EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology 2022, 23(2), 215–220
https://doi.org/10.12912/27197050/147765
ISSN 2719-7050, License CC-BY 4.0

Received: 2022.03.03
Accepted: 2022.03.18
Published: 2022.03.31

The Influence of Man-Made Elements on the State of Soil Pollution and Ways to Improve Environmental Safety

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ABSTRACT

In the paper research of environmental hazards based on the study of individual factors presented. The first stage was the analysis of the state of environmental hazard of equipment and technological processes. A system of organizational and technical measures and technological solutions was developed that will reduce the level of environmental risk. Soils was considered separately with the study of physical and chemical processes. Heavy metals that come from electroplating and etching processes interact with the soil system, that is, with the components of the soil and with each other, which leads to mutations in the physico-chemical system of soil. We identified two areas of possible forms and consequences of combining heavy metals in soils – the formation of hard-to-dissolve compounds, and its absorption by its components. Studies shown that the accumulation of heavy metals passing through the atmosphere and soil, created in plants, and then with the help of the food chain gets into the human body.

Keywords: development, eco-safe system, ecology, soils.

INTRODUCTION

The degree of environmental pollution, analysis of the anthropogenic impact of the production complex is determined by a detailed analysis and creation of an information system that allows ensuring the quality of the ecological system both in individual territories around enterprises and within large areas (Al Mamun, 2018). Assessment of man-made soil contamination involves determining the concentration of individual chemical elements, the ratio of elements in plants and soils, or the action of the toxic reaction mechanism (Biswas, 2015). Large chemical industry enterprises, electroplating shops and board manufacturing shops are the main stationary environmental pollutants of heavy metals. Such heavy metals are Zn, Pb, Cu, Co, Cr, Cd, Sr. Some of these pollutants combine with heavy metal cations to form poorly soluble compounds or sediments (Carfora, 2017). Soil is a system whose chemical components are in constant interaction, which is influenced by various factors of geochemical migration. This fact is well covered in the relevant works (Cerri, 2018). The interaction of elements in soils is considered by the following systems: water– soil, soil–underground water, soil–flora.The following factors influence the peculiarities of heavy metal entry into plants: redox conditions, ph, hydrolysis, and salt formation. Chemical toxic analysis of heavy metals, including heavy metals present in waste during the production of boards, the activities of electroplating shops (PB, Hg, Cd, Cu, Ni, Co, Zn) shows their high toxicity and migration ability. Migration substances in the soil occur mainly due to water, which is an integral part of the soil and creates the water-soil system.

Behavior of toxicants in different environments

The behavior of toxicant substances in different environments depends on their biogeochemical properties, the characteristics of which are presented in Table 1 (Chekima, 2016). Copper has a fairly high biochemical property among heavy metals, and this highlights the importance of reducing the amount of copper that is discharged into the NPS, worsening its state (Chen, 2016). Conducting monitoring studies of soils at the production sites of boards and electroplating shops provides information on the state of soils for forecasting the ecological state and further decision-making. Analysis of sludge from electroplating production, DP production and sludge from sludge accumulators showed a high content of metals in them. Under the influence of precipitation, especially acid rain, there is a gradual secondary pollution of the environment with this waste.

High water content of the territory, loose water-permeable soils make it difficult to choose industrial waste landfills and limit their area, create conditions for heavy metal ions to pollute not only the soil cover and surface water adjacent to storage sites, but also Underground Water Horizons. Today, many countries around the world still use the method of neutralizing toxic waste by burial in special landfills using protective facing materials made of clay, polyethylene, polyvinyl chloride and other relatively water-resistant materials. An economical method of burying sediments of many types is chemical fixation, which is carried out by dosing special agents into the sludge: sodium silicate, cement. As a result, toxic substances are fixed in the solid mass, but their leaching may occur over time (Choi, 2019). Among liquid waste, there is a large group of heavy metals that are widely used in various industrial industries, and despite the treatment methods used, heavy metal compounds penetrate into industrial wastewater. A significant amount of these compounds also enter the aquatic environment through precipitation (Bittar, 2018).The environmental danger of heavy metals is that they are actively absorbed by phytoplankton, and then enter the human food chain. Enterprises that use printed circuit board manufacturing processes to ensure the operation of modern electronic equipment contribute to the deterioration of the ecological state of the environment. Such enterprises include the production of: household; military; automobile; space equipment; spacecraft equipment, radio and television (Do Paco, 2019). Copper is widely used in the production of DP, as an active conductor. The main source of copper entering the natural environment in such production is waste water from copper etching operations to ensure drawing, washing water, and sludge. For the forecast calculation, the origin is chosen on the Earth's surface, the distance between the calculated points $\Delta x = 0.5$ m, salinity Co = 0.2%, Cn = 40.0%, n = 0.23, Dm = $1 \cdot 10^{-5}$ m^2/day.

