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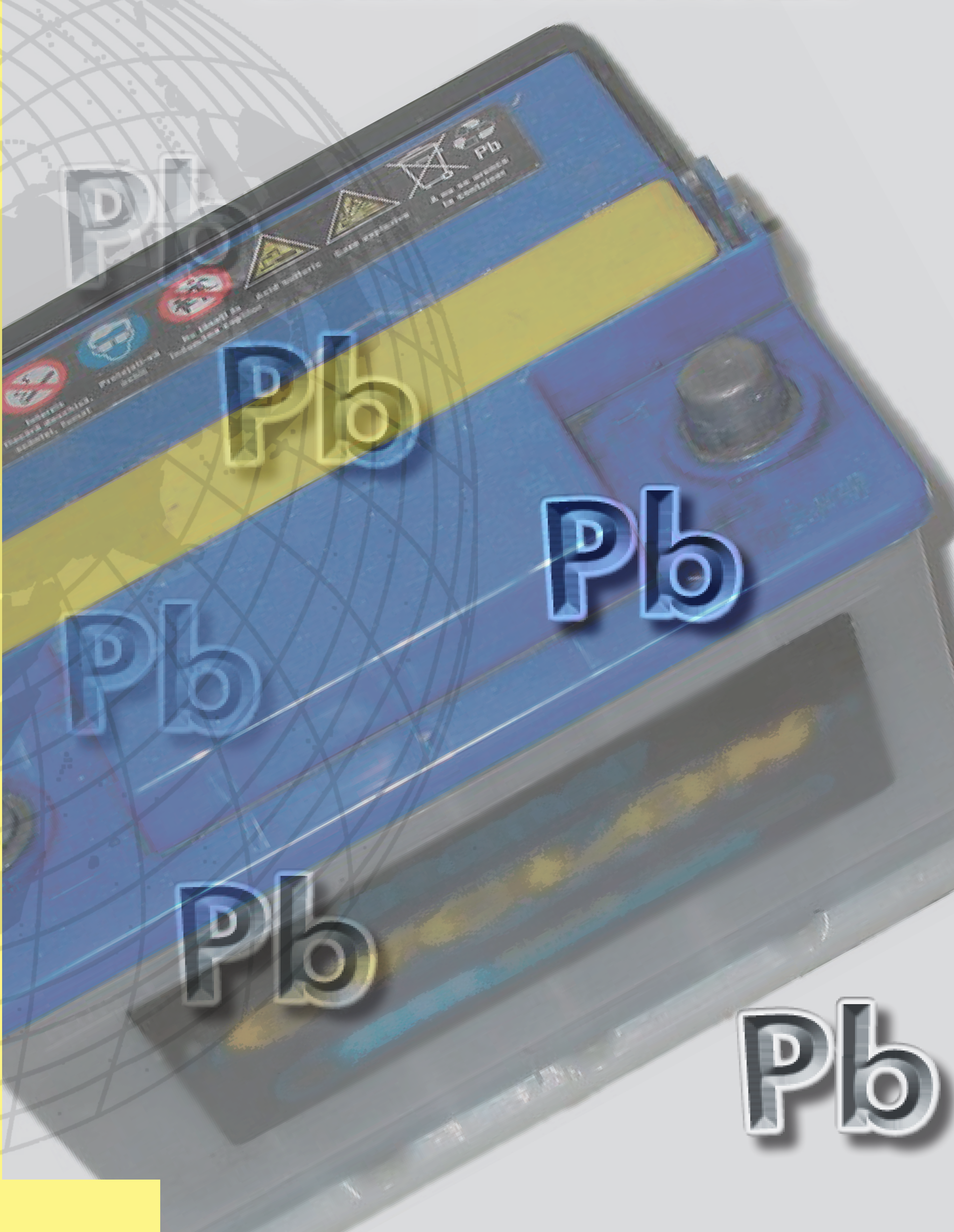
KEY SCIENTIFIC FINDINGS FOR LEAD



United Nations Environment Programme

Key scientific findings for lead: an excerpt from Final review of scientific information on lead, version of December 2010

Key scientific findings for lead

I. Hazardous properties, exposures and effects

1. Lead is a heavy metal that is toxic at very low exposure levels and has acute and chronic effects on human health. It is a multi-organ system toxicant that can cause neurological, cardiovascular, renal, gastrointestinal, haematological and reproductive effects. The type and severity of effects depend on the level, duration and timing of exposure. Lead is accumulated in bone and may serve as a source of exposure later in life. Organo-lead compounds, such as tri-alkyl-lead and tetra-alkyl-lead compounds, are more toxic than inorganic forms of lead.

