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LEAD POLLUTION SOURCES AND IMPACTS

by

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ABSTRACT

Despite the medical awareness of lead toxicity, and despite legislation designed to reduce environmental contamination, lead is one of the most widely used heavy metals. Significant human exposure occurs from automobile exhaust fumes, cigarette smoking, lead-based paints and plumbing systems

Lead spread in the environment can take place in several ways, the most important of which is through the lead compounds released in automobile exhaust as a direct result of the addition of tetraethyl or tetraethyl lead to gasoline as octane boosting agents. Of special concern is the effect of lead pollution on children, which affects their behavioral and educational attributes considerably. The major channel through which lead is absorbed is through inhalation of Lead compounds in the atmosphere.

Lead is a heavy metal characterized by its malleability, ductility and poor conduction of electricity. So, it has a wide range of applications ranging from battery manufacturing to glazing ceramics. It is rarely found free in nature but is present in several minerals and compounds

The aim of this paper is to discuss natural and anthropogenic sources of lead together with its distribution and trends with emphasis on Egypt. The effects of lead pollution on human health, vegetation and welfare are also presented.

It could be concluded that, the excessive release of lead into the environment, especially through the atmosphere, can produce many detrimental and sometimes fatal effects on human, agriculture and zoological life. Besides, it is very plain that there is a serious problem of pollution by lead in Egypt and specially in Cairo.

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INTRODUCTION

Means of transportation utilization for energy sources is escalating to meet the demands of the population growth encountered in Egypt. Mass and privet transportation is consuming massive amounts of leaded gasoline as the common fuel used in cars and variable size trucks. Tetraethyl Lead used as anti-knock chemical to improve the octane number of gasoline is still in use though it is phasing out now in Egypt. Other sources of lead pollution in the Egyptian environment is localized around its sources of industrial generation and its combat should be focused in those impacted areas.

Lead is present in two major forms. The first is inorganic lead as various salts and oxides. The second is alkyl or organic lead, which includes tetraethyl lead. Lead is cumulative poison affecting multiple systems within the body. Most notably it affects the central and peripheral nervous system, the kidney, and hematopoieses and heme synthesis. Absorption varies with age, as adults absorb about 10% of an oral dose while children can absorb up to 50%. Lead is stored in the bone with minimal excretion in the bile and urine. From the kidney, lead is excreted in the urine and redistributed to other tissues mainly the bones [1].

Lead (Pb) is a soft, silvery-white or grayish metal in Group IVa of the periodic table. It is very malleable, ductile, dense and a poor conductor of electricity. Known to be the oldest of metals, lead is highly durable and resistant to corrosion (that is why it was used by the ancient Romans in the manufacture of water pipes [2]).

Lead is rarely found free in nature, but is present in several minerals, the most significant of which is the sulfide, PbS, also known as galena or lead glance. This is the major source of lead production throughout the world. Lead may be extracted by roasting the ore (heating in a stream of air) in an open -hearth furnace or by roasting and smelting the ore in a blast furnace. Lead oxidizes quickly, forming a dull gray coating (a mixture of lead and lead monoxide, PbO) which protects the metal from further corrosion.

A traditional use of lead is in sheet and pipe, mainly in building and also in chemical plants. Lead sheets are used in building for roof coverings, in walls to block the transmission of

sound, in foundations to absorb vibrations from street traffic and other sources. The main use of lead sheets and pipes in chemical plants is for handling sulfuric acid. However, the demand for lead pipes used in water and wastewater has decreased drastically due to their substitution by cheaper alternatives such as plastics.

White Lead (basic lead carbonate) was in the past used as a pigment for paints, mainly in wood primers, but was weathered and washed away by rain, to be dispersed in the environment. Red Lead and calcium plumbate are used as rust-inhibiting pigments in primers for iron and steel. Another important pigment is yellow Lead chromate, used in exterior paints and plastic compounds for road marking. Lead-pigmented paints tend to be eroded and can therefore be considered as an added minor source of lead contributing to the environmental pollution.

