of clinics could have health risks.

D- The fourth and final category of clinics is those clinics that completely stopped the use of mercury amalgam for a long period of time. These clinics have shown to have similar mercury concentrations to locations in the vicinity of dental clinics. The level of mercury in this category is between 2.4 - 31.4 ng/m^3. This level of mercury concentration is low, but given the severe toxicity of mercury, it is not to be neglected.

Indoor mercury concentrations air in the rest of the health care sector, such as hospitals and clinics in Lebanon and Morocco, has also been measured. In all the sampled sites in Lebanon and Morocco, measurements varied from low, medium to sometimes high levels. The highest levels measured in this sector pose a real risk to exposed doctors, nurses, laboratory technicians, other personnel, patients, and especially newborns. Even the lowest concentration levels are not devoid of danger in cases of long-term exposure.

Finally, measurements taken inside some university laboratories in Lebanon and the poison control center in Rabat, Morocco are relatively low and medium. This could be a result of not having any recent accidents involving mercury, or due to the low rate of evaporation of mercury from apparatus and analytical instruments. The highest concentration recorded in the sampling was in the poison control center in Rabat, which was 47.4 ng/m^3. This could be due to an accident that involved mercury.

Conclusions:

1- In Lebanon, the health care sector is the sector that uses mercury the most. Dentistry is the sub-sector where we found the highest concentrations of mercury. Staff working in this sector is the most exposed to mercury in Lebanon. This is also true in the case of Morocco where this sector was found to be one of the sectors that uses mercury the most.

2- Unintentional emissions of mercury from industrial zones and contaminated sites have raised mercury concentrations in areas far away from the source.

3- During the measurement period, it was found that there is little awareness on the health impact of mercury in both Lebanon and Morocco.

4- Mercury containing waste is disposed of with the rest of the solid wastes stream without any specific precautions or handling.

5- There is a lack of specialized sites for the temporary or perpetual storage of mercury waste and instruments containing mercury.

General recommendations:

1- Lebanon and Morocco need to give more importance to the assessment and reduction of mercury releases into the environment.

2- Lebanon and Morocco should develop a national strategy to phase out the use of mercury and its products.

3- Due to the lack of information on mercury, Lebanon and Morocco need to monitor more closely mercury pollution in air, water, soil, sediments and nutrients (especially in fish).

4- Lebanon and Morocco need to set specialized storage sites for mercury waste and mercury containing waste on the local and national level.

5- Necessary national legislation needs to be developed to assess and reduce mercury contamination.

6- Lebanese and Moroccan governments need to strongly engage in the current intergovernmental negotiations for the elaboration of a new international legal instrument on mercury.

2 Introduction

Our review of the work and activities related to mercury and mercury pollution in Lebanon conducted so far indicates that this issue has not yet received enough attention and follow-up. Public still lacks knowledge about the danger of this metal, and national steps are needed to reduce its use and to minimize its environmental impact. Mercury, in all its organic and inorganic forms, poses serious risk to public health in the country.

A regional workshop, which attempted to raise awareness about mercury pollution, was organized by the United Nations Environmental Program in Lebanon in October of 2004. There was no serious follow-up, and its recommendations, such as having a clear and comprehensive national inventory, are not implemented yet.

Literature review revealed that the only research conducted so far on the topic in Lebanon includes the occupational exposure of dentists to mercury, mercury exposure through food, mercury levels in fish stocks, and the level of mercury in seawater. There is no national report or comprehensive study on the status of mercury in Lebanon, or any statistics on the quantities of mercury that enter the country. The country also lacks an inventory of existing mercury-containing products, as well as their distribution in the various economic sectors. The most available data was estimations on the mercury content of the healthcare waste stream, which was around 31 kg per year. Most of the mercury in this waste stream is derived from thermometers and sphygmomanometers.

In brief, Lebanon still lacks a comprehensive national survey that allows for an objective assessment of the risks resulting from mercury use in Lebanon.

As for the mercury air emissions from various sources, again there is little information on the subject in Lebanon. There are two papers that address mercury emissions in Lebanon from a Mediterranean perspective. The first one is on mercury emissions from natural sources and human activities in the Mediterranean region, and the other is on mercury emissions from forest fires in the Mediterranean region and Russia.

Little information was also found on the levels of mercury in various media: air, fresh water, and soil. According to one of the documents issued by the Lebanese Ministry of Environment on February 2010 it stated that „it is not available in Lebanon to date any tools for assessing and monitoring of mercury at national levels“.

Therefore, this study has high importance due to the fact that it starts to explore a new topic that is difficult and delicate. Despite its limited means and scope, it can be considered a first step in an unknown area. In order to have preliminary understanding of the degree of mercury air pollution within the medical sector, samples have been taken from hospitals and dental clinics, where mercury contains tools and devices are mostly used. In addition, air samples were taken in various industrial and non-industrial zones where mercury could be a potential emission. It is important for this study to note the following information related to mercury in Lebanon:

- Lebanon as a country is not a producer of mercury or manufacturer of mercury containing products.
- There are no gold mines in Lebanon, which commonly use large amounts of mercury.
- There are no chemical industries or any other industries, in Lebanon, using mercury in its operations and processes.
- Mercury enters into Lebanon through the import of the needs of the medical dental sector. There is no reference that refers to the quantities of mercury imported by this sector.
- The products and devices containing mercury are imported from abroad, but there are no available statistics showing the quantities of such products, nor the devices imported, nor the companies that import these products.
- The decree that regulates health care waste management and their disposal has not been fully implemented, except (to a certain extent) on the issue related to the management and disposal of biologically contaminated (infectious) waste. Article VI, which imposes the separate collection of specific materials including mercury and waste containing mercury, still needs to be implemented. Thus, most of the mercury waste generated from the health sector is disposed of through the municipal waste stream.
- The open dumping sites scattered in all regions of Lebanon, as well as the two sanitary landfills in Beirut and Beqaa Valley that receive most of Lebanon's waste including the waste from the medical sector. Therefore, these dumping sites and landfills are a potential source of mercury contamination.
- Petroleum products of all kinds, including the fuel used in the industry, especially in energy and cement sectors, and those used for heating and other sectors, contain a small percentage mercury. Thus these sectors are a source of mercury.
- Some of the natural raw materials used by the industry could contain mercury. For example, the manufacturing of phosphate fertilizers and sulfuric and phosphoric acids use mined phosphate rocks that could contain certain levels of mercury. Another industry is the cement industry, which uses limestone and petroleum coal, are also a source of mercury deposits.
- Some industrial and non-industrial waste with high calorific value is used sometimes by the cement industry as an alternative fuel for their cement kilns. The combustion of this waste could contain mercury deposits.

3 PART I - GENERAL PART

3.1 Chemistry

Mercury is a naturally occurring heavy metal. At ambient temperature and pressure, it is a liquid that vaporizes and may stay in the atmosphere for up to a year. When released in the air, mercury is transported and deposited globally. Most of the mercury found in the atmosphere is elemental mercury vapor.

Mercury combines easily with other metals, and expands and contracts evenly with temperature changes. Due to these properties, mercury has been used in many household, medical and industrial products (electric switches, fluorescent or mercury-vapor lights, thermometers and thermostats, barometers and other pressure detection devices).

Mercury can enter the environment very easily; it can be difficult to clean up and may persist for a long time.

Mercury exists in several forms: metallic mercury (also known as elemental mercury), inorganic mercury, and organic mercury. Metallic mercury is the familiar liquid metal used in thermometers and some electrical switches. Mercury vapors are colorless and odorless.

Inorganic mercuric compounds include mercuric sulphide (HgS), mercuric oxide (HgO), and mercuric chloride ($HgCl_2$). Some mercury salts (such as $HgCl_2$) are sufficiently volatile to exist as an atmospheric gas.

When mercury combines with carbon, the compounds formed are called „organic“ mercury compounds or organomercurials. The most common organic mercury compound in the environment is methyl mercury.

Being an element, mercury cannot be broken down or degraded into harmless substances. Mercury may change between different states and species in its cycle, but its simplest form is elemental mercury, which itself is harmful to humans and the environment.

Mercury exists in the atmosphere as elemental mercury, Hg (0), and oxidized mercury, Hg (II). Hg (II) can be inorganic (mercuric chloride, $HgCl_2$) ororganic (methyl mercury, MeHg). It can also be present as particulate mercury (mercuric oxide, HgO, or mercury sulfide, HgS). In the global atmosphere, Hg (0) is the dominant form.

3.2 Emission of mercury

Mercury is emitted into the atmosphere through both naturally occurring and anthropogenic processes. Natural processes include volatilization of mercury in marine and aquatic environments, volatilization from vegetation, soils and volcanic emissions. The natural emissions are thought to be primarily in the elemental mercury form.

Anthropogenic sources of mercury are numerous and worldwide. Mercury is produced by the mining and smelting of cinnabar ore. It is used in chlor-alkali plants (producing chlorine and sodium hydroxide), in paints as preservatives or pigments, in electrical switching equipment and batteries, in measuring and control equipment (thermometers, medical equipment), as a catalyst in chemical processes, in mercury quartz and luminescent lamps, in the production and use of high explosives using mercury fulminates, in copper and silver amalgams in tooth-filling materials, and as fungicides in agriculture (especially as seed dressings).

Globally, the major sources of anthropogenic mercury emissions are fossil fuels combustion for power and heating, artisanal and small-scale gold production, metal production, cement production, waste incineration, land filling, steel scrap, release by breaking and waste recycling.

Burning of waste containing-mercury is also one of the sources of the anthropogenic mercury emissions. In most cases, waste products are treated in an environmentally unsound manner, such as open burning, landfill fire, incinerators, etc.

Cremation is not practiced in Lebanon or Morocco.

Mercury in the atmosphere

In the atmosphere, only Hg0 has been tentatively identified with spectroscopic methods.

In the literature, we found that the typical concentrations of mercury and its compounds in ambient air in Europe may range between 1.0 and 3.6 ng/m^3 for elemental mercury.

Atmospheric mercury concentrations are generally very low; the dominant form in the atmosphere is a vapor-phase elemental mercury.

Mercury releases into the atmosphere are emitted from different points:

- Emissions from major point sources and diffuse sources such as industrial and housing fossil fuel combustion;
- Diffuse releases from uncontrolled waste products (fluorescent lamps, batteries, thermometers, mercury switches, lost teeth with amalgam fillings etc.);
- Evaporation of previous discharges to soil and water;

- Evaporation of mercury disposed of on landfills;
- Re-emission of mercury deposited from atmosphere.

Behavior of mercury in the environment

Once mercury enters into the environment, it permanently exists in the environment by changing its chemical forms. It may change between different states and species in its cycle, but its simplest form is elemental mercury, which itself is harmful to humans and the environment.

Hg0 has an average residence time in the atmosphere of about one year and will thus be distributed fairly evenly in the atmosphere.

3.3 Toxicity and health impacts

Mercury is highly toxic and may be fatal if inhaled and harmful if absorbed through the skin. Around 80% of inhaled mercury vapor is absorbed in the blood through the lungs. It may cause harmful effects to the nervous, digestive, respiratory, immune systems and to the kidneys, besides causing lung damage. Adverse health effects from mercury exposure can be: tremors, impaired vision and hearing, paralysis, insomnia, emotional instability, development deficits during fetal development, attention deficit, and development delays during childhood. **Recent studies suggest that mercury may have no threshold below which some adverse effects don't occur.**

The health effects of mercury vapor have been well studied. Damage is mainly to the nervous system, but effects are also seen, depending on the dose, in the oral mucosa and the kidney. There have been several instances of mercury poisoning reported worldwide. The most famous large-scale mercury poisoning occurred at Minamata Bay, Japan, in 1952. The Chisson Chemical Company dumped mercury in Minamata harbor. The population of Minamata Bay ate contaminated fish from this harbor. As a result, 397 people were affected. Of these, 68 people died. Minamata was the first known instance of widespread mercury poisoning. Mercury poisoning is sometimes referred to as „Minamata disease“. In 1965 in Niigata, Japan, 330 people were affected by eating contaminated fish. 13 of these people died. In Iraq in 1961, in Pakistan in 1963, and in Guatemala in 1966, over 30 people were affected in each case by eating flour made from seeds treated with mercury containing fungicides.

3.4 Mercury use in health care settings and dentistry

Mercury is used in many different ways in hospitals, clinics, and doctor's offices. First, mercury is contained in many common medical measuring devices: sphygmomanometers - blood pressure devices, thermometers, and a number of gastro-intestinal devices, such as cantor tubes, esophageal dilators (bougie tubes), feeding tubes and Miller Abbot Tubes. As in other types of instruments, mercury has traditionally been used in these devices because of its unique physical properties, including its ability to provide highly accurate measurements.