2. In the environment, lead is toxic to plants, animals and micro-organisms. It bioaccumulates in most organisms. In surface waters, residence times of biological particles containing lead have been estimated at up to two years. Although lead is not very mobile in soil, lead may enter surface waters as a result of the erosion of lead-containing soil particles and the dumping of waste containing lead products.

II. Environmental transport: extent to which lead is transported on intercontinental, regional, national and local scales.

3. Lead is released by various natural and anthropogenic sources to the atmosphere and to aquatic and terrestrial environments and there are fluxes between these compartments. Lead released into the atmosphere is deposited on land and into aquatic environments and some lead released onto soil over time is also washed out to aquatic environments.

4. Once emitted to air, lead is subject to atmospheric transport. It is mainly emitted to the atmosphere in particle form. The atmospheric transport of lead is governed by aerosol (particle) transport mechanisms: in the atmosphere, lead may be transported on local, national, regional or intercontinental scales, depending on various factors, including particle size, the height of the emission outlet and meteorology. Because it has a relatively short residence time in the atmosphere (days or weeks), this metal is mainly transported over local, national or regional distances. For example, based on modelling results, the annual contribution of external emission sources to the total lead deposition in Europe has been estimated not to exceed 5 per cent, and in North America may be even lower. Episodically, however, the contribution of intercontinental transport may be significantly higher at certain locations in these two continents on some days of the year, although annual lead contribution from intercontinental transport is low.

5. While the model used to produce these results is state-of-the-art, it should be noted that the data underlying the model are based mainly on emission estimates from 1990. Another model calculation published in 1997 estimated that 5–10 per cent of emissions in the Euro-Asiatic region in the winter are deposited in the northern Arctic. It should be noted that model results have uncertainties and the resulting figures should therefore be interpreted with caution.

6. The regional and intercontinental atmospheric transport of lead contributes to deposition in remote regions such as the Arctic, where there are few local sources for lead releases. Some evidence of the limited intercontinental transport of lead is obtained from measurements of stable isotope signatures of the airborne dust in combination with air-mass back trajectories. These measurements indicate the origin of dust particles transported by air masses, and thereby provide evidence that aerosols carrying lead are transported intercontinentally and from industrialized regions to remote regions such as the

Arctic, where there are very few local emission sources. Soil in Kauai, Hawaii, was found to contain lead from diverse distant sources, including lead from anthropogenic sources in Asia and North America. Another study, in Japan, shows long-range transport of air pollution (including lead) from continental Asia.

7. Europe and the Asian part of the Russian Federation contribute all but a small percentage of the airborne lead reaching the Arctic. Models show that the main atmospheric pathways lie across the north Atlantic, from Europe and from Siberia. Between 95 and 99 per cent of the lead deposition in the Arctic is anthropogenic. Furthermore, over the period 1993–1998, snow samples in the part of the Arctic north of Russia showed a concentration gradient with levels increasing from the easternmost to the westernmost monitoring sites. This was the consequence of the different times at which leaded petrol was phased out in different regions and of varying trends in industrial development. The transport of lead follows seasonal patterns. Lead levels in airborne particles are lowest in early autumn, and at that time of year lead reaching the Canadian Arctic comes mostly from natural sources in the Canadian Arctic archipelago and western Greenland. In late autumn and in winter, airborne lead comes primarily from industrial sources in Europe. The measured snow concentrations, however, are low compared with deposition in industrialized areas.

8. The largest single ice-core based dataset used to reconstruct Arctic metal deposition comes from the Greenland Summit deep drilling programme. The data show that the lead levels increased significantly following the industrial revolution in the nineteenth century. Lead deposition in the 1960s and 1990s was eight times higher than in pre-industrial times. With the phase-out of leaded petrol since 1970 and the implementation of emission controls, lead concentration in the ice-core has sharply decreased. The results of the programme indicate that anthropogenic emissions – and, in particular, releases of lead through the use of leaded petrol – during a given period constituted a more important source than natural sources of lead deposited in Greenland. The remarkable reduction, in parallel with the removal of lead in petrol in 1970–1997, has resulted in a return to pre-industrial levels of lead in the ice-core data.

