Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 21, Issue 3, 2021
PRINT ISSN 2284-7995, E-ISSN 2285-3952

THE IMPACT OF IRRIGATION ON THE HEAVY METALS DISTRIBUTION IN SOILS OF THE LOWER DNIEPER UKRAINE

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Abstract

The content of Cu, Zn, Co, Ni, Pb, Cd, Cr, Mn was determined in samples of irrigation water, irrigated and non-irrigated soils of the Lower Dnieper river of Ukraine. The vertical distribution of heavy metals in soils was also determined. The results indicated that irrigation water is not contaminated, and its use cannot lead to excessive accumulation of heavy metals in the soil. The content of heavy metals in the humiferous horizons of both soils is at the background level. The content of mobile forms of Zn, Cd, Ni, Cr, Mn in the humiferous horizon of irrigated soils is slightly higher than in non-irrigated soil. This may be due to a significant change in the soil hydrological regime during irrigation and an increase in the solubility of elements. Most of the elements are characterized by accumulation in the upper humiferous horizon, its content decrease in the first transitional horizon, and transition to the parent rock and in the gleyic horizons.

Key words**:** *heavy metals, distribution, irrigation, Lower Dnieper, soils.*

INTRODUCTION

The largest part of the territory of Ukraine is experiencing a shortage of natural moisture supply and the effective use of the country's agro-resource potential is impossible without its elimination. Recently, due to climate change, an increase in average annual temperatures, strengthening of drought and aridity, changes in precipitation distribution modes, additional risks have arisen and the unpredictability of crop yields has increased.
Global climate changes cause an increase in the role of irrigation in ensuring sustainable plant production and make irrigation an obligatory measure, and for many crops into the decisive element of intensive cultivation technology [11, 13]. At the same time, the environmental safety of irrigation, together with an increase in the volume of food production, irrigation increases environmental risks, especially in regions with a difficult environmental situation. In this contest, the heavy metals (HM) are one of the main indicators of anthropogenic pressure on the natural environment [1, 4, 6, 7]. The study of changes in the content of heavy metals in the components of the irrigated agricultural landscape of the Lower Dnieper River will allow to determine the possibility of their environmentally safe use, ways to increase productivity, to assess the possibility of sustainable soil functioning.
The objectives were: determination the mobile forms content of Cu, Zn, Co, Ni, Pb, Cd, Cr, Mn (HM) in irrigation waters of Dnieper River; in irrigated and non-irrigated soils of the Lower Dnieper meadow; determination the regularity of accumulation and vertical distribution of HM mobile forms in the soil profile deep under irrigation.

MATERIALS AND METHODS

Samples of irrigated and non-irrigated typical soils from the Lower Dnieper, Steppe zone of Ukraine were collected for determination the mobile forms of Cu, Zn, Co, Ni, Pb, Cd, Cr, Mn. Soil samples were selected on the irregular grid with GPS referencing. For carrying out the works provided by project the field pedological research and laboratory geochemical analyses the classical methods were used. Mobile forms of HM in the soils were determined by extraction with ammonium acetate solution at pH 4.8, using the 1:5 - soil : extract ratio. The HM content in water samples were analysed after drying and dissolving the precipitate in 1 M HCl. The determination of heavy metals was performed by atomic absorption spectrophotometry on the SATURN-4 device.

RESULTS AND DISCUSSIONS

Food security of Ukraine largely depends on the availability, condition and efficiency of irrigated land use. The largest area (2.6 million hectares) of irrigated land was occupied in the early of 90s of the last century [12]. After that, the area of irrigated land has significantly decreased for various economic and political reasons. Nowadays in the Ukraine only 500-600 thousand hectares are irrigated. However, the need to ensure the country's food security and adapt to climate change indicates an urgent need to restore, modernize and expand the irrigation. Therefore, in 2019, the Cabinet of Ministries of Ukraine approved the "Strategy for Irrigation and Drainage of Ukraine until 2030" [5].