Mercury is also used in a number of products in health care settings not specified to healthcare. These include electrical and electronic devices, switches (including thermostats) and relays, measuring and control equipment, energy-efficient fluorescent light bulbs, batteries, dental amalgam, and laboratory chemicals.

Mercury spills in hospitals, clinics and laboratories pose risks to doctors, nurses, other health care workers and patients. The most common exposure routes are through inhalation or through contact with the skin. The risk of exposure to mercury is highest in warm or poorly ventilated rooms.

If not cleaned up properly, spills even of small amounts of elemental mercury, such as from breakage of thermometers, can contaminate indoor air and lead to serious health consequences. Since mercury vapor is odorless and colorless, people can breathe mercury vapor without knowing it.

Incubators used to house premature infants have been found to contain mercury droplets from broken mercury thermostats. Use of mercury products and devices in a hospital setting can also affect the downstream environment. Medical waste containing mercury, including the remains of a cleaned-up spill, can end up in aquatic environments and the atmosphere through improper disposal.

Dentistry

Approximately 240-300 tons of mercury are used as an ingredient in dental amalgam by dentists worldwide each year. Dental amalgam contains approximately 50% elemental mercury, 30% silver and 20% other metals such as copper, tin and zinc.

Some countries are taking a precautionary approach to protect the environment from the harmful effects of mercury and are taking measures to reduce the use of mercury in dentistry. In Lebanon and Morocco, many dentists have begun to voluntarily reduce the use of mercury amalgams.

Alternatives to mercury dental amalgam exist, such as composites (most common), glass ionomers and copolymers (modified composites). These are all effective alternatives that are generally considered more attractive than traditional amalgam.

Some countries have restricted the use usage of mercury thermometers or have banned them without prescription. A variety of associations have adopted resolutions encouraging physicians and hospitals to reduce and eliminate their use of mercury containing equipment.

3.5 Potential sources of mercury emissions to the atmosphere

In Lebanon there is very limited information on atmospheric mercury emissions from different potential emission sources. Mercury emissions are not regulated in Lebanon for industrial plants and other combustion processes.

Combustion processes

The major sources of atmospheric mercury emission are the combustion of fossil fuel in power generation plants, industrial commercial boilers, cement plants, and residential combustion.

About 90% of Lebanon's total capacity to generate electricity is based on fossil fuel combustion processes. Heavy fuel oil and various diesel fuel grades are being used in thermal power plants and industrial and commercial boilers. Mercury is not tested in the fuel, and it is not routinely analyzed in the slag or ash from their steam boilers.

Concentrations of mercury in fuel oil depend on the type of oil used. No comprehensive oil characterization studies have been done, but data from literature reports indicate that mercury concentrations in crude oil range from 0.023 ppm wt to 30 ppm wt, while the range of concentrations in residual fuel oil is from 0.007 to 0.17 ppm wt, for heavy fuel oil is about 0.004 ppm wt of mercury, and for distillate oil is 0.001 ppm wt mercury. In Lebanon heavy fuel oil and diesel fuel appear to be the principal fuel used in power plants and industrial and commercial boilers.

The petroleum cock is the principal fuel used in cement factories in Lebanon. Some of them burn „alternate“ fuel, including some kind of waste (used oil and used tires etc.).

Mercury emitted to the air from dumps and landfills

Mercury is also emitted by fluorescent lamp breakage. In Lebanon, there is neither a recycling process of fluorescent lamps nor any other mercury containing electric devices nor is there a separate collection system established.

The delivery and crushing activities can trigger the release of the mercury from the products. A significant amount of mercury is released from broken fluorescent light bulbs disposal at solid waste facilities. Fluorescent bulbs contain a small amount of mercury vapor and a larger amount of mercury in a phosphor powder or dust form.

Mercury emitted from dental amalgam

Mercury is emitted from dental amalgam during amalgam formulation operations and from spills and scraps in the dentist offices during dental operations. No official information has been compiled regarding amount of dental amalgam formulated in Lebanon. Some unofficial data indicates that an average 214 kg of mercury per year are imported to Lebanon. Amalgam is prepared in several dentist offices.

Forest fires increase mercury emissions

Mercury is a global pollutant arising from many sources, including biomass burning which includes both wildfires and intentional fires to clear land. A recent study estimates that mercury emissions from biomass burning make up 8% of total global mercury emissions.

Mercury emissions from biomass burning have received growing attention. Forests in particular act as mercury sinks because atmospheric mercury collects on foliage. Studies estimate that global mercury emissions from biomass burning are about 8% of known anthropogenic and natural atmospheric emissions.

3.6 Mercury-related information in Lebanon

Mercury baseline information from Lebanon (2001-2005) indicates that the average imported mercury quantity is about 214 kg/year, and the quantity of thermometers imported is about 427,517. The estimated releases of mercury are about 31 kg/year, which is about 14.5% of the total imported quantity.

A number of academic research papers have been carried out in Lebanese academic institutes and universities. These papers studied the occupational exposure of dentists to mercury by measuring mercury concentration in the hair of professionals in dentist clinics. Some studies are related to food exposure-mercury in fish stocks- in Lebanon while others are related to the levels of mercury in the Lebanese sea water, or in soils and sediments. Studies related to mercury air emissions are a missing fragment.

A GEF funded project titled: „Demonstrating and promoting best techniques and practices for reducing health-care waste to avoid environmental releases of dioxins and mercury" has been executed by the Ministry of Environment and managed by UNDP. The overall goal of this project is to protect public health and the global environment from impacts of dioxin and mercury releases. The project focuses primarily on activities such as promoting the use of non-burn waste treatment technologies, improved waste segregation practices, and the use of appropriate alternatives to mercury-containing devices.

Currently, there are no national mercury assessment or evaluation instruments available.

The only legal texts concerning hazardous goods and waste in Lebanon are two laws:

- Law 64/1988: protection of environment from pollution from harmful wastes and hazardous materials.
- Decree 13398/2004: specification of types of medical wastes and their disposal. This decree, in his sixth article, 10th point, required the separate collection for recycling, reusing or recovery of mercury and mercury-containing waste.

However, these and other environmental legislation are not implemented fully.

3.7 Concerns on mercury

Mercury has become an increasingly popular chemical of concern over the last several years, both on the local, regional, and international levels.

Efforts have been taken to assess and put solid figures on mercury use, demand, and emissions around the globe. The United Nations Environment Program (UNEP) released its Global Mercury Assessment in 2002 (UNEP Report), citing information and comments submitted by 81 countries in Africa, Asia, Europe, Latin America and the Caribbean, North America and the Southwest Pacific.

Several significant findings emphasize the reality of mercury pollution as a global problem.

A comprehensive global treaty on the reduction of mercury releases to protect human health and the environment, organized and developed by the United Nations Environment Program, was agreed to be developed by 140 countries in a historic UNEP Governing Council decision in 2009.

It aims to reduce mercury supply and demand, and boost capacity for safe storage of mercury stockpiles, among others. Two sessions of the Intergovernmental Negotiating Committee (INC) have been concluded so far - INC1 in Stockholm, Sweden, and INC2 in Chiba, Japan. The third session INC3 will be held in Nairobi, Kenya, in October-November 2011. UNEP aims to have the treaty adopted in 2013, after five more global negotiating sessions.

4 PART II - OBJECTIVES AND METHODOLOGY

4.1 Objectives

IndyACT initiated a measurement campaign of mercury pollution levels in several areas in Lebanon and Morocco as preliminary step to address the gap in information on mercury in these two countries. There is no available data that assess mercury pollution in the air - indoor and outdoor - in Lebanon or Morocco. With the technical assistance of the European Environment Bureau and the Zero Mercury Working Group, and with the collaboration of the Moroccan Centre Anti-Poison in Morocco, IndyACT collected data using Lumex RA-915+ mercury vapor analyzer to investigate mercury air pollution in Lebanon and Morocco. The objectives of this research are as follows:

A- Raising public and political concern around mercury contamination in Lebanon and the region through providing scientific evidence on instances or examples of mercury contamination in Lebanon and Morocco;
B- Determine mercury concentrations in air in various chosen locations in Lebanon and Morocco;
C- Establish a preliminary background level of mercury vapor contamination in Lebanon and Morocco;
D- Enhance public awareness on hidden mercury air pollution and its impacts to society; and
E- Encourage action from governments, academies, related industries, civil societies and other relevant stakeholders.

4.2 Lumex RA-915+ Mercury Spectrometer

The RA-915+ Mercury Analyzer is a continuous ambient air monitor direct-read instrument based upon the principle of differential atomic absorption spectrometry technique, which is implemented using the direct Zeeman effect (Zeeman Atomic Absorption Spectrometry using High Frequency Modulation of Light Polarization ZAAS-HFM). A glow discharge mercury lamp is placed in a permanent magnetic field, whereby the 254-nm mercury resonance line is split into three polarized components, only two of those, s+ and s-, which are circularly polarized in the opposite directions, being detected for analysis. After passing through a polarization modulator, which modulates the polarization at a frequency of 50 kHz and thus triggers the line components in turn, the radiation then passes through a multi-path cell, whose equivalent optical length is about 10 m. Being equipped with narrow-band high reflectivity mirrors, the cell isolates solely the 254-nm resonance line and suppresses all the no-resonance and stray radiation. A logarithm of the intensity ratio of s+ and s-, which is proportional to the mercury atom concentration in the cell, is determined upon detecting the radiation by a photo-detector and subsequent analog-digital conversion of its electric signal by a built-in microprocessor. The measurement results are read out from a built-in LC display, or are transmitted to a computer for further processing or data storage. In this measurement technique, the analytical signal depends only on mercury concentration and is independent of the presence of dust, aerosols, and other foreign contaminants in the analytical cell.

The Lumex is also capable of testing mercury concentration in water, soil and other media; however, these media require special attachments. For the purpose of this investigation, only mercury in air was detected and quantified.

Advantages of Lumex:

- Direct detection of mercury without its preliminary accumulation on a gold sorbent;
- Extremely low mercury detection limit and high selectivity;
- Field operation from a built-in battery for mercury detection in atmospheric air and industrial gases;
- Totally automated unattended standalone mode of operation for continuous monitoring of the environment for mercury pollution.
- Built-in microprocessor, LC display and computer interface for operational customized report output and storage in a standalone computer.
- Optional attachments using the „cold vapor“ technique for assaying water solutions and the pyrolysis with afterburning for assaying solid samples of complex composition.

The portable Lumex has been used for continuous automobile surveys of mercury distribution in ambient air. Car-borne mercury surveys were carried out in a several cities in Russia, Ukraine, Kyrgyzstan, Slovenia, Croatia and Czech Republic.

The portable spectrometer is used for continuous mercury determination in air. It is extremely sensitive device. It allows direct measurement of mercury at the background level - even below 2 ng/m^3 with a response time of 1 sec.

In the case of the automobile survey, the analyzer is placed in a car, and ambient air is continuously pumped through the analytical cell at a rate of 20 L/min. The car speeds from 5-60 km/h. Experiments with serial instruments show that the real detection limit values for Lumex are 0.3 ng/m^3 during stop, and 2 ng/m^3 on the way with speed of 30-60 km/h.

The Lumex is a popular apparatus for a wide range of environmental monitoring applications in Europe and the United States.

In our investigation in Lebanon and Morocco, we used the Lumex unit that is property of the European Environmental Bureau and has been offered to IndyACT during the execution of the project.

Specifications:

- Size and weight (with a storage battery and recharger): 460x210x110 mm, 7.58 kg
- Power requirements: 110/220 V, 50/60 Hz 15 W AC or 10-14 V DC

Analytical characteristics

Samples	Detection limit	Sample volume	Atomization technique	Number of analyses per hour
Ambient air	0.3 - 2 ng/m^3	20 L/min	without atomization	real-time assaying with a response time

4.3 Methodology

Parameters of measurements

For the realization of our investigation in Lebanon and Morocco we chose to set the following operation parameters:

- The baseline correction time (Tbas = 20 seconds);
- The frame time (Tfr = 10 seconds);
- The integration time (Tint = 150 seconds);
- The low limit (LL = 2ng/m^3);
- The high limit (HL = 2000 ng/m^3);
- The duration of each measurement is 10 minutes. The results are the average readings for each 10 seconds during 10 minutes, ie the average concentration of 60 scans.
- The measurement units: Mercury vapor concentration is measured in terms of ng/m^3.
  1 ng/m^3 = 0.001 μg/m^3 = 0.000001 mg/m^3
  1mg/m^3 = 1000 μg/m^3 = 1000.000 ng/m^3

  Conversion Factors:
  To convert concentrations in air (25°C) from ppm to mg/m^3: mg/m^3 = (ppm) × (molecular weight of the compound)/(24.45). For elemental mercury: 1 ppm = 8.2 mg/m^3. For mercuric chloride: 1 ppm = 11.1 mg/m^3. For methyl mercuric chloride: 1 ppm = 10.3 mg/m^3.

