1.0 INTRODUCTION

Mercury is a heavy metal. Under normal conditions it exists as a silvery-white liquid with a density of 13.564 g/ml at 20^{o}C. Due to its unique ability to form amalgam with other metals it is used extensively in the mining industry, especially in the extraction of gold. In Ghana, in the past, large-scale underground mining as well as artisanal gold miners used the metal to process the gold. In recent times most mining companies have moved from the use of mercury and are now practising more efficient methods. Now mainly artisanal and small-scale miners practise amalgamation.

Mercury (both in elemental and compound form) is also used in research, can be found in drug /cosmetic formulations, in dental care etc. The metal and some of its compound are very volatile and can escape easily into the environment during handling and use. The toxicity of mercury, as a heavy metal, is of concern.

1.1 Aim and Objectives

The aim of the assessment is to collect and collate information on the life cycle of mercury and mercury-compounds in the country and identify the potential problems they pose to health and environment. The specific objectives include the following:

1. Review effects of mercury on man;
2. Identify importation and distribution of mercury in Ghana;
3. Review the use of mercury in the economy;
4. Identify the storage and disposal of mercury;
5. Review the levels of mercury in the environment (soil, water, vegetation, organism);
6. Identify and review all laws, bye-laws, and institutional framework regulating the use and management of mercury and its compounds;
7. Identify the level of awareness on the hazards of the chemical;
8. Identify gaps, bottlenecks in all of the above;
9. Make recommendations.

2.0 TOXICOLOGY OF MERCURY

Mercury may enter the body through the skin, gastrointestinal tract, and the respiratory tract (by breathing of mercury vapour or mercury-contaminated dust). Elemental mercury, its vapours and most of its organic and inorganic compounds are protoplasmic poisons that can be fatal to humans, animals, and plants. In general the vapour is very toxic to man compared to the liquid. The most toxic are, however, the compounds whereby the divalent mercury, Hg^{2+} or Hg(II) is more toxic than the monovalent, Hg_2^{2+} or Hg(I); inorganic compounds are generally less toxic than the organic mercury compounds. The methyl mercury compounds are more potent toxins than are the salts of Hg^{2+} because they are more soluble in fatty tissue in animals and bioaccumulate leading to biomagnification in the food chain. The half-life of methyl mercury compounds in humans, about 70 days, is much longer than that for Hg^{2+} salts. Consequently, methyl mercury can accumulate in the body to a much higher steady-state concentration even if on a daily basis a person consumes doses, which individually would not be harmful [1,4].

It is now known that ingested divalent methyl mercury compounds are converted to the unpolar chloride which accumulate in the red blood cells, from where the mercury is more or less distributed to all parts of the body. Also inhaled mercury diffuses from the lungs into the blood stream, and then crosses the blood/brain barrier to enter the brain. The result is serious damage to the central nervous system, which is manifested by difficulties with co-ordination, eyesight, and tactile senses. Other symptoms of chronic mercury poisoning are inflammation of the mouth, easy excitation, and trembling of the hands. Mercury intoxication can lead to loss of memory, or total stupidity and death [1,4].

Factors that determine the effect of mercury poisoning on humans include the amount and rate of absorption, the physico-chemical properties of the compound, and individual susceptibility. The immediate causes of industrial mercury poisoning are usually the absorption and retention of small quantities of mercury metal, vapour, or compounds over a long period of time. Chronic poisoning may develop gradually without conspicuous warning.

3.0 IMPORTATION AND DISTRIBUTION OF MERCURY

Mercury is not produced in the country. The metal and all its compounds are imported mainly from Germany, United Kingdom, Spain, Canada and the Netherlands. Available information at the Ministry of Trade, EPA, Ghana Standards Board and Customs, Excise and Preventive Service revealed that, private companies as well as institutions or their agents could obtain licence to import mercury. Available statistics show that the mercury enters the country through the main points of entry: Kotoka International Airport (KIA) (55.1%), Tema (36.7%), Takoradi (6.3%) and Aflao (2.1%). The values in parenthesis represent the proportion of imports passing through the respective point between 1989 and 2000.

