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EFFECT OF MERCURY AND LEAD ON THE TOTAL ENVIRONMENT

Mercury and lead are widely used in nowadays economy. However, by using these toxic metals, we disperse them around the planet, pollute it and, since they are not biodegradable, threaten future generation with unsafe environment. The other side of the problem is that they are nonrenewable resources and therefore current estimates suggest that, at present levels of consumption, there is enough lead for 58 years and mercury for 46 years, to mention just a few of the best known heavy metals. A role of these metals in the total environment is discussed in the paper.

1. INTRODUCTION

The concept of sustainable development was introduced in Burtland's famous report *Our Common Future*, which generally says that sustainable development is that which meets the needs of the present without threatening the abilities of future generations to meet their needs.

Talking about sustainable development on the ground of moral values, one can speak of inter- and intra-generational justice. Inter-generational justice refers to the demands of future generations that resources and the quality of the environment be left in a state that allows them to live [1]. Intra-generational justice (i.e. justice within a generation) refers to the present generation and demands equal access to available resources. Both of these principles must be borne in mind when discussing sustainable development.

Practical implementation of these principles is complicated because of many dimensions: philosophical, social, ecological, economical and technical [2]. In this discussion, let us focus on defining the duties arising from the implementation of sustainable development. That means the transition to defined duties on the basis of ethics, where we can talk about the need to ensure inter- and intra-generational justice [3, 4].

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Initially heavy metals are used as new materials for the production of goods. Since they are non-renewable resources and their amounts are limited on our planet, sooner or later they may be exhausted, and thus future generations may not be able to meet their needs for heavy metals. This is one side of the problem. The other is that by the use of heavy metals by our civilization, they do not disappear from the planet, but are dispersed throughout Earth's surface, polluting it, and thus threatening a safe environment for future generations.

The present world is developing unsustainably. There has been enormous technological progress; however, our technical abilities to change the world are so powerful that they may even lead to its destruction [4, 5]. The almost geometric progress of our technical abilities to change the world has left the development of social sciences far behind, and does not allow answering the question of what values such changes serve. The fact that resources are becoming less available makes it all the more serious [6, 7].

A lot has been said and written in recent years about climate change, and much less about the fact that the main fossil fuels and non-renewable resources may be exhausted. The consequences to the world of energy and non-renewable resource shortages could be much more severe than the greenhouse effect [8].

Current estimates are that, at the present levels of consumption, there is enough oil for about 40–50 years, natural gas for about 60–70 years and coal for ca. 140–150 years. The situation is no better for metals. At the present level of consumption, there is enough copper for about 66 years, zinc for 23, lead for 58, mercury for 46, and cadmium for ca. 31 years, to mention just a few of the best-known heavy metals [9]. This does not mean that after that time heavy metals would cease to be available; their shortage would cause poorer deposits to be exploited and substitutes to be more widely used. Nevertheless, the resources of heavy metals are not infinite, and sooner or later they may be exhausted. The sustainable approach requires the slowing of use of heavy metals by saving, recycling and substitution by more available materials, and as well preventing their dispersion throughout the environment.

Even if we assume a large error in the estimates, one must accept that a major crisis in access to conventional resources will occur within a short time, measured rather in decades than in centuries. This means that one of the cardinal rules of sustainable development, namely inter-generational justice, is at stake. The present generation seems to be living at the expense of future generations [10].

All the above clearly indicates that the development of modern civilization is highly unsustainable [11], and seems to show that full sustainability is impossible; however, this does not mean that we can do nothing. From a practical standpoint, the goal of sustainability should be to minimize, as far as practical, the use of energy and irreplaceable raw materials. We should also seek to develop sources of energy and materials which are replaceable or self-regenerating, and as non-polluting as practically possible [12–14].

2. PROBLEMS WITH HEAVY METALS

Mercury and lead are the best-known heavy metals and have been used by mankind since ancient times. They belong to a limited class of elements that can be described as purely toxic, and are still widely used and important to our economy. However, because they are toxic, persistent and bioaccumulative pollutants continuously dispersing through the whole surface of the earth, they pose a serious threat to the global environment.