The soils of the study territory contain a significant amount of nutrients and often have favorable physical and biological properties. Quite fertile soils are formed in the central floodplain of Dnieper, which makes them attractive for irrigation. Non-irrigated soils of the central floodplain of the Lower Dnieper are now considered as promising for the expansion of irrigation, therefore, the study of issues of environmental safety of irrigation in this region is very important. It is known that irrigation affects the direction of soil processes and soil evolution, often leading to the development of soil degradation, which requires the study of changes in soil properties under irrigation impact [2, 9, 12].

Soil contamination with HM is one of the most common types of irrigated soil degradation. These changes, first of all, depend on: the initial state of soils (geochemical background), the irrigation water quality, the water supply volume, the regional level of arable farming.

The study results of the irrigation water quality indicate that irrigation is carried out with water of the 1st class (norms of Ukraine), and not contaminated with heavy metals and are suitable for irrigation [10], which does not cause the contamination danger of soils and plant productions (Table 1).

Table 1. Content of heavy metals in irrigation water, mg/dm^3

Irrigation water		Zn	Cd	Ni	Co	Mn	Pb	Cu	Cr
Dnieper River		0.016	0.002	0.011	0.003	0.018	0.018	0.007	0.002
Steppe, average		0.013	0.005	0.023	0.023	0.022	0.032	0.008	0.009
The quality of irrigation water by heavy metals and microelements content for Ukraine	Class 1 - Suitable	0.50	0.005	0.08	0.02	0.50	0.02	0.08	0.05
	Class 2 - Limited suitability	05-1.0	0.005-0,01	0.08-0.20	0.02-0.05	0.50-1.00	0.02-0.05	0.08-0.20	0.05-0.10

Source: Own determination on the analysis of water samples.

The content of heavy metals in irrigation water is at the background level for Steppe zone of Ukraine. The background level was determined according to the results of long-term observations of the surface water quality during the plant growing season (about 280 water samples were analysed). In the studied region, the soil cover is characterized by significant variegation. In its formation, the diversity of geomorphological and lithological characteristics of the territory is decisive. It determines the lithological profile of soils, the humus accumulation, gleyzation and salinization processes, and determined the differences between the adjacent soils, with an insignificant height difference. The difference in the soils is very clearly manifested in morphological and genetically researches and is reflected in the soil profiles description.

Irrigated soil (Fig. 1a) - chestnut saline on the loess-like loam. In the irrigated soil profile the following horizons are highlighted: 0-28 cm – arable , grey-brown, moist, compacted, lumpy-granular, clear colour transition, smooth transition; 28-37 cm – the first transitional horizon, light brown, fresh, compacted, nutty-lumpy, weak colloidal varnishing, clear colour transition, smooth transition; 37-50 cm - the second transitional horizon, grey-fawn, fresh, compacted, structure less, gradual transition; 50-70 cm - loess-like loam, fawn with dark spots, humus flowing along the root paths, fresh, compacted, structureless, effervescence of 10% HCl from 58 cm, clear color transition; >70 cm - loess-like loam, fawn, fresh, calcareous, loose, bieloglasca - elongated shape, from 70 cm.

Non-irrigated soil (Fig. 1b) - meadow-chestnut weakly solonetzic clayey on gleyic loess-like loams. In the non-irrigated soil profile the following horizons are highlighted: 0-32 cm - arable horizon, grey-whitish, dry, loose, nutty-silty, medium-structured, silica powder, sharp transition on density; 32-72 cm - the first transitional horizon, dark grey, fresh, compacted, lumpy-nutty, weakly structured, the transition is clear in colour, smooth transition; 72-90 cm - second transitional horizon, greyish-brownish-bluish, fresh, rusty spots, compacted, structure less, black iron-manganese nodules, brittle, gradual colour transition; >90 cm - gleyic loess-like loam, light-grey, fresh, compacted, structure less, brown and rusty spots, black iron-manganese nodules, fragile molehills of humus, non-calcareous.,

Fig. 1. Profiles: a) irrigated saline chestnut soil; b) non-irrigated meadow-chestnut weakly solonetzic
Source: Own field survey.

The content of heavy metals mobile forms in the humiferous (arable) horizons of the studied soils is somewhat different (Table 2).

