DOI: https://doi.org/10.31073/mivg202401-385
Available at (PDF): https://mivg.iwpim.com.ua/index.php/mivg/article/view/385

UDC 557.4:502.7;631.67:626.8

POST-DESIGN MONITORING OF THE IRRIGATION IMPACT ON THE ENVIRONMENT

A.M. Shevchenko[1], Ph.D. in Agricultural Sciences, R.P. Bozhenko[2]

[1] Institute of Water Problems and Land Reclamation of NAAS, Kyiv, 03022, Ukraine;
https://orcid.org/0000-0002-2637-6538; e-mail: monitoring_protect@ukr.net;
[2] Institute of Water Problems and Land Reclamation of NAAS, Kyiv, 03022, Ukraine;
https://orcid.org/0000-0003-3661-8120; e-mail: ruslana_lp@ukr.net

Abstract. *Approaches to conducting post-design monitoring of the impact of irrigation on soil condition are highlighted on the example of an individual agricultural farm of LLC "Granex-Cherkasy". The results of the implementation of the five-year post-design monitoring program under the conditions of irrigation by groundwater using sprinkling and drip methods proved the need to develop both unified general approaches to the formation of monitoring programs, as well as the mandatory consideration of the peculiarities of its management under different irrigation methods and hydrogeological-ameliorative conditions on the irrigation sites. As a basis for the development of a system of post-design monitoring of the impact of irrigation on the state of environmental components, it is proposed to use approaches to the organization and performance of local (on-site) monitoring of irrigated lands based on the requirements of current regulatory and methodological documents. The observation system, formed on the basis of previous studies, included periodic determination of irrigation water quality indicators in storage ponds or in the places of watering and routine observations of soil conditions at permanent monitoring points (observation points), which are recommended to be taken as coordinate points of the previously conducted testing study (at the stage of the preparation of the environmental impact assessment report). The results of the post-design monitoring proved the ecological admissibility of the impact of irrigation within the farm with groundwater of I and II quality classes (suitable and limitedly suitable according to individual quality indicators). Based on the results of monitoring, it was established that the soils under irrigation did not undergo significant classification changes in terms of deterioration for 5 years. The lack of manifestations of secondary (irrigation) salinization, sodification, and alkalinization of soils under the influence of irrigation indicates the environmental safety of the latter in accordance with the accepted standards for indicators of the degree of development of the specified soil degradation processes.*

Key words: *soil, salinization, irrigation, irrigation water, sodification, post-design monitoring, water quality*

Relevance of research. During the last decade, the process of restoring irrigation on existing irrigation systems in the regions of traditional irrigated agriculture, as well as the construction of the new irrigation networks in almost all the regions of the country, due to the progressive increase in the aridity of the climate and the significant deterioration of the conditions of natural moisture sufficiency for the cultivation of agricultural crops has begun in Ukraine [1−3]. The need to restore and increase the areas of actual irrigation is also emphasized in the "Irrigation and Drainage Strategy in Ukraine for the period until 2030" [4] and the Action Plan for its implementation [5].

The full-scale military aggression of the Russian Federation against Ukraine, the partial occupation of the territories, the destruction of the Kakhovska HPP dam and the emptying of the Kakhovska Reservoir led to a 70 % reduction in the irrigated area (Kherson, Mykolaiv, Zaporizhzhya, and Dnipropetrovsk regions), actually leaving almost 95 % of irrigation systems without a source of water in Kherson, 74 % – in Zaporizhia, and 30 % – in Dnipropetrovsk regions [6]. Such circumstances encourage farmers in other regions to increase the area under vegetables and other crops that were previously grown on the occupied territories or affected by the military invasion of the Russian Federation, and to use irrigation more widely to obtain guaranteed yields.

The experience of irrigation in different natural and climatic zones of Ukraine shows both the increase in the productivity of irrigated lands and certain negative ecological consequences of irrigated agriculture, in particular the development of soil degradation processes (flooding, irrigation erosion, secondary salinization and alkalinization of soils, pollution of soils and groundwater etc.) [7−9]. Therefore, obviously, and because of this, land reclamation, in particular, irrigation, on territories with an area of 20 hectares or more along with the construction of reclamation systems and specific facilities of the engineering infrastructure of reclamation systems are classified in the second category of types of planned activities and objects that can have a significant environmental impact and are subject to the environmental impact assessment (EIA) procedure in accordance with the Law of Ukraine "On Environmental Impact Assessment" adopted in 2017 [10].

According to the Article 13 of the aforementioned law, in order to identify any discrepancies and deviations in the predicted levels of impact on the effectiveness of measures to prevent environmental pollution and its reduction, the conclusion of the environmental impact assessment may provide for the implementation of post-design monitoring (PDM) by the business entity. In such a case, the order, terms and requirements for monitoring the impact of such activity on individual components of the environment, in particular on the soil cover, groundwater, etc., must be determined in the conclusion of the EIA of the planned activity related to irrigation. According to the results of the post-design monitoring, if necessary, the business entity and the relevant authorized authorities agree on taking additional measures to prevent, minimize, or eliminate the adverse consequences of the influence of irrigation on the condition of soils, groundwater, etc.

However, there are currently no unified approaches to the organization and implementation of such monitoring, requirements for reporting materials, and the implementation of necessary environmental protection measures. Only recently, the Ministry of Environmental Protection and Natural Resources of Ukraine approved the Methodological Recommendations for post-design monitoring, which contain general recommendations on the structure, content, and drawing up of the post-design monitoring report, on data and evaluation of PDM results [11].

The analysis of the available EIA conclusions confirms that most of them do not contain clear requirements for conducting monitoring, the terms and procedure for its implementation. During the practical implementation of monitoring, there may be problems related to the methodical provision of monitoring works, the composition and periodicity of certain types of observations, evaluation of their results, in particular, the admissibility and ecological safety of changes in soil fertility indicators and other environmental elements caused by irrigation.

In the context of the regulation of the latter and the impact of irrigation, the role of environmental standards established by the Resolution of the Cabinet of Ministers of Ukraine dated September 2, 2020 No. 766 "On the standards of environmentally safe irrigation, drainage, watering, and water disposal management" should be decisive [12]. However, some aforementioned indicators and their norms raise certain doubts and cannot be used for correct assessment of irrigation safety (norms of indicators relating to irrigation water, salinity, and alkalinity of soil, "ameliorative plantation plowing according to the depth of groundwater with mineralization of more than 5 g/dm^3» and "fractional composition of soils by susceptibility to wind erosion" indicators, etc.).

An urgent issue is taking into account the specifics of irrigation methods in monitoring observations. The problem of assessing the ecological and reclamation state of irrigated lands and the irrigation water quality for the Polissia zone needs to be solved.

Solving the vast majority of problematic issues and increasing the effectiveness and role of post-design monitoring of the irrigation systems impact can be ensured by involving in its organization and performance of the specialists with relevant experience in scientific and methodological support and implementation of ecological and remedial monitoring of irrigated lands. It is optimal to involve such specialists at the stage of preparation of the EIA Report.

Analysis of recent research and publications. Ecological and remedial monitoring is an important component of the information provision of control, primarily of the State, of the conditions of irrigated lands to substantiate measures for their rational and ecologically safe use, prevent or minimize soil degradation processes [13]. In Ukraine, irrigated lands monitoring (ILM) is carried out in accordance with the Law of Ukraine "On Land Reclamation", Resolution of the Cabinet of Ministers of Ukraine dated March 30, 1998 No. 391 "On Approval of the Regulation on the State Environmental Monitoring System" as a branch component of state environmental monitoring.