Since heavy metals are elements, they cannot be broken down and therefore thus persist in the environment. Unlike many organic pollutants, which eventually degrade to carbon dioxide (CO_2) and water, heavy metals tend to accumulate in the environment, especially in lake, estuarine or marine sediments. Metals can be transported from one environmental compartment to another. Many heavy metals are toxic to organisms at low concentrations; however, some such as copper and zinc are also essential elements. Concentrations of essential elements in organisms are normally homeostatically controlled, with uptake from the environment regulated according to nutritional demand. Effects on the organisms are manifested when this regulation mechanism breaks down as a result of either insufficient (deficiency) or excess (toxicity) metal. Mercury and lead, however, have adverse effects even at exposure to low concentrations.

2.1. MERCURY

The oldest information on the use of mercury is from China. The ancient Chinese believed that mercury had a positive effect on health and could prolong life. One of China's emperors, Qin Shi Huang Di, drank mercury because he believed that it gave him eternal life. The ancient Egyptians and the Romans used mercury in cosmetics, and alchemists thought mercury was the first matter from which all metals were formed.

Nowadays, mercury is one of the most widely used heavy metals in industry (Table 1). More significant, however, is its anthropogenic emission in the environment. According to Pacyna et al. [16] and Streets et al. [17], total mercury emissions from anthropogenic sources were 2 320 Mg (Table 2) – calculated from estimated of emission factors (Table 3).

The greatest mercury emissions are from coal and oil combustion (810 Mg/yr) and gold mining (400 Mg/yr). Mercury emissions from natural sources (Table 4) are much higher (5207 Mg/yr) than from anthropogenic sources (2320 Mg/yr). The higher emission from natural sources is caused by the circulation of mercury in the environment. Due to oxidation-reduction and microbial processes, mercury is volatilized mostly to the atmosphere and redeposited back on the surface of the Earth, then emitted again to the atmosphere due to the above mentioned processes. The flux of mercury from natural sources is therefore much higher than that from anthropogenic origins. The circulation of mercury in the environment is responsible for the growing contamination of the whole surface of our planet. The levels of atmospheric mercury are increasing in the remote troposphere, far from known sources [20].

There are two main types of reaction in the mercury cycle that convert mercury into its various forms: oxidation-reduction and methylation-demethylation. In oxidation-reduction reactions, mercury is either oxidized to a higher valence state (e.g., from the relatively inert Hg^0 to the more reactive Hg^{2+}) or through the loss of electrons reduced, the reverse of being oxidized, to a lower valence state.

Table 1

Mercury consumed [Mg] in 2000 [15]

Item	European Union	United States	Rest of world	Totals
Hg consumed in batteries	15	16	1050	1081
Hg consumed in dental amalgams	70	44	158	272
Hg consumed in lighting	21	17	53	91
Hg consumed in electrical control and switching	25	50	79	154
Hg consumed in other products and processes	50	50	75	175
Hg consumed in measuring and control devices	26	35	105	166

Table 2

Global mercury emission from anthropogenic sources, data for 2008

Source category	Hg emission [Mg/yr]	Reference
Coal and oil combustion	810	[18]
Non-ferrous metal production	310	
Pig iron and steel production	43	
Cement production	236	
Caustic soda production	163	
Mercury production	50	
Artisanal gold mining production	400	[19]
Waste disposal	187	[18]
Coal bed fires	32	
VCM production	24	
Others	65	
Total	2320	

Another problem with pollution with mercury is an indoor environment, since this is where an average person spends most of their life. When spilled in a small, poorly-ventilated room, mercury can pose significant health threats. Very small amounts of metallic mercury, released into an enclosed space, can raise air concentrations to levels harmful to health. In addition, metallic mercury and its vapours are extremely difficult to remove from clothes, furniture, carpets and other porous items.