Lead bisilicate is widely used in glazing ceramics. Lead compounds go into the manufacturing of glass, fluorescent lights and television tubes. Small quantities can enter the environment from these applications, but they are unlikely to cause significant lead concentrations [3]. Minor cumulative concentration can be leached from lead base glaze when used in food utensils and oven and table ware, where acidic food is kept for prolonged time.

Many other uses of Lead in metallic form exist, such as lead shot for bullets , but the most important are lead alloys such as printing metals and solders. It is also used as shielding around nuclear reactors, particle accelerators and X-ray equipment due to its absorption of electromagnetic radiation [2].

However, for a long time, the largest application of lead was in cable sheathing, mostly for cables buried in the ground. Lead sheathing is almost hard to destroy and chances of lead entry to the environment are slight [3].

Nevertheless, lead batteries for auto industry is a major application of lead. Batteries are, in fact, enclosed packages of lead which therefore does not enter the environment during their use. Almost all of the lead used in batteries is recovered and goes back to smelters and refiners.

Tetraethyl and tetraethyl lead are added to gasoline since this has always been considered the most convenient and economic method to improve the anti-knock characteristics (increasing the octane rating) of gasoline. This application has been the major source of lead pollution [5].

As it can be seen from figure 1, the production and consumption of lead started rising steeply starting from around 1950. Consumption continued to grow at a rate of about 3½ percent annually and was expected to continue in doing so until the year 2000. Recently, consumption has slowed down, mainly due to the increased usage of alternative anti-knock additives in gasoline. Both production and consumption are expected to level off; eventually mining has also slowed down greatly due to increased recycling [5].

SOURCES AND EMISSION OF LEAD

Lead is a widespread constituent in the earth's crust and has always been present in soils, , rivers, lakes and seas. It has also been present in the air (following the burning of wood and coal) and in both edible and inedible plants. Lead in soil ranges from 2 to 200 ppm and averages 16 ppm. The compounds of lead are generally insoluble, therefore, concentrations of lead in natural water bodies are usually very low (ranging from 0.001 to 0.01 ppm.)

There are various ways in which lead can enter the environment : from primary and secondary smelting operations, from fabricating processes, as a result of ways in which it is used, in the combustion of coal and other natural products, and in the disposal of unwanted materials containing lead products and combustion of leaded gasoline [5].

The biggest source of Lead emitted into the atmosphere by far, is the combustion of fuels containing Lead additives [7].

In USA, the lead emission has decreased dramatically in the late 1970's and early 1980's as a direct result of the introduction of unleaded fuel. However, a study conducted in England shows that in 1976, 46% of lead in the atmosphere came from the burning of gasoline only [3]. Also, for a decrease in lead constituents in petrol of 56%, an average decrease in lead blood levels was found to be 37% [7].

Table 1 : Sources and emissions of Lead in USA, million metric ton/year.

source	1975	1984
Transportation	122.6	34.7
Fuel combustion	9.3	0.5
Industrial processes	10.3	2.3
Solid waste	4.8	2.6
Total	147.0	40.1

A very useful study was conducted in the USA to survey the lead sources and emission for 100 years during 1880-1980 [7]. It was conducted on the Hudson -Raritan river in New York State and provides an input - output matrix for a material balance method . The matrix consists of pure sources, intermediate receptors, and retention & final fates.

It was clear from this study that over 54 % of the lead emitted was due to fossil fuel combustion, the majority of which comes from alkyl - lead compounds in automotive gasoline. On the other hand, only 1% of the lead came from natural sources, which implies that through man's activities, the amount of lead in the environment has been increased one hundred fold.

It was obvious that lead may reach the environment through several channels. It is retained on land and in the soil, and is therefore absorbed by vegetation, and in turn by animals eating the vegetation. It moves into surface waters, upsetting the ecological balance and having a toxic effect on marine life.

In Egypt, pollution by lead has reached alarming levels, especially in big cities and most markedly in Cairo, due to the high population density and the dense traffic in Cairo.

The lead levels in the atmosphere in Cairo were found to be concentrated at street level, and decrease gradually with altitude. In some areas, the level has reached six times the allowable ambient level in the USA (0.15 ug/m^3), and it is estimated that the average person living in the crowded regions of Cairo absorbs about 32.5 micrograms of lead per year [9].