Starting from the second half of the 90s of the last century, the hydrogeological and land reclamation service (expeditions and parties) of the State Water Administration (later State Water Agency) of Ukraine has been providing practical ecological and reclamation monitoring on irrigated lands of Ukraine. However, in the absence of sufficient funding, reduction of irrigation areas, optimization of the structure of organizations subordinate to the State Water Agency (reorganization and, essentially, semi-liquidation of the specialized hydrogeological and melioration service), annexation by the

Russian Federation of the Autonomous Republic of Crimea, partial occupation of Donetsk and Luhansk regions, cancellation of statistical reporting on irrigated lands according to form 1-OVG, in the last 10–15 years, there has been a decrease in the actual areas of reclaimed land under control, the volume of monitoring works, the number of observation networks, as well as a partial decrease in the informativeness of certain obtained results of the ILM [14].

New challenges and threats for the irrigated lands monitoring are associated both with the full-scale armed aggression of the Russian Federation against Ukraine, and with the declared and to some extent semi-spontaneously initiated institutional reform of the organizational structure of water resources management and land reclamation with the need to separate water resources management functions from water infrastructure management functions and provision of services. The transfer of powers related to hydrotechnical reclamation from the State Water Agency to the State Agency of Reclamation and Fisheries and their partial reorganization have led to the fact that, in practice, the implementation of the ILM by water management organizations of the State Water Agency has mostly been suspended.

A similar situation is observed with the publications in the sphere of irrigated lands monitoring, although in previous years sufficient attention was paid to the coverage of certain aspects of scientific and methodological support of the conduct of the sectoral ILM, methods for processing of its data, analysis of the results of assessment of the ecological and reclamation conditions of irrigated lands, etc, both by the scientists and the specialists of water management organizations [7, 15−17].

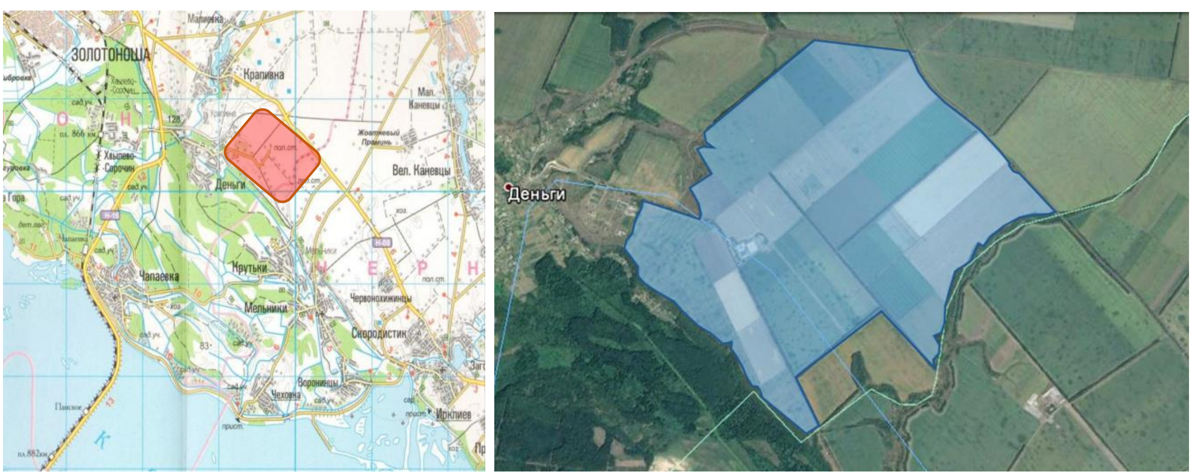
There are almost no freely available reports on post-design monitoring of newly created or reconstructed irrigation systems.

In general, the issue of methodical and information provision of post-design monitoring of the irrigation impact on the components of the environment, in particular on drip irrigation systems, with the use of groundwater for irrigation, primarily in the forest-steppe and Polissia zone, is poorly studied, and there are almost no publications on the results of its conduct [18, 19], which indicates the relevance of research and highlighting of possible changes in the environment associated with the irrigation systems functioning.

The experience of substantiating the post-design monitoring of the irrigation impact on environmental components and its conduct is considered on the example of planning and implementation of activities to ensure the irrigation of lands with underground water by sprinkling and drip methods in the agricultural farm LLC "Granex-Cherkasy", Zolotonosha district, Cherkasy region.

The purpose of the research is to assess changes in the quality of irrigation water and the conditions of irrigated soils on the lands of LLC "Granex-Cherkasy".

Research materials and methods. The post-design monitoring studies of soil conditions and irrigation water quality, which were carried out during 2019−2023, are territorially limited to the land plot, which is in use under the lease rights of LLC "Granex-Cherkasy" and is located northeast of the village Denhy in the administrative boundaries of Denhy starosta okruh (eldership) of the Zolotosha territorial community, Zolotonosha district, Cherkasy region (Fig. 1).



a b

Fig. 1. Overview map (a) and situational scheme (b) of the location of the research plot for post-design monitoring of irrigated lands of LLC "Granex-Cherkasy"

In terms of geomorphology, the territory of the research plot belongs to the orographic region of the Dnipro lowland, represented on the left bank of the Dnipro river by the Middle Dnipro terrace plain. Directly, the land plot of LLC "Granex-Cherkasy", within which monitoring studies of the irrigation influence were carried out, is located within the boundaries of the ancient fourth supraflood (moraine) terrace of the Dnipro River. The surface of the plot is mainly characterized by a flat relief with the presence of micro depressions.

Within the research area, the first from the surface is an aquifer complex in unbounded Lower Neopleistocene alluvial and fluvioglacial sediments and Middle Neopleistocene water-glacial sediments. The most water sufficient part of this complex is an aquifer tied to the alluvial Lower Neopleistocene deposits of the fourth supraflood terrace of the Dnipro River.

The soil cover on the plot is represented mainly by typical zonal black soils, low-humus, light- and medium-loamy, and low-humus black soils in a complex with sweetened light-loamy soils, as well as regraded black soils with slightly and medium-washed and alluvial light-loamy, sod clay, and sodic (deeply leached) medium-loamy soils (in closed depressions-saucers).

Irrigation on the plot began in 2013–2014. Irrigation in LLC "Granex-Cherkasy" is based on the use of Lower Neopleistocene alluvial and fluvioglacial deposits for groundwater. As of 2023, 15 water intake wells are used for agricultural crops irrigation. Water from the wells is supplied to the storage pool, and from it by a container-type pumping station to a hydrant for watering agricultural crops with sprinkler machines. Currently, the farm uses three frontal machines for irrigation: Valley and Otech, as well as sprinklers of the hose drum type. In addition, since 2019, drip irrigation systems have been used on areas from 5.0 to 38.5 hectares.

Various grain, oil, and vegetable crops are grown on the farm's land: wheat, barley, soybeans, millet, rapeseed, potatoes, corn, beets, onions, etc, with unequal water demand and irrigation regime, as well as the requirements for soil environment.

