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EFFECT OF IRRIGATION ON CONTENT AND DISTRIBUTION OF HEAVY METALS IN ALLUVIAL SOILS OF THE LOWER DNIESTER

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Abstract

In the samples of alluvial meadow soils (irrigated and non-irrigated) in the Lower Dniester River were determinate the Cu, Zn, Co, Ni, Pb, Cd, Cr, Mn contents and their vertical distribution. The results indicated that irrigation has led to obvious accumulation of heavy metals in the alluvial soil: in the humiferous, gleyic and carbonatic horizons in different concentration. The non-irrigated fallow alluvial soils differ from the arable irrigated soils by a higher content of elements in profile, especially in the humiferous horizon, which is related to the specific conditions of their genesis, geomorphological characteristics, the hydrological regime etc. Thus, in the alluvial soils, approximately 50% of the total reserves of mobile forms of microelements are concentrated in the upper part of the soil profile (0-38 cm).

Key words: *alluvial soils, irrigation, heavy metals, Lower Dniester meadow.*

INTRODUCTION

Under conditions of soil cover degradation and climate change, food security in the Republic of Moldova can be ensured by expanding the surfaces with irrigated soils. The most suitable areas for development of irrigated agriculture are the lands in the floodplains with alluvial soils. On the territory of the Republic of Moldova, within the agricultural land the alluvial soils occupy the area of about 120 thousand hectares and are the main object for development of irrigated agriculture, because they can be easily provided with irrigation water from the neighboring rivers (Kuharuk et al., 2017; Leah, 2014). In this case, a major interest for the extension of irrigated agriculture is represented by the alluvial soils of the Lower Dniester meadow.
The research purpose was to determine the geochemical regularity of migration and accumulation of heavy metals (Cr, Mn, Co, Ni, Cu, Zn, Cd, Pb) in the irrigated and non-irrigated alluvial soils of the Lower Dniester river of Moldova.
The research objectives:
1) to determine the total content and mobile forms of heavy metals in the irrigated (arable) and non-irrigated (fallow) alluvial soils of the Lower Dniester river meadow;
2) to determine the regularity regarding the accumulation and vertical distribution of the elements in the profiles of alluvial soil under the irrigation impact.

MATERIALS AND METHODS

Samples of irrigated and non-irrigated typical alluvial soils from the Lower Dniester meadow were collected for determination of total content and mobile forms of Cr, Mn, Co, Ni, Cu, Zn, Cd, Pb. To irrigate the alluvial soils, the water from the Dniester River was used.
For carrying out the works provided by project the field pedological research and laboratory geochemical analyzes the classical methods were used. The determination of heavy metals was performed by atomic absorption spectrophotometry method.

RESULTS AND DISCUSSIONS

Soils of meadow landscapes are an integral component of very complex and productive ecosystems. The complexity of soil genesis process, its high dynamism, the specifics of water supply, the significant influence of intrazonal factors (alluvial and flood processes) are the main reasons for the poor knowledge of these ecosystems from geochemical positions (Leah, 2014; 2018a). This is manifested in the insufficiency of materials on the biological, chemical and physico-chemical processes in meadow alluvial soils, in the small amount of data regarding content and distribution of trace elements. Therefore, environmentally ways of rational use and protection of alluvial soils are poorly developed. The effect of the anthropogenic factor (agricultural use and irrigation) on them is steadily increasing due to the fact that these soils are the basis of natural fodder lands and vegetable growing (Сулин, 1980).

The typical alluvial soils of the lower Dniester meadow are characterized by a clayey or clayey-loamy profile, weakly gleyed at a depth of 80 cm, weakly carbonated, moderate humiferous, with differentiated profile in genetic horizons, weakly alkaline reaction (Leah et al., 2018; Zaharova et al., 2018).

The availability of heavy metals and other elements in alluvial meadow soils largely depends on the composition of the underlying alluvium and the specific conditions of soil formation (Букин, 2012). In the alluvial soils, the distribution of total and mobile forms of trace elements along the profile is not the same, due to the peculiarities of the composition and properties of soils, and is the result of the influence of soil genesis - formation processes. There is still no consensus on the patterns of distribution of trace elements along the profile of alluvial soils (Leah, 2018c).