It is established that one year after the filling of salts, the upper half-meter layer of the aeration zone will pass into the category of weakly and moderately saline. In the following years, the salt content will increase with time and depth. After 10 years, the Salt profile will look as shown in Figure 1 with such a salt content, the complete absence of any living organisms and plants is

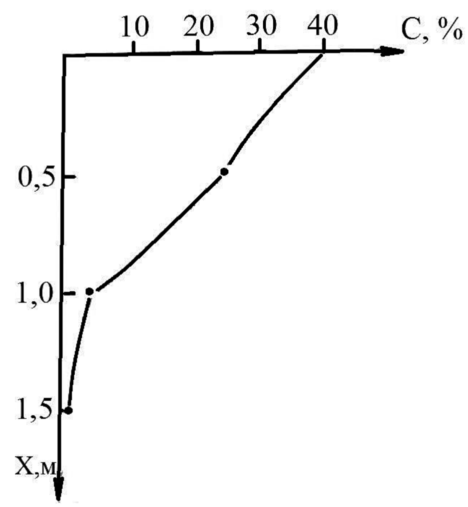

Figure 1. Salt profile after 10 years of storage etching salts of printed circuit boards

Table 1. Biogeochemical properties of heavy metals

Properties	Co	Ni	Cu	Zn	Cd	Hg	Pb
Toxicity	M	M	M	M	H	H	H
Mobility	L	L	M	M	H	H	H
Accumulation	M	M	H	H	H	H	H
Complex formation	L	L	H	H	M	M	L
Tendency to electrolysis	L	M	H	H	M	M	M
Solubility	L	L	H	H	H	H	H
Note: H – high, L – low, M – middle.							

guaranteed for many years and after the elimination of the sludge storage warehouse. The results obtained show the harmfulness of sludge storage on the territory of the enterprise and indicate the direction of work for the development of technologies for processing and reuse of etching solutions in the production of printed circuit boards.

Ecological danger of urban soils

The greatest damage and transformation is experienced by urban soils, which are characterized by high absorption capacity. The difference between urban and natural soils is over-compaction, which is a consequence of construction, the presence of transport flows and leads to changes in agrochemical indicators (Follows, 2014).

As an example, consider the city of St. Petersburg, which is a typical administrative center. St. Petersburg, covers an area of 215 km^2 and a population of about 2271 thousand people. According to socio-economic indicators, the city is typical among the regional centers of Russia. The largest share in the structure of industrial production in the city is occupied by the machine-building (with electroplating shops and PCB etching shops) and food industries, as well as expanded construction using the latest high-speed technologies. In general, man-made factors of the city of St. Petersburg are formed as a result of the impact on the environment of transport, industrial enterprises and utilities. The natural soils of the city of St. Petersburg were formed mainly on carbonate Loess deposits, the most common are forest-steppe podzolic soils. The expansion of the city leads to a steady reduction in the area of land with natural soils. More than half of the territory of St. Petersburg today is occupied by anthropogenic deposits (bulk, including the soil of bulk structures, artificial road surfaces, construction dumps, planar cultural layer, deposits of artificial reservoirs) (Foukaras, 2014).

To assess the ecological state of the soils, 7 test areas were identified, where soil samples were taken. Test areas were laid out on the territory of the city so that they included various types of anthropogenic impact characteristic of medium – sized cities: 1, 2 – industrial zones (influence of industrial enterprises); 3, 4 – territories of water protection zones of water bodies of the city; 5, 6, 7-the main highways of the city. The most common heavy metal in urban soils is lead. This metal in the human body causes pathological changes in the nervous system, hematopoietic organs, digestive system, kidneys, affects the reproductive organs, blocks the work of enzyme systems (Gonçalves, 2016). As a result of the conducted research (Table 2) it is established that the highest gross lead content is typical for the industrial zone and highways. According to the table, it can be concluded that the concentrations of gross lead in samples of test areas of recreational areas and water protection zones were 1.4–2.6 times less than in industrial and transport areas.