The development of the program (plan) of post-design monitoring (for 5 years) stipulated by the conclusion on environmental impact assessment provided by the Ministry of Natural Resources of Ukraine was based on the requirements of current regulatory and methodological documents on the irrigated lands monitoring organization [13, 20–23]. According to them, monitoring should be carried out through the periodic determination of indicators of the ecological and reclamation conditions of lands based on the results of routine observations at designated monitoring points and planar surveys. Based on the tasks and features of the post-design monitoring of the irrigation impact on soil conditions, the soil-ameliorative indicators and the indicators of irrigation water quality (in the storage basin of underground water or in the watering places) were primarily subject to control. At the same time, the system of local (objective) monitoring of irrigated lands of the farm (existing and prospective) was created on the basis of studies previously carried out in 2018 on the assessment of the quality of groundwater for irrigation and its possible impact on soil conditions, taking the determined indicators as the baseline for further comparisons and changes detection in soil fertility and the ecological and reclamation conditions of lands, as well as the quality of water used for irrigation.

The specific work program, primarily in the part of soil sampling, was formed taking into account the actual use of irrigation in a certain plot, as well as the initial conditions of soil salinity or alkalinity.

In order to provide determination, based on the monitoring studies results, the changes in soil conditions on the plot under the influence of long-term, in particular, periodic, irrigation, the work program included the implementation of a complex of field, laboratory, and analytical studies.

Field work included carrying out an annual (at the end of an irrigation season) field survey of the land with the soil samples collection down to a depth of 100 cm (next to the wells – down to 200 cm) and water sampling. Analyzing samples from soil surface and subsoil, the salt composition and pH, the composition of exchangeable cations, the content of carbonates, humus and nutrients content, soils granulometric composition, and soil density were determined.

For the irrigation water (groundwater) samples the chemical composition, basic cations and anions, dry residue, pH, and individual microcomponents were determined.

The classification of soils by the degree of salinity by the total amount of salts and by the content of toxic salts in the water extract was carried out in accordance with [13, 20], the classification of the soil by the degree of alkalinity, in particular secondary – by [13, 24], the grouping of soils by the degree of acidity and alkalinity, content of humus, mobile forms of nitrogen, phosphorus, potassium, mobile compounds of trace elements and heavy metals, etc, according to [25]. Assessment of water quality according to agronomic criteria was carried out in accordance with the provisions of DSTU 2730:2015 [26].

In the context of regulating the irrigation impact, the standards of environmentally safe irrigation and irrigation management established by the Resolution of the Cabinet of Ministers of Ukraine dated September 2, 2020 No. 766 were taken into account [12].

The data recorded by observations and laboratory analyzes are components of the information base of local monitoring, based on which the directions, nature, and degree of irrigation transformation of the conditions of irrigated soils are estimated taking into account specific factors of influence during the period of monitoring studies conduct.

Research results and their discussion. During monitoring observations, in certain years, irrigation was carried out within different fields depending on the agricultural crops grown on them. The total irrigated area ranged from 132 ha in 2021 to 471 ha in 2022. So, in 2023, irrigation was carried out on fields with potatoes (field 1–11) on an area of 72,2 ha, with soybeans (fields 1–10, 1–15) on a total area of 206,9 ha, winter wheat on an area of 87,8 ha (fields 1–14a and 1–11), and onions on an area of 44,0 ha within the boundaries of a part of the field 1–10 – with frontal sprinklers, as well as on a site with a drip irrigation system installed within the boundaries of the field 1–17 on an area of 5,2 ha with potatoes (Fig. 2). In general, the vast majority of the land was covered by irrigation – 416,1 ha, 410,9 ha of which were sprinkled and 5,2 ha were under drip irrigation.

During the irrigation season of 2021 308 thousand m^3 of irrigation water was supplied. In 2022 this volume was 516,0 thousand m^3. So, in 2023, irrigation on the farm started in June and ended in September. During the irrigation season, 413,324 m^3 of water was poured onto irrigated land, in particular, 172,352 m^3 in June, 144,496 m^3 in July, 66,183 m^3 in August, and 30,293 m^3 in September. In May, due to a significant amount of precipitation, irrigation was not carried out, which led to a generally lower total irrigation rate. Sprinklers of frontal action supplied 400,824 m^3 of water to fields 1–10, 1–11, 1–14a, and 1–15, i.e. the average total irrigation rate was 975 m^3/ha, although it was slightly higher for potatoes. The water supply to the drip irrigation system was 12,500 m^3 for the potato with total irrigation area of 5,2 ha (about 2,400 m^3/ha). In some years, the total irrigation rate for sprinkler irrigation reached 2200–2500 m^3/ha.

The plot is characterized by a deep (over 10 m) groundwater table, which indicates a good ecological and reclamation conditions of the land according to this indicator.

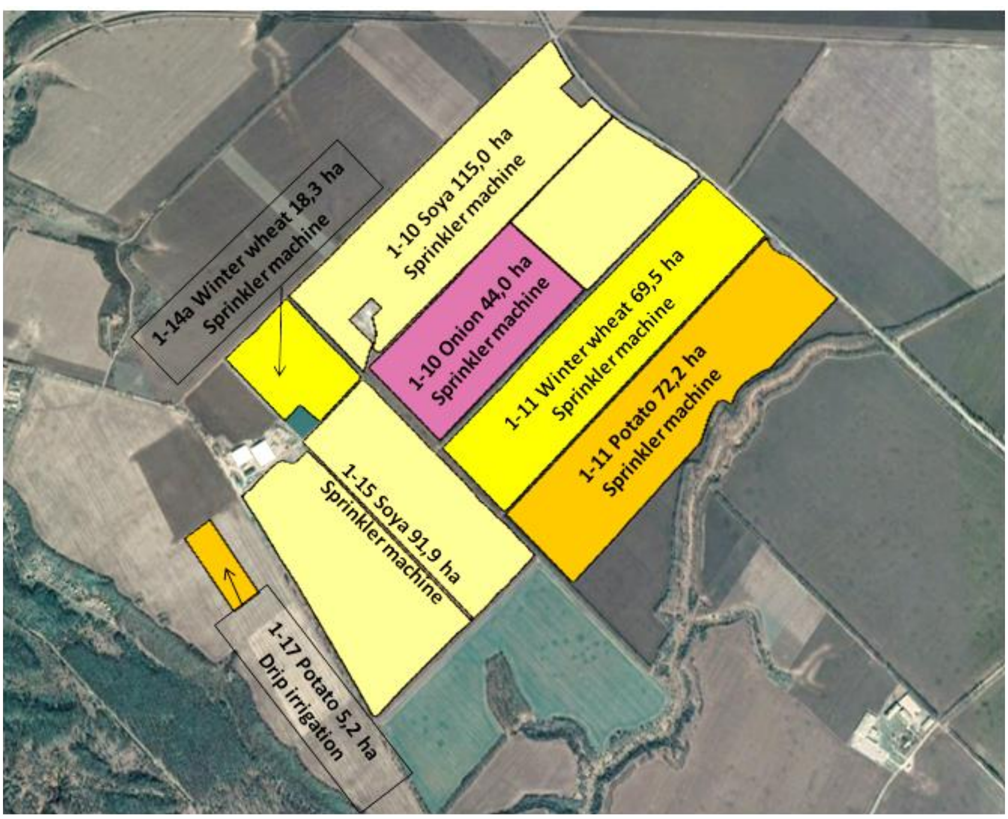


Fig. 2. Contours of irrigated fields at LLC Granex-Cherkasy LLC in 2023

Assessment of irrigation water quality. Assessment of the quality of water used by LLC "Granex-Cherkasy" for agricultural crops irrigation was carried out on the basis of the results of chemical analysis of groundwater samples taken during irrigation periods (from the storage pool).