The Lebanese time is the time displayed on the machine and on the diagrams minus 5 hours.

The Moroccan time is the time displayed on the machine and the diagrams minus 7 hours.

Preparatory steps

Before each measurement of mercury concentration in the air, the Lumex was allowed to warm-up using the machine's baseline function for at least 20 minutes, and then the device was ready for measurements. We proceed to verify the operation parameters. After that, we check the analyzer serviceability by proceeding the test command. During the test, we observe the deviation (R%), which is the relative deviation of the measured value of the mercury vapor concentration in the test cell from the tabulated value. If the deviation is below 30% we consider the analyzer is ready for measurements.

Data collection

The Lumex collects real-time readings continuously. A reading is taken every second, and readings are averaged over every period of ten seconds. For extended monitoring periods, the accompanying Data Logger software was used for convenience. This program logs all readings for a pre-set monitoring period. For our monitoring, IndyACT used a default monitoring period of 10 minutes. The machine was placed in the center of the sampling area and allowed to run for the pre-set monitoring period. To address the problem of large sampling sites, multiple points were sampled in the specified site (multi-point monitoring).
In some sites we have made continuous measurements while riding in a car with a speed between 30-50 km/h.

The amount of mercury vapor detected by the Lumex is dependent not only on the actual amount of mercury in the area, but on weather and climate factors as well.

Temperature

In general, the Lumex will be able to detect a higher concentration of mercury in areas with higher temperature. Heat causes mercury to volatilize or evaporate more easily, meaning that mercury vapor will be more „available" for the machine to detect. The Lumex, however, does not necessarily depend on higher temperatures to pick up any mercury reading. As long as mercury is present in the air, the Lumex analyzer is able to pick this up.

Wind direction and speed

If the wind is blowing the ambient air away from the input hose of the Lumex, rather than towards the input hose, this may result in a lower concentration detected. Similarly, wind traveling at high speeds may result in lower readings.
Other climactic factors such as humidity and air pressure have also been seen to affect the readings.

A Kestrel 4500 Pocket Weather Tracker was used to record the atmospheric conditions during the measurements periods.

Data processing

Data is retrieved from the Lumex using the Data Logger software. For each monitoring, the program produces a graph plotting the instantaneous mercury vapor concentration per second for the entire period. The minimum, maximum, average mercury concentration and the deviation are also given automatically.

For all measurements made in Lebanon and in Morocco, any measurement that has a deviation greater than 30% was considered void.

5 PART III - RESULTS, DISCUSSION AND RECOMMENDATIONS

5.1 Mercury levels measured in rural areas - Lebanon

In Table 1 and Figure 1 the results of the measurements for mercury levels in atmospheric air in rural areas in Lebanon are shown. Measurements were taken in areas very far off from any industrial sources, in Anti-Lebanese Mountains regions, in the South, the North and Mount Lebanon. The average values of concentration may range between 1.6 - 2.7 ng/m^3, and the maximum values range between 3.3 - 4.7 ng/m^3.

We consider these levels as medium values for the ambient air in rural areas.

Mercury is emitted to the atmosphere through both naturally occurring and anthropogenic activities.

In Europe, the typical concentrations of mercury in ambient air may range between 1.0 and 3.6 ng/m^3. The average levels measured in Lebanese rural areas are comparable to those in Europe, despite the incomparability in term of industrialization and quantities of mercury used or released into the environment between Lebanon and Europe. The maximum values measured in Lebanon rural areas may have their explanation by two facts: the first is the existence of uncontrolled dumps everywhere in the rural areas. Such dumps receive any kind of wastes, including mercury-containing waste (fluorescent lamps, batteries, broken thermometers etc.). The second is the burning of waste containing-mercury. In most of cases, waste products are treated in an environmentally unsound manner, such as open burning, dump fire, etc. Forest fires and the burning of biomass, which is a bad practice in the Lebanese rural regions, are considered also a factor explaining the source of rural mercury levels.

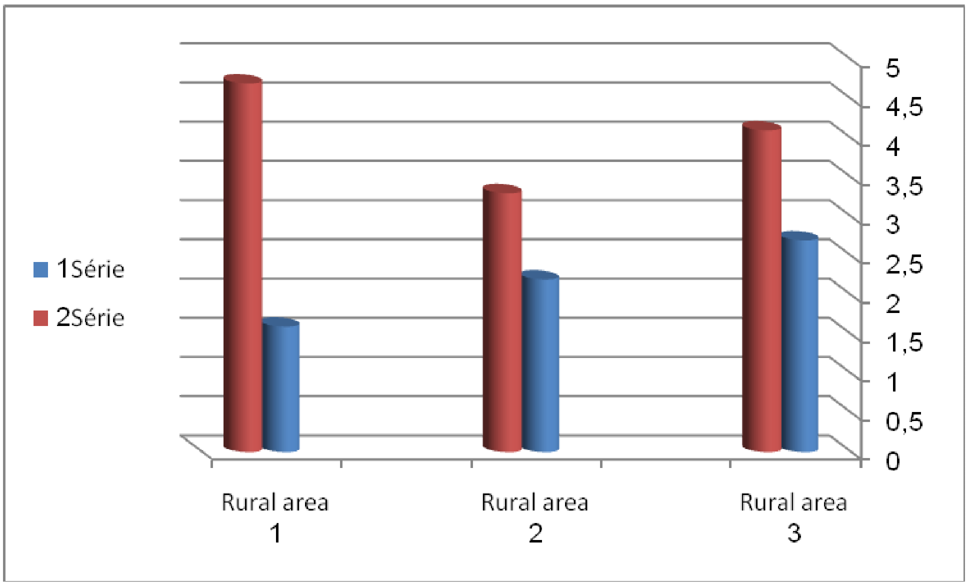
Recommendations:

- Limit the spread of uncontrolled dumps on the hills and valleys near villages. Encourage environmentally sound management of waste, and develop a system of separate collection of waste containing mercury.
- Avoid burning waste in uncontrolled dumps. Develop a strategy to prevent forest fires.
- Develop a proper waste management, including segregation and collection at source of mercury containing waste.
- Stop the practices of burning dry grass and garden waste, and encourage composting of such organic farm waste.

Table 1: Mercury levels in atmospheric air in rural areas, Lebanon

Location	Sampling date/Time	Average reading (ng/m^3)	Maximum reading (ng/m^3)	Minimum reading (ng/m^3)	Deviation (%)
Rural area 1, South Lebanon	May 20, 2011/ 12:23-12:33	1.6	4.7	0.3	0.8
Rural area 2, South Lebanon	May 20, 2011/ 12:35-12:45	2.2	3.3	0.9	0.6
Rural area 3, South Lebanon	May 20, 2011/ 12:45-12:55	2.7	4.1	1.5	0.7

Figure 1: Mercury levels in atmospheric air in rural areas, Lebanon



Series 1: average values
Series 2: maximum values

5.2 Mercury levels in the atmospheric air in the cities - Lebanon and Morocco

In Table 2 and Figure 2, the results of measurements of mercury in the atmospheric air of some cities in northern, southern, and central Lebanon, and in Moroccan cities are shown.

We can distinguish two groups of results: mercury levels measured in urban areas at Choueyfat, Khaldeh, Jbeyl, Beirut Sassine Square, Beirut Berj Abou Haydar and Saida's North entrance in Lebanon, and Rabat's South entrance in Morocco are the first group. The results are compatible with the values of rural areas (between 0.5 and 4.3 ng/m^3). Mercury levels found in other areas, in Saida Etoile Square, and in Beirut in locations near to hospitals at Ashrafiyeh (Rizk Hospital) and Manara (AUH Hospital) and near boilers of AUH in Lebanon, and in Casablanca in Morocco are the second group. The results are 4 to 5 times higher (between 5 and 20 ng/m^3).

These levels are comparable to results found in the basin of the Uatuma River in Amazon, Brazil, where the mean concentrations of mercury were 9.1 - 14.0 ng/m^3.[1] This location is in the tropical rain forest and is influenced by gold mining sites where quantities of mercury are used and released. The levels from the second group in Lebanese and Moroccan cities are also comparable to mercury concentrations in air in a central Italian region where they were in the range of 5.7 - 20.2 ng/m^3.[2]

So we can conclude that in parts of the city where there are no direct sources of mercury such as hospitals and other healthcare establishments, the concentrations of mercury in the atmospheric air are very low and comparable to those found in rural areas. While near hospitals, especially when practicing the incineration of hospital waste at the site from time to time, and in the vicinity of the boilers when burning large amount of fuel, and when traffic is heavy, it is found that mercury concentrations in the air grows in a significant manner. Knowing that the levels of mercury in oil refinery products should not be neglected, we can say that combustion gases also contribute to higher levels of mercury in urban air. In the table below are found the levels of mercury in various petroleum refinery products.

[1] „Atmospheric mercury concentrations in the basin of the Amazon, Brazil". Noriyuki Hachiya and all. November 19, 1997. hachiya@ipc.akita-u.ac.jp

[2] „Mercury levels in rain and air and the subsequent washout mechanism in a Central Italian region." Romano Ferrara and all. Available online April 14, 2003.

Level of mercury in refinery products

Product	Amount (ppb) parts per billion
LPG	<10
Gasoline	0.22 - 3.2
Diesel	0.4 - 3
Naphtha	3 - 60
Petroleum coke	up to 250
Elemental sulfur	10 - 10000

Source: Hydrocarbon Engineering September 2006

Recommendations:

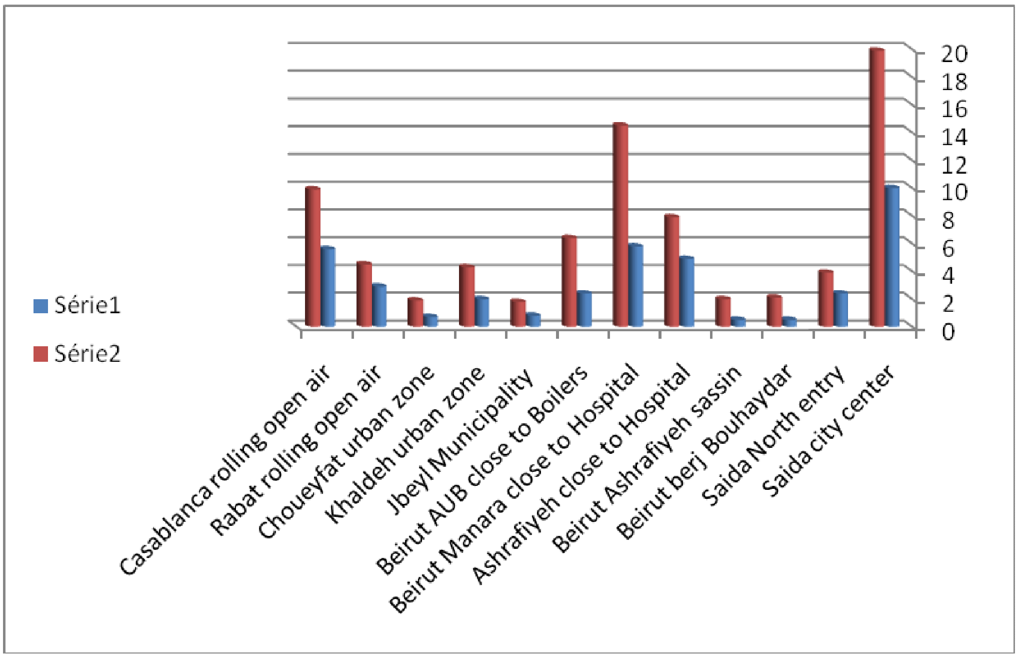
- Avoid construction of coal-fire power plants in the future.
- Avoid waste incineration, and in particular hospital waste.
- Develop a transportation plan in cities to avoid traffic jams.
- Introduce electric or hybrid powered transport.
- Encourage the urban use of solar energy for water heating and lighting.

