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ПРОБЛЕМНАЯ СТАТЬЯ

ANTHROPOGENIC POLLUTION BY CHEMICAL ELEMENTS (POST-TRANSITION METALS): AL, GA, IN, SN, TL, PB, BI

***A.A. Sherstneva*[1], *A.V. Galchenko*[2]**

[1] Nelyubin Institute of Pharmacy of Federal State Autonomous Educational Institution of Higher Education,
I.M. Sechenov First Moscow State Medical University
of the Ministry of Health of the Russian Federation (Sechenov University),
Trubetskaya st., 8/2, Moscow, 119991, Russian Federation

[2] Melodia Vitae, Earth

ABSTRACT. Technological progress is rapidly growing, but the side effect of this process is an increase in the anthropogenic impact on the environment. These factors can cause serious ecological problems. Uncontrolled hunting and exploitation of animals leads to the extinction of many species. The widespread use of plastic products results in large amounts of plastic waste that is not biodegradable and breaks up into micro- and nanoplastics. These particles accumulate in living organisms and can cause toxicity. Deforestation (especially of tropical forests) to the needs of urbanization and agriculture leads to climate change and extinction of many species of plants and animals. Industrial development and farming cause the large production of greenhouse gases (CO_2, CH_4). This leads to a greenhouse effect and climate change. Waste of metallurgical, chemical, pharmaceutical industries, as well as household waste, enters the environment in large quantities, contaminating it. A large number of chemical elements, including post-transition metals, can be considered as anthropogenic pollutants. The purpose of this manuscript was to overview the facts of environmental pollution with post-transition metals.

These metals are naturally present in the Earth's crust, however, their use in the industrial cycle has significantly increased their release into the environment. Many of them are emitted to the environment during the combustion of coal and oil, use and disposal of products, as the waste from industrial plants. Extensive pollution of water, soil, and air has been discovered. The accumulation of metals in living organisms is risky since in this way they become a component of the food chain and have a toxic effect on organisms. To date, some sources of pollution are already being restricted, e.g., more environmentally friendly alternatives are chosen, the use of leaded gasoline, *Pb* or *Sn* paints in many countries are limited. Some elements, such as *Ga*, *In*, *Tl*, became especially widespread with the development of the electronics. Given the exponential growth of this industry and the lack of eco-friendly recycling ways, severe environmental pollution by these metals may develop. To date, it already occurs in areas of e-waste in some countries, such as Ghana, Nigeria, India, where the accumulation of *Ga*, *In*, *Tl* is found not only in the environment, but also in plants, animals, and people. Increased emissions of industrial untreated waste can lead to acute toxic stress for the entire planet. The development of optimal methods for the production and utilization of these metals and their compounds is crucial in order to preserve the biosphere.

KEYWORDS: environment, ecological crisis, biogeochemistry, biohazard, aluminum, gallium, indium, tin, thallium, lead, bismuth.

INTRODUCTION

Modern civilization is developing and growing at an enormous rate. A side effect of this progress is the equally rapid degradation of the environment in the world. Global problems affect all cellular organisms. Nevertheless, it is human who is greatly the cause of these negative changes.

The number and distribution of living organisms on the planet are affected by anthropogenic factors. Hunting for wild animals has led 301 species of terrestrial animals to the verge of extinction (Ripple et al., 2016).

For example, in Africa, wild populations of lion (*Panthera leo*) are threatened with extinction because of hunting and using for entertainment by humans (Black et al., 2013). Other associated factors are deforestation, expansion of the agro-industry, struggle for existence between species in the context

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* Corresponding author:
Galchenko Alexey Vladimirovich
E-mail: gav.jina@gmail.com

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of shrinking habitats, and human invasion in these habitats (Ripple et al., 2016).

The usage of plastic products is increasing. They are found literally in every area and are firmly established in everyday life. The problem is that the widespread distribution of plastic pollutes nature due to the fact that this material does not decompose and remains in the environment for hundreds of years. A frightening example of human pollution is the Great Pacific Garbage Patch, located in the northern part of the Pacific Ocean and representing a giant accumulation of plastic waste on an area of 1.6 million km^2 (Lebreton et al., 2018): this is more than triple the size of France or up to 4,5 times bigger than Germany. An even greater danger is the shredding of large objects into microplastics and even nanoplastics (Bradney et al., 2019). These particles enter the organisms of animals and people with water, air, and food, resulting in accumulation and toxicity. For example, during microplastics circulation in the oceans, it accumulates in fish and invertebrates, thus entering the food chain (Kik et al., 2020). There is evidence that microplastics can interact with various chemical elements (e.g., *Al*, *Cd*, *Co*, *Cr*, *Cu*, *Fe*, *Ni*, *Pb*, and *Zn*). Such complexes are stable, they are easily distributed in the environment and are absorbed by many organisms (Bradney et al., 2019).