Mercury is imported mainly for the mining sector (80.4%), health (11.7%) and education (7.8%). The values represent the frequency of import. The estimated quantity of mercury metal imported into the country between 1989 and 2000 is about 36,000 kg. This excludes mercury compounds for educational and health institutions.

The right to import possess and distribute/sell the chemical is regulated by the Mercury Law, 1989 and Small-Scale Gold Mining Law, 1989. But currently there is no information on the distribution pattern and transportation of the chemical in the country.

4.0 REVIEW OF USES OF MERCURY IN GHANA

The major use of mercury in the country is in gold processing by both legal and illegal small-scale gold miners (SSGM). Most of the big gold mining companies are now adopting more efficient processing methods that preclude the use of mercury. The mercury is used mainly within the gold belt of the six regions namely, Western, Central, Eastern, Ashanti, Upper East and Upper West.

Available information indicates that the small-time gold miners (galamsey) get their supply of mercury from middlemen, who acquire mercury in medium quantities (about one beer bottle full) from importers or their agents. These middlemen retail the commodity to the miners in smaller quantities (about 5mL). Because of its non-wetting ability the mercury is put into all sorts of containers including glass bottles, polythene sachets, matchboxes etc. No special precautions are taken.

The mercury is used to dissolve the gold from the ore by amalgam formation. The amount of mercury consumed by ‘galamsey’ annually has been estimated to 270 - 300 kg per person. This is based on the Hg: Au ratio of 4:1 attributed to the Precious Minerals Marketing Company, Tarkwa Office; this may vary with the ore richness.

The mixing of the amalgam is done with bare hands by most SSGMs. The amalgam is then roasted by burning off the mercury till ‘cooked’, which is determined by the change in colour of the gold. The mercury vapour is either deposited on the surrounding soils and vegetation, or is inhaled by people. The miners and the immediate environment are thus exposed to the very toxic mercury vapour.

Mercury and its compounds have been used widely in laboratories in experimental and research work but such usage has declined because of a growing awareness of the toxicity of the metal. Standard laboratory uses include reagents, indicators, calibration, sealing, radioactive diagnosis, and tissue fixature. No study has been conducted on the amount and fate of the chemical in teaching and research laboratories in the country.

Mercury is used in industrial and medical instruments to measure and control reaction and equipment functions, including thermometers, manometers, barometers, and other pressure sensing devices, gauges, valves, seals etc. In the textile industry mercury is found in the testometer, an instrument used in measuring moisture content of the cotton. In all these mercury can escape into the environment during breakage and spill.

Mercury is also used in electrical appliances, especially electrical lamps called mercury lamps, batteries, wiring and switching devices [1]. Mercury lamps are generally electric discharge tubes that contain varying volumes of mercury vapour. The two main types of mercury lamps are the low pressure, or fluorescent lamps and the high-pressure mercury lamps used in industrial plants and workshops, in large, high-ceiling buildings such as aircraft hangers and in street lighting and floodlighting. Mercury lamps are more efficient and produce more lumens-per-watt and are used widely for outdoor lighting. In recent times sodium is gradually replacing mercury in the vapour discharge lamps. In batteries mercury is included in zinc-carbon cells, alkaline -manganese dioxide cells, carbon-zinc air cells, and zinc-silver oxide cell. These batteries are used in portable products such as toys, cameras, portable radios, calculators, measuring devices, wristwatches, mobile phones etc. Mercury is added to the zinc anode of zinc-carbon or alkaline cells to reduce corrosion and to inhibit the build-up of potentially explosive hydrogen gas. In addition, mercury helps to prevent the batteries from self-discharging and leaking. Recent environmental concerns have resulted in attempts to reduce the mercury in alkaline and zinc-carbon batteries. For example, batteries that contained 1% mercury by weight in the mid -1980s are now being produced with mercury concentrations of 0.0001 to 0.025 percent. Total elimination of added mercury in zinc-carbon batteries is anticipated in the near future [2].

Mercury compounds are used in agriculture and related applications as fungicides, pesticides, bactericides, and disinfectants. Most of the mercury-based pesticides and fungicides have been banned or severely restricted as being hazardous substances.