Table 3

Emission factors adopted to estimate anthropogenic emissions [16]

Source category	Unit	Emission factor
Coal combustion power plants	$g \cdot Mg^{-1}$	0.04–0.3
Coal combustion in residential and commercial boilers		0.1–0.5
Oil combustion		0.058
Biofuel combustion		0.02
Cu smelting		5.0–6.0
Pb smelting		3.0
Zu smelting		7.5–8.0
Cement production		0.065–0.1
Pig iron and steel production		0.04
Municipal wastes incineration		1.0
Sewage sludge wastes		5.0
Mercury production (primary)	$kg \cdot Mg^{-1}$	0.2
Gold production (large scale)	$g \cdot g^{-1}$	0.5

Table 4

Global mercury emissions by natural sources estimated for 2008 [18]

Source	Emission [$Mg \cdot yr^{-1}$]	Contribution [%]
Oceans	2682	52
Lakes	96	2
Forests	342	7
Tundra/grassland/savannah/prairie/chaparral	448	9
Desert/metalliferous/non-vegetated zones	546	10
Agricultural areas	128	2
Evasion after mercury depletion events	200	4
Biomass burning	675	13
Volcanoes and geothermal areas	90	2
Total	5207	100

As mentioned above, implementation of sustainable development requires a reduction in energy consumption because natural reserves are limited and their combustion increases the concentration of CO_2 in the atmosphere, which seems to lead to climate change [7]. One proposed method of reducing energy consumption is to use fluorescent bulbs. However, the solution to one global problem creates another – fluorescent bulbs contain a small amounts of mercury vapour and a larger amounts of mercury in a powder or dust form, both of which can become airborne if the bulb breaks. If the breakage is not cleaned up properly, the mercury may continue to circulate. Disposing of these bulbs in the trash can cause also serious harm to health and the environment.

The US Environmental Protection Agency sets a reference concentration of 0.3 μg Hg/m^3 for inhalation exposure to mercury. The reference concentration is a screening tool to help risk assessors to determine where to focus their investigation into hazardous exposures – adverse health effects do not necessarily result from exposure at that concentration. For example, if 0.3 μg Hg/m^3 was measured in an air inside a building, the EPA would further investigate the exposure.

Similarly, the US Agency for Toxic Substances and Disease Registry (ATSDR) has set a minimal risk level (MRL) for inhalation exposure for mercury at 0.2 μg Hg/m^3. The MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse health effect over a specified period of time. ATSDR also recommends an action level of 1.0 μg Hg/m^3 for remediation if exceeded in indoor air.

Table 5

Projected global mercury use in 2020 [15]

Use category	Global demand 2000 [Mg]	Prospects for mercury demand to 2020	Projected global demand 2020 [Mg]
Chlor-alkali industry	797	significant decline over next 10–20 years	280
Small-scale gold/silver mining	650	unpredictable, but some decrease in the level of exploitation	400
Batteries	1081	steep decline	100
Dental amalgam	272	gentle decline	250
Measuring and control	166	general decline	100
Lighting	91	gradual increase, at least in the foreseeable future	120
Electrical control and switching	154	general decline	100
Other uses	175	variable, especially in cosmetics	150
Total demand	2286		1500

Control of mercury concentration in indoor environments seems to be very important due to mass use of fluorescent lamps in EU countries. One must consider that fluorescent bulbs contain 0.5–1000 mg Hg per bulb. This is only the source where use of mercury will increase in years to come (Table 5).

2.2. LEAD

Lead is another heavy metal with a global impact. It was one of the earliest metals discovered by man and was in use by 3000 BC. The ancient Romans used lead for making water pipes and lining baths. They also used lead pots or lead-lined copper for boiling crushed grapes to make wine. According to the Roman winemaker Columella, lead improves the taste of wine. It was discovered later that, in lead pots, lead acetate with a sweet taste is formed. Lead touched many areas of Roman life. It was used in pipes, dishes, cosmetics, coins and paints. Some historians believe that many among the Roman aristocracy suffered from lead poisoning and that the fall of the Roman Empire was caused by the degeneration of the ruling class caused by lead poisoning. Even in the Middle Ages, lead acetate, called sugar of lead, was used to sweeten wine.