During the entire period of research (2019‒2023), the mineralization of irrigation water was on average 500 mg/dm^3 for the hydrogen carbonate magnesium-calcium, less often calcium, type of chemistry. The reaction of water is mainly slightly alkaline (pH – from 7,2 to 7,7). According to the indicator of total hardness, the water belonged to both moderately hard and hard classes.

During water evaluation, it was taken into account that the soil cover within the irrigated plots is mainly represented by typical, low-humus, light- and medium-loamy black soils in a complex with solodic soils with a mostly neutral reaction (at the time of the surveys), medium-buffering with respect to salinization (by $CaCO_3$ content).

Regarding the danger of irrigation salinization of the soil based on the calculated indicator of the sum of toxic salts in equivalents of chloride ions (eCl$^-$), the value of which for water in the storage pool during the irrigation season of 2023 was 2.1 and 1.6 meq/dm^3, water according to DSTU 2730:2015 [26] belongs to the Ist class (suitable) for all groups of soils according to their granulometric composition in the 0‒100 cm soil layer. It is worth to mention that during the entire period of monitoring observations of the irrigation water quality, the amount of toxic salts (in equivalents of chloride ions) in it fluctuated between 1.6–2.4 meq/dm^3, that is, it was low enough and did not cause a threat of irrigation salinization of the soil.

The assessment of water quality regarding the danger of soil alkalinization was based on taking into account pH indicators, the content of CO_3^{2-}, and toxic alkalinity (HCO_3^- – Ca_2^{2+}) with differentiation by soil groups and the reaction of the environment according to [26] (Table 1).

Therefore, according to the danger of soil alkalization due to increased values of toxic alkalinity indicators (from 3,1 to 4,3 meq/dm^3) and pH (for alkaline soils), the water belongs to the IInd class, both in previous years and in 2023 ("limited use").

Assessment of the irrigation water quality regarding on the risk of soil sodification gives reason to assign it to the Ist class (Table 2). The amount of alkaline cations of sodium and potassium in the water was from 9 to 14 % of the amount of all cations, which is much lower than the threshold value (45 %) of this indicator for loamy medium-buffer black soils, even for the IInd water class according to the alkalization danger.

According to the risk of toxic effects on plants during sprinkler irrigation, irrigation water from water intake wells (from the pool) in 2023, in general, according to a set of evaluation indicators, belongs to the IInd class as of July due to increased pH values (over 7,5) and to the Ist class as of August, which confirms a certain constancy of water quality indicators in the time dimension (Table 3).

1. Assessment of the irrigation water quality according to the risk of soil alkalinization on the lands of LLC "Granex-Cherkasy"

Sampling date from the storage pool	Water quality indicators			Water quality class according to individual indicators			Water quality class
	pH	content CO_3^{2-}	content of toxic alkalinity (HCO_3^- – Ca^{2+})	pH*	CO_3^{2-}	toxic alkalinity	
		meq/dm^3					
25.06.2019	7,7	0,0	4,0	I/II	I	II	II
20.09.2019	7,5	0,0	3,8	I/I	I	II	II
24.06.2020	7,4	0,0	4,0	I/I	I	II	II
22.09.2020	7,6	0,0	3,8	I/II	I	II	II
03.07.2021	7,6	0,0	3,2	I/II	I	II	II
22.09.2021	7,6	0,0	4,3	I/II	I	II	II
22.06.2022	7,7	0,0	3,7	I/II	I	II	II
29.09.2022	7,7	0,0	3,9	I/II	I	II	II
12.07.2023	7,6	0,0	3,3	I/II	I	II	II
10.08.2023	7,2	0,0	3,1	I	I	II	II

*Before a slash – for acidic and neutral soils, after a slash – for alkaline soils.

2. Assessment of the irrigation water quality according to the risk of sodification of the soil on the lands of LLC "Granex-Cherkasy" near the village Denhy, Zolotonosha district, Cherkasy region (the storage pool)

Sampling date from the storage pool	Irrigation water class according to the risk of alkalinity	The ratio of the sum of alkaline cations to the sum of all cations, %*	Water quality class
25.06.2019	II	14,3	I
20.09.2019	II	12,6	I
24.06.2020	II	11,4	I
22.09.2020	II	9,3	I
03.07.2021	II	12,3	I
22.09.2021	II	9,6	I
22.06.2022	II	9,5	I
29.09.2022	II	14,3	I
12.07.2023	II	11,3	I
10.08.2023	II	7,7	I

* Threshold value for water of the Ist class is 45 %.

3. Assessment of the irrigation water quality from the storage pool according to the risk of toxic effects on plants during sprinkler irrigation (LLC "Granex-Cherkasy")

Sampling date from the storage pool	Water quality indicators			Toxic ions, equivalents Cl	Water quality class
	pH	CO_3^{2-}	Cl^-		
		meq/dm³			
25.06.2019	7,72	Absent	0,4	2,0	II
20.09.2019	7,48	The same	0,6	2,2	I
24.06.2020	7,36	» »	0,6	2,2	I
22.09.2020	7,63	» »	0,6	2,1	II
03.07.2021	7,58	» »	1,1	2,4	II
22.09.2021	7,58	» »	0,5	2,2	II
22.06.2022	7,72	» »	0,4	1,9	II
29.09.2022	7,67	» »	0,4	2,0	II
12.07.2023	7,65	» »	0,1	2,1	II
10.08.2023	7,16	» »	0,4	1,6	I

We can conclude, that from the point of view of assessing the irrigation water quality of water according to agronomic criteria provided by DSTU 2730:2015, the underground water withdrawn from wells to irrigate the lands of LLC "Granex-Cherkasy" near the village of Denhy, belongs to the Ist class ("suitable") with respect to irrigation salinization and sodification danger for the soils and to the IInd class ("limitedly suitable") with respect to alkalinization danger for soils (according to the indicators of pH and toxic alkalinity) and toxic effect on plants in case of direct ingress of water on the leaves, fruits, etc (in specific periods according to the pH indicator), that, as a whole, means that it is a water of the IInd class. According to [12], watering with such water is possible if restorative measures are applied.

Groundwater in the study area, due to its use for drip irrigation systems, belongs to the Ist class with respect to the danger of irrigation salinization and sodification of soils and to the IInd class with respect to the danger of soil alkalization (exceeding the threshold values of pH and toxic alkalinity).

Assessment of soil condition by individual indicators. The main attention during monitoring studies of the irrigated soils' condition was devoted to the study of possible changes in their salt characteristics due to irrigation water influence, i.e., the income of an additional amount of salts with it, taking into account their qualitative composition. Thus, based on the average values of water mineralization and average irrigation rates, approximately from 0,49 to 1,25 t/ha of salts were added to the fields with irrigation water during the irrigation period. In addition, every year, during the works, some indicators of soil fertility (pH, content of $CaCO_3$, microelements, and heavy metals) were determined at individual points.

In 2023, during continuous testing of all fields, soil samples were extracted in order to determine in laboratory conditions the values of agrophysical and agrochemical indicators (granulometric and aggregate composition of soils, their density, humus and nutrients content, salt and exchangeable cations compositions).

The study of the soil condition in 2023 was carried out both at the designated monitoring points as well as at the additional test points for soil and salt survey, the layout of which is shown in Fig. 3.