A study was conducted by the Faculty of Medicine (Cairo University) to monitor lead levels in the atmosphere in Cairo and their effect on traffic Police men in 1986. The level of lead in the blood was found to range from 8 to 30 micrograms per 100 ml.of blood. In crowded regions, the average was 62.78 micrograms/100 ml as opposed to 20 micrograms/100 ml which is the maximum limit set by health authorities [10].

Another study conducted by the National Research Center showed that the atmospheric level of lead reached 3.4 micrograms /m^3 in Cairo in 1985 as opposed to a maximum international limit of 1.5 micrograms /m^3 [10].

EFFECTS OF LEAD POLLUTION ON HEALTH

General

The adverse health effects of lead on reproduction has been known since the mid-1800s. Exposure to lead may decrease fertility in both sexes; it can increase the frequency of abnormal pregnancy, spontaneous abortion, and stillbirths. The concentration of umbilical cord blood lead was discovered to be associated, in a dose-related fashion, with an increased risk for minor anomalies [11]. A higher proportion of retarded infants were born to women who drank water containing excessive amounts of lead during pregnancy. It has been suggested that the teratogenic effects of lead represent a paradigm for transplacental toxicant.

Airborne lead can be inhaled directly, absorbed through the skin or inhaled with dust particles to which it readily clings [11].

Human exposure to lead in the various ways discussed previously can lead to many different effects on health. These can be split into acute effects, which arise abruptly, in a few days or weeks of exposure to relatively high lead levels, and chronic effects, which occur slowly, getting slightly worse year by year. The latter are associated with long term exposure to relatively low levels of lead pollution, and are of greater concern because they represent the majority of poisoning cases, and also because they are difficult to be assessed [7].

The threshold limit value of lead in air in the UK and USA is 0.2 mg per cubic meter [6]. This is considered to be a borderline level for most people who work regularly with lead. In Russia, the limit is 0.01 mg per cubic meter . Japan has set a threshold value of 0.12 mg per cubic meter for a 48 to 60 hour working week [3].

Acute lead poisoning produces neurological, blood and kidney effects, which may be accompanied by headache, dizziness, insomnia, loss of appetite and a metallic taste in the mouth. Symptoms of neurological damage include weakness, nervous irritability, muscle and joint pain and tremors. Severe poisoning can result in brain damage leading to coma and death. Constipation and abdominal cramping are also signs of acute poisoning, sometimes relieved only by surgery.

Chronic lead poisoning is evident in blood and neurological disorders. Lead interferes with the synthesis of hemoglobin, resulting in anemia. Even at very low levels before anemia is evident, lead inhibits certain enzymes important in the formation of blood components. The toxic effects of lead on the nervous system vary with the duration and intensity of exposure. Hearing, eye - hand coordination and muscular strength and endurance are all affected by the amount of lead in the body. Tremors and psychological symptoms (hostility, aggression and anxiety) are also evident, indicating that brain and nerve damage result from low - level exposure to lead. Slow reaction time and slow growth have also been associated with chronic lead poisoning.[7]

The proportion of lead entering the body through inhalation has been found to be very high. Figure 2 shows the contribution of airborne lead to total lead intake. Clearly, airborne lead can reach humans through a variety of channels, but the only direct one is inhalation. Also, Figure 3 shows the direct and obvious relationship between lead in the air and in blood. It has been estimated that 20-40 % of inhaled lead settles in the lungs, while 50% or more is absorbed into the blood and accumulated in the bones. Since it has been proven that the majority of airborne lead results from that used in petrol, a direct relationship should be expected to exist between lead in petrol and lead in the human body. This relationship is demonstrated in Figure 4.

Children

Children are of particular concern in consideration of lead exposure and effects. Not only are children exposed to additional sources of lead, but they are more susceptible to its toxic effects, exhibiting symptoms at lower levels than adults. They are more sensitive to lead anemia and may experience subtle neurological damage which is very difficult to monitor, but is evident in loss of motor skills and speech ability. Learning ability may be affected due to motor in-coordination. Lack of sensory perception, inability to concentrate and kidney disease have also been found to be more prevalent in children than in adults. It has been estimated that lead can cause a deficit of 7 IQ (Intelligence quotient) points in children.