Mercury is formulated into paints as a fungicide to prevent mildew after the paint has been applied and as a bactericide or preservative to prevent bacterial attack while the paint is in storage. Most commonly used are phenyl mercuric acetate and phenyl mercuric oleate, both of which are highly toxic. Their use is rapidly declining.

Mercury compounds are used in diuretics, antiseptics, skin preparations and preservatives. Included in this category are the mercuric oxide, mercuric chloride, mercuric cyanide, mercuric amide chloride, mercuric iodide and mercurous chloride (calomel). However pharmaceutical use has declined sharply. The solid “dental amalgam” used to fill cavities in teeth is prepared by combining approximately equal proportions of liquid mercury and a mixture that is mainly silver and tin. Due to concern over the effect of mercury on health, mercury - free “amalgams” for use in dentistry are currently under development [1].

5.0 MERCURY WASTE AND DISPOSAL

Waste material involving mercury may arise during the importation, distribution, storage and use of mercury, mercury compounds and mercury-containing materials.

1. Gold processing releases mercury vapour to the atmosphere. It also produces mercury contaminated mine waste (tailings), which are thrown away indiscriminately. The dust from this mine waste can be carried over long distances by the wind and deposited in rivers and on vegetation and soils.
2. Damaged, broken down or obsolete electrical equipment containing mercury constitute mercury waste e.g. fluorescent lamp, thermometer.
3. Used, old dry cells containing mercury abound on the Ghanaian market. The batteries have been used in portable radios, calculators, wristwatches, toys, etc. Currently these are thrown away with normal household solid waste. There are no guidelines as to their management.
4. Waste laboratory reagents and compounds containing mercury are disposed of by flushing down the drain or end up in the garbage bin.
5. Obsolete Mercury-containing pesticides. Presently no information

Currently there are no guidelines or monitoring system of the disposal of mercury waste in the country.

6.0 LEVELS OF MERCURY IN HUMANS AND IN THE ENVIRONMENT (SOIL, VEGETATION, WATER, ORGANISMS)

Mercury is the most volatile of all metals. The major release of mercury into the Ghanaian environment is through anthropogenic activities as outlined above. Of these it is only the release from the artisanal mining sector that has been assessed in some mining sites in the country [4,5,7].

In the processing of gold by the SSGMs, a large amount of the chemical is used. In most cases the mercury is not recovered, but rather released into rivers during amalgamation and into the air during the roasting of the gold amalgam to drive off the mercury. Even with the use of a retort, which permits recovery of the mercury, the loss to the atmosphere is substantial. Accidental releases of the chemical may also occur from the bottles used by the galamseys for keeping mercury. Some of the miners are therefore directly exposed to these mercury vapours. Mean blood and urine concentrations of mercury found in 50 mine workers from Anwiaso in the Ankobra River Basin were 102.0ug/L and 34.5ug/L respectively. None of the Anwiaso blood mercury concentration was less than 3ug/L, the limit for non-exposed persons. The WHO (1980) urine mercury level at which industrial workers are recommended to be removed from further exposure is 50ug/L. This value was exceeded by 26% of the Anwiaso subjects. Similar results were obtained from mine workers in Tanoso and Elubo all in the Tano river Basin [3].

Mercury may also be released into the environment as a result of burning of coal and fuel oil, both of which contain traces of the element. Airborne mercury may travel long distances before being deposited on vegetation, land or in waterways.

Mercury may also get into the environment when a fluorescent lamp, a thermometer or any other device containing mercury breaks or is damaged. In research and school laboratories, waste products containing the compounds of mercury and other heavy metals are flushed down the drain. Old dry cells are lumped together with municipal solid waste and either burnt or buried. In the former case the mercury enters the air compartment while in the latter case it enters the soil and can get into surface and ground water systems. Mercury finally gets into vegetation and aquatic organisms where it bioaccumulates and biomagnifies in the food chain [4]. In this country there are no guidelines regulating the disposal of mercury-containing waste.