For centuries, lead compounds have provided pigments for paints, and are still widely used. The total consumption of lead continues to grow, from 7.297 mln Mg in 2004 to 8.649 mln Mg in 2009. One positive aspect, from the sustainability standpoint, is that a significant proportion of the lead used has been recycled (Table 6).

Table 6

Global lead production and consumption [mln Mg] [21]

Source	Year					
	2004	2005	2006	2007	2008	2009
Mine production	3.865	4.202	4.410	4.500	4.857	4.798
Recycling	3.130	3.422	3.525	3.626	3.896	4.029
Total production	7.005	7.624	7.935	8.126	8.653	8.827
Total consumption	7.297	7.786	8.063	8.182	8.649	8.756

In terms of tonnage consumption of lead since 1960, the battery market increased almost seven-fold while almost all the other sectors experienced real as well as proportional declines. The growth in total demand for lead has therefore been due almost exclusively to the demands of the battery market. Despite the decline in many of the non-battery uses of lead, some interesting prospects exist for new commercial-scale applications in the future. Significant among these is the use of lead for nuclear waste disposal. Because lead absorbs alpha and gamma rays it can be used as containers for nuclear wastes. As the demand for non-fossil-fuel energy sources intensifies, prospects for nuclear power – and hence for nuclear waste disposal – seem likely to grow. Liquid metal magnetohydrodynamics (LMMHD) is another energy-related potential use of lead. In LMMHD (currently only at the pilot stage), molten lead flows in an enclosed loop through an intense magnetic field to generate an electric current. The system can employ low-grade heat sources and would be particularly suitable for installation in remote locations. With a requirement of about 200 tonnes of lead per MW of installed power, could be an important new market for the metal. A third new use of lead which has already proven its effectiveness is in earthquake to stabilize buildings.

The present emissions of lead to the environment is declining like the emissions from burnt gasoline, where in 1960 nearly 200 000 Mg of lead was used, reaching a peak of 300 000 Mg in the early 1970s and has declined steadily ever since. By 2005, consumption of lead as gasoline additives accounted for < 10 000 Mg. However, it is estimated that over the past five millennia about 300 million t of lead were released into the environment. Such consumption caused a global lead contamination of the whole environment due to circulation in soil, water and air. The amount of lead emitted to the environment over time is such that levels in the human body of today's population are 500–1000 times greater than that of their pre-industrial ancestors [22].

Low-level environmental exposure to lead is associated with multiple sources (petrol, industrial processes, paint, and solder in canned food, water pipes) and pathways (air, household dust, street dirt, soil, water and food). Evaluation of the relative contributions of sources is therefore complex and likely to differ between areas and population groups.

3. INTER- AND INTRA-GENERATIONAL JUSTICE

Referring to moral obligations drawn from the idea of sustainable development, one can distinguish two important terms: inter- and intra-generational justice.

3.1. INTER-GENERATIONAL JUSTICE

This is justice between the current generation and those that follow. The term was used in the Brundtland report definition of sustainable development.

Democracies – both the representative and the direct type – face a structural problem, namely the tendency to favour the present over the future. Future individuals are not yet born, and thus are unable to be involved in today's decision-making process.

Apart from an exhaustion of the source of heavy metals what may create a problem with manufacturing of some goods, the other problems for the future generation seems to be even more severe. All heavy metals when released to the environment remain there for an unlimited time, recycling among all compartments through the following mechanisms:

- Natural-source releases due to natural mobilization of naturally occurring heavy metals from Earth's crust such as by volcanic activity and weathering of rocks.
- Current anthropogenic (associated with human activity) releases from the mobilization of heavy metals impurities in raw materials such as fuels – particularly coal, and to a lesser extent gas and oil – and other extracted, treated and recycled minerals.
- Current anthropogenic releases of heavy metals used intentionally in products and processes, due to releases during manufacturing, leaks, disposal or incineration of spent products or other releases.
- Re-mobilization of historic anthropogenic heavy metals releases previously deposited in soil, sediments, water bodies, landfills and waste/tailings piles.