9. With regard to aquatic systems, rivers are transport media for lead on a national and regional scale. The oceans are also a transport medium. The oceanic residence time of lead ranges from about 100 to 1,000 years, which may indicate a potential for ocean transport. Concentrations of scavenge type trace metals, however, typically decrease with distance from the sources and, in general, concentrations of scavenge-type metals such as lead generally tend to decrease along flow paths of deep water because of continual particle scavenging and subsequent sedimentation.

10. The contribution of lead to the marine environment from Belgium, Denmark, France, Germany, the Netherlands, Norway, Sweden and the United Kingdom via rivers is currently larger than the airborne inputs.

III. Sources of releases.

11. Important releases of lead may be grouped into the following categories: releases from natural sources, in other words, releases resulting from the natural mobilization of naturally occurring lead from the Earth’s crust and mantle, such as volcanic activity and the weathering of rocks; current anthropogenic releases from the mobilization of lead impurities in raw materials such as fossil fuels and other extracted and treated metals; current anthropogenic releases of lead used in products and processes as a result of mining and processing activities, manufacturing, use, disposal, recycling and reclamation; releases from incineration and installations for municipal waste, open burning and from residues containing lead; and the mobilization of historical lead releases previously deposited in soils, sediments and wastes. Emissions from leaded petrol, metal processing including recycling, mining activity and probably oceans can be considered as the sources of relevance for the long-range transport of lead.

A. Atmospheric releases (emissions).

12. The most recent study of total anthropogenic atmospheric emissions estimated the total emissions in the mid-1990s at 120,000 tonnes, of which 89,000 tonnes originated from the use of petrol additives. Besides fuel additives, non-ferrous metal production and coal combustion were the major sources. The major natural sources of emissions to air are volcanoes, airborne soil particles, sea spray, biogenic material and forest fires.

13. Very different estimates on total emissions by natural processes have been reported. A study from 1989 estimates the total emission in 1983 at between 970 and 23,000 tonnes per year, whereas a new study estimates the total emissions from natural sources at between 220,000 and 4.9 million tonnes per year. The large disparity is mainly due to different estimates on the amount of lead moved around with soil particles.

14. As of June 2006, only two countries worldwide exclusively used leaded petrol, while 26 countries used both leaded and unleaded petrol. Since sub-Saharan Africa completely eliminated the import and production of leaded petrol in January 2006, the majority of countries still using leaded petrol are in the Asia-Pacific region. The global consumption of lead for manufacturing of petrol additives decreased from 31,500 tonnes in 1998 to 14,400 tonnes in 2003. In 1970, when the use of leaded petrol was peaking, about 310,000 tonnes was used for petrol additives in member countries of the Organization for Economic Cooperation and Development (OECD).

15. The total emission and distribution by sources vary considerably among countries. From 1983 to the mid-1990s, the quantified global anthropogenic emission of lead decreased from about 330,000 tonnes to 120,000 tonnes. Emissions have been decreasing in virtually all industrialized countries over the past twenty years. For example, in Europe, from 1990 to 2003, lead emissions decreased by about 92 per cent. In the United States of America, emissions decreased sharply during the 1980s and early 1990s due to the phase out of lead in petrol and reductions from industrial sources. Lead emissions continued to decline, but to a lesser extent, in the period from the mid-1990s to 2002. Overall emissions of lead decreased by about 95 per cent over the 21-year period from 1982 to 2002, falling from about 54,500 tonnes per year in 1982 to about 1,550 tonnes in 2002.

16. The significant reduction of lead emissions was mainly due to restrictions and bans on the use of leaded petrol for vehicles, but also implementation of improved air pollution controls. As an example, in eight European countries, the reported emissions from ferrous and non-ferrous production were, on average, reduced by about 50 per cent over the period 1990–2003, while emissions from waste incineration and from public electricity and heat production, on average, dropped by 98 per cent and 81 per cent respectively. Data on lead emissions and emission trends in developing countries were not available at the time of the preparation of the present document.