Table 2: Mercury levels in the atmospheric air in the Cities - Lebanon and Morocco
(Saida, Beirut, Jbeyl, Khaldeh, Choueyfat, Rabat and Casablanca)

Location	Sampling date/Time	Average reading (ng/m^3)	Maximum reading (ng/m^3)	Minimum reading (ng/m^3)	Deviation (%)
Saida, City, Etoile Palace	May 06, 2011/ 10:23-10:33	10.0	19.9	0.7	5.1
Saida, North city entry	May 07, 2011/ 13:28-13:38	2.4	3.9	0.3	1.0
Beirut, Berj Bouhaydar, urban area, open air	May 25, 2011/ 09:31-09:41	0.5	2.1	0.2	0.4
Beirut, Achrafiye, Sassin Place	May 25, 2011/ 9:59-10:09	0.5	2.0	0.0	0.9
Beirut, Achrafiye, close to Hotel Dieu Hospital	May 25, 2011/ 10:14-10:24	4.9	7.9	2.0	1.7
Beirut, Manara corniche, close to AUH Hospital	May 25, 2011/ 10:42-10:52	5.8	14.5	0.0	3.6
Beirut, AUB, close to boilers	May 25, 2011/ 10:56-11:06	2.4	6.4	0.7	1.1
Jbeyl, Municipality, open air	May 21, 2011/ 10:50-11:00	0.8	1.8	0.0	0.5
Khaldeh, urban zone, open air	July 19, 2011/ 10:17-10:27	2.0	4.3	0.8	0.8

Choueyfat, urban zone, open air	July 19, 2011/ 10:32-10:42	0.7	1.9	0.4	0.5
Casablanca city, rolling , open atmospheric air	June 15, 2011/ 11:28-11:38	5.6	9.9	1.2	2.3
Entry Rabat city, open atmospheric air, rolling	June 15, 2011/ 16:47-16:57	2.9	4.5	0.2	1.2

Figure 2: Mercury levels in the atmospheric air in the Cities - Lebanon and Morocco



Series 1: average values
Series 2: maximum values

5.3 Mercury levels in the atmospheric air in cement industry zones in Lebanon and Morocco

(Chekka-Heriy and Sibline in Lebanon and Temara-Ein Atiq in Morocco)

Table 3 and Figure 3 show the results of the measurements of mercury in the atmospheric air in cement industry areas in Lebanon and Morocco. The measurements are performed several times in different parts of the industrial zones and at different times, and consequently, in varying weather conditions, particularly in terms of wind directions. All measured levels are higher than those found at rural areas, a fact which shows the influence of the cement industry on the quality of the atmospheric air in terms of mercury pollution.

We know that all the cement factories in Lebanon, those found in Chekka - Heriy and Sibline, use petroleum coke as a fuel of choice in first place. Some factories also use by-products as alternative fuels (tires and other types of energy-rich waste).

In Morocco, the summary report of June 2010 „Assessment of exposure due to pollution by mercury, lead and cadmium“ indicates that the release of mercury in the atmospheric air in the manufacture of cement in Morocco is estimated at 1596 kg/year (2008). As we saw in point (2), the petroleum coke contains more than 250 ppb of mercury waste. Given the huge amounts of petroleum coke and other by-products used in cement kilns, we can conclude that releases of mercury in atmospheric air are important and deserve to be studied in depth.

We can distinguish three groups of levels:

- Low: between 2 to 6 ng/m^3
- Medium: between 6 to 20 ng/m^3
- Moderate: between 20 to 80 ng/m^3

The difference between the three groups is due to several factors:

- First, the difference in wind direction regarding the emission source and the measuring point. In areas where the wind direction is opposite to the direction of the source low levels of mercury in the air were measured.
- Medium levels are due to turbulence in the wind that disperses the pollutants in all directions.
- The relatively moderate levels are possibly due to the introduction of an alternative fuel more or less rich in residue of mercury, or a batch of petroleum coke richer in mercury.

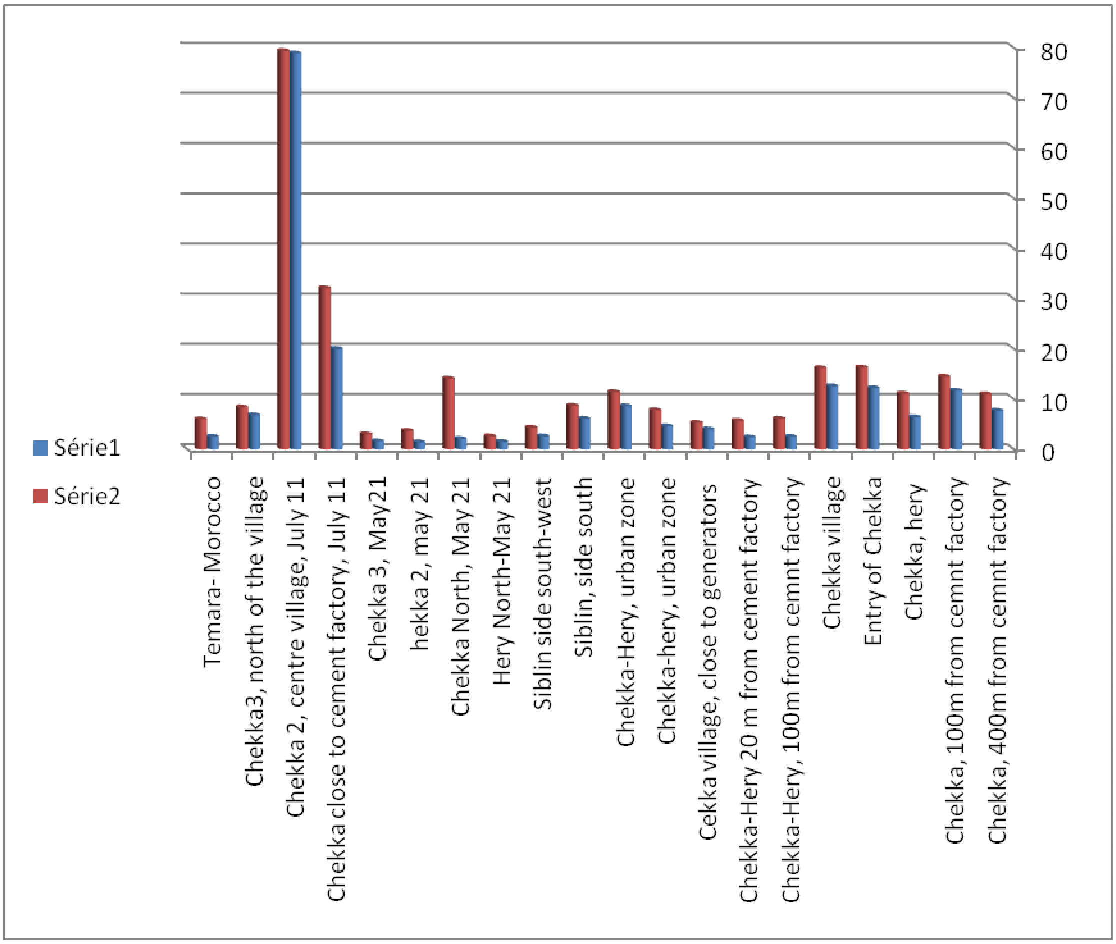
Table 3: Mercury levels in atmospheric air in cement industrial zones - Lebanon (Chekka-Heriy and Siblin) and Morocco (Temara)

Location	Sampling date/ Time	Average reading (ng/m^3)	Maximum reading (ng/m^3)	Minimum reading (ng/m^3)	Deviation (%)
North, Heriy-Chekka, cement industrial zone, Heriy, 400 m from cement factory, open air	May 16, 2011/ 10:20-10:30	7.7	11.0	4.2	1.6
North, Heriy-Chekka, cement industrial zone, Heriy, 100 m from cement factory, open air	May 16, 2011/ 10:33-10:43	11.7	14.5	7.2	1.5
North, Heriy-Chekka, cement industrial zone, Heriy, open air	May 16, 2011/ 10:46-10:56	6.4	11.1	3.1	2.1
North, Heriy-Chekka, cement industrial zone, entry of Chekka open air	May 16, 2011/ 11:00-11:10	12.2	16.3	9.2	1.9
North, Heriy-Chekka, cement industrial zone, Chekka village, open air	May 16, 2011/ 11:11-11:21	12.6	16.2	8.3	1.6

North, Heriy-Chekka, cement industrial zone, Heriy, Chekka village, 100 m from cement factory, open air	May 16, 2011/ 11:24-11:34	2.5	6.1	0.3	1.2
North, Heriy-Chekka, cement industrial zone, Chekka village, 20 m from cement factory, open air	May 16, 2011/ 11:37-11:47	2.4	5.7	0.6	1.1
North, Heriy-Chekka, cement industrial zone, Chekka village, cement factory, Generators open air	May 16, 2011/ 11:48-11:58	4.0	5.3	3.0	0.4
North, Heriy-Chekka, cement industrial zone, Chekka, urban zone, open air	May 16, 2011/ 12:04-12:14	4.6	7.8	1.9	1.2
North, Heriy-Chekka, cement industrial zone, Chekka -Heriy village, urban zone, open air	May 16, 2011/ 12:22-12:32	8.6	11.4	3.1	1.6
Cement industrial zone, Siblin, Mont-Lebanon, side south	May 20, 2011/ 13:56-14:06	6.1	8.7	2.8	0.7

Cement industrial zone, Siblin, Mont-Lebanon, side south-west	May 20, 2011/ 14:25-14:35	2.6	4.3	0.6	0.9
Heriy, North Lebanon, open air	May 21, 2011/ 11:52-12:02	1.5	2.6	0.1	0.6
Chekka 1, North Lebanon, open air	May 21, 2011/ 12:21-12:31	2.1	14.1	0.0	3.8
Chekka 2, North Lebanon, open air	May 21, 2011/ 12:33-12:43	1.4	3.7	0.1	1.0
Chekka 3, North Lebanon, open air	May 21, 2011/ 12:45-12:55	1.6	3.0	0.2	0.6
Cement industrial zone (Chekka) point 1 close to Holci	July 11, 2011/ 11:24-11:34	20.0	32.1	4.0	9.4
Cement industrial zone (Chekka) point 2 in the center village	July 11,2011/ 12:09-12:12	78.9	79.4	78.5	0.3
Cement industrial zone (Chekka) point 3 north of the village	July 11, 2011/ 12:22-12:25	6.8	8.4	4.9	1.0
Temara, EinAtiq, Skheyrat, Cement factory zone, 500 m, open atmospheric air	June 15, 2011/ 11:13-11:23	2.5	6.0	0.4	1.9

Figure 3: Mercury levels in atmospheric air in cement industrial zones - Lebanon (Chekka-Hery and Siblin) and Morocco (Temara)



Series 1: average values
Series 2: maximum values

5.4 Mercury levels in the atmospheric air in chemical industry zone - Lebanon: Selaata. Multiple visits: effect of wind direction

In Table 4 and Figure 4 are shown the results of measurements of mercury in the atmospheric air in the region of Selaata, north Lebanon, near a chemical plant which produces sulfuric acid, phosphoric acid and fertilizer superphosphate and triple-superphosphate.

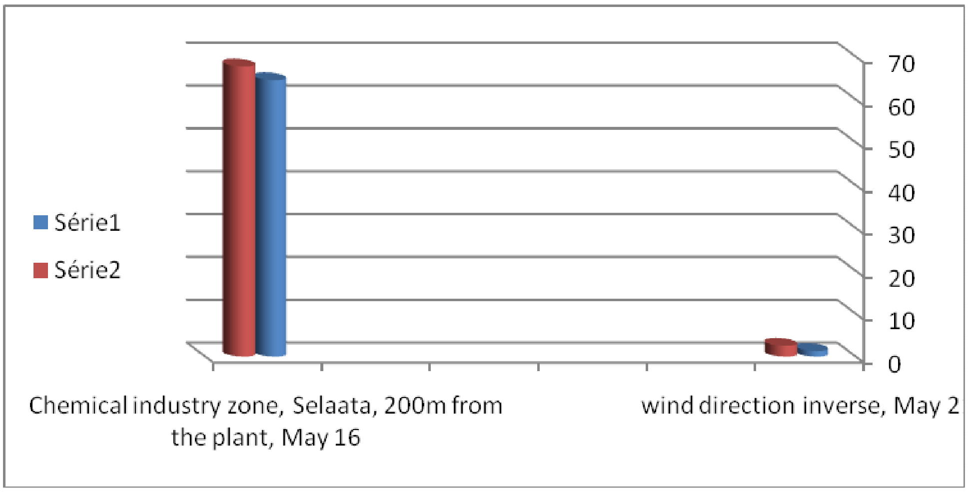
We visited the area two times, on May 16 and 21, 2011. We took measures about 200 m southeast of the plant. The first time we found a concentration of mercury in atmospheric air varying between 64.5 - 67.7 ng/m^3. The second measurement was at the same point and a concentration varying between 1.3 - 2.5 ng/m^3 was found. This important difference is certainly due to the change in wind direction between the two measures. This difference was also observed on the same dates in Chekka - Heriy, area of cement industry, which is only a few kilometers from Selaata.

This type of industry for the production of phosphoric acid and phosphate fertilizers, a large amount of phosphate rock is used, which contains residues of mercury levels varied according to the origin (for example, Moroccan phosphate contains from 44 to 66 ng/g). The plant uses the phosphate imported from Syria, which has rates similar to those of Morocco. It is also used for the production of sulfuric acid, a large amount of elemental sulfur, which contains, as we saw in the point (2), between 10 to 10,000 ppb of mercury, also varies depending on its origin. On the other hand, the fuel used for energy also contains a small amount of mercury deposit. Some of the mercury found in the different raw materials and fuels is emitted into the atmosphere.

