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Impact of waste on soil cover in Chişinău urban ecosystem

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Abstract. Exceedances of maximum admissible concentrations (MAC) for Br, Cr, Cl, Pb, Zn, Sr-90, Cs-137, and Zn found in the chernozemoid from the valley of River Bâc tributary are more substantial in comparison with the ones on the superior terrace. This indicates the fact that the flux of pollutants migrates with rainwater from the upper terraces of the slope and gets into the tributary of the River Bâc. The study of the structural composition on the middle terrace (carbonate chernozem, moderately eroded) attests dry sieving indicators of 29.5% and wet sieving of 42.8%, which denotes an unsatisfactory state. Due to the natural vegetal cover, the indicators of the chernozemoid soil in the valley are established as good and high for the valuable agronomic aggregates at dry sieving (81.8%) and at wet sieving (84.4%). The samples of the soil from the Biological Wastewater Treatment Plant (BTP) revealed exceedances of the maximum admissible concentrations of harmful elements, which can be explained by the accumulation of large quantities of sludge at BTP that contain essential quantities of toxic substances which are accumulated in the soil from the sludge.
Key Words: soil, pollution, heavy metal, urban ecosystem.

Introduction. The economic activity within the limits of the city territory leads to significant changes, often irreversible ones, of the environment and namely: the relief and the hydrographical network are subject to changes; the vegetation cover is replaced by man-made artificial phytocenosis; a specifically urban microclimate is formed; the large share of paved surfaces and of those under construction substantially modify the soil cover. All these contribute to the formation of a specifically urban ensemble of scenery (urban landscape) containing respective components of the environment which as a result of multiple physical, physico-chemical and chemical processes favours the formation of specific soils – urbanozems. These soils (urbanozems) are defined as urban soils with a manmade layer whose depth exceeds 50 cm and which is obtained by mixing soil with various building materials, household waste or soil pollution with natural and/or anthropogenic substances not related to the soil. In general, urban soil is any soil transformed in the city environment. This term implies the soil under anthropogenic “pressure” and formed as consequence of human activity (Dobrovolsky et al 1997).

As a result of the research carried out in the urban area of Chişinău, there were established the following specific features of urban soils that clearly distinguish them from natural soils:

- they are formed on embankment materials, rain or mixed reshuffles;
- there is presence of construction waste inclusions and solid household waste in the superjacent horizons;
- the acid-base balance is displaced towards the alkaline environment;
- increased pollution with heavy metals and radioactive isotopes;
- changes in hydro-physical properties and physico-mechanical properties of soils (low adsorption capacity of water, insignificant content of hydrostatic aggregates, high degree of compaction, increased petrification, increased apparent density);
- increased profile depth due to anthropogenic sediments.

Urban soil differs significantly from the soils in natural areas by its morphogenetic characteristics and physicochemical properties. They are characterized by disruption of the natural succession of horizons, lack of natural biogeocenosis, essential change of pH in the alkaline part, enrichment with basic elements of plant nutrition, over-compaction, as well as change of soil hydrothermal regimes.

As major limiting factors for proper soil fertility serve: high pH, over-compaction, pollution with heavy metals and other toxic substances. Over-compaction and pollution of the surface layer cause specific development of plant root system. The roots begin to develop mostly not at the top of the profile, as in natural conditions, but at a certain depth of 5-10 cm. Fedoretc & Medvedeva (2009) affirm the fact that pedogenesis processes such as humus accumulation, redistribution of mineral components, etc. are identified in urban soils, which undoubtedly demonstrates that urban soils can be considered soils in the literal sense of the term.

Previously Krupenikov (1967) and Ursu (2006) have conducted complex research on agricultural and natural land cover in the Republic of Moldova, but no such research has been conducted on urban soils until present, although the impact of waste on these soils is known (Kuharuk et al 2011).

What regards the Chişinău urban ecosystem, there have been studied a number of areas, where the human impact on phytocenosis has been established, such as: residential areas, natural recreation areas, agricultural land, land of waste landfills, industrial sites, etc. (Bulimaga 2009). The soil cover in the municipality consists of a wide range of soil varieties bearing the imprint of human impact: from arable soils with different degree of soil erosion to specific soils - urbanozems. But no study on the impact of waste on the soil in an urban ecosystem has been conducted so far.