Table 2. Content of heavy metals in the arable horizon of irrigated and non-irrigated soils of the Lower Dnieper, mg/kg

Soil		Zn	Cd	Ni	Co	Mn	Pb	Cu	Cr
Irrigated	Average	1.45	0.018	1.01	0.27	22.69	0.72	0.10	0.47
	min	1.28	0.011	0.77	0.12	18.49	0.70	0.08	0.31
	max	1.77	0.034	1.21	0.42	28.91	0.75	0.43	0.57
Non-irrigated	Average	1.04	0.011	0.73	0.50	5.84	0.87	0.22	0.14
	min	0.47	0.008	0.46	0.17	3.45	0.50	0.14	0.10
	max	1.36	0.021	0.87	0.67	19.97	1.06	0.28	0.49
Background level		1.00	0.10	1.00	0.50	43.00	0.50	0.50	0.10
Maximum allowable concentrations		23.0	-	4.0	5.0	500.0	6.0	3.0	6.0

Source: Own determination of HM in the soil samples.

On average, the content of most elements is at the background level or slightly differs. The content of elements in the soils is significantly lower than the maximum allowable concentrations. The average content of Pb, Cu and Co mobile forms is slightly higher in non-irrigated soil (1.2-2.2 times); Zn, Ni and Cd in irrigated (1.4-2.0 times), that is associated with natural geochemical differences in soils. The average concentrations of mobile forms of Mn and Cr in the arable horizon of irrigated soil are much higher than in non-irrigated soil

Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
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PRINT ISSN 2284-7995, E-ISSN 2285-3952

and the excess is 3.3-3.8 times.

The good quality of the irrigation water allowed to exclude the possibility of a significant supply of these elements from this source. At the same time, the Mn and Cr are elements with variable valence and the content of their mobile forms is largely determined by the conditions of soil moisture, by the development intensity of the recovery processes in them. Most likely, the higher content of these elements is associated with an increase of their solubility during prolonged irrigation process with high water rates.

The limiting values of the mobile forms content of Cd, Co, Mn, Cu, and Cr are characterized by significant variation. For most elements, the amplitude of fluctuations in the content of their mobile forms is in the range of 1.1-3.9 mg/kg. Large fluctuations amplitudes in the content were noted: for Cu in irrigated soil, which may be associated with the use of plant protection products with copper-containing preparations; for Mn and Cr in non-irrigated soil, which we associate with different levels of natural moisture in non-irrigated meadow chestnut soil at the sampling points. Cultivation of crops with intensive technologies significantly increases their yield. Under conditions with a lack of microelements in the soils, their deficiency in plant products, a decrease in standard consumption and effect of "hidden hunger" can occur [3]. Therefore, was evaluated the content of mobile forms of Mn, Zn, Co, Cu in the soils as trace elements necessary for plants growth and development, the formation of a high and high-quality crop yield [14], and the supply of plants with these trace elements.

The mobile forms content of Zn, Co and Cu in the irrigated soil corresponds to a low supply of plants grown in a high agricultural background, Mn - to an average supply. The content of Mn, Zn, Co, Cu in non-irrigated soil corresponds to a low supply of plants. To obtain a high and high-quality crop yield, it is necessary to introduce micro - fertilizers with the obligatory content of Mn, Zn, Co and Cu [3]. The profile distribution of HM mobile forms, as a rule, in similar soils, is characterized by the presence of biological accumulation (humus) and elluvial-illuvial horizons in accordance with the leading soil-forming process [8]. For mobile forms of biogenic elements (Cu, Zn, Co), the following tendencies are noted: an accumulation in the 0-30 cm; a decrease in their concentrations with an increase in the profile depth in the 30-70 cm; an increase in their content in the 70-90 cm layer. The mobile Ni, Cd, Mn are characterized by a relatively uniform distribution along the soil profile with a slightly increase in 30-70 cm layer. The uniform distribution in the soil profile deep is noted for Pb and Cr.