Table 4: Mercury levels in atmospheric air in chemical industry zone, Selaata - Lebanon. Effect of wind direction.

Location	Sampling date/Time	Average reading (ng/m^3)	Maximum reading (ng/m^3)	Minimum reading (ng/m^3)	Deviation (%)
North, zone chemical industry, open air, Selaata village, 200 m from a chemical factory	May 16, 2011/ 12:47-12:57	64.5	67.7	52.7	2.4
Selaata, North Lebanon, open air	May 21, 2011/ 11:31-11:41	1.3	2.5	0.4	0.4

Figure 4: Mercury levels in the atmospheric air in chemical industry zone, Selaata - Lebanon



Series 1: average values
Series 2: maximum values

5M - Mercury levels in atmospheric air in chemical industry zone - Morocco Tetouane chlor-alkali, Coelma factory

In Table 5M and Figure 5M are shown the mercury concentrations measurements results in the atmospheric air in the region of Tetouane, Morocco, close to the factory Coelma of chlor-alkali, and along the small river, which passes next to the factory across the city of Tetouane to Madiaq, and receives industrial effluents from this plant. This plant is of particular importance regarding mercury pollution. It produces caustic soda, chlorine and other products according to the old technology (mercury cell) that uses mercury as a catalyst in its processes. Even as the mercury-catalyst is recovered at the end of the process, an amount is evaporated at work places posing occupational health challenges and another quantity is rejected with the liquid discharges from the factory posing environmental and public health challenges.

The summary report of June 2010 „Assessment of exposure due to pollution by mercury, lead and cadmium" indicates that the chlor-alkali factory uses an amount of 5.4 t/year of mercury and estimates that releases of mercury in atmospheric air from chlor-alkali plant in Morocco are 53 kg/year.

The measurement results clearly demonstrate that mercury exists all over the atmosphere of the entire region of the plant. This pollution is still detected in regions which are at far distances of the plant and on different levels of the atmosphere. This confirms that the plant is a **primary source** of pollution by mercury vapors.

Concentrations of mercury varying between 8.2 and 16.8 ng/m^3 were found at a distance of about 50 m in the open air, in front of the factory. This concentration is due most probably to evaporation from inside the factory, from stores of mercury and the operations room where the mercury cell function. This level of concentration measured outside allows us to assume, that the concentration of mercury in the air, on the workplace will reach tens or hundreds of times higher.

A few hundred meters away from the factory on the banks of the river, we could identify a point of sewage discharge. At this point the concentration of mercury measured in the air is between 9.8 - 37.7 ng/m^3. This concentration confirms the presence of mercury even in the discharge of sanitary wastewater, but this point is not the main point of discharge of industrial effluents from the factory.

At about 200 m from this point along the river we found a relatively significant concentration of mercury in the air reached 168 ng/m^3. So, this is close to the main point of discharge of industrial effluents, which remained unidentified because of the difficult nature of the shore. Nevertheless, the level of mercury stored in the air beside the river, during June when the temperature did not exceed 26°C and the evaporation was not accelerated by heat, means that mercury releases to the river are important, and pollution is probably disturbing the river and deserves to be studied in depth one.

Along the river, few kilometers away from the factory, the mercury concentrations in the atmospheric air were 82.9 ng/m^3. This fact also confirms the significant pollution of the river.

Even at about 10 km from the factory, but at 50-100 m from the shore, the mercury concentration was 7.7 ng/m^3 and in the city of Mediaq at about 15-20 km from the factory, the concentration in the air remained about 6.5 ng/m^3.

Three important conclusions can be drawn from these findings mentioned above:

1- In addition to the air at workplaces, the atmospheric air in Tetouane and suburbs should also be monitored periodically and should be a subject to an independent and comprehensive study.
2- The river is polluted by mercury and it is risky to practice any activities of recreation, leisure or fishing, and it is a real risk on the environment and public health.
3- The mercury concentrations in the air along the river, even at long distances confirm the conclusion that **the river has become a secondary source of mercury emissions in the atmospheric air.** Evaporation of mercury from river water depends on the temperature, and the concentration of mercury in a given location will depend also on the wind direction.

Recommendations:

1- We urge a change in the mercury cell technology in this plant as soon as possible and follow the modern technology of membrane or diaphragm as an existing mercury-free alternative.

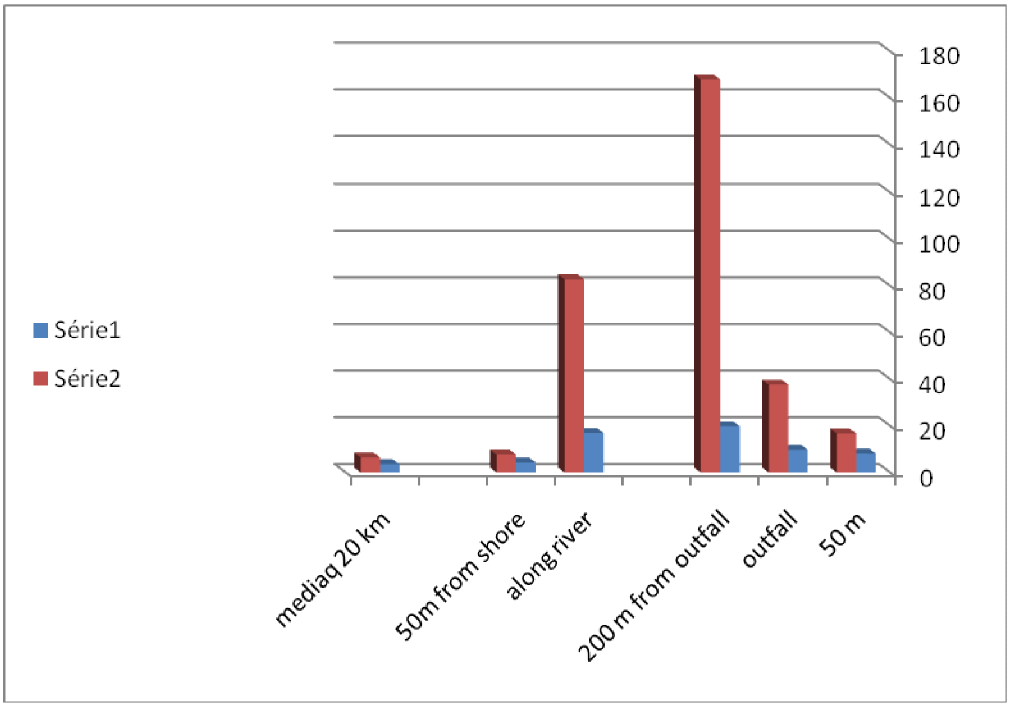
2- Placing the excess mercury from the plant in an environmentally sound storage to prevent the recirculation of the mercury in the Moroccan market and environment.
3- Develop a treatment plan of the river and all contaminated sites existing in the plant and its environment and the region.
4- Develop an environmentally sound disposal of wastes contaminated with mercury.

Table 5M: Mercury levels in atmospheric air in chemical industry zone, chlor-alkali, Coelma factory, Tetouane - Morocco

Location	Sampling date/Time	Average reading (ng/m^3)	Maximum reading (ng/m^3)	Minimum reading (ng/m^3)	Deviation (%)
Tetouane, Coelma front of the plant, chlor-alkali 50 m	June 11, 2011/ 11:42-11:52	8.2	16.8	2.7	4.3
Tetouane, the surroundings of the factory Coelma chlor-alkali in the point of discharge of sewage into the river	June 11, 2011/ 12:11-12:21	9.8	37.7	3.6	9.8
Tetouane, the surroundings of the factory Coelma chlor-alkali 200 m of the discharge of sewage into the river	June 11, 2011/ 12:25-12:35	19.9	168.0	0.3	34.2
Tetouane, the surroundings of the factory Coelma, chlor-alkali, rolling along the river next to the factory	June 11, 2011/ 12:39-12:49	17.0	82.9	1.3	18.1

Tetouane, the surroundings of the factory Coelma, chlor-alkali while driving along the river, next to left 50 m from the shore to the north,	June 11, 2011/ 12:52-13:02	4.4	7.7	0.9	2.0
Mediaq at 15-20 km from the plant Coelma, chlor-alkali, rolling along the same river, which crosses	June 11, 2011/ 13:16-13:26	3.6	6.5	1.6	1.3

Figure 5M: Mercury levels in atmospheric air in chemical industry zone, chlor-alkali, Coelma factory, Tetouane - Morocco



Series 1: average values
Series 2: maximum values

5.5 Mercury levels in the atmospheric air around power plants areas - Lebanon and Morocco

(Jieh power plant - Lebanon and refinery, chemical factory and power plant - Mohammedia, Morocco)

In Table 6 and Figure 6 are shown the results of the measurements of mercury concentrations in the atmospheric air near Jieh power plant in Lebanon and in Mohammedia in Morocco. In Jieh the power plant is the only industry in the region, while at Mohammedia in Morocco, in the region of the power plant there is also a refinery (SAMIR) and a petrochemical and electrolysis plant (SNEP).

Jieh thermal power plant in Lebanon uses heavy fuel oil and occasionally used oil which is mixed with the fuel that feeds the boiler. The total capacity of this plant is 330 MW.

According to the summary report given on June 2010 „Evaluation of exposures due to pollution by mercury, lead and cadmium“ the power plant of Mohammedia, Morocco, has two units that use coal and emit 133 kg/year of mercury into the atmosphere and other units use fuel and emit 420 kg/year of mercury into atmospheric air. A renovation project and back into compliance coal units with European standard was completed in July 2009. The production of these two units is 300 MW and the total output of the plant is 600 MW.

Measurements were taken at different distances from power plants. In Jieh, Lebanon, mercury was measured in the atmospheric air at a distance of 400 m, where we found a concentration between 6.6 - 12.7 ng/m^3, and at a distance of about 800 m where we found a higher concentration of 7.9 - 18.3 ng/m^3. In Mohammedia, Morocco, mercury in air was measured at 400 m, where we found a low concentration of 1.9 - 4.1 ng/m^3. At about 1000 m the concentration increased to 4.6 - 7.5 ng/m^3. Driving in the car away from the industrial area about 5 km we found an even greater concentration between 5.1 - 13.0 ng/m^3.

The Mercury Technology Services has published data on the amount of mercury in different types of fuel:

Mercury concentration in oil by oil type

Mercury concentration, ppm wt.			
Fuel oil type	-	**Range**	**Typical value**
Residual no. 6	-	0.002 - 0.006	0.004
Distillate no. 2	-		<0.12
Crude	46	0.007 - 30	3.5

Source: Mercury Technology Services, S. Mark Wilhelm, Ph.D. President and Principal Scientist.

As we see in heavy fuel oil No. 6 the mercury concentration is of average of 0.004 ppm wt.

It is known that coal is the richest fossil fuel in residue of mercury. Thus, the power plants that use heavy residual fuel oil and / or coal are a source of emission of mercury vapor in atmospheric air. A significant portion of mercury existing in the fuel and the coal will exit with exhaust gases, while another part remains in the ash.

It was found in Jieh, Lebanon, and in Mohammedia, Morocco, that the dispersion of mercury out of the way of power plant is at long distance along the plume of smoke following the wind direction.

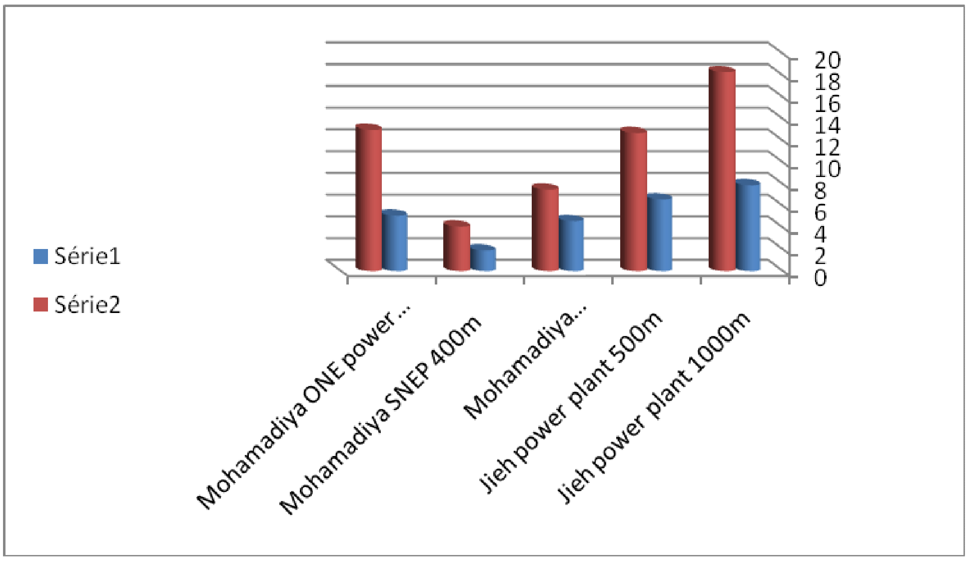
The issue of dispersion of pollution emitted from industrial sources and the development of the area at risk of pollution deserves to be studied in relation with unintentional emissions of mercury.

