

Heavy Metals Technogenic Pollution of Plough Lands Arable Layer in the Chelyabinsk Region

G F Mantorova

Department of Urban Planning, Engineering Networks and Structures, South Ural State University, 76, Lenin Avenue, Chelyabinsk 454080, The Russian Federation

E-mail: aily1972@inbox.ru

Abstract. Environmental protection and rational use of natural resources in agriculture are the main directions of this scientific research. Contamination is caused by the substances of chemical, radiation and biological origin above the maximum permissible concentration (MPC). The main source of soil contamination in the arable land, hayfields and pastures is the waste of livestock complexes, agricultural chemicals (fertilizers, pesticides), motor vehicle exhausts, industrial emissions, sewage from settlements, etc.

The ecological state of the soil and vegetation cover is largely determined by agricultural activities. The agricultural production technology complicating is accompanied by increase in the degree of environmental risk, especially in the chemicalization of agriculture. Pollution also enters the soil with atmospheric precipitation, surface waste. They are also introduced into the soil layer by soil and groundwater.

The most dangerous for human health is considered to be contamination with heavy metals (HM)—lead, mercury and cadmium. However, the concentration of the rest elements is no less harmful. The paradox of heavy metals is that in certain quantities they are necessary to ensure the normal life of plants and organisms but their excess can lead to serious diseases and even death. A nutritional cycle causes harmful compounds to enter the human body and often cause great harm to health.

The present work reveals the results of the research of a long-term experience on accumulation and distribution of heavy metals on the arable layer profile depending on the concentration in humus soil and the system of ground processing.

1. Introduction

The production of ecologically clean agricultural products is unthinkable outside of a favorable, "healthy" environment. A particularly important component of the environment in the production of agricultural products (grain, vegetables, fodder for farm animals) is soil, which serves as an indicator of the ecological well-being of any region [1-7].

One of the most important indicators of soil quality is the content of heavy metals in it. The soil, in turn, serves as the main source of the entry of HM into plants. Fertile soil must contain micro- and macronutrient substances necessary for the growth and development of plants. All soils contain in an insignificant quantity many elements in organic and in inorganic form. The content of microelements in different soils is not the same and depends on its fertility and utilization [8-10].

2. Pollution of the biosphere of the earth by heavy metals introduction



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

The higher concentration of heavy metals (HM) is noted in the upper (0-10 cm), most humified layer of soil, which is one of the reasons for the high content of HM in agricultural products. The danger lies in the fact that chemical contamination can not appear for a long time, and grown on such soil, with the appearance of normal agricultural products, can have a toxic effect on human health [11,12].

The Chelyabinsk Region, located in the South Urals, is an anomalous territory in terms of the degree of man-made pollution and it is impossible to determine the degree of technogenic pollution, because it cannot be compared with the background value, since the background soils must belong to the same type of biogeocenosis as the contaminated ones. There should be no economic activity on them, and they should be removed from sources of pollution by 50-100 km [13]. There are practically no such soils due to the high density of industrial production in the Chelyabinsk region, see Figure 1 (14).

One of the most harmful pollutants to the Earth's biosphere, having the most diverse harmful consequences, both for human health and life of living organisms, is heavy metal contamination. The increasing scale of environmental pollution results in the growth of genetic mutations, cancer, cardiovascular and occupational diseases, poisoning, dermatoses, decreased immunity and related diseases. In the overwhelming majority of cases, the primary source of pollution is the environmentally illiterate human activity. Among hazardous to health substances heavy metals and their compounds occupy a special place, because they are constant companions in human life. Nature is not always able to regulate their content in the soil [15-19].

Accumulation of heavy metals by the arable layer, especially with a high content of humus, on the one hand, promotes strong binding of HM and exclusion of their entry into adjacent environments. But on the other hand, the loss of soil humus, which is now observed everywhere due to intensive agricultural use of soils and non-compliance with the law of return, especially in such an abnormal zone as the Southern Urals and, in particular, the Chelyabinsk region, threatens an ecological catastrophe in the form of a gradual poisoning of living organisms toxicants of different nature, since humus firmly binds many chemical elements and prevents them from getting into soil solution and washing out.