The same trend is observed for the mobile form of lead. In areas near industrial enterprises, the lead content is the highest and is 2-3 times higher than its concentration on the territory of water protection zones of water bodies. Taking

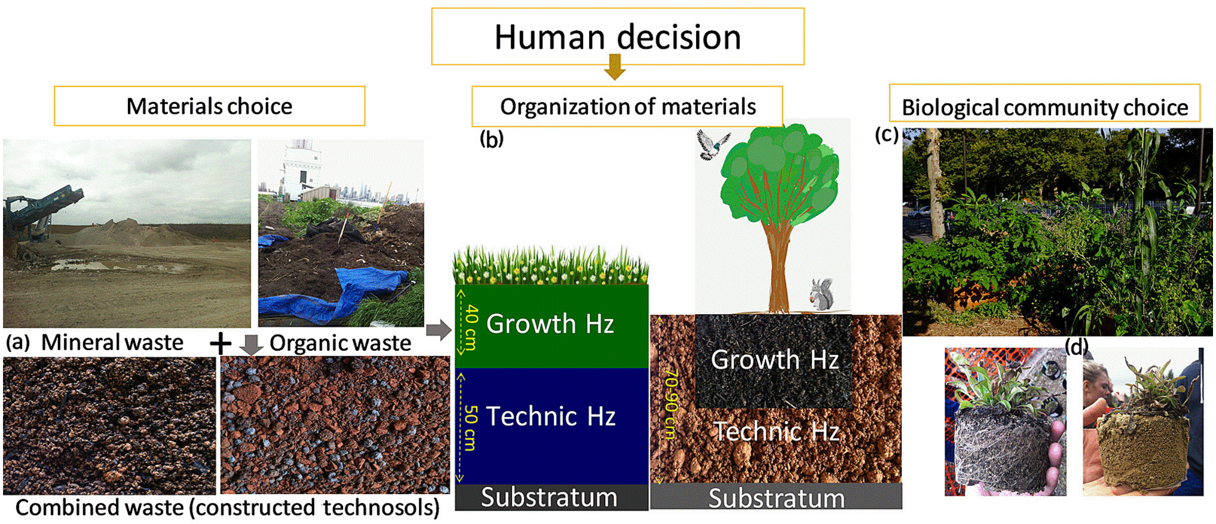

Figure 2. Diagram presents abiotic and biotic components of constructed Technosols and waste

Table 2. Content of mobile and gross forms of lead in the soils of St. Petersburg, mg / kg

Area number	1	2	3	4	5	6	7
Gross lead content	34.2	40.1	22.3	14.3	33.8	34.9	35.6
Mobile lead content	8.1	12.9	4.9	3.3	2.6	4.9	9.8

into account the fact that the maximum permissible concentration for a mobile form of lead is 2 mg/kg, most of the city's territory is characterized by a significant excess of the maximum permissible concentration (from 1.3 to 6.45 times). For highways and industrial zones, an excess of the maximum permissible concentration for gross form (30 mg/kg) was recorded (Grimmer, 2013). So, the main contribution of lead to the urban ecosystem of St. Petersburg is associated with the activities of industrial enterprises and motor transport. Since the excess of the norm is significant in certain areas, this creates a danger for the urban ecosystem as a whole, because the soil is one of the most important links in the cycle of elements in ecosystems, through which heavy metals enter living organisms.

Risk assessment from accidents during storage of electroplating waste

High-risk objects are those where hazardous substances or categories of substances are used, manufactured, processed, stored or transformed in an amount equal to or exceeding the normatively established threshold masses, as well as other objects that are a real threat to the occurrence of man-made and natural emergencies. Environmentally hazardous activities and facilities are important factors that require the development of optimal measures to ensure environmental safety. These facilities include electroplating shops and PCB manufacturing shops.

Problems with the accumulation and disposal of solid industrial waste arise and need to be solved in every civilized country. Russia is no exception. Inventory and statistical reporting over the past 10 years shows that Russian enterprises generate 1 1 billion annually. solid industrial waste. Of these, 100 million tons are toxic, and 2-4 million tons are highly toxic, which according to European standards belong to the first hazard class. The number of enterprises that record toxic waste exceeds 2,500. The total amount of toxic waste accumulation is 4.5 billion tons, and the current cost of their maintenance is annually more than 25% of the cost of manufactured products.