In a study conducted in Boston Massachusetts [12], the relationship between lead levels (measured in the teeth) and behavioral and educational difficulties in school children was studied. The results are depicted in Figure 5. The following characteristics were found to have a direct relationship with elevated lead levels: distractible, not persistent, dependent, unorganized, hyperactive, impulsive, frustrated, daydreamer, unable to follow directions and sequences and low overall functioning.[12]

In Egypt, a study was conducted [10] in which random samples of children from different areas of Cairo were tested for lead levels in the blood. It can be seen that the average lies in the 111-120 micrograms per liter sector, i.e. above the maximum limit. Indeed, the percentage of children tested between the ages of 0 and 12 whose lead blood level exceeded the allowable limit was 74%, which is alarmingly high. In Figure 6, the distribution of children is shown geographically, illustrating the proportion of children between ages 0 and 6 who have exceeded the allowable blood level in each area. It is very clear that the situation becomes progressively worse as one moves from Maadi to Zamalek to Mohandessin to Dokki and Giza. In the latter two, 100% of the children tested had lead blood levels exceeding 100 micrograms per liter, Fig. 7 [13].

Lead also affects unborn children whose mothers have high lead blood levels, since it is readily transferred across the placenta. Therefore, the concentration of lead in the blood of new born children will be similar to that of their mothers [8].

EFFECT OF LEAD POLLUTION ON VEGETATION AND ANIMAL LIFE

The movement of lead in the environment results in further accumulation throughout food chains. Therefore, lead in the atmosphere can be washed down by rain, enter the soil and be absorbed by plants, which may be consumed by animals, which may in turn be consumed by human beings. Four barriers restrict the movement of lead otherwise the effects of this chain would be catastrophic. The first is in the soil, where only a small proportion of the lead is available to plant roots. The second is in the roots, from which only a small proportion of the absorbed lead is transported to the shoots. The third is in the intestines of animals, from which only a small proportion of the ingested lead is absorbed, the remainder being excreted. Finally , the fourth barrier results from the partitioning of lead in the tissues of animals where it accumulates in the bones, and does not therefore contribute significantly to the dietary intake of man.[4]

Laboratory and field data have shown that at high concentrations, lead can affect certain plants and inhibit photosynthesis, reduce growth and alter species composition. It can also alter the composition of soil microbial communities and inhibit invertebrate activity resulting in delayed decomposition of organic matter, reduced nutrient supply, and altered soil properties, such as lower organic content.[4]

Lead is toxic to all Phyla of aquatic biota. Water concentrations as low as 19 mg / liter have been associated with increased mortality and impaired reproduction in aquatic invertebrates. Vertebrates (fish) appear to be even more sensitive.[4].

Lead poisoning in livestock is reported in the vicinity of lead smelting operations and usually takes place due to the ingestion of lead dust-contaminated foliage, either in the acute or chronic form.

Acute lead poisoning in cattle is characterized by excessive thirst, salivation, loss of appetite, constipation, delirium and reduced milk production, which all may lead to death. Chronic poisoning involves a spectrum of symptoms including diarrhea, colic , nervous disorders, swollen joints, lethargy, in-coordination, bellowing stupor, tough coats, and emaciation, as well as a variety of metabolic changes similar to those experienced by human beings. Lead is retained, as in humans , in increasing quantities by the tissues, particularly in the bone. [15]

CONCLUSION

It can be seen that the excessive release of lead into the environment, especially through the atmosphere, can produce many detrimental, and sometimes fatal, effects on human , agricultural and zoological life, as well as the environment on the whole.

It is clear that there is a serious problem of pollution by lead in Egypt and especially in Cairo. Keeping in mind that the above statistics are not very recent, and lead levels are expected to have increased throughout the previous years due to the increase in population density, number of cars, and overall congestion. Decreased levels of calcium intake and malnutrition in children exacerbate the lead pollutional health impacts in the children the most vulnerable category of population to lead poisoning. Parasitic infections predominantly increasing between Egyptian population is an added contributing factor to children malnutrition which enhance the negative health impacts of lead on children, and women.

It is seriously needed to monitor continuously the lead level in the crowded urban centers where large number of people are affected with lead concentration especially if they are repetitively exposed to it. Emission control devices should be installed on the car exhaust to limit the environmental health degradation created by the use of unleaded gasoline.