Another negative consequence of the use of plastics is the release of bisphenol-A into the environment, which causes reproductive dysfunction in many vertebrates (Faheem et al., 2017).

Overpopulation is associated with the increased needs of all the people. It results in deforestation in order to transform territories to the urban and agricultural needs. In the Amazon forests, 25,000–50,000 km^2 is cut down annually, which can lead to the complete disappearance of these forests in 50–100 years (Shukla et al., 1990). In Rwanda, forest ecosystems, which occupied 30% of the country's total area in 1930, fell to 8.9% by 2000. These losses have led to more than a 90% reduction in the fauna of national parks. Deforestation is associated with climate change: for 40 years, Rwanda has seen a monthly increase in temperature of 0.5°C and a decrease in rainfall of 10 mm (Habiyaremye et al., 2011). Forests regulate climate, soil and water quality, biological diversity, and are also carbon accumulators and future oil and coal (Habiyaremye et al., 2011). Thus, by cutting down forests, a person deprives himself of not only the present but also the future.

Climate change is a global threat to biodiversity and ecosystems (Weiskopf et al., 2020). The widespread use of aerosols, refrigerants, and insecticides (especially chlorofluorocarbons) can cause the destruction of the ozone layer, which protects the planet from excessive UV radiation (Kowalok, 1993). The continuous production of “greenhouse gases” (CO_2, CH_4) by the industry and cuttle farming (Slade et al., 2016) in combination with deforestation (Habiyaremye et al., 2011) leads to the well-known “greenhouse effect” and global warming (Kowalok, 1993).

Industrialization has a very strong impact on the environment. The development of industry has led to the appearance of acid rains. A side effect of this phenomenon is a change in the acidity of water and soil; poisoning of fish and other inhabitants of these ecosystems; leaching of toxic metals from the soil and the Earth's crust; reduced plant and forest growth, not to mention the harm to humans and their products (Kowalok, 1993). Moreover, industrial waste, drugs, household chemicals enter the environment (Lehtonen et al., 2017).

Another problem is eutrophication (cultural or unintentional) which is associated with the release of chemical elements into the environment. Substances such as nitrogen and phosphorus are biogenic elements and their entry into water stimulates an excessive growth of phytoplankton, algae, cyanobacteria. Such an increase in biological density in water discourages the penetration of sunlight and oxygen. It leads to the death of bottom plants and animals, and then of the rest (Chislock et al., 2013).

Environmental pollution by toxic elements and heavy metals is a dangerous problem since living organisms are not normally exposed to great amounts of these elements. Their release into the environment has increased significantly due to technical, industrial and agricultural progress, while the methods of waste disposal and recycling lack (Blacksmith Institute World’s …, 2010).

The main goal of the paper was to give a brief review of environmental pollution with post-transitional metals, as well as show the main areas of application of these elements and highlight the leading patterns of human activity leading to their spread.

Post-transition metals are a fairly conventional group of chemical elements that exhibit more metallic properties than metalloids do, but not enough to include them in the group of transition metals. To date, there is no consensus on the final list of post-transition metals. The most accepted composition of the group is *Al*, *Ga*, *In*, *Sn*, *Tl*, *Pb*, *Bi*, *Nh*, *Fl*, *Mc*, *Lv*. The last four elements are probably not present on Earth outside laboratory conditions, they have been synthesized in small quantities, and, fortunately, yet there are no incidents of them being released to the environment to discuss. Therefore, the facts of environmental pollution with *Al*, *Ga*, *In*, *Sn*, *Tl*, *Pb*, and *Bi* will be considered in this manuscript.

ALUMINUM

Al is a widely distributed element in the Earth's crust. It has found wide application in human activities: it is used to make cans, cookware, foil, airplanes, cars, building materials, fireworks. It is also applied in medicine (as antacids), industry ($AlCl_3$ acts as a catalyst) and in water-treatment; it is part of pesticides, cosmetics, antiperspirants (Agency for Toxic Substances…, 2010).