The seasonal dynamics of the elements of the Dniester River is weakly expressed, but the concentration of Zn, Al, Ti, Cu is greater in the spring, Fe and Mo - in the autumn, Mn and Ni - in the winter, which is associated with the hydrological characteristics of the river.

The Maximum Allowable Limit in the Dniester irrigation water, in µg/ml, is: for hazard class I: Pb - 30, Zn - 1000; for hazard class II: Co - 1000, Ni - 100, Cu - 1000, Cr - 500, Mn - 10000 (Перельман, 1975).

Content, distribution and availability of heavy metals to plants is important when assessing the environmental quality of area for purposes in vegetable growing or other field crops.

Areas in which there is a sharp decrease in the intensity of migration of elements and, therefore, their concentration are called geochemical barriers. The systematic of barriers are based on those processes that lead to the concentration of elements. In the conditions of Moldova, carbonatic, alkaline, humiferous, gleyic, etc. are of the greatest importance for environment.

In the non-irrigated (fallow) soils, there is an accumulation of total Cd, Pb, Co, Ni and Cr in the gleyic horizon (95-115 cm), the Cu and Zn in the humiferous horizon (0-38 cm).

In the irrigated alluvial soil the content of heavy metals (except Cr) is much higher (0.5-2.0 times), than in non-irrigated soil (Figures 1-8).

This is explained by the fact that the studied elements are classified as moderate, but Cr - weakly available (Кирилюк, 2006).

The highest values were attested for Cu, Zn, Mn, Cd and Pb in the humiferous layers (0-57 cm) of the irrigated soils, which is associated with their biogenic accumulation. However, the nature of the formation of the composition, including trace elements, of these soils has its own characteristics.

A characteristic feature of the heavy metals distribution in the profiles of irrigation alluvial soils is the relatively high content of both the total amount and mobile forms of microelements (Cu, Zn, Mn, Cd and Pb) in the upper humus horizon, which is associated with organic matter formation.

The significant accumulation of Cd, Pb, Co and Ni content was detected at the geochemical barrier passing from the gleyic horizon to the carbonatic horizon (95-115 cm).

The accumulation of Mn was observed in the carbonatic parental rock at the depth of 160 - 200 cm; the higher concentration than in the humiferous layer 0-20 cm.

The middle layers (57-115 cm) are gleyic, that unless drained, is saturated with groundwater for long or short period. In these periods the layer develop a characteristic gleyic colour pattern is essentially made up of green-yellowish colours. In these horizons of irrigated soils more Cd, Pb, Mn and Zn accumulated. In non-irrigated analogues - Co, Ni, Cd and Pb was accumulated (Figures 1-8).

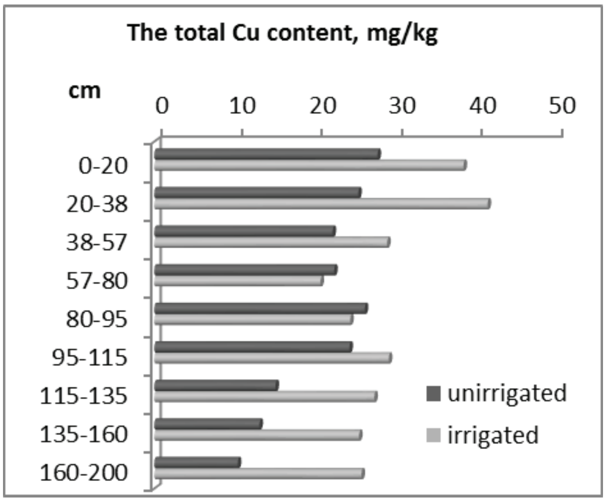

Figure 1. The total content of Cu in the irrigated and non-irrigated alluvial soils