Research results on secondary soil salinity. In 2023, according to research results of the easily soluble salts content in the soil layer (down to 1.0−2.0 m) based on the analysis of water extracts, both irrigated and non-irrigated soils within the examined farm fields were classified as non-saline. At the same time, the soils are non-saline both by the sum of all easily soluble salts and by the content of a part of these salts that in certain concentrations have a toxic effect on plants, inhibiting their growth and development, i.e. toxic salts, according to their division by the degree of salinity according to the current regulatory documents [13, 23]. A similar situation was observed in all previous years of study.

The total weighted average content of easily soluble salts in the upper 1 m soil layer in 2023 on the examined fields was quite low and was within 0,043−0,084 % of dry soil (according to the data of the continuous survey of 2018 – 0,040−0,062 %). The toxic salts content in the one-meter layer of soil ranges from 0,013 to 0,036 %, which is 17,2-47,1 % of the total amount of salts. In some years, the value of the easily soluble salts content increased up to 0,062-0,192 %, of toxic ones – up to 0,014-0,061 % (2021).

At the same time, the main types of soil salinization in the upper 1 m layer in 2023 were hydrocarbonate and sulfate-hydrocarbonate, in 2022 – sulfate-hydrocarbonate; in 2021 – sulfate-hydrocarbonate, hydrocarbonate-sulfate; in 2020 – hydrocarbonate, in 2019 – hydrocarbonate

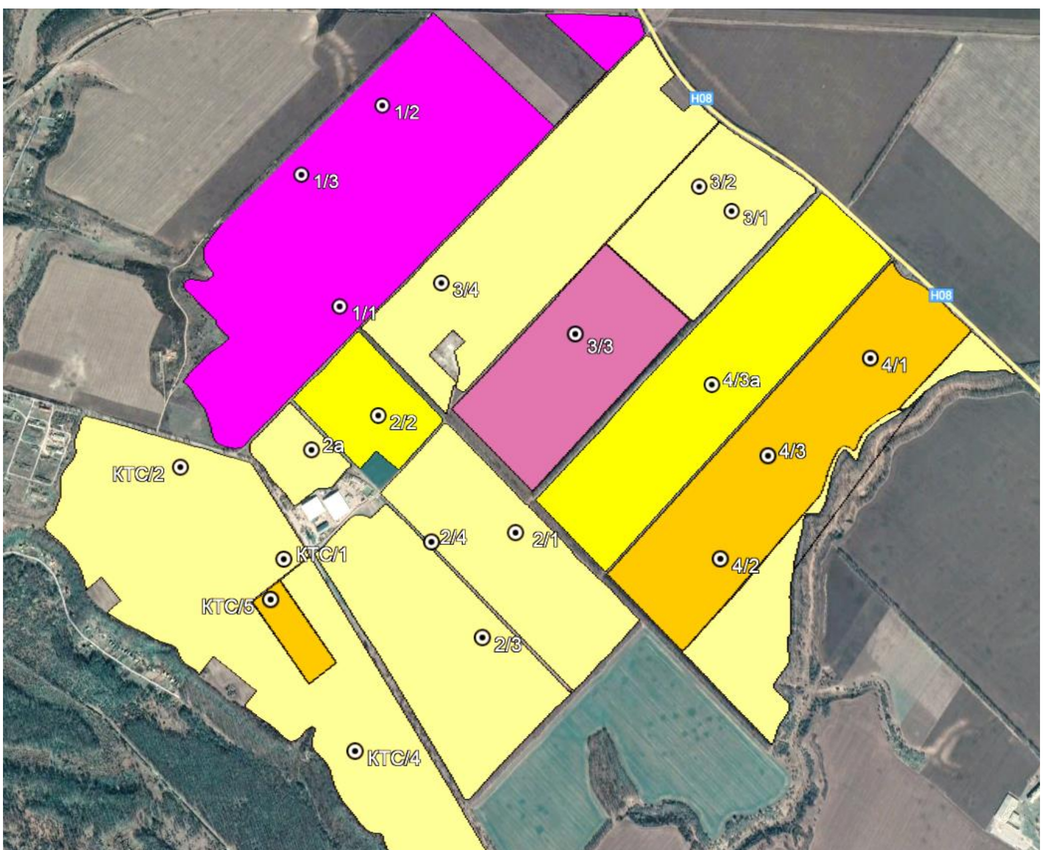


Fig. 3. Layout of soil sampling points in the area of monitoring studies

and sulfate-hydrocarbonate – by anionic composition, magnesium-calcium and calcium – by cationic composition.

It is worth noting that the heterogeneity of the salinity chemistry and the salts content is observed within individual layers of 1 m thickness and deeper, although in terms of the total salts content and their toxic part, the studied sediments in the test intervals are everywhere non-saline. Maximum salinity in the soil profile was noted at different depths (Fig. 4).

The weighted average total content of water-soluble salts in the interval of 100–200 cm at individual monitoring points tested in 2023 is 0,079–0,116 %, and toxic salts – 0,017–0,077 %, that means that the share of the latter is from 25,9 to 51,0 % of the total amount of easily soluble salts. According to the type of salinity, the soils of this interval are hydrocarbonate and sulfate-hydrocarbonate (by anions) and mainly magnesium-calcium by cation composition. Therefore, in this layer, the soil is also non-saline, although compared to the 2018 survey, slightly higher values of both the total content of easily soluble salts and their toxic part were recorded, which previously amounted to 0,058−0,070 % and 0,018−0,029 %, respectively.

Attention should also be paid to certain differentiation in area and profile at the individual test points (wells) of salinization chemistry, especially in terms of anionic composition, although the predominant types of salinization are associated with the predominance of hydrocarbonate and sulfate ions along with

2a
2/4
3/3

Fig. 4. Typical salt profiles of the distribution of the ions and salts content in the water extract (2023)

calcium and magnesium cations. At the same time, an unfavorable trend is a certain increase in the amount of chlorine salts and sodium ions at certain points.

Over the years of monitoring studies, the ranges of the content of easily soluble salts in the arable layer (0−25 cm) were 0,040−0,079 % (2018), 0,023−0,073 (2019), 0,032−0,058 (2020), 0,046−0,091 (2021), and 0,024−0,084 % (2022).

The arable layer at the time of the survey in August 2023 was distinguished by a generally low salts content (from 0,022 to 0,081 %), in particular, toxic ones (from 0,004 to 0,044 %, that is below the toxicity threshold) and heterogeneous types of salinity by anions: bicarbonate-sulfate, sulfate- hydrocarbonate, hydrocarbonate, calcium, calcium-magnesium and magnesium-calcium types according to the cationic composition, that means that it is considered as non-saline.

In general, the monitoring studies results and soil-salt survey provide grounds for assigning all lands on the site to the non-saline category throughout the entire observation period, i.e. 2019−2023, which indicates, according to [12], the environmental safety of the performed irrigation.

Determination of soils sodification. The sum of exchangeable cations in the 0−25 cm soil layer varies on the farm plot from 12,5 to 27,5 meq/100 g of soil, and in the 25−50 cm layer – from 16,3 to 28,8 meq/100 g of soil, which corresponds to the optimal parameters of fertility indicators of typical black soils [27].

Among the exchangeable cations of the examined soils in the 0−50 cm layer, absorbed calcium dominates in most points, the share of which is from 43,4 to 94,5 % of the sum of all cations. The content of absorbed magnesium ranges from 5,3 to 56,4 %. In the test points 3/3, KTS/4 (layer 25−50 cm), and KTS/5 (layer 0−25 cm) the magnesium content is close to the calcium content with a slight excess over the latter at points on the field 1−17 (KTS).