17. The open burning in some developing countries of waste products containing lead could be an important source of local and regional lead emissions to the atmosphere.

B. Releases to land and aquatic systems.

18. Some lead-containing products are disposed of in various waste deposits or released to soil or the aquatic environment. The major categories are: waste and loss of ammunition from hunting, disposal of products, mine tailings and smelter slag and waste. Other products and wastes, in no particular order, that may contribute to releases during their life-cycle, include paints with lead, lead balancing weights for vehicles, lead sheathing of cables left in the ground and lead batteries (loss by breakage and recycling), and mine tailings and other wastes. The handling of wastes may lead to elevated local and regional release levels in developing countries.

19. Direct industrial and municipal releases to aquatic environments in developed countries are considered small when compared to releases to the atmosphere and land. The major industrial sources are mining and non-ferrous metal production. Weathering of rocks releases natural lead to soils and aquatic systems, which plays a significant role in the global cycle. This release is enhanced by acidic

emissions. The open burning in some developing countries of waste products containing lead could be an important source of local and regional lead releases to land and aquatic systems.

IV. Production and uses of lead

20. Lead is mined in more than 40 countries, the major producers being China and Australia, which represent about 30 per cent and 22 per cent of global mining production respectively. Lead-rich minerals most often occur together with other metals, and about two thirds of worldwide lead output is obtained from mixed lead-zinc ores.

21. The total global production of lead from mining has decreased slightly, from 3.6 million tonnes in 1975 to 3.1 million tonnes in 2004. Over the same period, global refined lead production and metal consumption have increased from about 4.7 million tonnes to about 7.1 million tonnes. The reason for the difference between mine production and lead consumption is due to the fact that recycled lead accounts for an increasingly large part of the supply: recycled lead accounted for 45 per cent of global supply in 2003.

22. Lead is used and traded globally as a metal in various products. The major use of lead in recent years is lead batteries, accounting for 78 per cent of reported global consumption in 2003. Other major application areas are lead compounds (8 per cent of the total), lead sheets (5 per cent), ammunition (2 per cent), alloys (2 per cent), cable sheathing (1.2 per cent), and petrol additives (less than 1 per cent). The most significant change in the overall use pattern over the period 1970–2003 is that batteries account for an increasing part of the total, whereas the share of cable sheathing and petrol additives has decreased. Lead as pigment in paints has been discontinued in developed countries but is still used in some developing countries, specifically in industrial settings.

V. Lead issues in developing countries

23. As awareness of the adverse impacts of lead has increased, many uses have been reduced significantly in industrialized countries. In addition, as public awareness has grown, waste management systems have increasingly been put in place in industrialized countries to reduce releases of lead to the environment. That said, however, some of the uses of lead which have been phased out in industrialized countries have continued in developing countries. In addition, use of lead has continued or increased in some less developed regions or countries, for example, in plastics or in paints. Regulations and restrictions are less comprehensive or less well enforced in some developing regions. This has resulted in some of the health and environmental risks, local and regional that accompany the use, management (including collection, storage, recycling and treatment) and disposal of products containing lead. These hazardous disposal practices include open burning and indiscriminate dumping in sensitive ecosystems such as rivers and wetlands.

24. Another issue faced by developing countries is the export of new and used products containing lead, including electronic equipment and batteries, to those countries which lack the capacity to manage and dispose of the lead in these products in an environmentally sound manner at the end of their life. Another problem is posed by products containing lead that may cause exposure through normal use, such as certain toys.

VI. Levels and time trends in air and deposition

25. Most identified monitoring data for atmospheric lead concentrations and deposition come from Europe and the United States of America, although results from Antarctica, Canada, Japan and New Zealand are also available. Available data generally show a decreasing trend in air concentrations and deposition since about 1990, or earlier, depending on the country and region. For example, in 1990 the

concentrations of lead in air were measured at stations located in the central part of Europe and along the coast of the North Sea. Measured background concentrations lay mainly within the 10–30 ng/m^3 range. In 2003 the concentrations mainly ranged between 5 and 15 ng/m^3. Concentrations in precipitation in central Europe in 1990 were around 2–5 µg /l. In 2003, these concentrations typically ranged from 1 to 3 µg/l.

