IMPACT OF HEAVY METAL SOIL POLLUTION AND EFFECTS ON HUMAN HEALTH - LEGISLATIVE PROVISIONS

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Abstract. As regards the research methodology, this paper used the comparative method between the current legislation in force in the Member States of the European Union on regulated standards for heavy metal content in soil. As can be seen, the legislative regulations vary from country to country, and in Romania, the legislation is the most stringent in terms of Pb content in soil, compared to the European Union and other Member States. Finland imposes higher restrictions for Cd, Ni and Zn content, while the Netherlands has stricter regulations for As content. Dutch legislation is more permissive for essential metals than other EU Member States.

Keywords: food safety, heavy metals, human health, soil pollution

Abbreviations
AAS-Atomic Absorption Spectroscopy
AR- Aqua Regia
FAAS- Flame Atomic Absorption Spectroscopy
HMs- Heavy Metals
ICP-AES- Inductively Coupled Plasma Atomic Emission Spectroscopy
ICP-MS- Inductively Coupled Plasma Mass Spectrometry
ICP-OES- Inductively Coupled Plasma-Optical Emission Spectrometry
ISO- International Organization for Standards
XRF- X-ray Fluorescence

INTRODUCTION

All soils contain heavy metals, but concentrations vary considerably and some cannot be detected by analytical procedures [5, 20, 44]. They are permanent because they are not subject to degradation or decomposition by bacteria and accumulate in the tissues of organisms through the process of bioaccumulation [39, 41, 43].

Sources of heavy metals in the environment are diverse and complex, of natural and anthropogenic origin. They affect soil and subsoil, groundwater, surface water and, last but not least, the atmosphere [15].

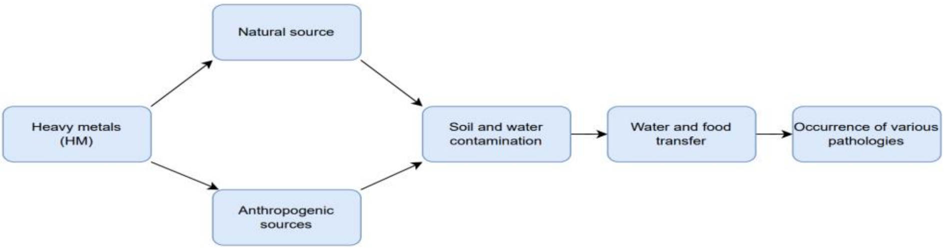

Fig.1.1. Heavy metal circuit

Natural sources of heavy metals are: magmatic rocks, sedimentary rocks, erosion, soil formation processes, fires and many others [12, 30].

Anthropogenic sources of heavy metals are generally influenced from industrial activities, transport and agriculture. Heavy metals are emitted to the atmosphere as: aerosols, particulate pollutants, aqueous phase or in solid wastes, and the sources are categorized as diffuse or point sources [12, 20].

Anthropogenic sources of some heavy metals are presented in **Table 1.2.**

Tab. 1.2. Anthropogenic sources of some heavy metals (processed table) [30].

Heavy metal	*Source*
Lead	Oil exploitation, pesticides
Cadmium	Oil exploitation, paint pigments, pesticides
Arsenic	Pesticides, mining and smelting of non-ferrous metals
Copper	Pesticides, mining and smelting of non-ferrous metals
Nickel	Galvanizing, painting, battery processing
Zinc	Rubber industry, paints, dyes, detergents

MATERIALS AND METHODS

As regards the research methodology, this paper used the comparative method between the current legislation in force in the Member States of the European Union regarding the regulated standards for the heavy metal content in soil.

Table 1.3. shows the maximum permissible limits of heavy metals in soil in some European countries.

Tab.1.3. Maximum limits of heavy metals in soil in some European countries (mg/kg)

Chemical element	*Romania*	*European Union*	*Netherlands*	*Austria*	*Poland*	*Germany*	*Finland*
Pb	50	300	150	100	100	500	60
Cd	3	3	5	5	3	2	1
As	15	5	4,5	-	20	-	5
Cu	100	140	250	100	100	50	100
Ni	75	75	100	100	100	100	50
Zn	300	300	500	300	300	300	200
Sources	**[3]**	**[1]**	**[24]**	**[24]**	**[24]**	**[24]**	**[2]**

Methods used in the determination of heavy metals in soil

Instrumental analytical methods, evolved from single-element spectroscopic techniques such as (FAAS) to multi-element techniques such as (ICP-MS), (ICP-AES) and (ICP-OES) are standardised methods for the determination of heavy metal samples in soil. ISO methods for some EU countries are as follows: Romania (AAS), Austria (AR, AAS), Germany (AR, XRF), Finland (AR) [11, 19, 21, 25, 35, 36, 37, 42, 57].