Elevated levels of *Al* in the environment may be associated with mining (including coastal), mineral processing, production of *Al* alloys, and compounds. Coal-fired power plants and incinerators release small amounts of *Al* in the atmosphere. These actions can increase the concentration of *Al* in coastal waters, rivers, and soil (Agency for Toxic Substances…, 2010; Gillmore et al., 2016).

The level of *Al* in the coastal waters of the United States (Florida Bay) was found to be 0.8–16.7 µg/L (Caccia, Millero, 2003); in Australia, it was 1.3–5 µg/L with a maximum concentration of 83 µg/L in industrial ports (Angel et al., 2012; 2016); in the UK — 1.4 – 2 µg/L (Upadhyay, 2008; 2012). At the same time, the level of *Al* in the open ocean does not exceed 0.68 µg/L (Angel et al., 2016).

The highest levels of *Al* in the drain water were found in the areas near the battery and automotive plants. In all cases, excess levels were observed (Iloms et al., 2020).

Data from the analysis of the level of *Al* in the rivers surrounding Dhaka (the capital of Bangladesh) showed that *Al* concentrations were high in urbanized and industrial areas. This confirms reports that wastewater is discharged into the environment without treatment. Besides, an excess amount of *Al* can spread downstream, polluting relatively ecologically clean areas (Rampley et al., 2019).

Al is known to be highly toxic to algae (Gillmore et al., 2016) and crustaceans (Van Dam et al., 2018) which may cause ecosystem imbalance in contaminated areas. Also, tea leaves have a great ability to accumulate high concentrations of *Al* (Dong et al., 1999).

It is important that the concentration of *Al* in the environment depends on its acidity. Thus, the solubility of *Al* increases in more acidic soil or water (Agency for Toxic Substances…, 2010), which should also be taken into account when assessing its concentration, and especially when comparing the degree of contamination of different areas.

GALLIUM

Ga is widely used in electronic equipment, semiconductors, LEDs, solar panels; in medicine; in metal alloys (Kjølholt et al., 2003; White, Shine, 2016; Jensen et al., 2018).

Environmental pollution by *Ga* occurs mainly during the production or disposal of electronic equipment; to a lesser extent, it comes from mineral processing and coal and oil burning (Kjølholt et al., 2003; White, Shine, 2016; Jensen et al., 2018). Robinson reports that e-waste pollution is less of a problem in developed countries than in developing ones (Robinson, 2009).

In a study in Taiwan, it was noted that *Ga* levels in groundwater around the Hsinchu Science-based Industrial Park (HSIP) were significantly higher than in control areas. Thus, in the first area, 100% of the samples had a *Ga* level above 1.0 µg/L (83.3% more than 10.0 µg/L with an average of 19.34 µg/L), and in the second area, it was only 6.7%. Concentrations of *Ga* in HSIP groundwater were approximately 1000 times higher than in the Hsiangshan District (control area in the city of Hsinchu). In the air propagating downwind from the HSIP, the *Ga* content was 2.5 times higher than when measured against the wind (Chen, 2006).

Increased concentrations of *Ga* in the environment were also found near mines and metallurgical plants (Shiller, Frilot, 1996).

With an increase of *Ga* pollution, living organisms become affected (Zeng et al., 2017). Suzuki et al. assessed the content of toxic elements in the body of Formosan squirrels (*Callosciurus erythraeus*) in Japan and Taiwan. The highest *Ga* concentrations were found in animals from Taiwan, namely, from the area close to the core of the semiconductor industry in Taiwan (Hsinchu City) (Suzuki et al., 2007). There is evidence that some algae can accumulate *Ga* (Kjølholt et al., 2003).

The rapid development of electronics increases the risk of severe environmental pollution by this element. The main problem is the lack of safe methods for recycling electronics containing *Ga* and other toxic elements. Moreover, *Ga* consumption is expected to increase due to a decrease in use of heavy metals (Kjølholt et al., 2003).

INDIUM

In is a rare element in the Earth's crust. It is widely used in semiconductor products, liquid crystal displays, touch screens, LEDs and solar panels. Due to the increasing use of these products, the release of *In* into the environment is inevitable (White, Hemond, 2012; Chang et al., 2019). In addition, this element is released into the environment during coal burning at power plants and ore processing as a by-product (White et al., 2015; Jensen et al., 2018).