26. Lead concentration measurements in air in the Canadian Arctic in the period 1980–2000 show a decline in lead concentrations of about 30–50 per cent, whereas data from the Eurasian side (Norway) do not reveal any noticeable trends during the same period.

27. Some modelling has been performed, mostly in Europe, to estimate deposition rates. When reported emissions are used in the models, they generally underestimate deposition (compared to measured data). The underestimation is believed to be due to the failure to include natural emissions and re-emissions of historical releases in models and to uncertainties in reported emissions.

28. In order to estimate long-term trends for different parts of Europe, measurement data were averaged over different countries. The long-term changes of air concentrations and concentrations in precipitation vary considerably across Europe. In central and north-western Europe, concentrations decreased by about 50–65 per cent between 1990 and 2003 based on these data. In northern Europe, concentrations in precipitation decreased by 30–65 per cent. Trend data for ambient lead concentrations in the United States of America for the period 1982–2001 show that, while urban and suburban sites had the greatest decrease in ambient lead concentrations during that period, rural sites also experienced significant reductions. Overall, lead air concentrations across the country have decreased by more than 94 per cent since 1983, based on available data. Furthermore, this trend has continued, although at a reduced rate throughout the 1990s, with lead concentrations decreasing by 57 per cent between 1993 and 2002. Available data indicate that atmospheric deposition is still causing the content of lead in topsoils in Europe to increase in some locations. As there were no data from some developing countries, trends of lead levels in air could not be determined.

29. The decline in use of leaded petrol is reflected in the 85 per cent decline in lead deposition rates in the Arctic from the 1970s to the early 1990s.

30. The main factors affecting the range and deposition of lead emissions include: characteristics of emission sources (higher outlets and higher emission temperatures result in higher emission plumes and, therefore, longer transport ranges); physical and chemical forms of lead in the atmosphere: large particles deposit within short ranges, small particles may be transported further; and meteorology (precipitation and wind speed), terrain, atmospheric stability and other factors.

VII. Human exposure pathways and effects

31. Neurodevelopmental effects in children, even at low levels of exposure, represent the most critical effect. Other adverse effects include neurological, cardiovascular, renal, gastrointestinal, haematological and reproductive effects.

32. Exposure to lead occurs mainly through inhalation of dust and air and ingestion of foodstuffs, water and dust. Attention is drawn to the following:

- Inhalation is an important route of exposure for people in the vicinity of point sources, including open burning of wastes containing lead products, in countries that still use lead in petrol, and in some occupational settings including secondary lead recovery

- Ingestion of lead in dust and soil is a major exposure pathway in children, because of their biological and behavioural characteristics

- Intake of food and beverages is usually the primary source of exposure for adults in the general population

33. There are multiple sources of exposure. Attention is drawn to the following:

- A wide range of exposure sources exist, whose characteristics vary both within and between countries

- In some countries, lead in petrol is still an important source of exposure. Other sources include lead in paint, low temperature-fired ceramics, informal sector recycling of car batteries, mine tailings and the air, soil and dust in the vicinity of point sources (e.g., smelters)

- Dust in homes with paint containing lead pigment can cause elevated blood lead levels in children

- Tap water from leaded pipes can also be an important exposure source

- Other potential sources of exposure include products containing lead, such as cosmetics, traditional medicines, toys and trinkets, contaminated spices and food colouring

34. Certain population groups are vulnerable and especially susceptible to lead. Attention is drawn to the following:

- New data highlight the special vulnerability of small children. Exposure of children can be magnified by their activities and behavioural patterns and biological characteristics

- Exposure starts in utero since lead passes through the placenta into the foetus; thus pregnant women are a population of concern

- Occupational exposure (e.g., some workers in the informal recycling sector)

- Other vulnerable population groups include socially and economically disadvantaged populations and the malnourished, whose diets are deficient in proteins and calcium

35. Lead is a well-documented neurotoxicant. Attention is drawn to the following:

- Lead exposure in children is linked to a lowering of their IQ

- Epidemiological studies consistently find adverse effects in children at blood lead levels down to 10 μg/dl. Recent studies reported lead-induced IQ decrements in children with blood lead levels below 10 μg/dl

- There is presently no known threshold for the effect of lead

- A growing number of studies suggest that exposure to lead may cause behavioural deficits and lower functional skills during childhood and later in life

