

Influence of the Ore Mining and Processing Enterprise on soil types in adjoining areas

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Abstract. Anthropogenic influence on surroundings has induced anthropogenic or technogenic biogeochemical anomalies, where sharp a increase in the content of chemical elements has been established. Due to technogenic contamination, the amount of microelements in soils comes close to the level of macroelements that negatively affect plants, soil qualities and biota.

Appearance of technogenic biogeochemical anomalies depends on such activities as mining and manufacturing, exploitation of mines, metallurgical and chemical industries, which, through the air and sewage, contaminate soils, the atmosphere, storage pools, the vegetational cover and other components of nature. The extent of technogenic pollution depends on industrial capacities of contaminating enterprises, the time of their exploitation and the working effectiveness of purifying constructions.

Regions considerably contaminated with chemical elements have been found to cover the area within a radius of 10–15 km, whereas in the direction of the dominating winds it has even reached 20–30 km. The zone is referred to as a technologically vastly polluted area where dominating chemical contaminants in the soil threaten the entire soil biota as well as its agrophysical and agrochemical properties.

Our observations revealed that heavy metals from open-cast mines of the Ore Mining and Processing Enterprise were scattered by the prevailing winds throughout the environment within a radius of 8–12 km, and transferred, via irrigating waters, to agricultural arables dozens of kilometers away.

Key words: microelements, heavy metals, soil types, arable lands, biogeochemical anomalies

INTRODUCTION

As it is known, content of chemical elements (macro- and microelements) in soils is determined by soil-forming processes. First of all, it depends on the chemical composition of soil-forming rocks as well as certain soil-forming conditions such as: climate, relief, vegetational cover, animal kingdom, and the factors that manage the processes of dissolving, accumulation, migration and natural redistribution of chemicals over the soil profile. For that reason, every genetic type of soil has its specific composition and balance between micro- and macroelements determined by genetic horizons (Glazovskaya, 1988).

MATERIALS AND METHODS

The field-works for the research were carried out in Eastern Georgia, in Kvemo Kartli region at a distance of 90 km to the south of Tbilisi, in the areas contiguous to the open-cast mines and the Ore Mining and Processing Enterprise. The lands there are mainly used as agricultural arables. The research field-works were conducted in 1993–1994, but statistical analyses, laboratory works and generalisation of obtained results lasted until 1999. Field-works in the region are still being conducted.

We studied the brown type of wood ground (Cinnamonic-eutric cambisols and calsic kastanozems), classified according to the FAO-system, adopted by the International Agricultural Committee of the UN. This type of soils is found in carbonate rocks and drained carbonate materials. Among soil-producing rocks, a significant role should be attributed to lios-like ones. They are rich in humus and characterised by voluminous adsorption capacities, perfect and tight structure. Lower layers represent rocky soils and contain a large amount of lime (CaCO_3). As for mechanical composition, in most cases they are hard clayey soils changing to mild clayey ones in the lower layers (the agricultural parameters have been presented in Table 1).

The soil probes to be tested were taken from areas away from the open-cast mines of copper-barytes, along the motor road, at distances of 300, 500, 1000, 1500, 2500 and 4000 m. Three elements were studied: (a) copper, as a dominating element among the heavy metals found in the mine; zinc, as an accompanying element, and manganese, as the most widely spread polymetal.

Several methods are actively used for studying heavy metal content of soils. These are: atom-adsorption spectrophotometry, emissive, polyarographic, x-ray-fluorescent, radiometric and activative methods. We applied the atom-absorption spectrophotometric method that had some advantages, in particular: high sensitiveness, high efficiency and existence in a single form. In the ground, copper, zinc and manganese were defined by tree-time solution in the royal water (kőning wasser). Each experiment was performed three times and averaged values were estimated.