The purpose of the research is to study the impact of waste on the soil cover in the urban areas of Chişinău characterized by the accumulation of heavy metals and other toxic elements in the soil and plants, and by the change of key indicators such as structural aggregate content with agronomic value and the content of humus.

Material and Method. As pedological research methods in the field and laboratory analysis, used to determine the physical, chemical and physico-chemical properties of soils, serve those standardized in the Republic of Moldova and at international level (Table 1) (Arinushkina 1962; Dospekhov 1979; Rowell 1998).

To meet the objectives in the sectors under investigation, field pedological research has been carried out and soil and vegetation samples have been collected. The analyses of soil samples were performed within the Institute of Ecology and Geography and the Institute of Pedology, Agrochemistry and Soil Protection “Nicolae Dimo”. The overall content of chemical elements was performed in the Laboratory of the International University “A. D. Sakharov” from Minsk, Belarus. Table 1 presents the methods of analysis used in the present investigation.

Table 1

Methods of laboratory analysis of soil samples

No	*Name of analysis*	*Methods of analysis*
1	Granulometric composition (texture)	Pipette method, soil preparation after Kacinski, Na pyrophosphate solution
2	Hygroscopicity	By drying in an oven at 105^{o}C and weighing on analytical balance
3	Humus	Method Tiurin
4	Carbonates	Gas-volumetric method
5	Acidity (pH)	Potentiometric method
6	Exchangeable cations	Melih method
7	Analysis of aqueous extract	The aqueous extract 1:5

Results and Discussion. The research on the impact of waste on the soil cover was conducted on the territory of the Biological Wastewater Treatment Plant (BTP) and in the Rascani sector of the city Chişinău.

The features of Rascani sector terrain. The investigated terrain is located in the Public Park adjacent to Florilor Street close to the College "Svetoci". The studied territory is, from the geochemical point of view, a transit and accumulation landscape - a valley in whose thalweg a stream without name flows into the river Bic (Figure 1). The land is wooded, but surface and depth erosion processes are developed: in some places the slope is affected by gullies and ravines. There are unauthorized landfills on the slope. The location of profiles, which is shown in the Figure 1, was performed on valley terraces and meadows. On slopes and terraces, there are delimited carbonate chernozems with different degrees of erosion; in the meadow, there are typical chernozemoid soils.

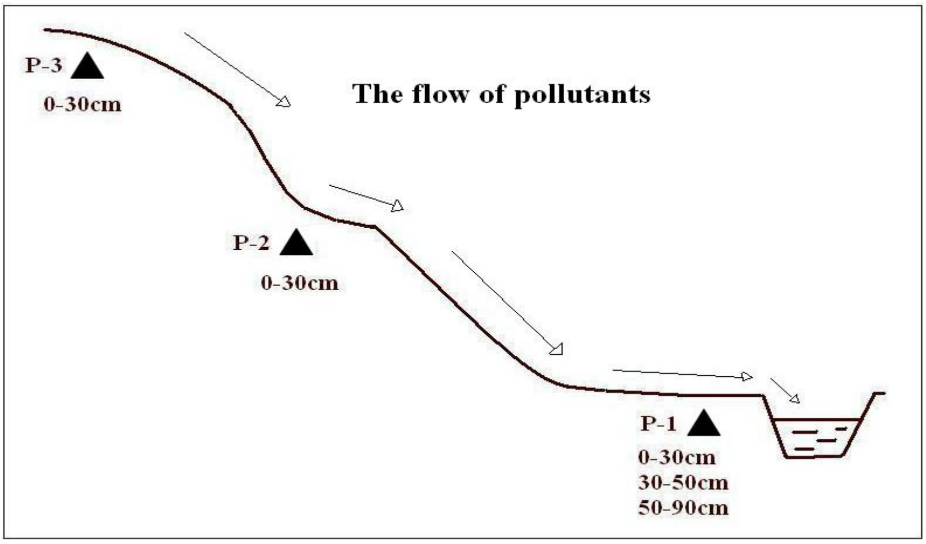

Figure 1. The location of soil profiles exceeding the MAC and the flux of pollutants in the Rascani sector are presented for Br, Cr, Pb, Zn, Sr-90 and Cs-137 (Florilor Street, Chişinău).

