УДК 502/504:331.102.323:631.6

FORMATION OF THE ECOLOGICAL-MELIORATIVE STATE OF THE DANUBE RICE IRRIGATION SYSTEMS AND THE WAYS OF ITS IMPROVEMENT

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Analysis of main reasons of unsatisfactory ecological-meliorative state of the rice irrigation system (RIS) has been carried out. Ways of improvement of water-air and salt condition of the soil by efficiency enhancement of the drainage system on the irrigated rice fields have been identified. *Keywords:* drainage, ecological-meliorative state, rice irrigation system.

Формування еколого-меліоративного стану придунайських рисових зрошувальних систем та шляхи його покращення. Турченюк В.О. Проведено аналіз основних причин незадовільного еколого-меліоративного стану рисових зрошувальних систем (РЗС). Визначено напрями покращення водоповітряного, сольового режимів грунтів шляхом підвищення ефективності роботи дренажу на зрошуваних землях рисових систем. *Ключові слова:* дренаж, еколого-меліоративний стан, рисова зрошувальна система.

Формирование эколого-мелиоративного состояния придунайских рисовых оросительных систем и пути его улучшения. Турченюк В.А. Проведен анализ основных причин неудовлетворительного эколого-мелиоративного состояния рисовых оросительных систем (РЗС). Определены направления улучшения водовоздушной, солевого режимов почв путем повышения эффективности работы дренажа на орошаемых землях рисовых систем. *Ключевые слова:* дренаж, эколого-мелиоративное состояние, рисовая оросительная система.

Ecological-meliorative state of the RIS is defined by several factors, being natural (climate) and technological (irrigation requirements, volume of the drained water, structure and parameters of the irrigation and drainage and water discharge network etc.). Most significant impact on the RIS ecological-meliorative state is exerted by the drainage and water discharge system, which is one of the most of important factors of the RIS. It is built for drainage of the surface waters from the rice fields and regulation of the ground water level in various periods of rice vegetation as well as further cultivation of other agricultural crops on the same fields. The drainage and water discharge system is the main method of active and targeted interference into the water-salt regime of the meliorated area and ground water during the vegetation as well as irrigation period of rice and other crops and is a core condition of the soil fertility.

Analysis of the drainage effectiveness on rice fields of Danube river delta [1,2,3,2] showed that the drainage, built in 1960 s as per then active standards, does not ensure acceptable drainage conditions of the rice fields, which is one of the main reasons of their unsatisfactory ecological-meliorative state and decrease of the rice and other crops' yields. Rice irrigation systems in Ukraine, including those in the Danube river delta, were built as per the well-known Krasnodar-type scheme of irrigation (KSI) and large checks of broad front of flooding and discharge of water (LCF) with one-side and two-side water control mainly open-air irrigation and drainage and water discharge canals with in-between distance of 200-500 meters and field drains of 1,5-1,7 meters in depth depending on the soil-and-hydrogeological conditions.

In the process of long-term usage the drainage and water discharge system was heavily distorted [1,2,2,5]. The canals stopped positively influencing the water-and-salt regime of the soil during the rice cultivation, and – most notably – during cultivation of other crops, when it is important to ensure a critical depth of the ground water at 1,3-1,5 meters for Danube delta soils.

Inability of the drainage system to ensure the required level of draining and, consequently, the sufficient aeration of the active soil layer during the irrigation interval and related efficiency and purpose of redox processes in soils and their percolation, stimulated by the water regime of the rice, has become the main reason of negative processes at RIS (clay-forming, consecutive clogging and swamping, etc.), decrease of soil fertility and, respectively, rice and other crops' yield.

The aim of the research is to define reasons of aggravation of the ecological-meliorative state of the rice irrigation systems and elaborate complex and systemic solutions for its improvement, based on the principles of systemic optimization of drainage parameters, justification of the need and ways of improvement of its composition and calculation methods, which would allow to support the positive ecological-meliorative state of the system.