In addition to the maximum permissible concentration (MPC), other criteria and norms are also defined in the investigations that study soil contamination levels. Among them, the coefficient of Clark concentration should be mentioned. The geoecological condition of soils is evaluated using the coefficient of polluting concentrations. To assess the soil contamination level, the coefficient of danger of pollution is applied (Saet, U. E., 1983).

We suppose, that a special interest should be paid to the criteria that evaluate the geoecological condition of soils. They are estimated by the formula:

$$Hc = \frac{C_{\text{actual concentration}}}{\text{background}}$$

where Hc - the coefficient of polluting concentration
 $C_{\text{actual concentration}}$ - the actual concentration of a chemical element
 background - the background parameter of a chemical element

Table 1. Some agricultural parameters of the brown type of wood ground in the regions studied.

No sect.	depth of obtainin g the probe, cm	Hum us %	pH	nitrogen total %	phosphorus soluble mg/100g	mechanical composition %	
						< 0.001 mm	< 0.01 mm
122	0–20	2.61	8.8	0.114	0.3	21.3	46.5
123	0–20	4.16	8.5	0.231	0.63	20.4	45.3
124	0–20	2.83	8.2	0.115	0.31	16.8	44.7
145	0–20	5.78	8.2	0.119	0.53	20.0	44.0
146	0–20	5.86	7.2	0.117	0.33	28.1	43.3
147	0–20	2.11	6.3	0.115	0.43	24.1	85.9
148	0–20	2.05	5.2	0.1	0.23	27.8	68.3
149	0–20	2.12	7.9	0.118	0.36	25.8	44.0
150	0–20	3.82	8.0	0.179	0.53	24.1	85.9
74	0–20	4.05	8.1	0.184	0.58	45.8	74.4
	20–40	3.12	7.9	0.175	0.43	43.4	72.1
	40–60	3.02	8.0	0.130	0.11	46.0	73.8
	60–80	2.97	8.2	was not detected	was not detected	45.2	66.3
	80–100	1.8	8.0	was not detected	0.59	28.1	69.9
75	0–20	3.7	8.2	0.188	0.47	20.5	46.3
	20–40	2.98	8.1	0.179		23.2	48.2

Since the studied region represents a district with a mountainous relief we applied the principle of Kathena for selecting the ranges for further research – we marked the entire ranges from the top of the relief down to the lowest point. Thereafter ground sections were made and the soil probes aimed for testing were taken. A special field-work drill was also used in order to obtain the mixed soil probes at a depth of 0–20 and 20–40 cm (Alekseev, 1987).

RESULTS AND DISCUSSION

The heavy metals (copper, zinc and manganese) were detected directly in the soils around the Ore Mining and Processing Enterprise - at a reservoir of technogenically treated sewage (section 122–123), at the open-cast mine and at distances of 300, 500, 1000, 1500, 2500 and 4000 m from the site along the motorway, and near the sanatorium of the enterprise. According to the FAO-system of classification, the soils there were found to be more or less stiff. They represented clayey soils with different degrees of thickness and belonged to the forest brown-soil fine-grained type. The chemical analyses performed revealed that the soils contained the humus in a little

Table 2. Content of copper in the soils of the Ore Mining and Processing Enterprise.

No sect.	depth of probe, cm	actual concentration mg/kg			coefficient of polluting concentration (<i>Hc</i>)	coefficient of polluting risk
		total forms	movable forms	% of total forms		
122	0–20	3,250	300	9.2	162.5	108.3
123	0–20	160	11.3	7.1	8	5.3
124	0–20	155	25	16.1	7.7	5.2
145	0–20	10,000	3,500	35	500	333.3
146	0–20	150	13.3	8.9	7.5	5.0
147	0–20	625	225	36	31.2	20.8
148	0–20	75	1	1.3	3.8	2.5
149	0–20	65	2	3.1	3.3	2.2
150	0–20	60.9	2.3	3.8	3	2
74	0–20	45	was not detected	was not detected	2.2	1.5
	20–40	45	-	-	2.2	1.5
	40–60	40	-	-	2	1.3
	60–80	42.5	-	-	2.1	1.5
	80–100	42.5	-	-	2.1	1.5
75	0–20	77.5	-	-	3.8	2.6
	20–40	42.5	-	-	2.1	1.5