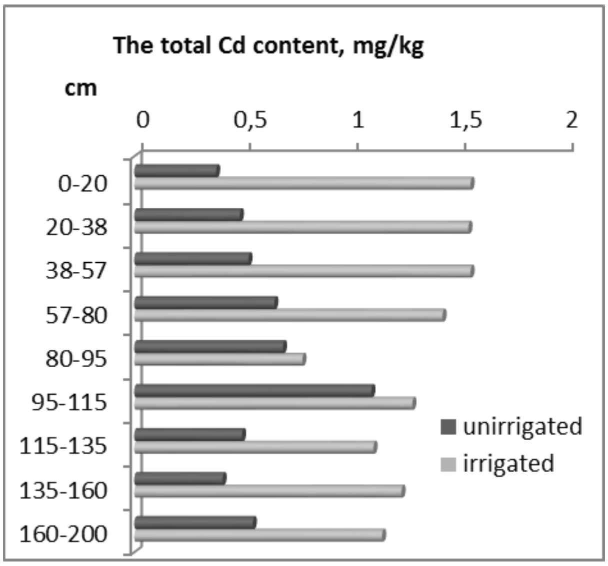

Figure 2. The total content of Cd in the irrigated and non-irrigated alluvial soils

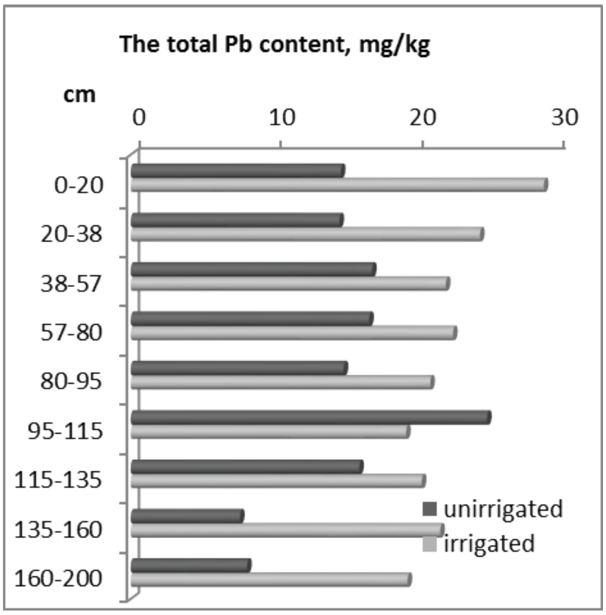

Figure 3. The total content of Pb in the irrigated and non-irrigated alluvial soils

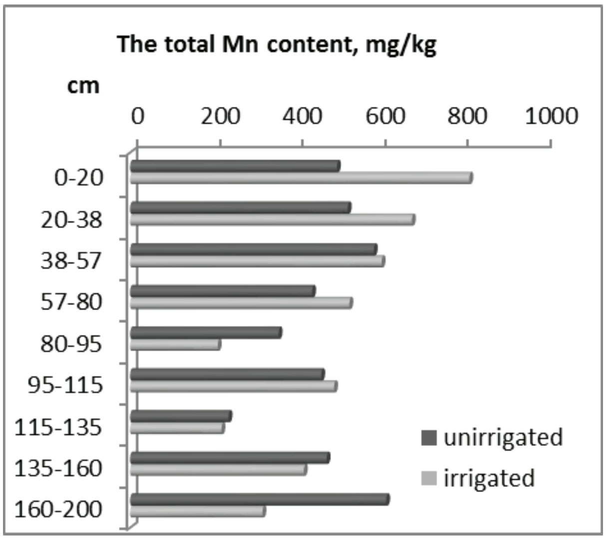

Figure 4. The total content of Mn in the irrigated and non-irrigated alluvial soils