Information on levels of mercury in the various compartments of the environment in Ghana is scanty. A recent study to assess the environmental contamination of mercury

in small-scale gold mining (galamsey) areas was conducted in Dumasi; a village located about 5 km from Bogoso on the road to Prestea in the Western Region. The group of scientists were drawn from the EPA, MOH, Noguchi Memorial Institute for Medical Research, Minerals Commission, Chemistry Department of UST, Cemagref and the University of Montpellier [5].

According to the study the concentration ranges 0.64 - 93.1ug/g found in soils and sediments could be related to the gold extraction process. The highest concentrations were found at places where mercury is manipulated - dropped into pans, washed or refined. The levels of the chemical found by the team in the sediment of the Apopre River in the Bogoso area indicate that the river is polluted with the chemical, a situation that reflects galamsey activities. In another study [7] the mercury levels found in soils/sediment in the Obuasi area range from 0.46 to 50.48ppm. Mercury is readily adsorbed onto sediment and is slowly released to the water forming a reservoir capable of causing chronic pollution long after the original source of mercury has been removed.

Generally there are many more studies on fish contamination, as it is considered the main source of food mercury [4]. Levels of the chemical found in fish (mudfish, tilapia and catfish) in the Dumasi area ranged from 0.46 - 6.42ug/g dry wt [6]. The values are in the same range of concentrations as found in other gold mining areas, especially Brazil and Tanzania. It would take an average consumption of only 45g of fish per day to exceed WHO's weekly tolerance of 300ug [8].

In another study in the Dunkwa and Tarkwa areas, total mercury levels in fish ranged from 0.01 to 2.50ug/g wet wt. 9.3% of the fish analysed exceeded 0.5ppm, the WHO (1976) guideline for mercury in fish [3].

With respect to vegetation, mercury levels have also been obtained for some selected plants in the Prestea-Bogoso area: cocoyam leaves (2.7 - 9.7mg/kg), garden egg (0.35 - 8.03mg/kg) and oil palm fruit (0.59 - 3.84mg/kg). Due to the limited nature of the database, it was difficult to make any comparison with literature data [6]. Significantly, the study did not cover other tubers (like cassava and yam) and their leaves, which are used by villagers for cooking various sauces. As corn constitutes an important proportion of the typical Ghanaian ration, it should be surveyed too.

In the case of water, levels of mercury obtained for surface and borehole water in the Prestea - Bogoso area are in the range of 0.14 - 0.76 and 0.12 - 0.27ug/L respectively [6]. In the Obuasi area drinking water (tap and borehole waters) range from 1.23 - 2.15ppb [7]. The WHO (1976) limit for drinking is 1ppb.

Mainly metallic mercury fumes contribute airborne mercury, which by its nature does not travel far but deposits on the surroundings. But dust carrying the chemical can be transported to distant places. Most inorganic mercury compounds have low vapour pressure, and generally do not contribute to atmospheric mercury. Organic mercurials also contribute to atmospheric mercury, possibly by virtue of the presence of extreme small amounts of metallic mercury present as an impurity. The maximum atmospheric concentration, MAC, for mercury in all forms except alkyls compounds is 0.1 mg Hg / m^3 air. For alkyl mercury compounds the threshold limit TLV is set at 0.01mg/m^3 air [1]. There are no values for Ghana. It appears there has not been any monitoring of atmospheric mercury in the country.

7.0 REGULATORY AND INSTITUTIONAL FRAMEWORK FOR THE USE AND MANAGEMENT OF MERCURY

Mercury gets into the country by legal and illegal means. When legal means are used to import the metal, it is cleared through the Customs, Excise and Preventive Service and quantities could be documented. It is however known that the chemical has also been smuggled into the country from neighbouring countries. In this case there would not be any statistics and institutional framework.

7.1 Institutional Framework

Investigations on the on the storage, transportation, distribution and disposal of the metal was done by talking to officials of the following institutions:

Institution	Role in Mercury Control/Management
Minerals Commission	A state institution that promotes and regulates mining activities It also advises the Minister on mining activities.
Customs Excise and Preventive Service	A state institution regulating imports of goods
Ghana Standards Board	A state institution, which sets quality standards for products in country.