(sect. 147, 148, 149), average (sect. 122, 123, 150) and a large (sect. 143, 145, 146) amount. A pH index was found to be very variable: we discovered there soil probes with high-acidic (sect. 148), acidic (sect. 144), slightly-acidic (sect. 147), neutral (sect. 146) and even alkaline (sect. 122, 123, 143, 145, 149, 150, 74, 75) reactions (see Table 2).

The content of copper was too high in sect. 122, with a total concentration of 3,250 mg/kg, the coefficient of polluting concentration (*Hc*) was equal to 162.5. a relatively lower content of copper was revealed by other mixed probes (sect. 123; 124). The total concentrations of copper in these sectors equaled 160 and 155 mg/kg, and the coefficients of polluting concentrations were 8 and 7.7, respectively (Table 2). According to the classification system proposed by A. Vinogradov (1957), based on heavy metal clarks, the above mentioned soils should be considered as extremely contaminated ones.

The mixed probes of soils obtained from the sites near the enterprise (to the north of it, at the Roger) and at a distance of 300 m contained a maximum total concentration of copper (sect. 144–145) equal to 10,000 mg/kg that exceeded the background parameter 500 times. The concentrations for movable forms were also high (3,400–3,500 mg/kg) that made up 34–35% of the values for total forms and exceeded the MPC 1,166 times. A much lesser amount of copper was fixed on the site, 1000 m

away from the open-cast mine: in the soil layer with a thickness of 0–20 cm taken from the wind-proof line, the total content of copper corresponded to 625 mg/kg that exceeded the background parameter only 31 times. However, it evidenced a high level of soil contamination with copper. A high concentration of copper was found in movable forms as well (225 mg/kg), that made up 36% of the total forms. In general, the dissolving capacity of copper depends on the pH of the soil. The total dissolubility of cation and anion forms decreases when pH equals 7–8. The only compound of copper not dependent on the soil pH is copper carbonate. After sediments brought by sewage are dried, the portion of soluble forms of copper sharply increases, favouring contamination of plants and subsoil waters. The tendency to accumulate this metal in upper layers of soils is one of the main factors in soil pollution (Kabata – Pendias, A. & Kabata – Pendias, Kh. 1989).

As compared with the above-considered sections, a far lesser content of copper was found in 0–20-cm thick layers of soil taken on sites situated 500, 1500, 2500 and 4000 m away from from the open-cast mine. It varied within a range of 40–60 mg/kg, which is only two three times higher than the background parameter (20 mg/kg). The movable copper forms were also smaller there: within 1–13.3 mg/kg.

Table 3. Content of zinc in the soils of the Ore Mining and Processing Enterprise.

No sect.	depth of obtaining the probe, cm	concentration mg/kg			coefficient of polluting concentration (<i>Hc</i>)
		total forms	movable forms	% of total forms	
122	0–20	1,625	50	3.1	32.5
123	0–20	115	5.3	4.6	2.3
124	0–20	235	62.5	26.5	4.7
145	0–20	7,250	45	0.6	145
146	0–20	95	9.2	10	1.9
147	0–20	245	60	24.5	4.9
148	0–20	85	2.3	2.7	1.7
149	0–20	90	2	2.2	1.8
150	0–20	185	1.3	0.7	2.5
74	0–20	95	was not detected	was not detected	1.9
	20–40	140	-	-	2.8
	40–60	90	-	-	1.8
	60–80	90	-	-	1.8
	80–100	95	-	-	1.9
75	0–20	115	-	-	2.3
	20–40	100	-	-	2