Table 6: Mercury levels in the atmospheric air around power plants areas - Lebanon and Morocco

Location	Sampling date/Time	Average reading (ng/m^3)	Maximum reading (ng/m^3)	Minimum reading (ng/m^3)	Deviation (%)
Open air near to Jieh power plant, 500 - 1000 m	May 11, 2011/ 14:55-15:05	7.9	18.3	4.1	2.6
Open air near to Jieh power plant, 200 - 500 m	May 11, 2011/ 15:05-15:15	6.6	12.7	0.0	3.2
Mohamadiya, SAMIR refinery, 1000 m, open atmospheric air	June 15, 2011/ 10:20-10:30	4.6	7.5	1.8	1.7

Mohammadia, SNEP chemical industry and SAMIR refinery about 400 m atmospheric open air	June 15, 2011/ 10:36-10:46	1.9	4.1	0.2	0.9
Mohammadiah ONE (power plant) close to SNEP	June 15, 2011/ 10:52-11:02	5.1	13.0	0.6	2.2

Figure 6: Mercury levels in the atmospheric air around Power plants areas-Lebanon and Morocco



Series 1: average values
Series 2: maximum values

5.6 Mercury levels in the atmospheric air around uncontrolled dumps in Lebanon and Morocco

(Nabatieh - Kfar Tibnit, Tyr - RasElAin, Saida in Lebanon, and Casablanca-Mediouna in Morocco)

In Table 7 and Figure 7 are shown the results of the measurements of mercury concentrations in the atmospheric air near some uncontrolled dumps in Lebanon and Morocco.

In Lebanon, it has not yet been established an environmentally sound and rational integral management of solid waste. The different types of waste are not managed efficiently and separately. We can say the same for Morocco, despite the great efforts made by the Moroccan government in this direction. Any type of waste founds its destiny on the uncontrolled dumps and landfills in Lebanon and Morocco, including waste containing mercury. Mercury is found in a variety of products, such as fluorescent and other lights, batteries, electrical switches and relays, barometers, and thermometers, much of which ends up in uncontrolled dumps and landfills. The mercury contained in these products can evaporate into the air or leach into the groundwater from the dump and landfill.

Some of the mercury content in waste is evaporated into the air while another part will be in the leachate and threats groundwater.

Despite the wide range of uncontrolled dumps of which we studied the surroundings, and despite the relatively small amount of mercury that exists in the tens or even hundreds of tons of solid waste on the dump, we could in some cases detect concentrations of mercury in the atmospheric air, several times larger than the baseline levels.

In the proximity of the dump of Nabatieh - Kfar Tibnit and the dump of Tyr - RasElAin, we found concentrations that reached 10 ng/m^3. While in the proximity of the dumping areas of Saida and Casablanca-Mediouna mercury concentrations in the air have slightly exceeded the baseline levels.

Mercury levels found confirm its existence in the atmosphere over these areas and dumps are a secondary source of polluting emissions of mercury into the air.

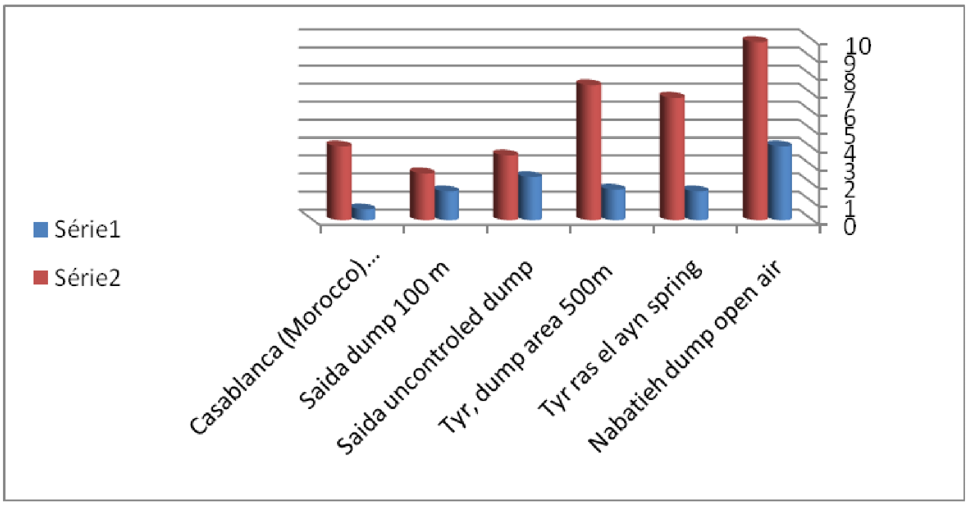
Recommendations:

1- We call insistently Lebanese and Moroccan governments to establish a comprehensive system of environmentally sound management of waste, and to avoid mixing of waste containing mercury with other municipal solid waste.
2- Develop a system of separate collection of waste containing mercury.
3- Stop the use of mercury in all areas where alternatives already exist.

Table 7: Mercury levels in atmospheric air around uncontrolled dumps - Lebanon and Morocco

Location	Sampling date/Time	Average reading (ng/m^3)	Maximum reading (ng/m^3)	Minimum reading (ng/m^3)	Deviation (%)
South open air near to dump of Nabatieh	May 11, 2011/ 13:40-13:50	4.1	9.9	0.3	2.3
Tyr, South Lebanon, RasElAin springs	May 30, 2011/ 12:56-13:06	1.6	6.8	0.0	1.7
Tyr, RasElAin, Dump area, 500 m from the dump, open air	May 30, 2011/ 13:31-13:41	1.7	7.5	0.4	1.6
Saida, uncontrol-led dump, 50 m, open air	June 30, 2011/ 10:48-10:58	2.4	3.6	0.0	0.7
Saida, uncontrol-led dump, 100 m, open air	June 30, 2011/ 11:03-11:13	1.6	2.6	0.8	0.4
Dump Casablanca (Mediouna), about 800 m	June 15, 2011/ 12:19-12:29	0.6	4.1	0.0	1.3

Figure 7: Mercury levels in atmospheric air around uncontrolled dumps - Lebanon and Morocco



Series 1: average values
Series 2: maximum values

5.7 Mercury levels in indoor air in dentistry clinics in Lebanon and Morocco

Dahiyeh, Beirut and Saida - Lebanon

Faculty of Dentistry Rabat: conservative odontology, material store, infirmary child care service, pedodontic clinic, waiting room; Tangier: dentistry private clinic - Morocco

In Table 8 and Figure 8 are shown the results of the measurements of mercury concentrations in indoor air in the dentistry sector in Lebanon and Morocco.

In Lebanon we visited dental clinics in Dahiyeh, Beirut and Saida, and we visited a pediatric practice near the dental clinic at Dahyieh, and a cabinet of Neurology near the dental clinic in Saida, on the same floor, to check the impact of neighborhood dental care clinic.

We have visited a dental clinic in Zahrani using mercury amalgam without reservation or limitation, and we found a concentration of mercury in indoor air that exceeded 3000 ng/m^3, but we have not taken this into consideration in our study because the deviation has exceeded the 30% we previously set. In any case, this enormous concentration of > 3000 ng/m^3, although not very precise, gives us an idea, that the use of mercury amalgam lets dentists and personal of dental care clinics exposed to high concentrations of mercury vapor that pose real risk of chronic intoxication by this highly toxic metal.

A number of clinics we visited reported the complete cessation of use of mercury amalgam for years. Others still use it but in packaged form and using a mechanical closed mixer; and other clinics use mercury amalgam, but very rarely and only in special cases.

In Morocco, we visited the dental faculty in Rabat, and we made measurements in different departments, clinics and locations. Officials who accompanied us during the visit said that the use of mercury amalgam in all faculty clinics has ceased. We measured the following locations: the office of conservative dentistry - odontology, nursing-care service for children, pediatric dentistry office, and the store of materials and in the waiting room. In Morocco, we also visited a private clinic for dental care and surgery in Tangier where we measured the concentration of mercury in indoor air in the waiting room and in the operating room.

Given the wide variation in clinics and locations visited, there are four categories according to levels of mercury concentrations in indoor air, including:

1 - The first category of dental care clinics uses mercury amalgam without reservation or limitation. The level of mercury exceeds 3000 ng/m^3. The dentists and staff in this category of dental care clinics are highly exposed and subjected to a high level of risk of chronic intoxication.

2 - The second category of dental care clinics still uses mercury amalgam, but in packaged form and using a mechanical closed mixer. The level of concentration in this clinical category is between 214 - 797.1 ng/m^3 (dental clinics in Saida 1 and in Beirut 1). This level of concentration is always important and poses real risks to the health of those exposed.

3 - The third category of dental care clinics has stopped the use of mercury amalgam completely, and can be used only very rarely in special cases. The level of mercury concentrations in indoor air in this category is between 62 - 170.4 ng/m^3, namely: dental clinics in Saida 2 and 3, the neurological clinic located in the vicinity and on the same floor as the clinic in Saida 1 of the second category - in Lebanon; the infirmary care services for children and the clinic of pedodontics in the Faculty of Dentistry in Rabat, and the operating room of the clinic dental care and surgery in Tangier. This concentration level is medium. It shows the persistence of mercury in closed rooms, and that its complete clearance will last a long time. The long-term exposure to such concentration is not without risk to health.

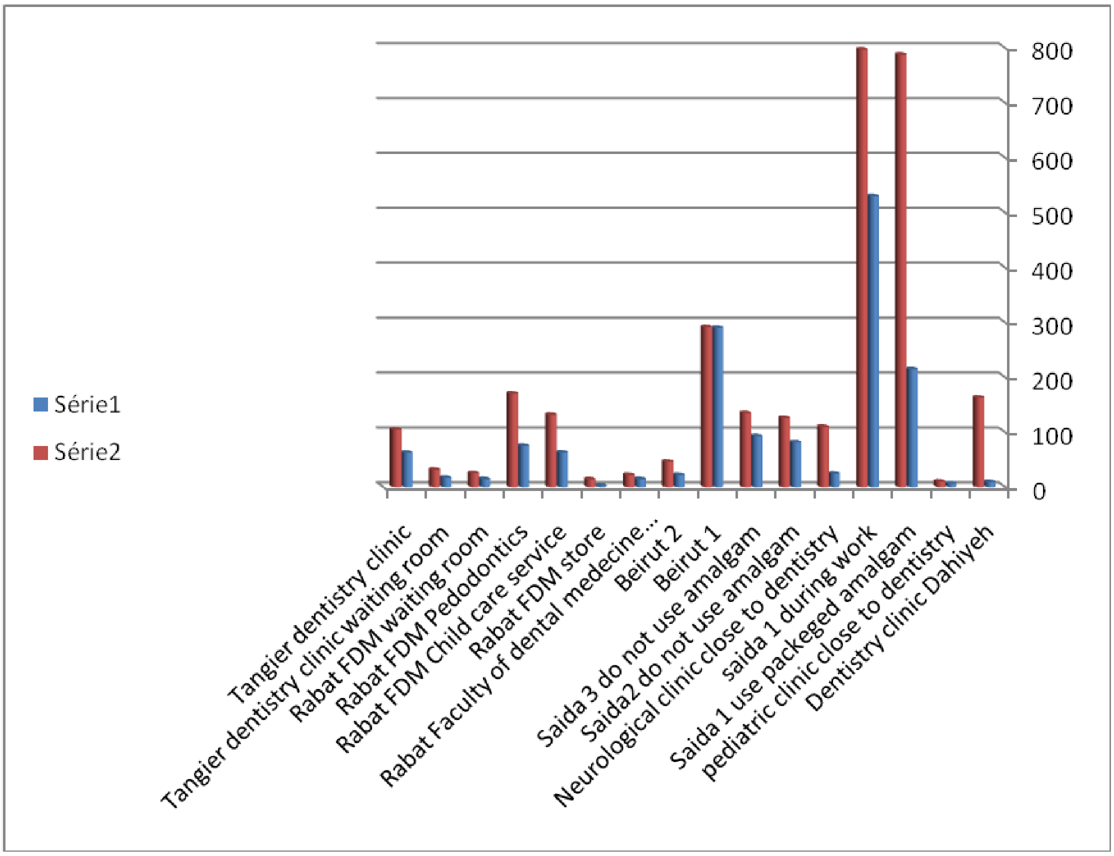
4 - The fourth category includes clinics and locations where they have completely stopped using mercury amalgam for a long time, and for locations where the mercury is not directly used, but they are in the vicinity of dental clinics. The level of concentration in indoor air in this category is between 2.4 - 31.4 ng/m^3, namely: the dental clinic in Beirut 2, and conservative dentistry office in Rabat, the pediatrician's office located next to the dental clinic in Dahiyeh, Lebanon; the store of materials at the Faculty of Dentistry in Rabat and the waiting rooms. This level of concentration is low, but given the severe toxicity of mercury, it is not to be neglected.