The content of absorbed sodium at all test points and all investigated fields in the intervals of 0−25 and 25−50 cm during the post-design monitoring does not exceed 0,5−1,7 % of the absorption capacity, which is typical for zonal forest-steppe soils. *Therefore, according to the content of absorbed sodium, the main types of soils on the research area are non-saline* (less than 3 % of Na for low-humus soils). The same applies to the possible secondary (irrigation) salinity of irrigated soils, especially since the light soils on the site in the 0−50 cm layer are mostly medium buffering with respect to sodification (in terms of $CaCO_3$ content – 6−10 %), for which the sodification threshold (transition to slightly saline) is the content of exchangeable alkaline cations (Na+K) equal to 5 % of the absorption capacity (Na+K+Mg+Ca) [13, 23, 24].

At the same time, it should be taken into account that the increased content of exchangeable magnesium (more than 20 % of the soil absorption complex capacity or the sum of all exchangeable cations), what is noted at most points of soil testing, according to separate approaches [13], can adversely affect soil fertility (20-30 % – weak impact, 30-40 % – medium impact, over 40 % – critical impact) and should be interpreted as magnesium sodification, especially since magnesium is one of the main cations in groundwater used for irrigation (up to 30-40 % of the total cations, according to the data of 2019−2021 and 2023), although, according to the research data of 2022, its content did not exceed 0,4−0,8 meq/dm^3 or 8−15 % of the sum of cations.

Evaluation of soils by the degree of their alkalization by the pH indicator, the content of CO_3^{2-}, and toxic alkalinity (HCO_3^--Ca^{2+}) in accordance with the current classification [13] indicates the absence of this unfavorable soil degradation process in the soil of the tests sites (pH less than 8 units; CO_3^{2-} is absent; the content of toxic alkalinity is less than 0,5 meq/100g of soil).

However, the fact that groundwater, from the point of view of assessing its suitability for irrigation, is limitedly suitable for irrigation due to the danger of soil alkalinization, and the pH of the water in some points at depths of 25–75 cm reach 7,5–7,8 units, indicates the need for further monitoring of this indicator as a component of the assessment of the ecological and reclamation state of irrigated lands.

In general, the results of monitoring studies indicate the absence of processes of secondary (irrigation) salinization, sodification, and alkalinization of soils as a result of lands irrigation in LLC "Granex-Cherkasy".

Agrophysical and agrochemical indicators of soil fertility. The results of soils granulometric composition determination in 2023 give reasons to classify them as light loams (field 1–14 – wells 2a, 2/1; field 1–15 – well 2/4; field 1–10 – well 3/4; field 1–11 – well 4/3, thickness 0−50 cm; field 1–17 – wells KTS/1, KTS/2, KTS/4) or as medium loams (field 1–9 – well 1/2; field 1–10 – wells 3/1, 3/2, 3/3; field 1–11 – well 4/3a). A certain heaving of the soil granulometric composition compared to the base values of 2018 is associated with an increase in the content of the smallest fraction (diameter less than 0,001 mm).

The determination of the soil density indicator during the on-site survey of the lands of LLC "Granex-Cherkasy" in August 2023 confirmed the presence of over-compacted soils in almost all fields that were the monitoring was carry out. Thus, the arable layer density (0−25 cm) generally fluctuated within the range of 1,26−1,53 g/cm^3, which exceeds the optimal parameters of this indicator for typical black soils (1,1−1,3 g/cm^3) and characterizes the soil as dense or very dense. This, under irrigation conditions, worsens the permeability of irrigation water into the soil and its moistening. The density in the soil layer of 25–50 cm is 1,36–1,62 g/cm^3, which are the typical values for subarable horizons. Therefore, in fields where increased values of the arable layer density are recorded, special attention should be paid to monitoring the compliance with the optimal parameters of this indicator through appropriate soil cultivation, the application of organic fertilizers and meliorants.

The content of humus in farm's soils, according to the study, is mainly in the range of 2,1–3,8 % (average level). To a lesser extent (test points 3/1, 3/2, 4/3a, KTS/2, KTS/4) the humus content values are 3.1–4.0 % (increased content). In most soil samples, the humus content gradually decreases with depth, which is natural, but at points 2/1, 2/2, 2/4, 3/1 the humus content in the soil layer 0−25 cm is lower than in the layer 25−50 cm by 0,21−0,35 in absolute percent. Compared to the survey of 2018, a certain increase in humus content is observed over the territory of most fields. In general, the humus content corresponds to the optimum for typical black soils with light loam granulometric composition.

The reaction of the soil solution of the studied fields is mostly neutral (pHsol 6,1−7,0), as well as slightly alkaline (pHsol 7,1−7,5), in some cases slightly acidic (pHsol 5,1−5,6), but generally acceptable for growing most crops.

Conclusions. Post-design local monitoring of the irrigated lands of LLC "Granex-Cherkasy" through the periodic determination of water quality indicators in the storage pool and soil reclamative indicators, primarily salt characteristics, at the monitoring points specified in the program, as well as the final soil and salt survey, provided an opportunity to assess the impact of the planned activities related to agricultural lands irrigation near the village Denhy, Zolotonosha district, Cherkasy region, on the soils and groundwater condition, which was provided by the conclusion of the environmental impact assessment provided by the Ministry of Natural Resources of Ukraine.

According to the results of the assessment in 2019−2023, we found that groundwater, which is taken from wells and supplied for irrigation, according to agronomic criteria can be classified to the Ist class (suitable) with respect to the danger of irrigation salinization and sodification of soils, and as limited suitable (the IInd class) with respect to the danger of soil alkalinization (according to pH and toxic alkalinity) and the danger of toxic effects on plants during sprinkler irrigation (according to pH).

According to the results of monitoring studies, we found that the soils under irrigation conditions did not undergo changes significant for their classification. According to the total easily soluble salts content and the toxic salts content in the upper 1 m layer, both irrigated and non-irrigated soils are classified as non-saline, mainly hydrocarbonate and sulfate-hydrocarbonate by anion composition and magnesium-calcium and calcium by cation types.

It was determined that the main types of soils on the investigated plot are non-saline based on the absorbed sodium and potassium alkaline cations content. A specific soils feature is the increased exchangeable magnesium content, which requires, after watering them with water of magnesium-calcium type, the control of the content of this indicator with, if necessary, application of calcium-containing meliorants.

The absence of manifestations of secondary (irrigation) salinization, sodification, and alkalinization of soils under the influence of irrigation indicates its environmental safety in accordance with the accepted norms for the indicators of the degree of specified soil degradation processes development.

References

1. Tarariko, Yu.O., Saydak, R.V., Soroka, Yu.V., & Vitvits'kyy, S.V. (2015). Rayonuvannya terytoriyi Ukrayiny za rivnem zabezpechenosti hidrotermichnymy resursamy ta obsyahamy vykorystannya sil's'kohospodars'kykh melioratsiy [Zoning of the territory of Ukraine according to the level of provision with hydrothermal resources and volumes of use of agricultural reclamation]. Kyiv: TSP "Komprynt" [in Ukrainian].

2. Romashhenko, M.I., Sajdak, R.V., Matiash, T.V., & Knysh, V.V. (2019). Vplyv klimatychnykh smin na volohosabespechennia terytoriyi Ukrayiny ta vyrobnytstvo silskogospodarskoyi produktsiyi [Influence of climate change on the water supply of the territory of Ukraine and production of

agricultural products]. Mizhnarodna naukovo-praktychna konferentsiia, prysviachena Vsesvitnomu dnju vodnykh resursiv (voda dlia vsikh). Kyiv, 179–180 [in Ukrainian].