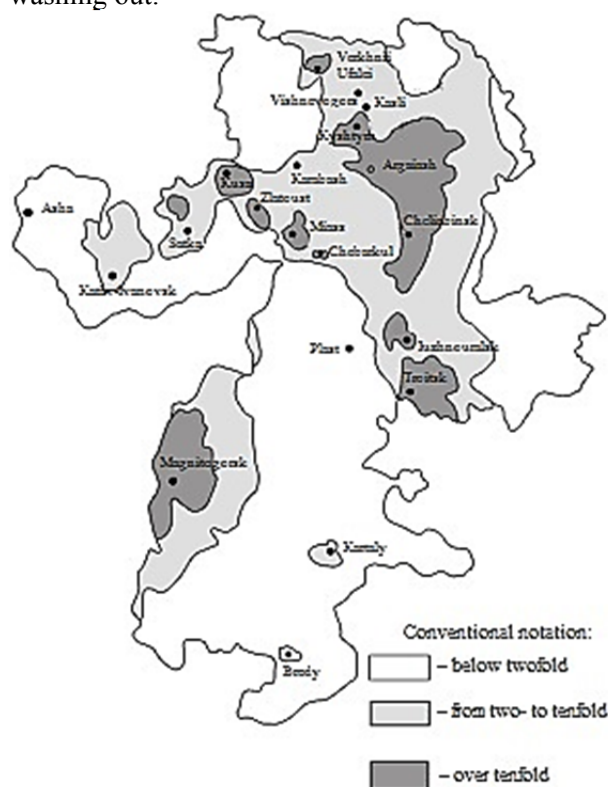


Figure 1. Scheme of chronic air pollution over the territory of the Chelyabinsk region.

3. Heavy metals in the soil

Our research on the accumulation and distribution of HM in the arable layer on leached black soil was carried out in a long-term stationary experiment, laid down in 1975 under different soil treatment systems: dump, combined and planed. With the dumping system of soil cultivation, i.e. When plowing, the soil was wrapped and mixed every year to the depth of the arable layer; With a planar cutting system, soil layers were not mixed; in the combined system, plowing was carried out twice for rotation of the five-field crop rotation, i.e. twice in five years there was a mixing of soil layers, and the rest of the time, flat-topped without mixing the layers. The results of the studies on this experiment are presented in Table 1.

The arable land, where research was conducted, was 50 km from Chelyabinsk. There were no other settlements with possible sources of pollution near. The results of the analysis of the content of HM in the soil on arable land showed that all the chemical elements studied were within the MPC limits. However, in comparison with the indices of the average chemical composition of the solid phase of the soil according to Vinogradov, in the arable 0-30 cm layer, the lead, nickel, cobalt and cadmium content was exceeded: lead by 4-8, nickel by 2-7, cobalt - by 4-7, cadmium - by 0.12-0.20 mg/kg soil.

Table 1. The content of humus and acid-soluble compounds of HM in the arable layer of the soil in a long-term stationary experiment under various treatment systems (the experiment was laid in 1975).

Layer of soil, cm	Humus, %	Heavy metals, mg/kg soil								
		copper	zinc	lead	nickel	cobalt	iron	manganese	cadmium	chromium
Dump										
0-10	6,56	14,9	39,1	17,9	47,2	14,2	13150	316	0,66	31,0
10-20	6,71	15,2	38,3	17,9	46,8	13,3	14950	322	0,66	31,8
20-30	6,32	14,2	37,9	16,2	45,7	13,4	13050	331	0,62	32,3
Average	6,53	14,8	38,4	17,2	46,6	13,6	13717	323	0,65	31,7
Combined										
0-10	7,28	15,4	38,2	15,9	42,0	15,0	13550	320	0,65	28,5
10-20	7,72	16,0	38,9	16,3	42,5	14,5	12900	332	0,67	32,5
20-30	6,56	15,0	37,6	15,0	43,3	13,8	12800	339	0,67	30,6
Average	7,19	15,5	38,2	15,7	42,6	14,4	13083	330	0,66	30,5
Flat-cut										
0-10	7,74	15,7	36,6	17,1	37,3	12,2	12550	341	0,70	30,1
10-20	7,56	16,0	36,7	14,3	41,0	12,2	11400	323	0,64	29,5
20-30	5,76	15,6	37,1	14,7	40,2	13,0	13900	270	0,65	28,0
Average	7,02	15,8	36,8	15,4	39,5	12,5	12617	311	0,67	29,2
Kloke MPC		100	300	100	50	-	-	-	3	100
Average chemical composition of the solid phase of the soil by Vinogradov		20	50	10	40	8	37000	800	0,5	200

If compare the methods of soil cultivation with one another, it can be noted that some deviations in the content of HM in the arable layer increased with annual dump processing compared to the planing: in zinc, the excess was 1.6, lead - 1.8, nickel - 7.1, cobalt - 1.1, iron - 1100, chromium - 2.5 mg/kg soil. With the combined soil treatment system, most of the HM content in the soil occupies an intermediate position between the parameters for dumping and flat cutting.

It should also be noted that in the dumping soil treatment system, more lead, nickel, cobalt, iron, chromium was accumulated in the upper 0-10 cm layer; In the 10-20 cm layer, zinc, lead, nickel, cobalt, iron, cadmium, chromium, and in the 20-30 cm layer, zinc, lead, nickel, cobalt, manganese, chromium. That is, the annual application of more than 40 years only for the dump cultivation of the soil, in comparison with the planar cutting, contributed to a greater accumulation of HM. This can be

explained by the intensity of use and the degree of mixing of soil layers with different methods of processing it.