Table 8: Mercury levels in indoor air in dentistry clinics - Lebanon and Morocco

Location	Sampling date/Time	Average reading (ng/m^3)	Maximum reading (ng/m^3)	Minimum reading (ng/m^3)	Deviation (%)
Dentistry clinic, Beirut, Dahiyeh, Sfair, don't use amalgam filling	May 17, 2011/ 11:46-11:56	9.5	163.1	0.0	27.1
Pediatric clinic, close to dentistry clinic Beirut Dahiyeh, don't use amalgam filling	May 17, 2011/ 12:00-12:10	6.7	10.3	4.3	1.3
Dentistry clinic use packaged amalgam - Saida 1	May 17, 2011/ 13:25-13::35	214.7	787.8	166.6	11.9
Dentistry clinic use packaged amalgam during work with patient - Saida 1	May 17, 2011/ 13:38-13:48	530	797.1	356.3	11.3
Neurological clinic, close to dentistry clinic, Saida, use packaged amalgam filling	May 17, 2011/ 13:15-13:25	24.4	109.8	0.0	30.3
Dentistry clinic, Saida, don't use amalgam filling, sample 2	May 17, 2011/ 14:12-14:22	81.4	126.1	40.5	26.8
Dentistry clinic, Saida, don't use amalgam filling, sample 3	May 17, 2011/ 14:25-14:35	92.7	134.8	40.4	20.9

Dentistry clinic, Beirut 1	July 04, 2011/ 11:02-11:12	290	291.4	232.4	12.6
Dentistry clinic, Beirut 2	July 04, 2011/ 11:20-11:25	22.3	46.5	3.3	12.1
Faculty of Dental Medicine Rabat, office of Conservative Dentistry	June 9, 2011/ 10:13-10:23	14.6	22.2	7.0	2.7
Faculty of Dental Medicine Rabat, store material	June 9, 2011/ 10:27-10:37	2.4	14.0	0.6	2.4
Faculty of Dental Medicine Rabat, nursing, child care service	June 9, 2011/ 10:52-11:02	63.1	131.6	19.0	24.6
Faculty of Dental Medicine Rabat, cabinet of Pedodontics	June 9, 2011/ 11:06-11:16	75.2	170.4	31.8	30.2
Faculty of Dental Medicine Rabat, waiting room	June 9, 2011/ 11:26-11:36	14.6	25.4	7.2	4.4
Tangier dentistry clinic, waiting room	June 12, 2011/ 11:00-11:10	17.1	31.4	10.5	4.7
Tangier dentistry clinic	June 12, 2011/ 11:10-11:20	62.8	104.8	13.0	19.1

Figure 8: Mercury levels in indoor air in dentistry clinics - Lebanon and Morocco



Series 1: average values
Series 2: maximum values

5.8 Mercury levels in indoor air in the health care sector (hospitals and clinics) in Lebanon and Morocco

Hospitals in Saida, Nabatieh, Beirut and Baabda, and a clinic in Khaldeh - Lebanon

Ibn Sina hospital and Pediatric hospital in Rabat - Morocco

In Table 9 and in Figure 9 we illustrate the results of the measurements of concentration of mercury in indoor air in the health care sector - hospitals and clinics in Lebanon and Morocco.

We have already mentioned in the general part, that the public health sector is an area where mercury strongly exists and possibly pollutes the air of health facilities - hospitals, clinics, and other offices. We can summarize the sources of mercury in the sector of health care in three:

1- The measuring instruments containing mercury: thermometers, sphygmo-manometers blood pressure devices, and number of gastrointestinal devices, such as cantor tubes, esophageal dilator (bougie tubes), feeding tubes and Miller Abbott tubes.

2- Mercury is also used in a number of products in health care settings not specified to healthcare. These include electrical and electronic devices, switches (including thermostats) and relays, measuring and control equipment, energy-efficient fluorescent light bulbs, batteries and laboratory chemicals.
3- Incubators used to house premature infants have been found to contain mercury droplets from broken mercury thermostats. The exposure to mercury vapor released from latex paint containing mercury compounds can reach important levels. Indoor air pollution caused by central-heating thermostats and by use of vacuum cleaners following thermometer breakage, etc. should also be considered.

A variety of studies demonstrates that mercury containing health-care equipment will invariably break. If not cleaned up properly, spills of even small amounts of elemental mercury, such as from breakage of thermometers, can contaminate indoor air and lead to serious health consequences. Since mercury vapor is odorless and colorless, people can breathe mercury vapor without knowing it.

Everywhere we measured in Lebanon and Morocco, we found low, medium, and sometimes even higher levels of mercury in indoor air.

Mercury levels detected in this study in Lebanon and Morocco are in a wide pitch range between the lower on the open area of waste collection at the hospital in Beirut (1.3 - 3.6 ng/m^3), to the highest in Ibn Sina hospital in Rabat on the reception, administrative side (137.7 - 205.0 ng/m^3), close to the reanimation room of the department of toxicology, to values in medium and higher or lower in different places.

From the comprehensive figure, we can distinguish four levels of mercury concentrations in the air in the health care sector in Lebanon and Morocco, namely:

1- Relatively low (0 - 50 ng/m^3):

17 places in total, 14 Lebanese sites, 3 Moroccan places, namely the following:

In Lebanon:

- Saida Hospital procedure room, storage, neonatology, laboratory
- Nabatieh Hospital - laboratory, storage of materials
- Beirut Hospital - laboratory, medical waste open area
- Baabda Hospital - all laboratories (blood bank, immunology, chemistry, bacteriology) and storage of material
- Khaldeh cardiology clinic.

In Morocco:

- Rabat Pediatric Hospital - neonatology, storage of materials and isolated rooms.

2- Relatively medium (50 - 100 ng/m^3):

5 places in total, 3 Lebanese places, 2 Moroccan places, namely the following:

In Lebanon:

- Saida Hospital - pharmacy and neonatology incubator room
- Nabatieh Hospital medical store.

In Morocco:

- Ibn Sina Hospital - Entree of toxicology reanimation department
- Rabat Pediatric Hospital - incubator neonatology room.

3- More than medium (moderate, 100 - 200 ng/m^3):

2 places in total, 1 Lebanese and 1 Moroccan place, namely:

In Lebanon:

- Beirut Hospital - medical store

In Morocco:

- Rabat Pediatric Hospital - reanimation department.

4- Relatively high (> 200 ng/m^3):

1 place

In Morocco:

- Ibn Sina Hospital in Rabat - reception reanimation department of toxicology.

We want to point out that this categorization of concentration levels is made only to clarify the actual situation in the sector of health care in hospitals and clinics in Lebanon and Morocco. We confirm that all the levels found pose a real risk to exposed persons, doctors, nurses, laboratory technicians and other personnel, and sick patients, especially newborns. Even the lowest concentration levels are not devoid of danger in cases of long-term exposure.

Recommendations:

1- We call insistently governments of Lebanon and Morocco, and all the Arab governments to eliminate the use of all instruments and products containing mercury used in the field of health care where alternatives exist and already practiced in many developed countries.

2- To well ventilate, cool and disinfect all the departments of the hospitals, with particular attention to neonatal rooms and neonatal incubators and pediatric intensive care and toxicology departments.
3- To well ventilate and aerate the stores and pharmacies.
4- Develop plans for management of waste containing mercury.
5- Develop a training and awareness program for all medical and paramedical personnel working in the field of health care.
6- Store phased-out mercury equipment in a designated area that is ventilated, secure and apart from other chemical products.
7- Do not dump or dispose of mercury or wastes containing or contaminated with mercury.

Table 9: Mercury levels in indoor air in the health care sector (hospitals and clinics) - Lebanon

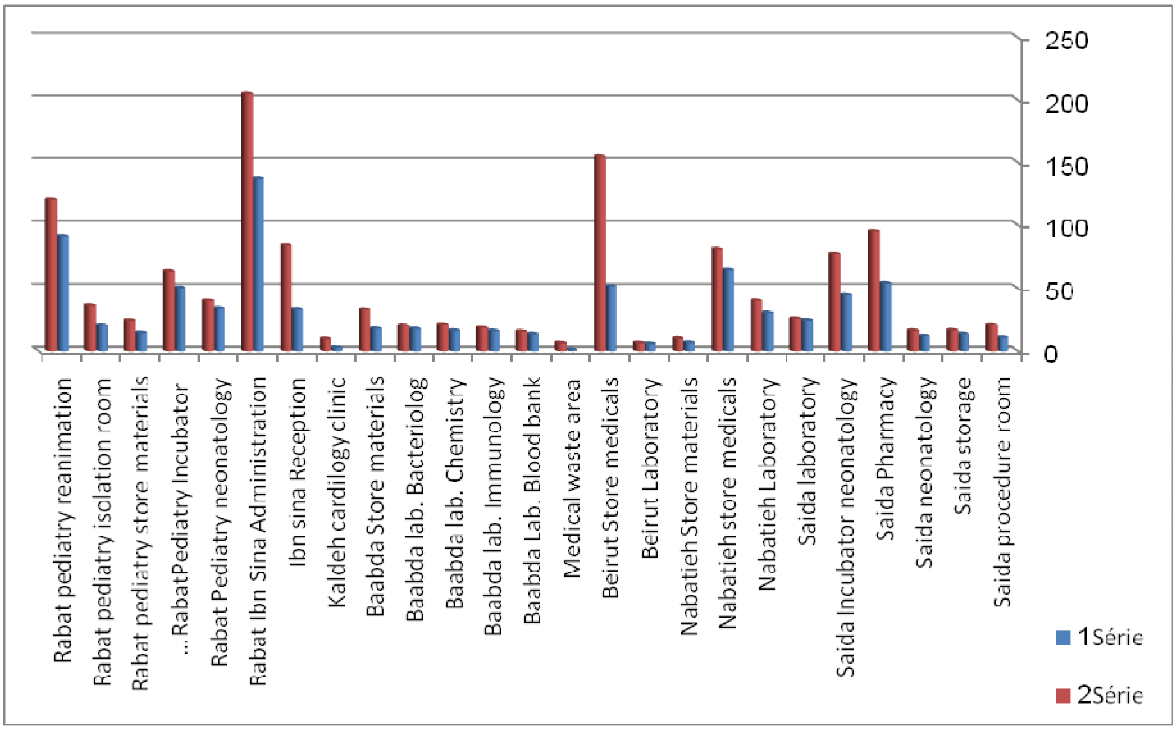
Location	Sampling date/Time	Average reading (ng/m^3)	Maximum reading (ng/m^3)	Minimum reading (ng/m^3)	Deviation (%)
Saida, Raee Hospital, procedure room	May 09, 2011/ 10:46-10:56	10.6	20.9	5.5	3.6
Saida, Raee Hospital, Storage area medical supply	May 09, 2011/ 10:58-11:08	13.2	16.1	11.6	1.0
Saida, Raee Hospital, nursery	May 09, 2011/ 11:10-11:20	11.7	15.8	7.9	1.8
Saida, Raee Hospital, pharmacy	May 09, 2011/ 11:25-11:35	54.3	95.2	17.0	18.3
Saida, Raee Hospital, INC nursery	May 09, 2011/ 11:35-11:45	44.4	77.8	6.2	18.4
Saida, Raee Hospital, Medical laboratory	May 09, 2011/ 11:56-12:06	24.6	26	22.6	0.9
Nabatieh, Secour populaire Hospital, medical laboratory	May 09, 2011/ 13:00-13:10	30.4	40.0	22.1	4.4