3. Romashhenko, M.I. Dekhtiar, O.O., Husiev, Yu.V., Yatsiuk, M.V., Saidak, R.V., Matiash, T.V., Shatkovskyi, A.P., Voropai, H.V., Voitovych, I.V., Muzyka, O.P., & Usatyi, S.V. (2020). Problemy ta osnovni napriamy rozvytku zroshennia ta drenazhu v Ukraini v umovakh zmin klimatu [Problems and main directions of development of irrigation and drainage in Ukraine under conditions of climate change]. *Melioratsiya i vodne hospodarstvo*, 1, 56–67. [in Ukrainian].

4. Stratehiia zroshennia ta drenazhu v Ukraini na period do 2030 roku [Irrigation and drainage strategy in Ukraine until 2030]: Skhvaleno rozporiadzhenniam Kabinetu Ministriv Ukrainy № 688-p. (2019, August 14). Uriadovyi kurier, 170. Retrieved from: https://zakon.rada.gov.ua/laws/show/688-2019-%D1%80. [in Ukrainian].

5. Plan zakhodiv z realizatsii Stratehii zroshennia ta drenazhu v Ukraini na period do 2030 roku [Action plan for the implementation of the Irrigation and Drainage Strategy in Ukraine for the period up to 2030]. (2020). Skhvaleno rozporiadzhenniam Kabinetu Ministriv Ukrainy vid 21.10.2020 [in Ukrainian].

6. Hadzalo Y. (2023). Vitchyzniane silske hospodarstvo v suchasnykh umovakh: vyklyky ta shliakhy yikh podolannia [Domestic agriculture in modern conditions: challenges and ways to overcome them]. Dopovid na sesii Zahalnykh zboriv Natsionalnoi akademii ahrarnykh nauk Ukrainy 29.11.2023. Kyiv: NNTS "Instytut ahrarnoi ekonomiky" [in Ukrainian].

7. Baliuk, S.A., Romashchenko, M.I., & Stashuk, V.A. (Ed.). Naukovi osnovy okhorony ta ratsionalnoho vykorystannia zroshuvanykh zemel Ukrainy [Scientific basis of protection and rational use of irrigated lands of Ukraine]. (2009). Kyiv: Ahrarna nauka. [in Ukrainian].

8. Baliuk, S.A., Romashchenko, M.I., & Stashuk, V.A. (Ed.). (2013). Kompleks protydehradatsiinykh zakhodiv na zroshuvanykh zemliakh Ukrainy [Complex of anti-degradation measures on irrigated lands of Ukraine]. Kyiv: Ahrar. nauka [in Ukrainian].

9. Romashchenko, M.I., Shevchenko, A.M., Savchuk, D.P., Babitska, O.A., Bozhenko, R.P., Bielikov, O.M., Kotykovych, I.V., Baliuk, S.A., Nasonenko, O.A., & Marushchak, H.M. (2016). Transformatsiia meliorovanykh terytorii. Osoblyvosti ta zakonomirnosti rozvytku protsesiv transformatsii pryrodno-ahromelioratyvnykh heosystem na zroshuvanykh zemliakh. Intehrovane upravlinnia vodnymy i zemelnymy resursamy na meliorovanykh terytoriiakh : Monohrafiia [Integrated management of water and land resources in reclaimed territories: Monograph]. Kyiv: Ahrarna nauka, 180–198. [in Ukrainian].

10. The Verkhovna Rada. (2017). Zakon Ukrainy Pro otsinku vplyvu na dovkillia [About environmental impact assessment]. Bulletin of the Verkhovna Rada, No. 29, Article 315 Retrieved from: https://zakon.rada.gov.ua/laws/show/2059-19#Text. [in Ukrainian].

11. Metodychni rekomendatsii shchodo zdiisnennia pisliaproektnoho monitorynhu [Methodological recommendations for post-project monitoring]. Zatverdzheno nakazom Ministerstva zakhystu dovkillia ta pryrodnykh resursiv Ukrainy № 291 vid 15.03.2024. (2024). Retrieved from: https://mepr.gov.ua/nakaz-mindovkillya-291-vid-15-03-2024/. [in Ukrainian].

12. Kabinet Ministriv Ukrainy.(2020). Postanova "Pro normatyvy ekolohichno bezpechnoho zroshennia, osushennia, upravlinnia polyvamy ta vodovidvedenniam [About standards of environmentally safe irrigation, drainage, irrigation and drainage management]: vid 2 veresnia 2020 r. № 766 (2020, September 2). Retrieved from: https://zakon.rada.gov.ua/laws/show/766-2020-%D0%BF#Text. [in Ukrainian].

13. Orhanizatsiia i vedennia ekoloho-melioratyvnoho monitorynhu, chastyna 1 – Zroshuvani zemli [Organization and conduct of ecological and reclamation monitoring, part 1 – Irrigated lands]. (2002). VBN 33-5.5-01-97. Kyiv : Derzhvodhosp Ukrainy. [in Ukrainian].

14. Shevchenko, A.M., & Romashchenko, M.I. (2023). Problemy ta perspektyvy funktsionuvannia monitorynhu meliorovanykh zemel v umovakh reformuvannia systemy upravlinnia vodnymy resursamy ta melioratsiieiu zemel [Problems and prospects of the functioning of the monitoring of reclaimed lands in the conditions of reforming the system of water resources management and land reclamation]. *Pryskorennia zmin dlia podolannia vodnoi kryzy v Ukraini* : zbirnyk tez XI Mizhnarodnoi naukovo-praktychnoi onlain-konferentsii. Kyiv: IVPiM NAAN. [in Ukrainian].

15. Romashchenko, M.I., Shevchenko, A.M, & Drachynska, E.S. (2004). Teoretychni osnovy ta problemy praktychnoi realizatsii monitorynhu zroshuvanykh zemel Ukrainy [Theoretical foundations and problems of practical implementation of monitoring of irrigated lands of Ukraine]. *Tavriiskyi naukovyi visnyk*, 32 [in Ukrainian].

16. Romashchenko, M. I. & Shevchenko, A.M. (2019). Suchasnyi stan ta perspektyvy vedennia monitorynhu meliorovanykh zemel [The current state and prospects of monitoring reclaimed land]. *Zbirnyk naukovykh prats "Okhorona hruntiv"*. Spetsialnyi vypusk. Materialy Vseukrainskoi naukovo-praktychnoi konferentsii "Monitorynh gruntiv yak nevid'iemna chastyna monitorynhu dovkillia" (m. Kyiv, 23–25 lypnia 2019 r.). Kyiv, 18–21 [in Ukrainian].

17. Shevchenko, A.M., & Miedviediev, O.O. (2023). Ekoloho-melioratyvnyi monitorynh na rysovykh zroshuvalnykh systemakh Ukrainy [Ecological and remedial monitoring of rice irrigation systems of Ukraine]. Stashuk V.A., Vozhehova R.A. &, Rokochynskyi A.M. (Ed.). Rysovi zroshuvalni systemy Ukrainy: pidvyshchennia efektyvnosti yikh funktsionuvannia: kolektyvna monohrafiia. Kyiv-Kherson-Rivne: NUVHP. 366–386 [in Ukrainian].