In mentioned above Taiwan study, it was noted that the level of *In* in groundwater around the HSIP was much higher than in control areas. 86.7% of the samples from the HSIP area had an *In* level higher than 1.0 µg/L (36.7% more than 10.0 µg/L) in contrast with the control area which had 100% samples with a pollution level lower than 1.0 µg/L (Chen, 2006). There are some data about increased *In* concentrations in soils in Vietnam (Ha et al., 2011), France (Boughriet et al., 2007).

Elevated concentrations of *In* in the environment are found not only in manufacturing areas (Chen et al., 2015) but also in places of electronic waste disposal (Robinson, 2009). It is known that e-waste is often illegally sent to some countries such as China, the Philippines, Nigeria, India, and Ghana. Toxic elements enter soil and water with rain or wind and may spread to other areas (Brigden et al., 2008). Thus, the degree of soil pollution by *In* in Ghana is estimated as high. These results are also supported by the fact that elevated *In* concentrations were found in the hairs of residents of the analyzed area compared to the control group (Tokumaru et al., 2017). A similar picture is presented in India (Ha et al., 2011). Robinson suggests that, as for *Ga*, developing countries are more affected by *In* pollution than developed countries (Robinson, 2009).

The increase of environmental pollution by *In* may affect all living organisms from humans (Amata et al., 2015) to microorganisms (Zeng et al., 2017). *In* spreads due to the movement of dust, and accumulation in soils, water and food products (Jensen et al., 2018).

TIN

*S*n is a spread element in the environment. Humanity uses it in the production of cans, aerosols, toothpastes, many alloys, and materials; as the catalyst; in the glass industry. Organic tin compounds have found application in the production of plastics, pesticides, paints (for example, antifouling paints for ships), preservatives, repellents (Agency for Toxic Substances…, 2005).

The increased *Sn* release to the environment can be caused by the process of its extraction and processing, combustion of fuel (including coal) and household waste. Organic compounds enter the environment when used in agriculture, applying paints, recycling the materials that contain organotin (e.g., plastics). They can degenerate under the influence of bacteria and sunlight, which leads to the release of inorganic *Sn* (Agency for Toxic Substances…, 2005). The main source of *Sn* for humans is its intake with canned food (Perring, Basic-Dvorzak, 2002).

In the e-waste area in Ghana, the degree of environmental pollution with *Sn* is estimated as high (the level in soils is 30 times higher than in the control areas; the difference between concentrations in water is 9 – 30 times). These results are also supported by the fact that residents of the analyzed area had elevated hair *Sn* concentrations in comparison with the control group (Tokumaru et al., 2017). Around e-waste recycling area in India, the levels of *Sn* in the soil are 18 – 35 times higher than in the control zone (maximum concentrations differ approximately by 22 – 180 times); the difference between air levels of *Sn* is about 20 times (Ha et al., 2011).

The concentration of *Sn* in the soil in a national park in Spain exceeds the average background value by 14 times. The reason for this can be uncontrolled soil fertilization and diffuse anthropogenic pollution of the environment (Jiménez-Ballesta et al., 2016). In Germany, this difference was 3 – 22 times (Rinklebe et al., 2019).

It is known that oysters and shellfish may accumulate organotin compounds, which has a toxic effect on shell formation and growth of organisms (Sebesvari et al., 2005; Díaz et al., 2007; Tang et al., 2010). The study of Sebesvari et al. showed that the concentration of organotin compounds was 4.5 times higher in the polluted section of the River Lippe in Germany (waste dumping from the largest tributyltin production plant) than in the upstream section (Sebesvari et al., 2005).

In the coastal waters of Spain, the level of butyltin in the sediment exceeded the permissible values by 28–336 times, which may indicate a risk of toxic effects on the biota (Díaz et al., 2007). Studies from Australia (Burton et al., 2015) India (Bhosle et al., 2016), and other areas of Spain (Díez et al., 2002) show that sediment *Sn* values are thousands of times higher than permissible concentrations.

Fishery and industry areas in Spain showed increased concentrations of butyltin in water (109 times higher than the permissible values) (Arambarri et al., 2003). Moreover, the historically wide use of *Sn* compounds can be tracked on the skeleton of the coral (Micronesia): high concentrations of *Sn* refer to the 1960 – 1980s when antifouling paints for ships began to be actively used. The subsequent decrease can be explained by the later limitation of these paints' use by some countries (Inoue et al., 2004).

Another dangerous environmental impact of *Sn* is the sensitization of Harbor Seals (*Phoca vitulina*) (Kakuschke et al., 2005).