The greater accumulation of acid-soluble HM in the dumping soil treatment system is also associated with a lower humus content in the soil - 6.53 versus 7.02 in the case of flat cutting, which is explained by its faster mineralization as a result of intensive soil use during annual plowing. Similar results were obtained for other precursors in different crop rotations in our experiments and in the studies of other authors [20-24].

4. Conclusion

Based on the studies carried out in the Chelyabinsk region on leached chernozem, it can be concluded that the content of HM in the soil on arable land depended on the humus content, the method and duration of soil application.

Acknowledgment

The work was supported by Act 211 Government of the Russian Federation, contract № 02.A03.21.0011.

References

- [1] Krylova L P and Vezentsev A I 2007 The content of heavy metals in the soils of garden and vegetable plots of the Belgorod Region *Problems of Regional Ecology* **6** pp 33–36
- [2] Gorbunova L G, Zadorina O A and Balushkina E N 2004 Influence of agrotechnogenic emissions of pulp-and-paper plants on the state of soils in the southern regions of the Arkhangelsk Region *Ecology: Education, Science, Industry and Health* (Belgorod) pp 41–42
- [3] Davydova S L 1991 *On the toxicity of metal ions* (Moscow: Knowledge) p 32
- [4] Vlasyuk P A 1980 *Microelements and natural radioactivity of soils* (Moscow: Kolos) pp 759–67
- [5] Garmash G 1986 *Accumulation of Heavy Metals in Soils and Plants around Metallurgical Enterprises* (Novosibirsk: IPA SB AS USSR) p 16
- [6] Garmash G A 1983 Element input into the soil with emissions of ferrous metallurgy enterprises *Chemistry in Agriculture* **10** pp 45–48
- [7] Gutneva N M Influence of Soil Pollution with Technogenic Emissions on the Harvest and the Chemical Composition of Barley *Chemistry in Agriculture* vol 20 **3** pp 26–28
- [8] Dobrovolsky V V 1997 Biospheric cycles of heavy metals and the regulatory role of soil *Pochvovedenie* **4** pp 431–41
- [9] Alexeev Yu V 1987 *Heavy metals in soils and plants* (Leningrad: Agropromizdat) p 142
- [10] Yagodin B A and Kidin V V 1996 Heavy metals in the soil-plant system *Chemistry in Agriculture* **5** p 17
- [11] Garmash N Yu 1986 *Influence of heavy metals on the magnitude and quality of the crop of agricultural crops* (Novosibirsk: IPA SB AS USSR) p 16
- [12] Alexeev Yu V 1987 *Heavy metals in soils and plants* (Leningrad: Agropromizdat) p 142
- [13] Mukha V D, Sulima A F, Karpinets T V and Levshakov L V 1998 Ratio of heavy metals in soil and soil-forming rock as a criterion for assessing soil contamination *Pochvovedenie* **10** pp 1265–70
- [14] Levit A I 2001 *Southern Urals: Geography, ecology, nature management* (Chelyabinsk: South-Ural. Book. Publishing house, South-Ural. Ed.-bargaining. House) p 246
- [15] Gorbato B C 1983 *Transformation of compounds and the state of zinc, lead and cadmium in soils* (Moscow: Moscow State University) p 24
- [16] Galiulin R V and Ukhvatov V P 1992 Evaluation of the influence of heavy metals on the self-cleaning of agrolandscape soils from residues of persistent pesticides *Agrochemistry* **3** pp 67–74
- [17] Glazovskaya M A 1979 Ability of the environment to self-purification *Nature* **3** pp 71–79

- [18] Dobrovolsky V V 1997 Biospheric cycles of heavy metals and the regulatory role of soil *Pochvovedenie* **4** pp 431–41
- [19] Dobrovolsky G V, Orlov D S and Grishina L A 1983 Principles and tasks of soil monitoring *Pochvovedenie* 11 pp 8–16
- [20] Doncheva A B 1978 *Landscapes in the zone of industrial impact* (Moscow: Forest Industry) p 94
- [21] Glukhovskiy A B, Sergeev V G and Yezhov M Yu 1994 The effect of manure, pesticides and the proximity of the highway on the content of heavy metals *Heavy metals and radionuclides in agro-systems* (Moscow) pp 109–13
- [22] Glukhovskiy A B, Malyuga N G and Kotlyarov N S 1994 Effect of fertilizers on the content of heavy metals in the soil *Heavy metals and radionuclides in agro-systems* (Ivanovo: State Department of the CCP) pp 101–3
- [23] Aderikhin P G 1970 *Phosphorus in soils and agriculture of the Central Black Earth zone of the strip* (Voronezh: Izd-vo VSU) p 248
- [24] Shafronov O D, Titova V I and Varlamov L D 1997 Ecological aspects of applying phosphate fertilizers *Agrochemical bulletin* **3-4** pp 42–43