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Zrównoważoność a globalna rola metali ciężkich

Sustainability and Global Role of Heavy Metals

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Streszczenie

Wiele mówi się o związkach zmian klimatu ze zrównoważonym rozwojem, dopatrując się głównego zagrożenia w nadmiernej emisji dwutlenku węgla. Tymczasem podobny, acz nieuświadamiany, problem dotyczy metali ciężkich.

Metale ciężkie zagrażają implementacji zrównoważonego rozwoju, gdyż naturalne ich zasoby są na wyczerpaniu. Ponadto, wyjątkowa toksyczność metali ciężkich (które rozprzestrzeniane są na całej powierzchni planety, zanieczyszczając ją) zagraża możliwości posiadania bezpiecznego środowiska dla przyszłych pokoleń. Zastosowanie zasady zrównoważonego rozwoju pozwala na ograniczenia rozprzestrzeniania się metali ciężkich w środowisku.

W artykule przedstawiono propozycje niezbędnych badań naukowych, które mogłyby przyczynić się do lepszego zrozumienia roli metali ciężkich w zapewnieniu zrównoważoności naszej cywilizacji.

Słowa klucze: zrównoważony rozwój, globalne zagrożenia, sprawiedliwość między-generacyjna, sprawiedliwość wśród-generacyjna.

Abstract

A lot has been written about the impact of climate change caused by excessive emission of carbon dioxide on sustainable development. There are, however, similar, but not so much widely known, problems caused by heavy metals.

The heavy metals threaten implementation of sustainable development, because the natural resources of heavy metals are running out. Moreover, high toxicity of the heavy metals (spreading throughout whole surface of the Earth, polluting it) is threatening the safe environment for future generation. Implementation of sustainable development can decrease spreading of the heavy metals.

In the paper scientific research was proposed, one which may help to better understand a role of heavy metals in implementation of sustainability in our civilization.

Key words: sustainable development, global threats, inter-generational justice, intra-generational justice

Introduction

The present world is developing unsustainably. There has been enormous technological progress and our technical abilities to change the world are so powerful that they may even lead to its destruction (Pawłowski, 2009a). 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 (Baumgaertner, Durbin, 2008; Hull, 2007). The fact that resources are becoming less available makes it all the more serious (Laszlo, 2008; Pawłowski, 2009b).

A lot has been said and written in recent years about the 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 (Lindzen, 2010).

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

about 140-150 years (Pawłowski, 2009b). The situation is no better for metals. At the present level of consumption, there is enough copper (Cu) for about 66 years, zinc (Zn) for 23, lead (Pb) for 58, mercury (Hg) for 46, and cadmium (Cd) for about 31 years, to mention just a few of the best-known heavy metals (Aron, 2005). This does not mean that after that time that 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 (Udo, Pawłowski, 2010).

All the above clearly indicates that the development of modern civilization is highly unsustainable (Ikerd, 2008), 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 (Pawłowski, 2007; Russel, 2010; Venkatesh, 2010).

Global role of heavy metals and sustainability

Initially heavy metals are used as new materials for the production of goods. Since they are non-renewable resources and their amount are limited on our planet, sooner or later they may be exhausted, and so 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.

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 throughout whole surface of the earth, they pose a serious threat to the global environment.

Since heavy metals are elements, they can not be broken down, and therefore 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 lakes, estuaries or marine sediments, these metals can be transported from one environmental compartment to another.

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. More significant, however, is its anthropogenic emissions in the environment. According to Jacyna (2010), total mercury emissions from anthropogenic sources were 2 320 Mg in 2008. The greatest mercury emissions are from coal and oil combustion (810 Mg/y) and gold mining (400 Mg/y).

Mercury emissions from natural sources are much higher (5207 Mg/y) than from anthropogenic sources (2320 Mg/y). 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 even in the remote troposphere, far from known sources (Doctor, 2000).

Lead is the second heavy metal with a global impact. Lead 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, a 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 of view, is that a significant proportion, close to 50% of the lead used, has been recycled.
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 tonnes 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 level of it in the human body of today's population is 500-1000 times greater than that of their pre-industrial ancestors (Nriagu, 1988).

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.

Inter-generational justice
This is justice between the current generation and those that follow. The term was used in the Brundtland raport definition of sustainable development.
Democracies - both the representative and the direct type - face a structural problem, namely the tendency to favor the present over the future. Future individuals are not yet born, and so 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 the 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 $\geq$ 100 µg/L. Such a level will negatively affect their health.
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 plancton growth. These may affect not only the food chain in the marine environment, but also decrease CO_2 assimilation by plancton, 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 successful. 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. 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 reported lower emissions of lead in 2007, compared with 1990, with the only exceptions being Malta and Bulgaria (EEA Report, 2010).
Global climate change and the role of CO_2 emissions has attracted worldwide attention (Golomb, 2008; Lindzen, 2010). Not many know, however, that heavy metals can also 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 plancton growth. This would disturb the food chain in the oceans and in consequence decrease fish production to a catastrophic level. Plancton 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 inter-generational 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.

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 (Fotopolous, 2007). As a consequence, the consumption of all environmental components increases, including non-renewable resources. This phenomenon was accompanied by a global concentration of economic power, associated by numerous ties with political influence (Baumgaertner, 2008).

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 (Fotopolous, 2007). 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 (2005) 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 (UNDP, 2005) 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 (Bulletin WHO, 2010) showed that, during 1976-1991, when lead was removed from gasoline, the prevalent blood lead level of ≥ 100 μg/L 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/L. In urban and rural areas and near mining centers, average lead concentrations reach 0.5-3.0 $\mu g/m^3$ 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 (Nriagu, 1996).

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 studies show that > 90% of the children in urban and rural communities of the Cape Province, South Africa have blood lead levels ≥ 100 $\mu g/dm^3$. Studies in other countries likewise suggest that childhood lead poisoning is a widespread urban health problem throughout the continent (Nriagu, 1996).

Conclusion

Heavy metals (especially mercury, lead and cadmium) are a global problem that needs to be addressed from a global and sustainability perspective, like climate change. Therefore, I suggest the EU to establish 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 the 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 then increase in the content of greenhouse gases.

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