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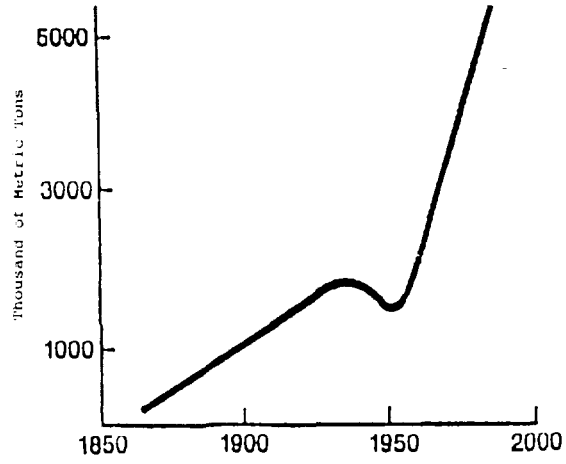

Fig.(1) Annual Industrial Production of lead [6]

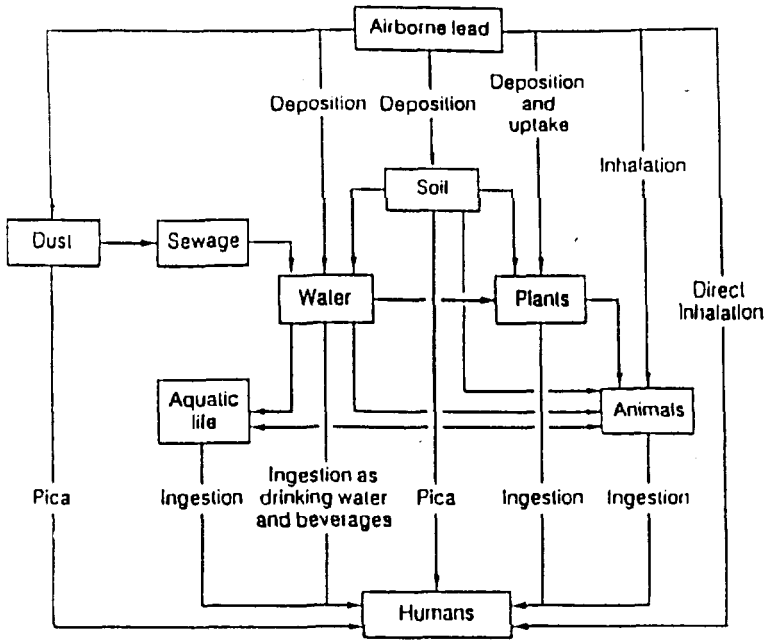

Fig. (2) Contribution of airborne lead to total lead intake.