Impact on human health

In recent times, pollution by heavy metals deserves more attention, as most metals are not found in water-soluble form, or if present, the respective chemical species are complexed with organic or inorganic ligands, leading to increased toxicity [16, 22, 55, 56].

On the one hand, heavy metals such as Cu, Ni or Zn are essential nutrients for plants and are only toxic in concentrations above the maximum permitted limits.

On the other hand, Pb, Cd and Hg are toxic metals with no role in metabolism [6, 8, 26, 40, 56].

Table 1.4 describes some of the critical metals, their source and effects on human health.

Tab. 1.4. Critical metal-source-effect on human health

Critical metal	*Source*	*Benefits*	*Excess*	*Deficiencies*	*Citations*
Pb	Pesticides, paint, smoking, car emissions, extraction of useful minerals	Lack of conclusive data	Developmental delays in children, encephalopathy, congenital paralysis, epilepsy, gastrointestinal disorders	Low IQ Emotional and behavioural problems	**[27] [29] [45] [47] [58]**
Cd	Galvanisation, welding, fertilisers, pesticides, battery production, smoking	Lack of conclusive data	Kidney dysfunction, osteoporosis, increased blood pressure, bronchitis	Cardiovascular diseases	**[4] [7] [18]**
As	Mining and smelting of non-ferrous metals, coal industry, wood industry	It is used in the manufacture of medicines to treat diabetes and joint problems.	Atherosclerosis, hypertension, ischemic heart disease, ventricular arrhythmias	Lack of conclusive data	**[9]**
Cu	Mining, pesticide production, chemical industry	Helps biological processes	Anaemia, digestive system disorders	Hypochromic anaemia	**[34] [51] [28]**
Ni	Electroplating, painting, battery processing	Increases hormonal activity and helps lipid metabolism.	Respiratory and cardiovascular impairment	Histological, biochemical changes followed by reduced iron reabsorption	**[46]**
Zn	Rubber industry, paints, dyes, detergents	Helps the immune system and metabolism	Cramps, stomach pain, loss of appetite, headaches	The appearance of various eczemas	**[33] [38]**

Lead (Pb) is a silvery metal that is found in organic and inorganic forms with high toxicity [9, 10, 13, 14, 23, 32, 48, 49, 50, 52, 53]. Exposure to concentrations above the maximum permissible limits of Pb, can induce certain neurological, respiratory, urinary, cardiovascular disorders, nausea, vomiting due to immunomodulatory, oxidative and inflammatory mechanisms [9, 48, 49].

Cadmium (Cd), which is relatively rare, is found in soil and minerals such as sulphide, sulphate, carbonate, chloride and hydroxide salts, as well as in water. This chemical element belongs to the same group as the elements Zn and Hg and shares common properties. Thus, high levels of Cd in water, air and soil can be caused by industrial activities. Ingestion of contaminated food can also lead to kidney, respiratory and central nervous system disorders [9].

Arsenic (As) is a ubiquitous metal, distributed in all environments in low concentrations. It is found in two parts, the inorganic part being trivalent and pentavalent and the second part represented by the organic part consisting of methylated metabolites **[9].**

Copper (Cu) is a transition metal with a chalcophilic geochemical affinity, a property that determines its association with Pb, Ni and Zn. It is low in abundance, but forms a wide range of minerals (sulphides, carbonates), which through surface weathering generate important natural resources of Cu in soil and water [17, 34].

Nickel (Ni) is a hard, ductile, ferromagnetic transition element, ranking 28th in the periodic table. It can exist in several oxidative states from -1 to +4, while Ni^{2+} is the most widely distributed in the environment [31].

Zinc (Zn) is a metal abundant in the earth's crust, necessary for the growth and development of living organisms, being a cofactor of proteins with a role in the regulation of immunomodulating substances [54, 33].

RESULTS AND DISCUSSIONS

The results of the research are mentioned below, together with figures made using Microsoft Excel software.

Regarding the maximum allowable limits for the chemical element **Pb**, we have:

Minimum value - 50 mg/kg in Romania

Maximum value - 500 mg/kg in Germany

Pb deficiency, although not an essential metal, has been associated in some studies with low IQ, while exceeding the limit values disrupts somatic development.