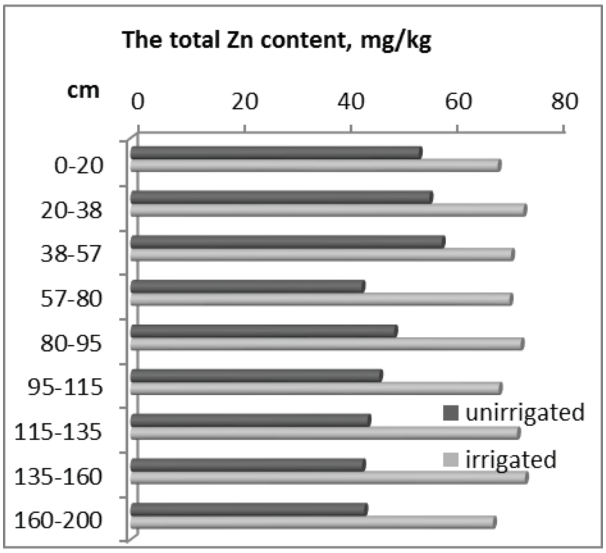

Figure 5. The total content of Zn in the irrigated and non-irrigated alluvial soils

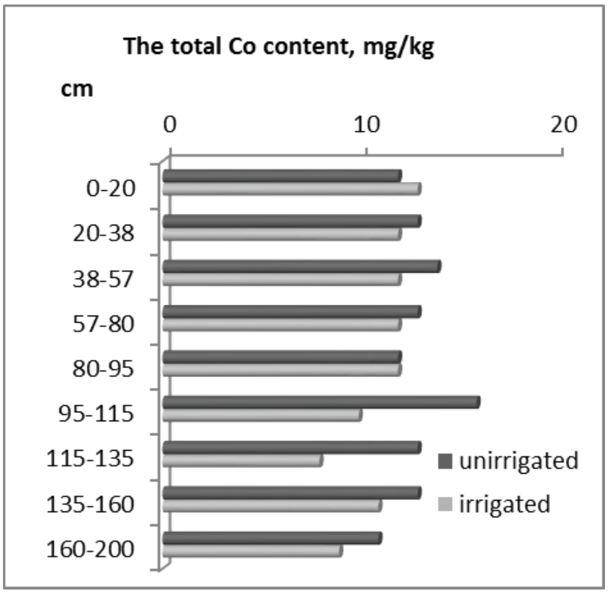

Figure 6. The total content of Co in the irrigated and non-irrigated alluvial soils

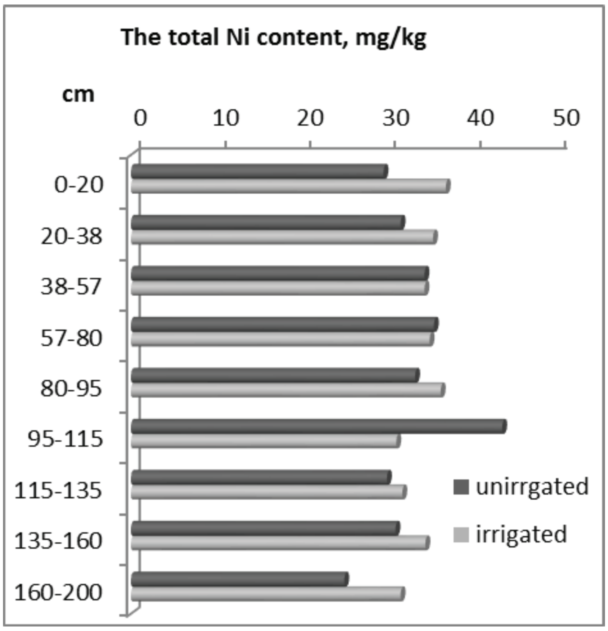

Figure 7. The total content of Ni in the irrigated and non-irrigated alluvial soils