Global emissions remain high and, taking into account accumulation of metals in the environment, further emissions may threaten, above all, the health of children. For example nearly 1.7 million children aged 1–5 have blood levels of Pb ≥ 100 μg/L. Such a level will negatively affect their wellbeing.

Since the oceans are a sink for most heavy metals, there is a danger that growing heavy metal concentrations in the marine environment will disturb plankton growth. These may affect not only the food chain in the marine environment, but also decrease CO_2 assimilation by plankton, one of the very important global sinks of CO_2 – this would accelerate climate change.

A positive trend can also be observed. The anthropogenic emissions of lead in 32 EEA (European Economics Area) countries have declined by 88% during 1990–2007. This is primarily due to reductions in the road transport sector. The promotion of unleaded petrol within the EU through a combination of fiscal and regulatory measures has been a particular success story. EU member states and other EEA member countries have now phased out the use of leaded petrol, a goal regulated in the EU by the Directive on the Quality of Petrol and Diesel Fuels (98/70/EC). In 2007, the largest emitters of lead were Poland (responsible for 20% of total EEA-32 emissions), Spain (10%), Italy (10%) and Bulgaria (9%). All countries report lower emissions of lead in 2007 compared with 1990, with the only exceptions being Malta and Bulgaria [23].

Global change related to climate change and the role of CO_2 emissions has attracted worldwide attention [8, 24]. Not many know, however, that heavy metals can disturb the equilibrium of the global environment. In the extreme case of an excessive increase in their concentrations in the oceans, which are the sink for heavy metals, they may inhibit plankton growth. This would disturb the food chain in the oceans and in consequence decrease fish production to a catastrophic level. Plankton also plays an important role in the absorption of CO_2 from the atmosphere – one of the major sinks for CO_2. The disappearance of plankton from oceans would cause a catastrophic growth in the concentration of CO_2 in the atmosphere. Therefore, control of heavy metal emissions is of great global importance.

The improper control of heavy metals can lead to a substantial threat to the intergenerational justice – one of the fundament principles of sustainable development. Therefore, studies of pathways of heavy metals in the environment are equally important as studies on greenhouse gases, as they may affect future life on our globe even more severely than greenhouse gas emissions.

In reference to the term ‘humanity ecological footprint’, which sets the smallest necessary area of the Earth’s surface for the human population to survive [25], it has been shown [26] that our planet’s capacity to sustain our population was exceeded in approximately 1986 (Fig. 1). Thus, the space available on our planet to sustain a decent life for the human population is already overloaded. There is no room for a growing population.

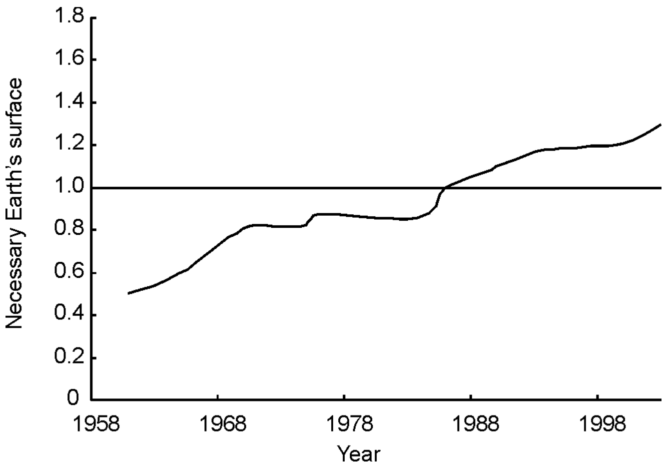

Fig. Global footprint for the period of 1958–1998.

3.2. INTRA-GENERATIONAL JUSTICE

Moreover, a second rule of sustainable development, intra-generational justice, is not respected either. The present course of development in our civilization makes it worse. With the fall of socialism, liberal capitalism, with its chief paradigm 'grow-or-die' became the leading socio-economic system [27]. As a consequence, the consumption of all environmental components increased, including non-renewable resources. This phenomenon was accompanied by a global concentration of economic power, associated by numerous ties with political influence [28].