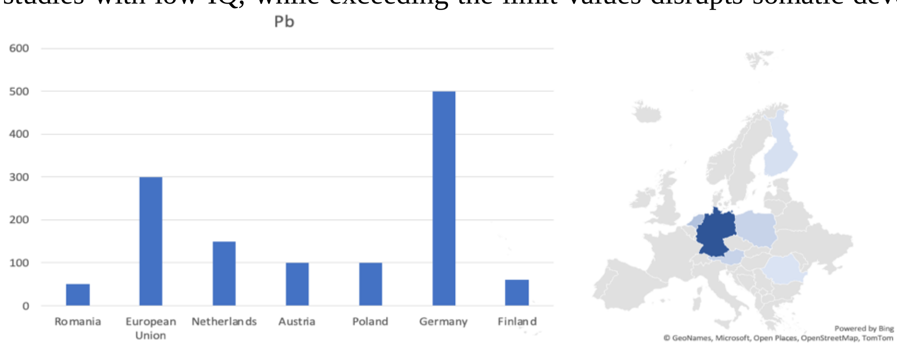

Fig. 1.5. Maximum permitted limits of Pb

Regarding the maximum allowable limits for the chemical element **Cd**, we have:

Minimum value - 1 mg/kg in Finland

Maximum value - 5 mg/kg in Austria and the Netherlands

Deficiency of **Cd** can lead to cardiovascular disease, while excess leads to kidney dysfunction and bronchitis.

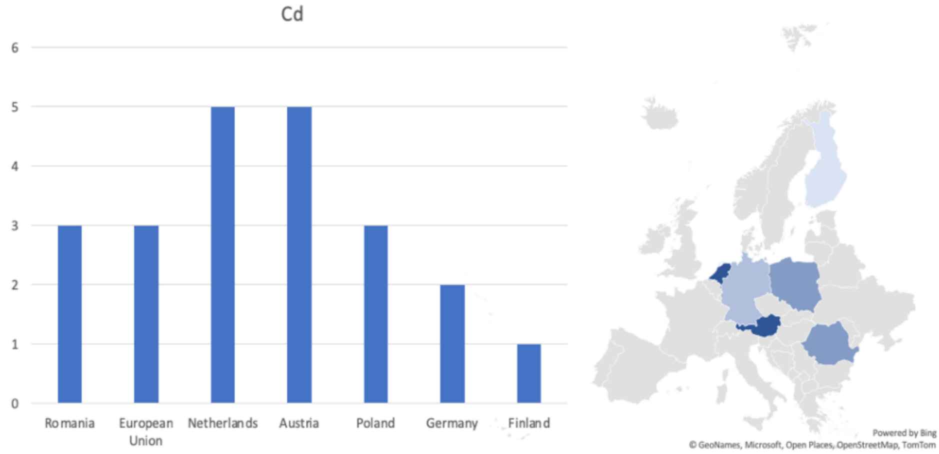

Fig. 1.6. Maximum permitted limits of Cd

Regarding the maximum allowable limits for the chemical element **As**, we have:

Minimum value - 4,5 mg/kg in the Netherlands

Maximum value - 20 mg/kg in Poland

There are currently no pathologies associated with **As** deficiency, but excess can lead to cardiovascular problems.

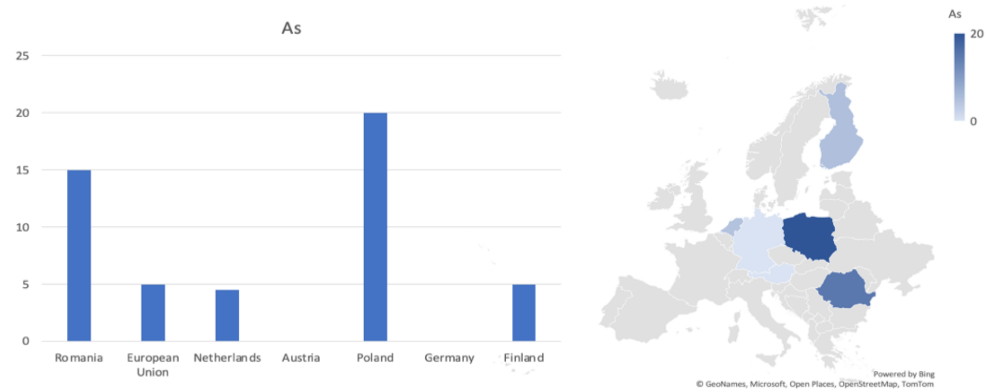

Fig. 1.7. Maximum permitted limits of As

Regarding the maximum allowable limits for the chemical element **Cu**, we have:

Minimum value - 50 mg/kg in Germany

Maximum value - 250 mg/kg in the Netherlands

Consequently, excess **Cu** can lead to the development of conditions such as anaemia. However, Cu has an essential functionality in biological processes.