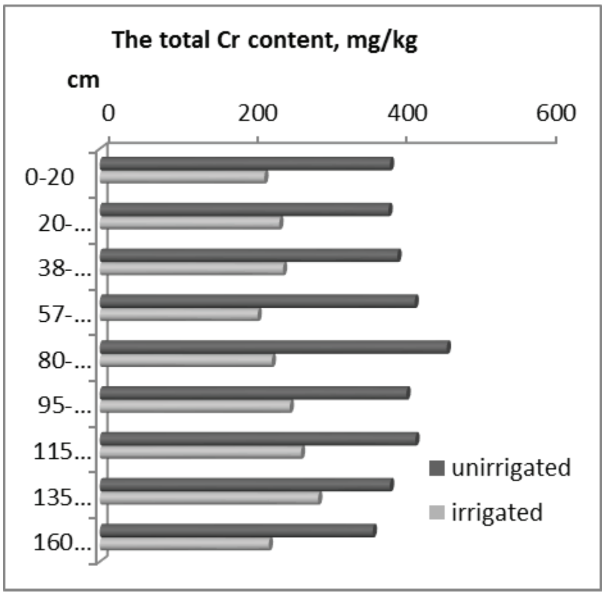

Figure 8. The total content of Cr in the irrigated and non-irrigated alluvial soils

The content of zinc, cobalt, nickel and chromium in natural soils (non-irrigated) is close to the amount in the parent rock.

A uniform vertical distribution in the profile of irrigated soil is shown for Cd, Zn, Ni; in the non-irrigated - Co, Ni, Zn. Part of heavy metals (Cu, Cd, Pb, Ni) is retained in the carbonate horizons (parental rock) of irrigated soils, in the carbonatic layers of non-irrigated soils - Mn.

The entry of trace elements from soil-groundwater destroyed the purely biogenic distribution of trace elements. Depending on the degree of hydrogenic accumulation and the level of groundwater, the most diverse distribution of trace elements is possible: the coincidence of the nutrient distribution, the prevalence of one or another form of accumulation at different depths in the soil. In the soil horizons of the evaporation of capillary currents from groundwater, microelements fall out and accumulate (Мартынов 2014; 2018; Микроэлементный, 2019).

On the other hand, despite the structure of the profile of alluvial soils, a general regularity in the distribution of trace elements is observed in them, expressed in a decrease in their amount from top to bottom with three maxima - in humus accumulative horizon (Cr, Mn, Cu, Zn), in the gleyic horizon (Mn, Cd, Pb, Co, Ni) and carbonatic horizons (Cu, Mn). Here, there is also the influence of the illuvial process, amplified by leaching water regime of these soils, other conditions.

One of the essential features of the distribution of trace elements along the profile of the soils under consideration is the relatively high concentration of most mobile forms of elements in the lower horizons, which is associated with their washing out of the upper horizons of the profile with irrigation water and a high content of organic matter involved in fixing the elements. The content of Cd, Pb, Cu, Zn, Ni is higher in the deep horizons of the profile of irrigation soil compared to fallow soil, which is associated with specific conditions of soil formation.

In general, the mobility of trace elements in individual genetic horizons of the profile of irrigated alluvial soils is somewhat higher compared to natural soil, which is associated with a greater supply of their organic substances and the ability of trace elements to migrate along the soil profile as part of organo-mineral complexes. However, unlike natural non-irrigated soils, the mobility of trace elements along the profile of alluvial irrigated soils varies unevenly, which is also due to the layered profile of these soils and significant participation of alluvial processes in their formation (Tables 1 and 2).

According to their accumulate ability in the genetic horizons of alluvial soils, the total forms of trace elements are arranged in the following order: Cd> Pb> Mn> Zn> Cu> Ni> Co> Cr, and mobile ones - Cd> Co> Pb> Mn> Cu> Zn> Ni> Cr.