THALLIUM

Tl is an extremely toxic metal (Liu et al., 2019a). It is used in the manufacture of electronics, semiconductors, photocells; in medicine; as a catalyst (Agency for Toxic Substances…, 1992).

Tl release into the environment can be a result of the activities of coal-fired power plants, cement plants, metal smelters, chemical plants, and mining plants (for example, in the production of pyrite) (Agency for Toxic Substances…, 1992; Campanella et al., 2016). In the e-waste recycling zone in India, *Tl* levels in the air were about 20 times higher than in the control zone (Ha et al., 2009).

China is the world leader in copper production. Wang et al. conducted a study of the bottom of the lake, located near the smelter in China. It was discovered that the lake was severely polluted by *Tl* over the past 60 years. The reason for this may be the waste discharge from a smelter that contains *Tl* (Wang et al., 2019).

Another source of environmental pollution in China is the steel industry. Thus, in the area of steel making plant in Guangdong Province in China, the content of *Tl* in the sediment of the river was 3 – 7 times higher than the limit level (Liu et al., 2019b). Liu et al. have also described incidents of local pollution in various regions of China. Authors consider the metallurgical industry to be one of the main reasons of that (Liu et al., 2018). In Guizhou province, *Tl* levels in the environment have also been found to exceed the average background values in soils by about 40 times (maximum values differ in 130 times). This level of pollution is considered to be high (Jiang et al., 2019).

In Tuscany (Italy), an elevated *Tl* content in groundwater was discovered. The source of pollution turned out to be *Tl*-containing ores in abandoned pyrite mining sites. The level of *Tl* in the urine and hair of residents of this region correlated with the concentration in tap water (Campanella et al., 2016).

Marine *Tl* pollution is confirmed by a study in Indonesia, where elevated concentrations of *Tl* in the skeleton of coral reefs were found near gold mining areas (Edinger et al., 2008).

In Katowice, Poland, *Tl* concentrations in the air exceeded the limit values by 660 times. This is associated with industrial dust and fumes pollution (Karbowska, 2016).

Suzuki et al. assessed the content of toxic elements in the body of Formosan squirrels (*Callosciurus erythraeus*) in Japan and Taiwan. The highest concentrations of *Tl* (2 – 3 times higher) were found in animals from Taiwan, namely from the area close to the core of the semiconductor industry of Taiwan (Hsinchu City) (Suzuki et al., 2007).

There is evidence that *Tl* can accumulate in aquatic organisms, and terrestrial plants, which ends up entering a food chain (Agency for Toxic Substances…, 1992). According to the research data, fish contains more *Tl* than other food products (Rodríguez-Mercado, Altamirano-Lozano, 2012).

There is evidence that plants accumulate *Tl* from contaminated soils, for example, cabbage, eggplant, water spinach (Li et al., 2016), which can be toxic for humans. The concentration of this metal in the soil at a distance of 100 m from the pollution source is 19 times higher than at a distance of 500 m (Li et al., 2016).

In China, severe contamination of many vegetables that grow near the pyrite mining site has been reported (Liu et al., 2019a).

LEAD

Pb ores are widespread throughout the world. The use of this metal by human is diverse. *Pb* is released during the extraction and processing of metal ores, burning coal and oil. It can be found in paints and pigments (when the paint wears out, *Pb* containing dust is formed); batteries; pesticides; cosmetics; plumbing and military products (Agency for Toxic Substances…; 2019). An important source of pollution is the release of tetraethyllead with exhaust gases when using leaded gasoline. Despite the fact that this fuel is banned in many countries, some of them continue using it. Lead containing particles enter the air, water, and soil (Agency for Toxic Substances…; 2019).