In the irrigated chestnut soil, in the presence of organic matter and high humidity, anaerobic conditions and vigorous activity of microorganisms, conditions arise for increasing the content of mobile forms of most elements.

Additional moisture created conditions for a more uniform distribution of mobile forms of elements along the profile of the irrigated soil.

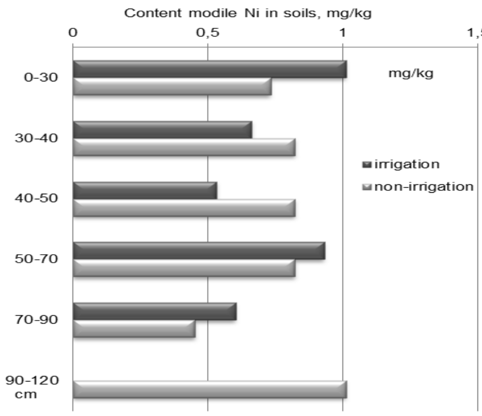

Fig. 2. The content of mobile Ni in the irrigated and non-irrigated soils
Source: Own design of the obtained results.

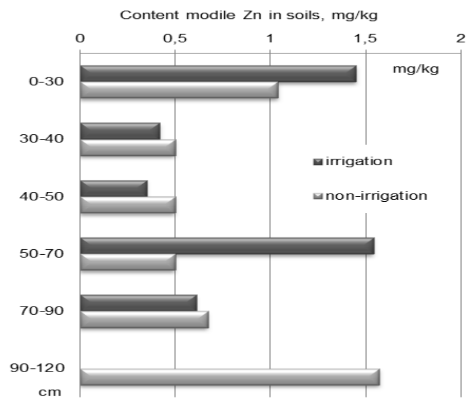

Fig. 3. The content of mobile Zn in the irrigated and non-irrigated soils
Source: Own design of the obtained results.

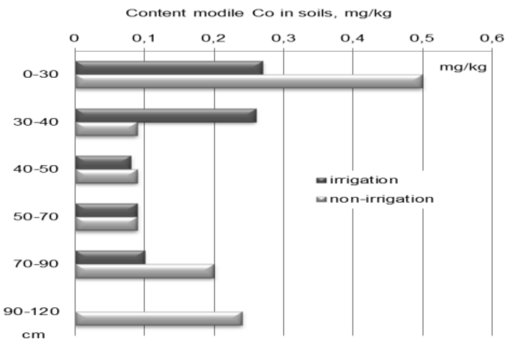

Fig. 4. The content of mobile Co in
the irrigated and non-irrigated soils
Source: Own design of the obtained results.

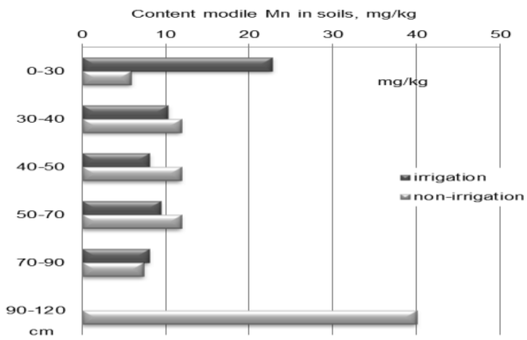

Fig. 5. The content mobile Mn in
the irrigated and non-irrigated soils
Source: Own design of the obtained results.

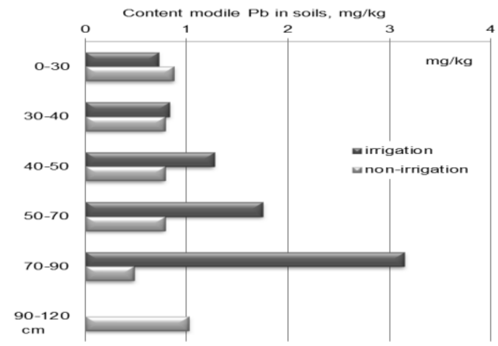

Fig. 6. The content mobile Pb in
the irrigated and non-irrigated soils
Source: Own design of the obtained results.