36. Attention is drawn to the following observations relating to exposure levels, trends and geographic scope:

- Lead exposures occur in most, or all, countries of the world. Available data suggest that, on the global scale, the highest blood lead levels occur in Latin America, the Middle East, Asia, parts of Eastern Europe and the Commonwealth of Independent States

- Available data indicate a substantial falling trend in environmental lead exposure in many developed countries mainly due to the elimination of lead from petrol, but also to reductions in other sources of exposure (e.g., lead in paint, lead in drinking water and lead in soldered cans). Thus, in the United States of America in the 1970s, over 80 per cent of children had blood lead levels (Pb-B) exceeding 10 μg/dl, but, in a 1999–2002 study, fewer than 2 per cent exceeded this level

- Exposure levels remain elevated in many locations, however, including in some developed countries

37. Lead remains an environmental health problem. Attention is drawn to the following:

- A growing number of countries (mainly developing countries and countries with economies in transition) are recognizing and reporting the problem of environmental lead exposure in some population groups

- In many parts of the world, for many decades, there was very little public awareness of and policies relating to the potential for lead contamination and its public health effects

- As a result of its health effects and impact on development, lead may cause significant economic losses for society

VIII. Impacts on the ecosystem

38. Environmental exposure to lead is greatest near point sources (e.g., smelters), or from lead shot and sinkers used for shooting and fishing. In locations not affected by local sources, there are generally no observed effects on terrestrial organisms and plants and, in the aquatic environment, lead concentrations are normally below known effect levels. One possible important exposure route which has not been included in the review owing to lack of data is the indiscriminate disposal of waste containing lead products in sensitive ecosystems such as the many rivers and wetlands in developing countries.

39. The environmental effects of lead are well documented. Secondary poisoning has also been extensively documented, especially for predators feeding on contaminated animals. There are many reports on the levels of lead in wild mammals, but few reports of toxic effects of the metal in wild or in non-laboratory species. In all species of experimental animals studied, however, lead has been shown to cause adverse effects in several organs and organ systems, including the blood system, central nervous system, the kidney and the reproductive and immune systems.

40. In a significant percentage of European soils, the lead concentrations estimated for areas away from point sources exceed the threshold concentration for adverse effects in soil, and therefore the terrestrial ecosystems are considered to be at risk.

IX. Data gaps

41. A number of data gaps and needs have been identified. Attention is drawn to the following:

- The need to develop and improve exposure assessments and use and release inventories, especially for developing countries

- The need for modelling for the southern hemisphere and a better understanding of ocean transport, re emissions, and natural releases

- The need to examine the role of long-range transport, the contribution of anthropogenic sources versus natural sources and the influence of local, regional and global sources

- The general lack of data from developing countries where environmental and health problems related to production, trade, use and disposal of lead may be more common and have a different nature that in other regions

- The need to monitor and assess lead levels in various media (such as soil and sediment) and data associated with impacts on humans, ecosystems and animals, including impacts from cumulative exposures to different forms of lead, as well as further emission data that help overcome the uncertainties in the results of the current models

- The need to collect data regarding accidental spills from mine tailings on a global scale and the real extent of these events, especially in developing countries, where capacity building is needed
- The need for real information about the quantities of lead disposed of in the environment, especially in developing countries, where the open burning of lead- containing products is a common practice, which results in atmospheric emissions
- The need to improve the information on the level of contamination of drinking water by lead as a result of leaching from landfills, especially in developing countries
- The need to collect data on concentration levels in large migrating marine mammals
- The need to examine the global flow of lead in products

About the UNEP Division of Technology, Industry and Economics

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The Division works to promote:

> sustainable consumption and production,

> the efficient use of renewable energy,

> sound management of chemicals,

> the integration of environmental costs in development policies.

The Office of the Director, located in Paris, coordinates activities through:

> The International Environmental Technology Centre - IETC (Osaka, Shiga), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.

> Production and Consumption (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.

> Chemicals (Geneva), which catalyzes global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.

> Energy (Paris), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.

> OzonAction (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.

> Economics and Trade (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

UNEP DTIE activities focus on raising awareness, improving the transfer of knowledge and information, fostering technological cooperation and partnerships, and implementing international conventions and agreements.

For more information,
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