Large landfills, containing *Pb* wastes, are a major environmental hazard in countries such as Tanzania, Kenya, Senegal, Nigeria, Indonesia, the Philippines, India, or Pakistan (Blacksmith Institute 2011). 2008 and 2014 studies showed that children living in US cities are more prone to *Pb* intoxication than those living in rural areas (Laidlaw, Filippelli, 2008; Stewart et al., 2014). A study in Hong Kong showed that average concentrations of *Pb* in soil and grass near roads are 991 μg/g and 134 μg/g, respectively. The level of environmental pollution along the roadway was proportional to the traffic on these roads (Laidlaw, Filippelli, 2008). A similar pattern is observed in Bangladesh (Naser et al., 2012). A high level of *Pb* leads to the accumulation in edible plants (e.g., carrots, potatoes, tomatoes, leafy vegetables), which become a source of *Pb* for humans (Brown et al., 2017). China is also affected by excessive *Pb* levels, in particular, it relates to important economic zones such as Shanghai and Guangzhou (Duan et al., 2016). Studies have shown that *Pb* concentrations in seawater on the South coast of China were higher than on the East and North coasts. The highest concentrations of *Pb* in China are found in the South China Sea (14 μg/L at Sanya Bay, grade IV), while in the eastern and northern regions of China (Bohai Sea, Yellow Sea, East China Sea) *Pb* levels do not exceed 5 μg/L (grade II) (Manzoor et al., 2017).

The *Pb* concentration in agricultural soils in some states of Nigeria exceeds acceptable levels. The highest levels of this metal were noted in rice and local pears (Orisakwe et al., 2012). The Pb content in spices (for example, chili peppers, nutmeg, and some typical local spices) exceeds the permissible limits by 8 – 30 times (Asomugha et al., 2016). Coconut fruit collected in contaminated areas shows a high level of this element (Hart et al., 2005). It is noteworthy that the concentration of *Pb* is higher in areas involved in oil production, which results in *Pb* accumulation in plantain and cassava in this area (Alum et al., 2014). In Bangladesh, industrial areas also show strong *Pb* contamination of plants and especially vegetables, e.g., cabbage (Ahmad, Goni, 2010), spinach (Mottalib et al., 2016), and potatoes (Islam et al., 2016).

A large amount of *Pb* is found in water, from where it spreads to the soil. For example, *Pb* content in soils irrigated from the polluted Sitalahya River (Bangladesh) exceeds acceptable limits (Ratul et al., 2018). High concentrations of *Pb* are also found in the Turag River, which flows through the industrial zone containing metallurgical, textile, pharmaceutical, food industries (Aktar, Moonajilin, 2017). As a result, fish living in polluted waters accumulate *Pb* in amounts ten times higher than the permissible values (Ahmad et al., 2010; 2013; 2016; Bhuyan et al., 2016). Elevated levels of *Pb* were found in fish and seafood in contaminated areas of Slovakia (Andreji et al., 2006), Spain (Besada et al., 2011), and the Persian Gulf region.

Pb spreads through its dust admission in the air and subsequent precipitation with rain. Thus, in Australia, it was found that the concentration of *Pb* in rainwater in different areas was 0.6 – 85 times higher than the allowable amount, and in Sydney, it differed by 278 times.

BISMUTH

Bi is a rare metal in the Earth's crust. It is used by humans in electronics, semiconductors; in the production of plastics, pigments, metal alloys; as an alternative to *Pb*; in pharmaceutical and cosmetic industries (Kjølhol et al., 2003; Filella, 2010).

Bi can enter the environment via the activity of coal- and oil-fired power plants and incinerators; electronics recycling; as a by-product in the purification of other metals; with pesticides (Kjølhol et al., 2003).

In Ghana, the degree of environmental pollution by *Bi* in the e-waste zone is estimated as high in soil and average in rivers (the average and maximum levels in soils were 9 and 30 times higher, respectively than in the control areas; in the water, they differed by 1 – 15 times). These results are also supported by the fact that higher concentrations of *Bi* were detected in the hair of residents of the analyzed area compared to the control group (Tokumaru et al., 2017).

In the e-waste area in India, *Bi* levels in soil and air were approximately 6 – 10 and 242 times higher, respectively, than in the control zone.

In the analysis of dust particles from atmospheric air in Northern China, it revealed that the relative *Bi* content in these samples exceeded background concentrations and the acceptable limits in the soil by 6 and 11 times, respectively. Xiong et al. concluded that this pollution was mainly associated with transport, metallurgy and coal industry (Xiong et al., 2015).

To date, *Bi* is considered as a more environment-friendly replacement for many heavy metals and a relatively non-toxic metal for humans (Filella, 2010). However, it has the ability to accumulate in living organisms, which can harm them and the environment in the case of an increased use (Kjølhol et al., 2003).