Toxic waste containing heavy metals (chromium, nickel, lead, cadmium, mercury) dominates in terms of formation volumes. These are mainly waste from enterprises of ferrous and non-ferrous metallurgy, mechanical engineering (electroplating production), mining and chemical plants and others. The need for research in the ecological direction, the problems of protecting atmospheric air, soils, and the aquatic environment, their state causes environmental degradation and harms the health of the population, especially in industrial areas. The practical and scientific significance of environmental problems is determined by the fact that air is the source of human life, wildlife, and is the basis of technological processes of existing enterprises. The reasons for the appearance of environmental risk are the occurrence of emergency situations at the enterprise and an increase in emissions of pollutants. The second reason may be the spread of design parameters of emission sources– disturbing factors. This probability characterizes the environmental risk of human exposure to pollution. There is no single definition of the concept of environmental risk, and there are no criteria for its assessment. The main difficulties are that new risk factors are constantly identified, sources of pollution that have not yet been studied, and therefore new knowledge of the mechanism of their impact, which is confirmed by the authors of the term "environmental risk (Huang, 2014).

Two examples of sludge from various Russian enterprises stored in factory territories are presented (Table 3). Based on the results of the study of the composition of electroplating sludge, the qualitative composition and content of hazardous substances were established. The name of waste was electroplated sludge with precipitator, alkali, soda (sludge of etching baths). Appearance and consistency was pasty mass of brown color. The material of waste was from the production and etching shop of pipe products. Etching is carried out with solutions of sulfuric acid. The sludge mainly contains iron compounds in the form of iron sulfate particles and foreign insoluble impurities (Joshi, 2015). The sludge is neutralized to pH 3–10 with solutions of soda ash or sodium hydroxide. Qualitative composition of

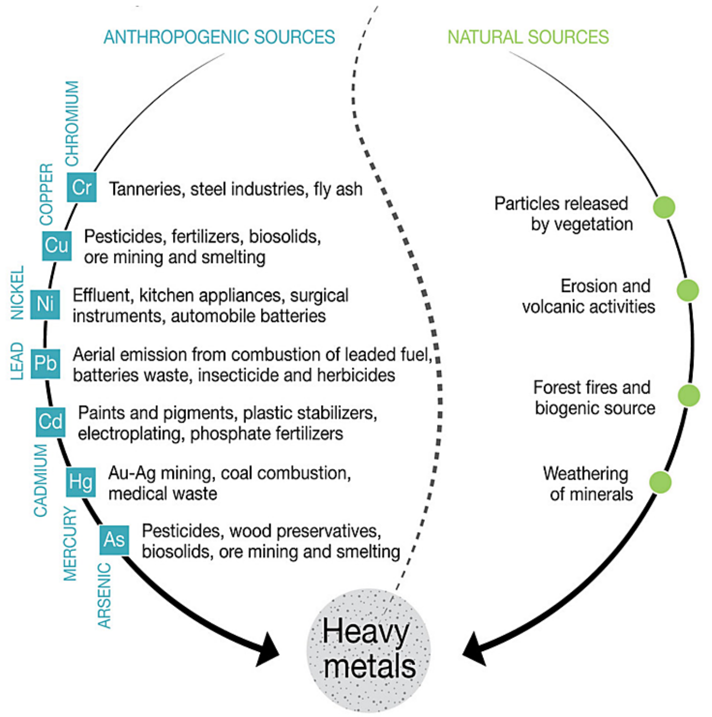

Figure 3. Source of heavy metals in soils

waste and the content of hazardous substances were iron sulfate of 35–40 wt.%, and sulfate-ion-up to 10 wt.%. The active reaction of the waste solution is Ph 5.33. Therefore, since the hazard index HI>1, this level of risk is unacceptable, and pollutants that are contained in electroplating sludge and entered environmental objects as a result of an emergency will negatively affect human health. Consequently, emergency situations that are accompanied by a violation of the integrity of storage areas (containers, bags, etc.) and lead to the ingress of electroplating sludge into the environment increase the risk to human health. The obtained levels of carcinogenic risk and Hazard Index indicate the need to make a set of decisions to prevent the occurrence of emergencies, as well as minimize their consequences. In this case, further research should be aimed at finding alternatives to the storage of sludge on the territories of enterprises, at waste processing with the removal of valuable components and the reuse of solutions in technological processes (Schlegelmilch, 1996). To solve this problem, it is necessary to identify ways to solve it in order to create environmentally friendly equipment.