18. Shevchenko, A.M. (2021). Pisliaproiektnyi monitorynh zroshuvanykh zemel yak informatsiina osnova zapobihannia dehradatsii gruntiv [Post-project monitoring of irrigated lands as an information basis for soil degradation prevention]. *Okhorona hruntiv* : Zbirnyk naukovykh prats. Spetsialnyi vypusk. Materialy Vseukrainskoi naukovo-praktychnoi konferentsii "Monitorynh hruntiv yak odyn z mekhanizmiv dosiahnennia neitralnoho rivnia dehradatsii". Kyiv, 83–85 [in Ukrainian].

19. Shevchenko, A.M., Bozhenko, R.P., & Liutnytskyi, S.M. (2023). Pisliaproiektnyi monitorynh yakosti zroshuvalnoi vody na systemakh kraplynnoho zroshennia v baseini richky Hirskyi Tikych [Post-project monitoring of irrigation water quality on drip irrigation systems in the Hirsky Tikich river basin]. Suchasni tekhnolohii ta dosiahnennia inzhenernykh nauk v haluzi hidrotekhnichnoho budivnytstva ta vodnoi inzhenerii: zbirnyk naukovykh prats, Iss. 5. Kherson: KhDAEU. 5–9 [in Ukrainian].

20. Instruktsiia z orhanizatsii ta zdiisnennia monitorynhu zroshuvanykh ta osushuvanykh zemel [Instructions on the organization and monitoring of irrigated and drained lands]. Zatverdzhena Nakazom Derzhvodhospu Ukrainy 16.04.2008 r. № 108, zareiestrovana Miniustom Ukrainy 16.07.2008r. za № 656/15347. (2008). Retrieved from: https://zakon.rada.gov.ua/laws/show/z0656-08. [in Ukrainian].

21. Metodyka provedennia kompleksu monitorynhovykh robit u systemi Derzhvodhospu. Chastyna 1. Kompleks monitorynhovykh robit na masyvakh zroshennia Ukrainy. Metody vykonannia analiziv i vyznachennia pokaznykiv ekoloho-melioratyvnoho stanu zemel [Methodology for carrying out a complex of monitoring works in the system Derzhvodhosp. Part 1. A complex of monitoring works on the irrigation arrays of Ukraine. Methods of performing analyzes and determining indicators of ecological and meliorational state of lands]. (2002). Posibnyk 1 do VBN 33-5.5-01-97 "Orhanizatsiia i vedennia ekoloho-melioratyvnoho monitorynhu". Ch. 1. Zroshuvani zemli. Kyiv [in Ukrainian].

22. Metodyka otsinky i prohnozu ekoloho-melioratyvnoho stanu meliorovanykh zemel. Chastyna 2. Metody otsinky i prohnozu ekoloho-melioratyvnoho stanu ta stiikosti zemel pry zrosheni. [Methods of appraisal and prognosis of the ecological and reclamation state of reclaimed lands. Part 2. Methods of assessment and forecasting of the ecological and reclamation state and stability of lands under irrigation]. (2002). Posibnyk 2 do VBN 33-5.5-01-97 "Orhanizatsiia i vedennia ekoloho-melioratyvnoho monitorynhu". Ch. 1. Zroshuvani zemli. Kyiv [in Ukrainian].

23. Yakist hruntu. Poriadok provedennia hruntovo-solovoi ziomky zemel [Soil quality. The shape procedure for soil and salt surveying of lands]. (2016). DSTU 7850:2015 Natsionalnyi standart Ukrainy. Kyiv : DP"UkrNDNTs" [in Ukrainian].

24. Grunty. Klasyfikatsiia gruntiv za stupenem vtorynnoi solontsiuvatosti. [Soils. Classification of soils according to the degree of secondary salinity]. (1999). DSTU 3866-99. Natsionalnyi standart Ukrainy. Kyiv : Derzhspozhyvstandart Ukrainy [in Ukrainian].

25. Yatsuk, I.P., & Baliuk, S.A. (Ed.). (2019). Metodyka povedennia ahrokhimichnoi pasportyzatsii zemel silskohospodarskoho pryznachennia: kerivnyi normatyvnyi document [Methodology for conducting agrochemical certification of agricultural lands: a guiding regulatory document]. (2nd ed.). Kyiv [in Ukrainian].

26. Zakhyst dovkillia. Yakist pryrodnoi vody dlia zroshennia. Ahronomichni kryterii [Environmental protection. Quality of natural water for irrigation. Agronomic criteria]. (2016). DSTU 2730:2015 Kyiv: Derzhspozhyvstandart Ukrainy [in Ukrainian].

27. Yakist gruntu. Pokaznyky rodiuchosti gruntiv [Soil quality. Indicators of soil fertility]. (2005). DSTU 4362:2004. Kyiv: Derzhspozhyvstandart Ukrainy [in Ukrainian].

УДК 557.4:502.7;631.67:626.8

ПІСЛЯПРОЄКТНИЙ МОНІТОРИНГ ВПЛИВУ ЗРОШЕННЯ НА ДОВКІЛЛЯ

А.М. Шевченко[1], канд. с.-г. наук, Р.П. Боженко[2]

[1] Інститут водних проблем і меліорації НААН, 03022, м. Київ, Україна;
https://orcid.org/0000-0002-2637-6538; e-mail: monitoring_protect@ukr.net;
[2] Інститут водних проблем і меліорації НААН, 03022, м. Київ, Україна;
https://orcid.org/0000-0003-3661-8120; e-mail: ruslana_lp@ukr.net

Анотація. *На прикладі окремого агрогосподарства ТОВ «Гранекс-Черкаси» висвітлено підходи до ведення післяпроєктного моніторингу впливу зрошення на стан ґрунтів. Результати виконання п'ятирічної програми післяпроєктного моніторингу за умов зрошення земель підземними водами дощуванням і краплинним способом засвідчили необхідність напрацювання як єдиних загальних підходів до формування програм моніторингу, так і обов'язкового врахування особливостей його ведення за різних способів поливу та гідрогеолого-меліоративних умов на ділянках зрошення. В основу розроблення системи післяпроєктного моніторингу впливу зрошення на стан складових довкілля запропоновано використовувати підходи до організації та ведення локального (об'єктового) моніторингу зрошуваних земель на основі вимог чинних нормативних і методичних документів. Сформована на підставі попередніх досліджень система спостережень включала періодичне визначення показників якості зрошувальної води у ставку-накопичувачі або у місцях поливу та режимні спостереження за станом ґрунтів на постійних моніторингових точках (пунктах спостережень), які рекомендують приймати як координатно прив'язані точки випробування проведеного раніше (на стадії підготовки звіту з оцінки впливу на довкілля) дослідження. Результати післяпроєктного моніторингу засвідчили екологічну допустимість впливу проведення зрошення земель у господарстві підземними водами I та II класів якості (придатними та обмежено придатними за окремими показниками якості). За результатами моніторингу встановлено, що ґрунти в умовах зрошення впродовж 5 років не зазнали класифікаційно значних змін щодо погіршення стану. Відсутність прояву процесів вторинного (іригаційного) засолення, осолонцювання та підлуження ґрунтів під впливом зрошення свідчить про екологічну безпечність останнього згідно з прийнятими нормативами за показниками ступеня розвитку зазначених ґрунтово-деградаційних процесів.*

Ключові слова: *ґрунти, засолення, зрошення, зрошувальна вода, осолонцювання, післяпроєктний моніторинг, якість води*