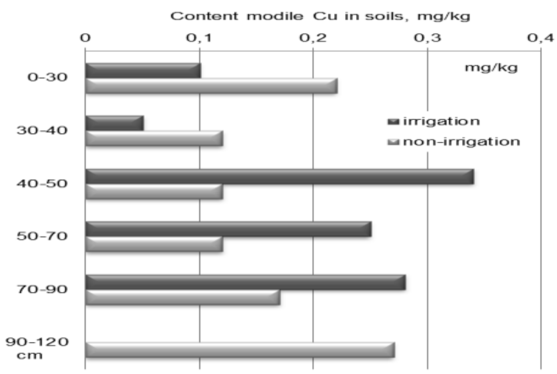

Fig. 7. The content mobile Cu in
the irrigated and non-irrigated soils
Source: Own design of the obtained results.

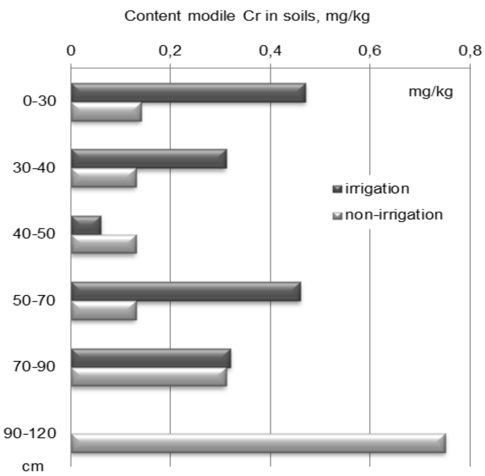

Fig. 8. The content mobile Cr in
the irrigated and non-irrigated soils
Source: Own design of the obtained results.

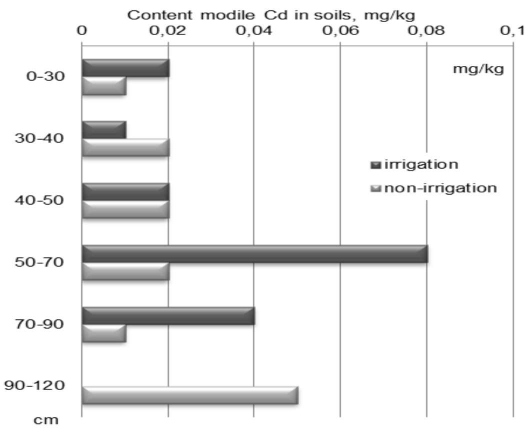

Fig. 9. The content mobile Cd in
the irrigated and non-irrigated soils
Source: Own design of the obtained results.

In non-irrigated soil, the distribution of HM along the profile depended more on the natural geochemical conditions, land use characteristics, intensity of agricultural technologies, and properties of heavy metals.

CONCLUSIONS

The content of Cu, Zn, Co, Ni, Pb, Cd, Cr, Mn in the irrigation water is at the background level. The irrigation water is not contaminated with HM and is suitable for irrigation according to the ecological criteria.The concentrations of Zn, Ni, Cd, Mn, and Cr are higher in the irrigated soil, which can be associated with natural geochemical differences in soils and an increase in the solubility of elements during irrigation. The content of HM mobile forms in soils is at a low level, which makes it necessary to use micronutrient fertilizers. In the irrigated soil, the HM are characterized by accumulation in the humiferous horizon, a decrease in the first transitional horizon, and an increase in the transition to the parental rock. In the non-irrigated soil, accumulation in the humiferous (arable) horizon was noted only for biogenic elements; most of the elements are characterized by a more uniform distribution along the profile; all elements are characterized by maximum concentrations in the parental rock (gleyic horizon). The research results will be used to develop measures and recommendations for sustainable use, protection and improvement the quality of irrigated soils in the Lower Dnieper River for implementation the Strategy for Irrigation and Drainage of Ukraine until 2030.

ACKNOWLEDGMENTS

This research study was carried out within the Project no. 17.80013.5107.09 MD-Ukr: Agrogeochemical regularities of heavy metals migration and accumulation in irrigated alluvial soils in the Dniester and Dnieper meadows (2018-2019).

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