Appealing to ruthless competition, with no regard to cooperation, has a disintegrating influence on social bonds and creates an atmosphere that favors struggle for dominance, especially economic, associated with political power [27]. In consequence we have economic and political elite with strong internal bonds, alienated from the rest of society, to an extent that ordinary people have little or no influence on social and economic processes. The criminal war in Iraq provides an example: had the decision to start the war been dependent on a referendum and not made in the privacy of cabinets of the economic and political elite, the war would never have begun.

As Hart [29] indicates, in 1960 the wealthiest 20% of the population owned 30 times as much wealth as the poorest 20%, whereas this ratio in 1991 reached 60 times, and 78 times in 2004. A UNDP report [30] provides information showing that the annual income of the 500 richest people in the world is equal to that of the 400 million most impoverished; Kofi Annan, Secretary-General of the UN, stated that almost half the population has an income of < $2 a day.

Young children are undergoing rapid development, their systems are not fully developed, and consequently they are more vulnerable than adults to the effects of heavy metals, especially lead. Children from poor families are more exposed to heavy metals because they live in older houses where paints containing heavy metals (Pb and Cd) have been used. They also live mostly in the more populated areas where emissions of Pb from gasoline are higher.

A study in the USA [31] showed that, during 1976–1991, when lead was removed from gasoline, the prevalent blood lead level of ≥ 100 μg/dm^3 for children aged 1–5 years declined from 85.0% to 5.5% for non-Hispanic white children, and from 97.7% to 20.6% for non-Hispanic black children. The major cause of this decline was the removal of lead from gasoline. Sociodemographic factors associated with higher lead levels in children of non-Hispanic black race were low income and living in older housing. It was concluded that programs for the prevention of lead poisoning should target high-risk persons, such as children living in old houses, belonging to minority groups, and living in families with low incomes.

The worst situation, however, is in developing countries like Africa. Gasoline sold in most African countries contains 0.5–0.8 g Pb/dm^3. In urban and rural areas and near mining centres, average lead concentrations reach 0.5–3.0 μg/m^3 in the atmosphere and >1000 μg/g in dust and soils. In addition to automotive and industrial sources, cottage industries and the burning of paper products, discarded rubber, battery casings and painted woods for cooking and heating represent additional hazards to individual households [32].

Although African children are particularly predisposed to environmental lead exposure, because of their lifestyle and socioecological factors, a true picture of childhood lead poisoning in the continent remains undefined. Recent prevalence studies show that > 90% of the children in urban and rural communities of the Cape Province, South Africa have blood lead levels ≥ 100 μg/dm^3. Studies in other countries likewise suggest that childhood lead poisoning is a widespread urban health problem throughout the continent [32].

4. CONCLUSION

Heavy metals, mainly mercury, lead and cadmium, are a global problem that needs to be addressed from a global and sustainable perspective, like climate change. Therefore, it was suggested the EU established a research project on the effects of heavy metals on the global environment. The research should concentrate on the following:

A better understanding of what happens to heavy metals from extraction through processing and manufacturing to their ultimate disposal.

Heavy metals have accumulated over the centuries in all parts of the environment and their fate and pathways within ecosystems need to be better understood.

The role of methylated heavy metals (monomethyl and dimethyl mercury; dimethyl, trimethyl and tetramethyl lead; and monomethyl cadmium) in the migration of heavy metals in the global environment needs to be better understood.

The role of heavy metals in the ocean biota needs to be better understood.

There is a need to develop a detailed global emissions inventory for mercury, lead and cadmium from anthropogenic sources for inclusion in the global tracer transport model.

There is a need to develop parameterizations for the exchange of mercury, lead and cadmium between the oceans, land surface and biosphere for inclusion in the global tracer transport model.