The results shown in Table 2 were obtained from the comparative analysis of the structural composition of the studied soils.

Table 2

The physical properties of the soils in the Public Park in the Rascani sector of the city Chişinău, Florilor street

Soil	*Genetic horizons and depth (cm)*	*Apparent density (g/cm³)*	*Aggregate content (%)/diameter (mm)*		
			>10	*Σ10-0,25*	*<0,25*
Moderately eroded calcareous chernozem, terrace middle	0-20	1.58	65.5/0	29.5*/42.8	5.0/57.2
	20-40	1.38	48.9/0	46.5/52.2	4.6/47.8
Cernoziomoid soil, meadow	Ah1 0-20	1.25	12.8/2.2	81.8/84.8	5.4/13.0
	AB 20-40	1.45	38.9/0.6	54.4/74.6	6.7/24.8

*) in the numerator – sifting dry, in the denominator – wet sieve.

The comparative analysis of the obtained data according to Ganzhara et al (2002) (Table 3) showed the following:

- the common moderately eroded carbonate chernozem on the middle terrace displays, in the surface horizon (0-20 cm), dry sieving indicators (29.5%) and wet sieving (42.8%), which attests the unsatisfactory state of structural composition. In the underlying horizon (20-40 cm), these indicators are more favourable, of 46.5 and 52.2% respectively;

- the chernozemoid soil of the meadow displays very good indicators and very large aggregates with agronomical value at dry sieving (81.8%) and wet sieving (84.8%) in the horizon (0-20 cm). The AB horizon (20-40 cm) shows medium and very large indicators, 54.4 and 74.6 respectively. Considering the overall structural composition of the given soil, we can reveal a high share of the fraction with agronomical value from dry sieving and also a very good hydro-stability, which is explained by the well-developed natural vegetal cover.

Table 3

Value classes of structure quality depending on aggregate content 0.25-10 mm with agronomic value, % (Ganzhara et al (2002)

Dry sieve	*Wet sieving, hydro-structural stability*
> 80 – very good	> 70 – huge
80-60 – good	70–55 – good
60-40 – middle	55-40 – middle
40-20 – unsatisfactory	40-20 – small
< 20 – very unsatisfactory	< 20 – very small

The overall analysis of the set of determined chemical elements highlighted exceeded MAC in Br, Cr, Cl, Pb, Zn, Sr-90 and Cs-137. Including, the excess in Zn is by 40 times, and in Sr-90 by 60 times (Table 4). The highest concentrations of toxic elements that essentially exceed the MAC were detected in the soil chernozemoid from the valley of the river Bâc tributary. This points out to the fact that the flux of pollutants washed with rain water from the wastes migrates from the upper terraces of the valley and gets directly into the stream of the river Bic (Figure 1).

Table 4

Content of chemical elements in soils investigated public park (Florilor Street, Chişinău)

Profile no. soil and sampling depth	*Content of chemical elements (mg kg^{-1})*						*The contents of humus, %*	*The contents of the particles smaller than 0.01mm, %*
	Br	*Cr*	*Pb*	*Zn*	*Sr-90*	*Cs-137*		
MAC	*10*	*90*	*32*	*55*	*400*	*0.3-26*		
Profile 1								
0-30 cm	**18.40**	**161.61**	**57.75**	**2809.99**	**26642.00**	2.06	3.4	57.2
30-50 cm	**15.94**	**110.39**	**97.14**	**80.27**	210.75	**78.50**	3.3	56.8
50-90 cm	**12.49**	**141.73**	**205.79**	**138.37**	194.57	**70.92**	2.9	59.5
Profile 2								
0-30 cm	**13.50**	**146.02**	**75.33**	**73.86**	60.46	**28.15**	1.6	49.6
Profile 3								
0-30 cm	**16.94**	**157.63**	**35.83**	**60.78**	75.38	4.59	1.9	52.1

With bold characters are indicated concentrations exceeding MAC (maximum allowable concentration).