Table 1. Content of heavy metals mobile forms (% of total content) in non-irrigated alluvial soils (ammonium acetate buffer solution, pH 4.8)

Horizon	Depth, cm	Cu	Zn	Co	Ni	Cd	Pb	Cr	Mn
Ahț	0-18	3.5	4.1	11.3	7.1	50	15.5	1.4	8.2
Ah	18-40	0.8	3.7	5.1	5.1	80	21.6	0.9	8.5
AB	40-62	0.5	2.9	7.4	4.3	83	11.4	0.6	6.3
Bg	62-80	2.7	3.1	4.8	4.1	40	7.6	0.2	5.2
Bhg1	80-100	1.3	4.4	4.7	6.4	48	10.9	0.1	5.5
Bhg2	100-112	1.6	5.5	2.5	2.8	30	9.6	0.3	6.4
Bhg3	112-130	5.3	4.8	6.4	4.4	64	16.7	0.5	5.5
G1k	130-150	6.3	5.2	5.6	1.1	49	16.6	0.4	5.0
G2k	150-175	6.5	7.3	4.4	3.2	53	13.6	0.5	7.0
G3k	175-200	5.7	2.3	3.8	5.0	49	13.1	0.5	7.5
Content limits of heavy metals mobile forms for R. Moldova, mg/kg	0-30	0.1-60	0.1-1.5	0.1-4.7	0.1-1.5	0.01-0.30	0.01-0.60	0.01-1.90	0.4-195

Table 2. Content of heavy metals mobile forms (% of total content) in irrigated alluvial soils (ammonium acetate buffer solution, pH 4.8)

Horizon	Depth, cm	Cu	Zn	Co	Ni	Cd	Pb	Cr	Mn
Ahp1	0-20	1.6	3.4	5.8	4.3	20.5	8.4	0.2	5.8
Ahp2	20-38	3.0	2.0	4.8	4.6	19.4	9.6	0.4	6.1
Ah	38-57	3.1	2.2	2.4	4.9	19.2	11.0	0.5	6.1
ABhg1	57-80	5,5	1.3	9.9	6.7	15.4	5.2	0.7	4.0
ABhg2	80-95	2.3	2.3	3.8	2.2	21.9	6.0	0.7	3.9
ABhg3	95-115	0.9	2.1	20.1	1.7	22.0	7.3	0.4	3.9
G1k	115-135	3.7	1.7	11.4	1.2	27.9	17.2	0.3	3.7
G2k	135-160	1.1	1.4	13.4	1.7	10.5	14.8	0.2	4.6
G3k	180-200	2.4	4.3	11.0	2.6	10.4	10.3	0.2	6.4

These soils are characterized by a relatively high accumulation of total forms of zinc and cadmium, as well as the mobile form of cadmium, cobalt, copper and manganese.

The percentage of mobile forms indicates a high availability of all studied heavy metals in the 0-20 cm layer of follow soil. In the arable irrigated soil the availability of metals is observed in the 20-38 cm for Cu, Zn, Mn.

In the steppe conditions of Moldova, with a lack of humidity, oxidizing conditions, a neutral reaction, and stability of humus, the mobility of metals is limited, and they accumulate in the upper horizons of soils.

Soil heavy metal pollution during irrigation has its own characteristics, the accumulation of pollutants occurs gradually, approaching the Maximum Allowable Limit; there are no visible negative consequences of the accumulation of trace elements; duration of exposure to adverse events and threats to human health (Рабинович and Тома, 1981).

In soils formed under different genesis conditions, there are differences in the biogenic accumulation of individual trace elements. They are more significant for total content in comparison with mobile ones.

The biogenic accumulation of mobile forms of heavy metals in fallow non-irrigated and irrigated soils have a similar nature. Significant differences are observed in the biogenic accumulation of the total content of heavy metals, emphasizing the specificity of the trace element composition of soil profiles of various types.

CONCLUSIONS

The profile distribution characters of different heavy metals in irrigated alluvial soil depend on the soil-genesis condition and irrigation impact. Obtained data showed that soil environment quality of irrigated soil is favorable for vegetable and fodder cultivation. Key area of irrigation should be monitored especially for spatial difference of heavy metals in the alluvial soils. Therefore, the impact of irrigate water on the alluvial soils were identified. Irrigated alluvial soils are not polluted with heavy metals; their concentration in the soil does not exceed the maximum permissible limits for Moldova. The results regarding the content of heavy metals will be used for elaboration of the measures and recommendations on sustainable use, protection and improvement the quality of irrigated alluvial soils with Dniester river water.

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