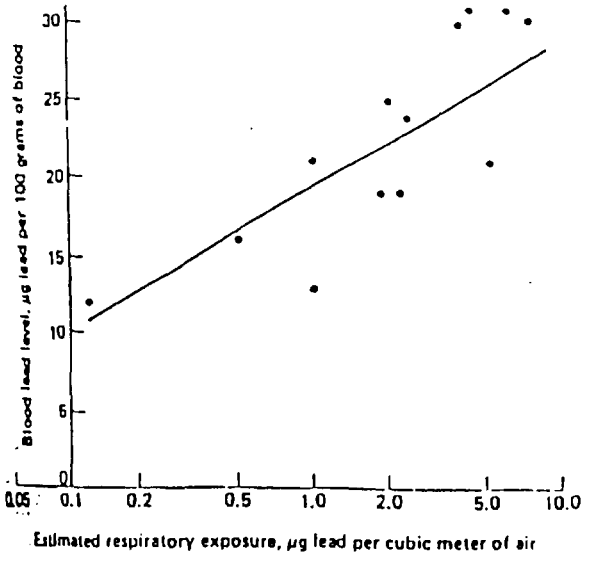

Fig. (3) Relationship between lead in the air and the blood

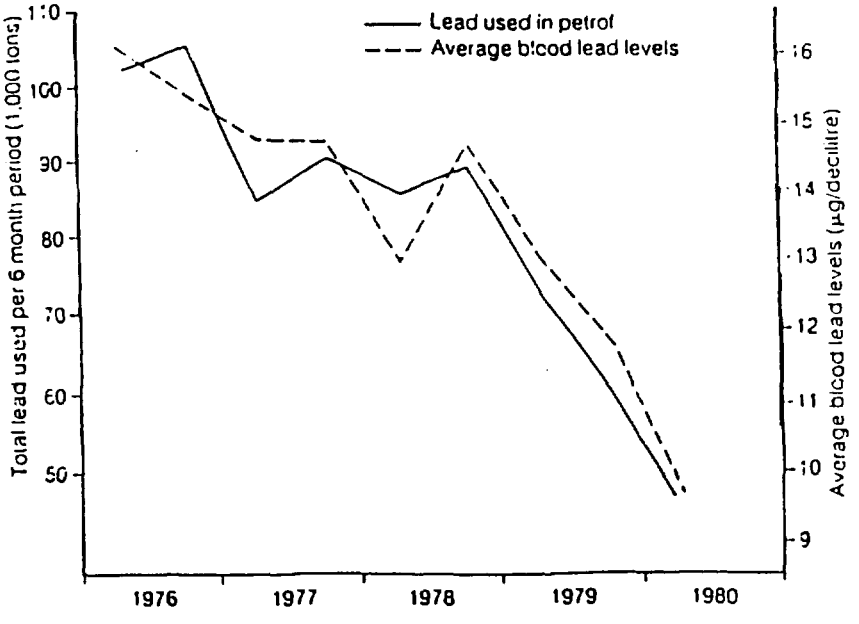

Fig. (4) Lead used in petrol production and blood level in the U.S.A.

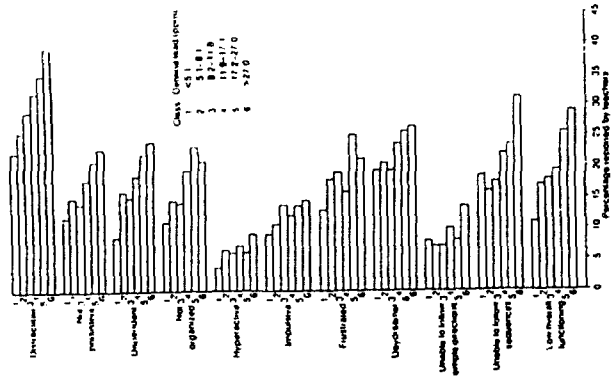

Fig. (5) The relationship between lead in teeth of children in Boston and their behavioral and educational difficulties.

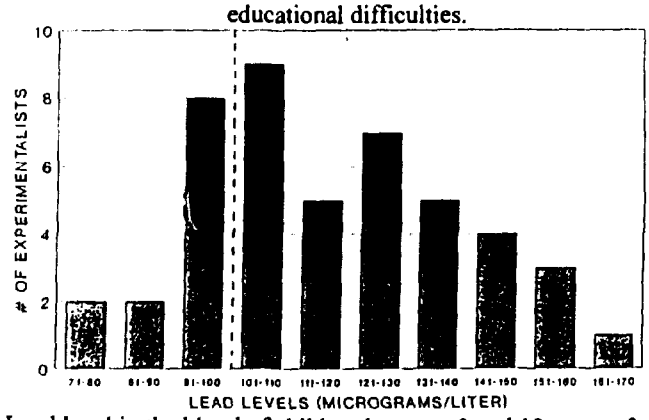

Fig. (6) Lead level in the blood of children between 0 and 12 years of age in Cairo.

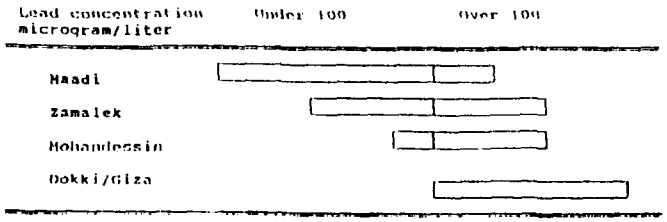

Fig. (7) Normal or elevated lead values in children up to age 6 in Cairo reference to residential area.