The anomalous total concentration of zinc (Table 3) was observed in sect. 122, 1,625 mg/kg, near the reservoir of technogenically treated sewage, being 32–times higher than the Clark index. With respect to the total content of zinc, these soils were mildly contaminated. The extremely high total concentration of zinc was fixed near

the open-cast mine. It equaled 7,250 mg/kg, being 145 times higher than the background parameter. Zinc belongs to the group of active toxic elements. The sources of its distribution are enterprises of coal-mining, processing of non-ferrous metals, ore mining, etc. The main movable form of zinc in soils is Zn^{2+} . Zinc is known as the best soluble chemical element. According to Landsev (1990), the clay and organic substances in soils can bind zinc. The dissolving capacity of a single zinc in soils is markedly lower than in compounds – $Zn(OH)_2$, $ZnCO_3$ and $Zn(PO_4)_2$. There are two different mechanisms of zinc adsorption: one occurs in acidic areas and depends on cation exchanges, but another is considered to be a process of chemisorption, occurring in alkaline areas and vastly depending on the content of organic substances (ligands) (Vada, 1988). Zinc is the most movable element, and living organisms can easily take it in from light soils.

Total and movable concentrations of manganese in the soils near the reservoir and the open-cast mine were increased several times (Table 4). The coefficient of polluting concentration (Hc) was within a range of 3.1–8.7. It seems interesting to mention that in the case of soils rich in copper and zinc, the concentration had decreased, and it increased only in the case of a relatively lower (two or three times higher than the background value) content of copper and zinc in the soil. A very low percentage of movable forms was defined among the total forms. It should be noted that these soils are mainly contaminated with copper and zinc.

Table 4. Content of manganese in the soils of the Ore Mining and Processing Enterprise.

No sect.	depth of obtaining the probe, cm	concentration mg/kg			coefficient of polluting concentration (Hc)
		total forms	movable forms	% of total forms	
122	0–20	120	2.5	2.1	1
123	0–20	1,125	7.2	0.6	5.6
124	0–20	1,625	17.5	1.1	8.1
145	0–20	625	9.8	1.6	3.1
146	0–20	1,000	8.8	0.8	5
147	0–20	1,750	9.3	0.5	8.7
148	0–20	750	2.8	0.3	3.7
149	0–20	750	3.3	0.4	3.7
150	0–20	1,000	10.3	1	5
74	0–20	875	7	0.8	4.4
	20–40	1,125	was not detected	was not detected	5.6
	40–60	1,000	-	-	5
	60–80	1,250	-	-	6.3
75	80–100	1,125	-	-	5.6
	0–20	1,000	-	-	5
	20–40	1,000	-	-	5

Of the soils studied, 16.6% were slightly polluted with copper, 33.4% mildly, and 50% extremely contaminated.

33.3% of the soils belong to the category of soils vastly polluted with zinc, while 41.7% are considered as slightly or moderately contaminated. According to the total values of the coefficient of polluting concentration (H_c), about 16.6% of the soils are less contaminated. The range of variability is 9.5–9.7. However, in the soils identified as less contaminated ones according to the values of polluting concentration coefficients, the decreasing ranges of chemical elements significantly differ from each other. In the first case, when $(n - 1) = 9.5$, the following consequence is valid: $Mn > Cu > Zn$, but in another case, for which $(n - 1) = 9.7$, copper is in the first position: $Cu > Mn > Zn$.

CONCLUSIONS

Our observations allowed us to come to the conclusion that the content of heavy metals is very contrasting in the soils of industrial grounds of the Kazreti Ore Mining and Processing Enterprise and in the nearby area. There we observed both anomalous and low concentrations of the metals similar to the spontaneous levels. Such a variability is a result of technogenesis and different ways of migration and accumulation of chemical elements.

We may notice here that mining and ore-dressing by open-cast mining methods and by means of old and damaged technologies, non-observance of measures of elementary safety, ignoring the necessity to recultivate damaged vegetational cover and soils cause irreparable harm to the environment.

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