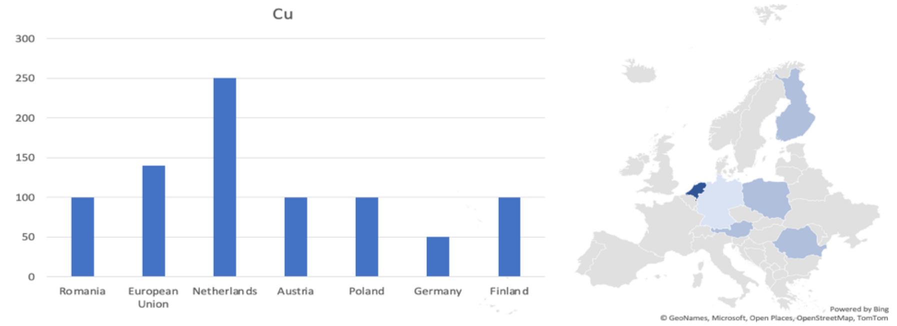

Fig. 1.8. Maximum permitted limits of Cu

Regarding the maximum allowable limits for the chemical element **Ni**, we have:

Minimum value - 50 mg/kg in Finland

Maximum value - 100 mg/kg in the Netherlands, Austria, Poland and Germany

If exceeded, lung damage can occur, leading to death. Also, the absence of **Ni** in the body premeditates biological, histological changes and reduced iron reabsorption in the body.

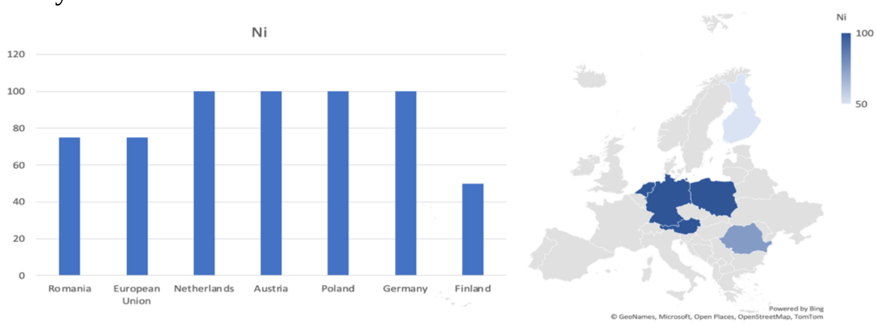

Fig. 1.9. Maximum permitted limits of Ni

Regarding the maximum allowable limits for the chemical element **Zn**, we have:

Minimum value - 200 mg/kg in Finland

Maximum value - 500 mg/kg in the Netherlands

Exceeding the pre-set limit levels can result in manifestations such as headache and abdominal discomfort, while its insufficiency can lead to kidney disorders.

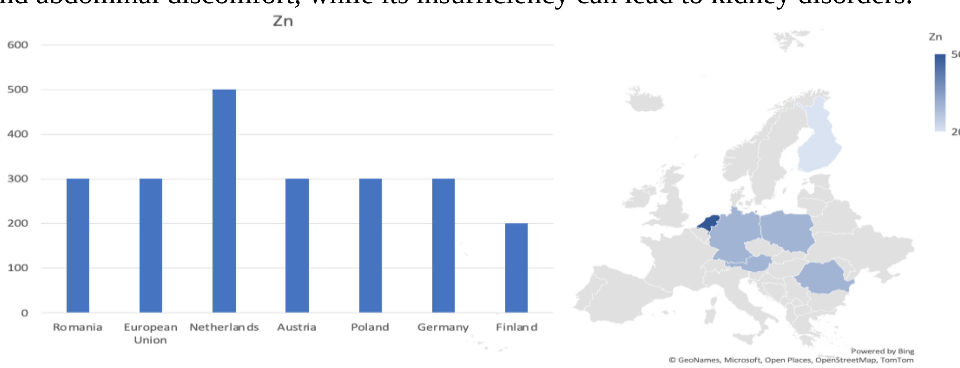

Fig. 1.10. Maximum permitted limits of Zn

CONCLUSIONS

As we can see, the legislative provisions are different depending on the country, and the Romanian legislation is the most demanding in terms of Pb content in soil, compared to the European Union and the rest of the member countries.

Finnish legislation is more restrictive for Cd, Ni and Zn, while Dutch legislation is more restrictive for As content.

Dutch legislation is much more permissive for essential metals than the rest of the EU Member States.

In conclusion, the comparison of national and European legislative provisions on heavy metal soil pollution reveals the complexity and diversity of approaches to this issue. This analysis contributes to the development of more effective policies and strategies to manage the impact of heavy metals in soils in line with environmental and public health principles.

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