Nabatieh, Secour populaire Hospital, store medical supply	May 09, 2011/ 13:10-13:20	64.5	81.4	37.3	12.1
Nabatieh, Secour populaire Hospital, store materials	May 09, 2011/ 13:35-13:45	6.6	9.9	3.4	1.6
Beirut, Rafic Hariri Hospital, laboratory	May 10, 2011/ 12:50-13:00	5.6	6.3	4.7	0.3
Beirut, Rafic Hariri Hospital, store medical supply	May 10, 2011/ 13:10-13:20	51.8	154.7	1.8	35.6
Beirut, Rafic Hariri Hospital, open store of medical waste	May 10, 2011/ 13:35-13:45	1.3	3.6	1.3	1.3
Sacré-Cœur Hospital, Baabda, laboratory, blood bank	May 18, 2011/ 10:05-10:15	13.1	15.2	8.9	1.5
Sacré-Cœur Hospital, Baabda, laboratory, immunology	May 18, 2011/ 10:16-10:26	15.6	18.2	13.8	1.0
Sacré-Cœur Hospital, Baabda, laboratory, chemistry	May 18, 2011/ 10:28-10:38	15.8	21.2	13.6	2.0
Sacré-Cœur Hospital, Baabda, laboratory, chemistry	May 18, 2011/ 10:28-10:38	15.8	21.2	13.6	2.0
Sacré-Cœur Hospital, Baabda, laboratory, bacteriology	May 18, 2011/ 10:39-10:49	17.4	20.5	16.1	0.7

Sacré-Cœur Hospital, Baabda, Store, material supply	May 18, 2011/ 10:56-11:06	17.6	32.9	4.7	5.2
Cardiology Clinic using sphygmo-manometer, Khaldeh	July 19, 2011/ 09:26-09:36	2.8	9.6	1.2	1.4
Cardiology Clinic using sphygmo-manometer, Khaldeh	July 19, 2011/ 09:46-09:56	4.6	6.2	2.8	0.6
Ibn Sina Hospital medical intensive care unit, circula-tion space, admi-nistrative side	June 7, 2011/ 11:52-12:02	33.2	84.5	7.1	24.6
Ibn Sina Hos Ibn Sina Hospital medical intensive care unit, recep-tion, adminis-trative side	June 7, 2011/ 12:04- 12:14	137.7	205.0	63.5	37.0
Children's Hospital Pediatrics, Rabat, neonatology	June 10, 2011/ 10:10-10:20	34.0	39.9	24.4	4.7
Children's Hospital Pediatrics, Rabat, neonatology room	June 10, 2011/ 10:21-10:31	50.5	63.3	41.3	5.2
Children's Hospital Pediatrics, Rabat, store material	June 10, 2011/ 10:35-10:45	14.2	24.4	7.0	5.1

Children's Hospital Pedia-trics, Rabat, isolated room, pediatric	June 10, 2011/ 10:53-11:03	20.6	36.1	11.2	5.4
Children's Hospital Pediatrics, Rabat, reanimation	June 10, 2011/ 11:08-11:18	91.3	120.6	59.8	16.9

Figure 9: Levels of mercury in indoor air in health sector in Lebanon and Morocco



Series 1: average values
Series 2: maximum values

5.9 Mercury levels in indoor air in university laboratories and professional control and research laboratories in Lebanon and Morocco

In Table 10 and Figure 10 we illustrate the results of the measurements of mercury concentrations in indoor air in university laboratories in Lebanon and laboratories of the poison control center in Rabat, Morocco.

University laboratories for chemistry and biology are designed and equipped for educational and academic purposes. The laboratories in poison control center in Rabat are designed and equipped for research and control in the field of toxicology and pharmacology.

The levels of mercury found in the studied laboratories range from 3 to 47.4 ng/m^3.These levels do not show that recent mercury accidents have taken place in these laboratories. The relatively low and medium concentrations are probably due to low evaporation from apparatus, analytical instruments, and chemicals; or possibly due to a broken thermometer from a long time ago, especially in the laboratory of extraction in poison control center in Rabat, where we found the highest concentration of 47.4 ng/m^3.

The staff working in laboratories including: teachers, researchers, students, laboratory technicians and administrators who manage laboratories should realize that whenever they perform any action with mercury it will inevitably spill and splash. It will form tiny beads that cling to many surfaces and roll several meters away. Large drops quickly break up into thousands of small ones. When spilled or misused it can present a significant hazard.

Mercury can present a health hazard under the following circumstances:

1- When a mercury spill is not cleaned up promptly it may be ground into the floor, fracturing into extremely small particles with a large total surface area (2m^2 for 1 ml as 10 micron spheres). Then mercury may vaporize at a rate faster than the room’s ventilation can safely dilute it.
2- The rate of mercury volatilization is directly related to temperature. Whenever elevated temperatures are involved special care must be exercised by providing adequate ventilation. A common occurrence in similar laboratories is the breaking of thermometers in ovens due to raising the oven temperature above the thermometer’s capacity.
3- The release of mercury into high air velocity systems will atomize mercury into extremely small particle sizes and large surface area. This generally results from inadequate connections in pressure systems containing mercury.

Laboratories should minimize or eliminate the use of mercury whenever possible. Therefore, the following precautions should be followed:

1- To begin with, an alternative to using mercury should be found:

   a) Use alcohol thermometers instead of mercury ones.
   b) Use oil bubblers instead of mercury bubblers when possible.
   c) Consider using reducing agents other than mercury amalgams in your laboratory procedures.

2- A mercury thermometer should not be placed in a laboratory oven. However, if this occurs and the thermometer breaks in the hot oven, then this will require a Hazardous Material response situation. The lab will have to be shut down, probably for several days, for cleaning and testing. The oven will then have to be disposed of as hazardous waste. A break in a cold oven is an equally serious situation.

3- In the event of a spill appropriate measures should be taken. Sprinkling elemental sulfur on spilled mercury is virtually ineffective; the reaction between Hg and S is not efficient at room temperature. Amalgamation with fresh zinc dust works fairly well for „soaking up“ those noisome tiny beads of mercury once the bulk of the spill has been collected manually.

4- Read the Material Safety Data Sheet (MSDS) for mercury before using it. As indicated in the MSDS, mercury is dangerously incompatible with aluminum, ammonia, chlorates, copper, copper alloys, ethylene oxide, halogens, iron, nitrates, sulfur, sulfuric acid, oxygen, acetylene, lithium, rubidium, sodium carbide, lead, nitromethane, peroxyformic acid, calcium, chlorine dioxide, metal oxides, azides, 3-bromopropyne, alkynes + silver perchlorate, methylsilane + oxygen, tetracarbonylnickel + oxygen and boron diiodophosphide.

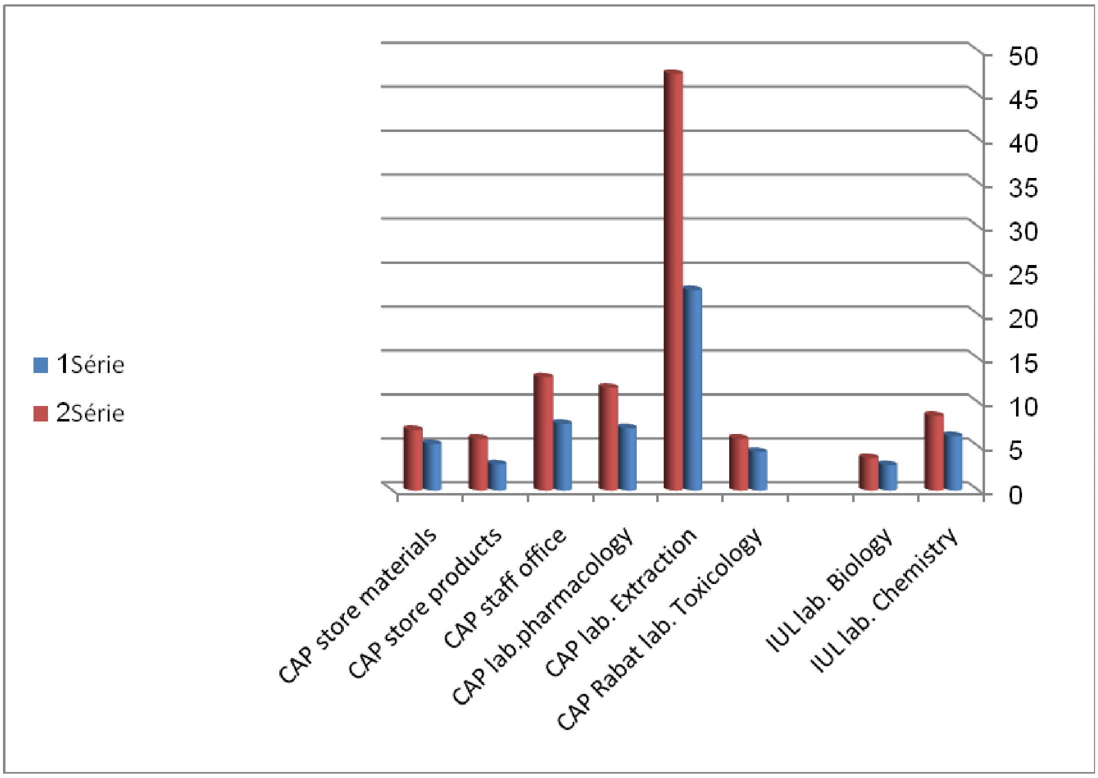
5- As with most other chemicals in the laboratory, access to mercury should be restricted to a locked cabinet or room. Do not leave mercury where a passerby or unauthorized person can swipe it.

Many universities, research centers and hospitals have instituted programs to reduce the use of mercury in their laboratories. Many communities have encouraged residents to turn in mercury fever thermometers in an attempt to keep metallic mercury from entering the domestic sewer. There are several reasonable alternatives to mercury thermometers and manometers. Therefore, before you purchase the next thermometer or manometer for your lab or field project, think thoroughly and avoid purchasing one that contains mercury.

Table 10: Mercury levels in indoor air in university laboratories and professional control and research laboratories in Lebanon and Morocco

Location	Sampling date/Time	Average reading (ng/m^3)	Maximum reading (ng/m^3)	Minimum reading (ng/m^3)	Deviation (%)
Islamic University, Khaldeh, laboratory, chemistry	May 26, 2011/ 12:07-12:17	6.2	8.5	4.8	1.1
Islamic University, khaldeh, Laboratory, Biology	May 26, 2011/ 12:19-12:29	2.9	3.7	2.1	0.4
Poison control center, Rabat, Toxicology Laboratory	June 8, 2011/ 10:53-11:03	4.4	5.9	3.4	0.6
Poison control center, Rabat, laboratory extraction - toxicology	June 8, 2011/ 11:15-11:25	22.8	47.4	8.4	7.2
Poison control center, Rabat, laboratory of pharmacology	June 8, 2011/ 11:31-11:41	7.1	11.7	2.6	2.4
Poison control center, Rabat, office staff	June 8, 2011/ 11:45-11:55	7.6	12.9	5.5	1.7
Poison control center, Rabat, store products	June 8, 2011/ 11:56-12:06	3.0	5.9	0.0	1.5
Poison control center, Rabat, store products and material	June 8, 2011/ 12:06-12:16	5.3	6.9	2.0	1.5

Figure 10: Mercury levels in university laboratories in Lebanon and laboratories of Center Anti Poison Rabat, Morocco



Series 1: average values
Series 2: maximum values

6 Conclusions and general recommendations

1- In Lebanon, the health care sector is the sector that uses the most mercury. Dentistry is the sub-sector where the highest concentration of mercury was found. Staff working in this sector - dentists and assistants - are the most exposed to mercury in Lebanon.
2- Unintentional emissions of mercury from industrial and polluted sites are dispersed over a long distances from the source.
3- During the sampling period, it was found that low general awareness exists on mercury, mercury-containing instruments and the risks it poses to health.
4- Wastes containing mercury are disposed of with other wastes without any special handling required to avoid mercury contamination.
5- There is a lack of special sites in hospitals or elsewhere for temporary or perpetual storage of mercury waste or outdated instruments containing mercury.

General recommendations:

1- The measurements we have undertaken in Lebanon and Morocco have demonstrated the existence of mercury vapor in the air we breathe. Although the concentrations are low in general, there have been some measurements that showed significant high concentrations. Therefore, it is recommended to reduce mercury release into the environment.
2- The reduction of mercury releases to the environment can be achieved by eliminating the use of products containing mercury wherever there are alternatives. Also it is possible to replace processes that include mercury by other mercury-free processes. Alternatives exist already to eliminate the use of mercury in medical and dental care, and many health care institutions have already achieved this around the world.
3- Develop a national strategy to phase out the use of mercury and its products.
4- Develop a strategy for monitoring and controlling mercury pollution (air, water, soils and sediments and nutrients especially in fish).
5- Set specific storage sites for mercury and its products locally, regionally and nationally. Hospitals and laboratories need to identify special places for temporary storage in plastic pots well secured and closed.
6- Develop the necessary national legislation in line with international legislation.
7- The Lebanese government is strongly and proactively involved in the intergovernmental negotiations for the elaboration of an international treaty on

mercury, while the Moroccan government should further strengthen its role in these negotiations.

8- Promote mercury-free alternatives.
9- Develop an infrastructure for proper collection of mercury, and for waste containing, consisting of or contaminated with mercury.
10- Actively engage in the ongoing negotiations for a globally binding treaty on mercury.

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MERCURY RISING

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