CONCLUSION

It is established that there is no unified methodology for determining environmental risk in modern, even developed countries. The study of soil contamination with lead in the territory of the city, where industrial enterprises are located, showed an increase in anthropogenic load (most of the city's

Table 3. Concentration and toxicity class of the substance

Form presence	Concentration, mg/kg (X), toxicity class of the substance						
	Pb(1)	Cd(I)	Zn(1)	Mn	Cu(2)	Cr(2)	Ni(2)
Gross	<0.5	<0.25	6.94	39.64	3.71	<0.1	27.87
Movable AT, t = 25 °C	<0.5	<0.25	2.39	39.62	0.74	<0.1	9.00
Water-soluble AT, t = 25 °C	<0.5	<0.25	0.29	9.38	<0.35	<0.1	2.90
Solubility in the experiment (g/100 g)	–	–	4.1	23.2	Not soluble	–	Not soluble
Average amount in waste (kg/t)	–	–	0.007	0.04	0.004	–	0.03
MPC in the soil (mg/kg) – gross form	32.0	1.5	–	1500.0	–	80.0	–
MPC in the soil (mg/kg)	–	–	23.0	–	3.0	6.0	4.0

territory) characterized by a significant excess of the maximum permissible concentration (from 1.3 to 6.45 times) of the mobile form of lead.

REFERENCES

1. Al Mamun, A.; Mohamad, M.R.; Bin Yaacob, M.R. 2018. Intention and behavior towards green consumption among low-income households. J. Environ. Manag. 227, 73–86.
2. Biswas, A.; Roy, M. 2015. Leveraging factors for sustained green consumption behavior based on consumption value perceptions: Testing the structural model. J. Clean. Prod, 95, 332–340.
3. Carfora, V.; Caso, D.; Sparks, P.; Conner, M. 2017. Moderating effects of pro-environmental self-identity on pro-environmental intentions and behaviour: A multi-behaviour study. J. Environ. Psychol. 53, 92–99.
4. Cerri, J.; Testa, F.; Rizzi, F. 2018. The more I care, the less I will listen to you: How information, environmental concern and ethical production in Fl Uence consumers' attitudes and the purchasing of sustainable products.
5. Chekima, B.C.; Syed KhalidWafa, S.A.W.; Igau, O.A.; Chekima, S.; Sondoh, S.L. 2016. Examining green consumerism motivational drivers: Does premium price and demographics matter to green purchasing? J. Clean. Prod. 112, 3436–3450.
6. Chen, S.-C.; Hung, C.-W. 2016. Technological forecasting & social change elucidating the factors influencing the acceptance of green products: An extension of theory of planned behavior. Technol. Forecast. Soc. Chang. 112, 155–163.
7. Choi, D.; Johnson, K. 2019. Influences of environmental and hedonic motivations on intention to purchase green products: An extension of the theory of planned behavior. Sustain. Prod. Consum. 18, 145–155.
8. De Vicente Bittar, A. 2018. Selling remanufactured products: Does consumer environmental consciousness matter? J. Clean. Prod. 181, 527–536.
9. Do Paço, A.; Shiel, C.; Alves, H. 2019. A new model for testing green consumer behaviour. J. Clean. Prod. 207, 998–1006.
10. Follows, S.B.; Jobber, D. 2014. Environmentally responsible purchase behaviour: A test of a consumer model. Eur. J. Mark. 34, 723–746.
11. Foukaras, A.; Toma, L. 2014. Buying and wasting sustainably. Determinants of green behaviour in Cyprus and Sweden. Procedia Econ. Financ. 14, 220–229.
12. Gonçalves, H.M.; Lourenço Ferreira, T.; Graça, M.S. 2016. Green buying behavior and the theory of consumption values: A fuzzy-set approach. J. Bus. Res. 69, 1484–1491.
13. Grimmer, M.; Bingham, T. 2013. Company environmental performance and consumer purchase intentions. J. Bus. Res. 66, 1945–1953.
14. Huang, H.; Lin, T.; Lai, M.; Lin, T 2014.. International journal of hospitality management environmental consciousness and green customer behavior: An examination of motivation crowding effect. Int. J. Hosp. Manag. 40, 139–149.
15. Joshi, Y.; Rahman, Z. 2015. Factors affecting green purchase behaviour and future research directions. Int. Strat. Manag. Rev. 3, 128–143.
16. Schlegelmilch, B.B.; Bohlen, G.M.; Diamantopoulos, A. 1996. The link between green purchasing decisions and measures of environmental consciousness. Eur. J. Mark. 30, 35–55.
17. Seo, S.; Ahn, H.-K.; Jeong, J.; Moon, J. 2016. Consumers' attitude toward sustainable food products: Ingredients vs. Packaging. Sustainability. 8, 1073.