CONCLUSION

Due to the intensive development of industry, transport, urbanization, and the scientific and technological progress, the anthropogenic toxic metals emission continues to increase. *Pb*, *Al*, *Bi*, *Sn* have been used by humans for many years and centuries, they may be found in many places on the planet: in water, soil, air dust, especially in polluted areas. Taking into account, that humanity has long been familiar with these elements and is aware of their toxicity, some precautions are already being taken, e.g., reducing the use of leaded gasoline, replacing *Pb* with less toxic *Bi*, limiting the use of *Sn*-containing paints for ships and metal-containing pesticides. *Ga*, *Tl*, *In* have just gained particular popularity with the development of the electronic industry, so data on their toxicity is still insufficient. However, it is already known that high levels of these elements are found in the soils and hair of people in the e-waste areas in developing countries (such as Ghana).

Given today's industry growth rate, especially electronics, the risk of developing irreversible environmental depression is high. It is necessary to develop optimal methods for the disposal and recycling of products and goods containing post-transition metals and their compounds in order to reduce the toxic load on nature and humans. The adoption of immediate measures to reduce pollution of the biosphere is the responsibility of humanity.

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АНТРОПОГЕННОЕ ЗАГРЯЗНЕНИЕ ОКРУЖАЮЩЕЙ СРЕДЫ ХИМИЧЕСКИМИ ЭЛЕМЕНТАМИ (ПОСТПЕРЕХОДНЫЕ МЕТАЛЛЫ): AL, GA, IN, SN, TL, PB, BI

А.А. Шерстнева[1], А.В. Гальченко[2]

[1]Институт Фармакологии имени Нелюбина, Первый МГМУ им. И.М. Сеченова,
Российская Федерация, 119991, Москва, ул. Трубецкая, 8/2
[2]Melodia Vitae, Земля,

РЕЗЮМЕ. Технологический прогресс быстро набирает обороты, но вместе с этим увеличивается антропогенное воздействие на окружающую среду. Этот факт может вызывать серьезные экологические проблемы. Бесконтрольная охота и эксплуатация животных приводят к исчезновению многих видов. Повсеместное внедрение изделий из пластмасс связано с большим количеством пластиковых отходов, которые не являются биоразлагаемыми и распадаются на микро- и нанопластик. Эти частицы накапливаются в живых организмах и могут оказывать токсические эффекты. Вырубка лесов (особенно тропических) под нужды урбанизации и агропромышленности приводит к нарушению климата и исчезновению многих видов растений и животных. Развитие промышленности и разведение животных связано с продукций большого количества «парниковых» газов» (CO_2, CH_4) приводят к «парниковому» эффекту и последующему изменению климата. Отходы металлургической, химической, фармацевтической промышленностей, а также бытовые отходы в большом количестве поступают в окружающую среду, загрязняя ее. В роли антропогенных загрязнителей может быть рассмотрено большое количество химических элементов, в том числе постпереходные металлы. Цель работы – краткий обзор основных фактов загрязнения окружающей среды постпереходными элементами.

Постпереходные металлы присутствуют естественным образом в земной коре, однако включение их человеком в промышленный цикл существенно повысило поступление этих элементов в окружающую среду. Многие из них выделяются при сжигании угля и нефтепродуктов, с отходами промышленных заводов, при использовании или утилизации изделий, содержащих эти металлы. Обнаружено обширное загрязнение водоемов, почв, воздуха. Особую опасность несет аккумуляция постпереходных металлов в живых организмах, так как таким образом они становятся компонентом пищевой цепи и оказывают токсическое действие на отдельных особей. На сегодняшний день проводится ограничение некоторых источников загрязнения, например, замена более экологичными альтернативами, запрет использования этилированного бензина во многих странах, ограничение применения свинец- и оловосодержащих красок. Некоторые элементы, такие как галлий, индий, таллий, получили особенно широкое распространение с развитием электронной промышленности. В условиях экспоненциального роста этой отрасли и отсутствия оптимальных и экологичных способов переработки и утилизации электротехники может развиться высокий уровень загрязнения этими металлами окружающей среды. Это уже встречается в районах свалок электронных отходов в таких странах, как Гана, Нигерия, Индия, где аккумуляция Ga, In, Ta происходит не только в окружающей среде, но и в организмах растений, животных и людей. Увеличение выброса промышленных отходов и неграмотная утилизация могут привести к острой токсической нагрузке для всей планеты. Остро стоит проблема разработки оптимальных способов производства и утилизации соединений этих металлов с целью сохранения биосферы.

КЛЮЧЕВЫЕ СЛОВА: окружающая среда, загрязнение, биогеохимия, биологические угрозы, алюминий, галлий, индий, олово, таллий, свинец, висмут.