The Biological Wastewater Treatment Plant (BTP) from the city Chişinău. The investigated land is located on the BTP territory and is an arable plain of the river Bâc valley. The investigated soil is a loam-sandy valley chernozemoid. This soil was improved by intake of sludge generated at BTP. The study of the set of chemical elements determined in the investigated profile revealed exceedances of MAC (Table 5): in As by 3-7 times in the 0-60 cm horizon, in Bi by 56 times in the 43-60 cm horizon, in Cl by 296-77 times in the 32-60 cm horizon, Cr excesses of MAC in the horizon 10-32 cm, Sb exceeds by 2 times in the horizon 32-60 cm, Se exceeds for the entire horizon of 0-60 cm. In the vegetal samples of cabbage grown in places of incorporation into the soil of the sludge from BTP, there were detected MAC exceeding in Br by 5-15 times, in Cl by 16-25 times and in Se by 2 times (Table 6), which points to the process of absorbing harmful elements from the soil by plants. This confirms the need for taking strict control measures on the content of chemical elements of soils to be used as fertilizers from sewage sludge generated at BTPs.

Table 5

Content of chemical elements in soils investigated within BTP
(Ciocana residence sector, Chişinău)

Profile no. soil and sampling depth	*Content of chemical elements (mg kg^{-1})*							*The contents of humus, %*	*The contents of the particles smaller than 0.01mm, %*
	As	*Bi*	*Cl*	*Cr*	*Cs-137*	*Sb*	*Se*		
MAC	*2*	*0.1-1.0*	*10*	*100*	*0.3-26*	*4.5*	*0.01-0.5*		
Profile 6									
0-10 cm	**10.14**	0.46	0	85.42	20.92	**6.23**	**1.16**	2.7	57.5
10-32 cm	**14.30**	0.57	0	**114.25**	**28.45**	1.51	**1.30**	2.6	57.2
32-43 cm	**7.32**	1.57	**2960.89**	38.44	**42.62**	**9.87**	**1.38**	1.5	56.8
43-60 cm	**10.32**	**56.40**	**774.12**	25.77	**29.36**	**8.68**	**0.98**	0.9	59.5

With bold characters are indicated concentrations exceeding MAC (maximum allowable concentration).

Table 6

Content of chemical elements in plant samples (cabbage) investigated
within BTP and com. Mereni (Ciocana resid. sect, Chişinău)

Content of chemical elements (mg kg^{-1})				
Element →		*Br*	*Cl*	*Se*
MAC →		*10*	*100*	*0.01-0.5*
BTP	core	**52.99**	**1617.53**	**0.55**
	leaf	**152.87**	**2532.83**	**1.05**
Mereni	core	9.98	**912.04**	0.35
	leaf	**102.44**	**1221.61**	0.21

With bold characters are indicated concentrations exceeding MAC (maximum allowable concentration).

In conclusion, we would like to mention that wastes cause soil pollution with various heavy metals (Cr, Pb, Zn, Sb, Se, Sr-90, Cs-137) and non-metals (Cl, Br, etc.) and the use of sludge as fertilizer in large quantities causes the pollution of crops with different elements.

Conclusions. It was established that pedogenesis processes are identified in urban soils, which confirms that these soils can be considered soils in the meaning of this notion as applied in the soil science.

In Rascani sector of the city Chişinău, MAC exceedings for Br, Cr, Cl, Pb, Zn, Sr-90 and Cs-137 were found. The maximal exceedings in Zn is by 51 times, in Sr-90 by 66 times. Concentrations of harmful elements that substantially exceed the MAC were also found in the chernozemoid from the valley of river Bâc tributary. This indicates the fact that the flux of pollutants migrates with the rainwater from the upper terraces of the slope and gets into the stream of the river Bâc.

MAC exceedings were also found in soil samples from the territory of the BTP; in As by 3-7 times in the 0-60 cm horizon, in Bi by 56 times in the 43-60 cm horizon, in Cl by 296-77 times in the 32-60 cm horizon, Cr exceeded 1 MAC in the 10-32 cm horizon, Sb exceeds by 2 times in the horizon 32-60 cm, Se exceeds MAC in the entire horizon of 0-60 cm, which is explained by the accumulation of these elements in the soil sludge from BTP.

Cabbage plant samples grown on land fertilized with sludge from BTP displayed MAC exceedings in Br by 5-15 times, in Cl by 16-25 times and in Se by 2 times, which points to the fact that the plants absorb the harmful elements. This confirms the need for strict control measures of chemical elements content in the event of cultivating these lands with agricultural crops.

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