No doubt heavy metals are equally important from sustainable development and global perspective as the greenhouse effect, and an increase in the content of heavy metal in the global environment is more dangerous than increase in the content of greenhouse gases.

REFERENCES

[1] DURBIN P.T., Problemy Ekorozwoju, 2008, 2 (3), 3.
[2] PAWLOWSKI A., Problemy Ekorozowoju, 2006, 1 (1), 23.
[3] HULL Z., Problemy Ekorozwoju, 2007, 1 (2), 49.
[4] PAWLOWSKI A., Problemy Ekorozwoju, 2009, 1 (4), 65.
[5] PAWLOWSKI A., Problemy Ekorozwoju, 2008, 1 (3), 3.
[6] LASZLO CH., Problemy Ekorozwoju, 2008, 2 (3), 25.
[7] PAWLOWSKI A., Problemy Ekorozwoju, 2009, 2 (4), 3.
[8] LINDZEN R.S., Problemy Ekorozwoju, 2010, 2 (5), 13.
[9] ARON S., S*ome statistics on limited natural resources*, 2005, http://scotaaron.com/resources2.html.
[10] UDO V., PAWŁOWSKI A., Problemy Ekorozwoju, 2010, (5) 4, 23.
[11] IKERD J., Problemy Ekorozwoju, 2008, 1 (3), 13.
[12] PAWLOWSKI A., Problemy Ekorozwoju, 2007, 1 (2), 59.
[13] RUSSEL D., Problemy Ekorozwoju, 2010, 1 (5), 15.
[14] VENKATESH G., Problemy Ekorozwoju, 2010, (2) 5, 29.
[15] *Mercury flows in Europe and the World*, Report of European Commission DG for Environment, 2004.
[16] PACYNA J.M., PACYNA E.G., SUNDSETH K., MUNTHE J., WILSOND S., LEANERE J., Geophys. Res. Abstr., 2010, 12.
[17] STREETS D.G., QIANG Z., WU Y., Environ. Sci. Technol., 2009, 42 (8), 2983.
[18] PIRRONE N., CINNIRELLA S., FENG X., FINKELMAN R.B., FRIEDLI H.R., LEANER J., MASON R., MUNKHERJEE A.B., STRACHER G.B., STREETS D.G.,TELMER K., Atmos. Chem. Phys. Discuss., 2010, 10, 4719.
[19] TELMER K.H., VEIGA M., W*orld emissions of mercury from artisanal and small scale gold mining*, Mercury fate and transport in the global atmosphere, Springer, New York, 2009, 131–172.
[20] DOCTOR R.D., TAYLOR J.A., SHANNON J.D., A*tmospheric mercury-global biogeochemical cycles, sources, and sink*, Climate and global change, series, 2000, No. ANL/CGC-003-0600.
[21] www.ilzsg.org
[22] NRIAGU J., OLERU N.T., CUDJOE C., CHINE A., Sci. Total. Environ., 1997 (1–3), 13.

[23] *EEA32 Heavy metal (HM) emissions (APE 005). Assessment*, EEA Report February 2010.
[24] GOLOMB D., Problemy Ekorozwoju, 2008, 1 (3), 23.
[25] WACKERNAGEE M., 2006, Global footprint network, hhtp://www.footprintnetwork.org (5.01.2010).
[26] *Global Footprint Network 2006*, Footprint network news, October 24, 2006.
[27] FOTOPOLOUS T., Int. J. Inclusive Democracy, 2007, 1 (3), 20.
[28] BAUMGAERTNER J., Problemy Ekorozwoju, 2008, 2 (3) 15.
[29] HART S.L., *Capitalism at the crossroads*, Wharton School Publishing, London, 2005.
[30] *Human development report*, *International cooperation at a crossroads: Aid, trade and security in an unequal world*, UNDP Report, New York, http://hdr.undp.org/reports/global/2005, 2010.
[31] *Environmental lead exposure*, Bulletin of the WHO, 2010,
[32] NRIAGU J.O., BLANKSON M.L., OCRAN K., Sci. Total Environ., 1996, 181 (2) 93.