Materials and methods of the research. The research was performed within 2003-2016 in the framework of the complex program for increase of the general effectiveness of the Danube RIS according to the common methodology, which included usage of the unified base of the long-term observations of the object; justification, as per the task given, of the efficiency criteria of the active Danube RIS; implementation of the water-salt balance method as generally accepted tool of estimation and forecasting of ecological-meliorative state of RIS.

Results of the research. Danube RIS operational experience showed that their ecological-meliorative state is defined by the stable work of all elements of the rice system and, first of all, drainage and water discharge system.

Long-term research identified that RIS salty soil drainage must comply with the following requirements:

- ensure unsalting of the top soil layer (1-1,5 meters) for 2-3 years to create favourable conditions for cultivation of rice and other crops;
- secure necessary level of the drainage for the beginning of new irrigation period at not less than the critical depth after water discharge from field drains (1,5-1,8 meters);

- exclude possibility of the consecutive salting of soil at fields, where other crops are cultivated;
- create and support optimal filtration speed at the rice field for removal of salt from the active soil layer.

Effective functioning of the drainage and water discharge network at the rice fields depends on the correct choice of its parameters, i.e. distance between drains and their depth. These parameters' values must be calculated for creation of the optimal conditions for cultivation of other agricultural crops and, first of all, prevention of the consecutive salting.

Diversified approach of the RIS drainage assumes application of the relevant theoretical dependencies, which help to set drainage parameters for water discharge as well as creation of sufficient intensity of the percolative water regime, evenly distributed over the field drain.

Various filtration speed across field drains leads to broad range of ground waters mineralization and salt content in the soil, which results in creation of different natural-meliorative conditions and, as a consequece, different crop yields.

Filtration speed observations from the surface of irrigation maps of the Danube delta rice systems [2,3] showed that highest value of the filtration speed (from 4 to 20 mm per day) is observed in by-drain areas of the rice field, within 50 meters from the field drains (fig. 1), under condition of absence of damming in drainage and water discharge canals and, consequently, maximal value of the pressure gradient. Up to the middle of the drain spacing the filtration speed, notwithstanding the composition of the irrigation maps and distance between the drainage canals, is between 1-2 mm/day, i.e. almost absent (fig. 2).

Therefore without improvement of work and finetuning of project parameters of the drainage and water drainage system to avoid these negative processes there is a real threat of rice systems' failure and irrecoverable loss of investments for their construction and maintenance.

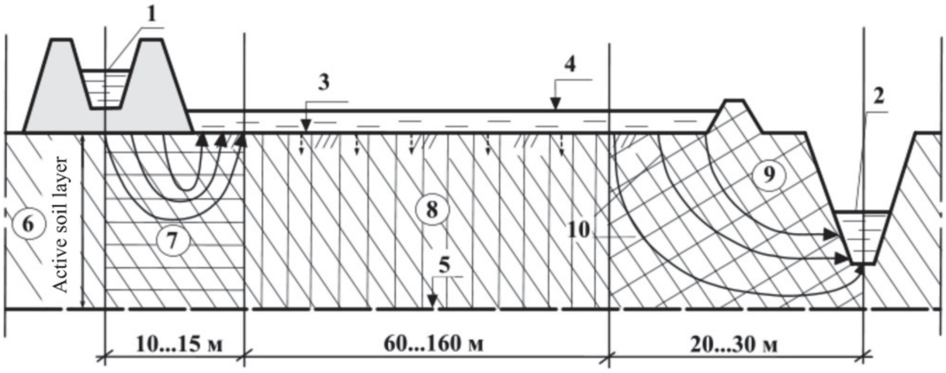

Fig. 1. Scheme of formation of distinctive areas of filtration by profile of rice field drain:
1 – field irrigation drain; 2 – field drainage and escape drain; 3 – soil surface; 4 – water surface;
5 – boundary of active soil layer; 6 – active soil layer; 7 – ground water evaporation zone;
8 – dead water zone; 9 – active filtration zone; 10 – directions of filtration flows

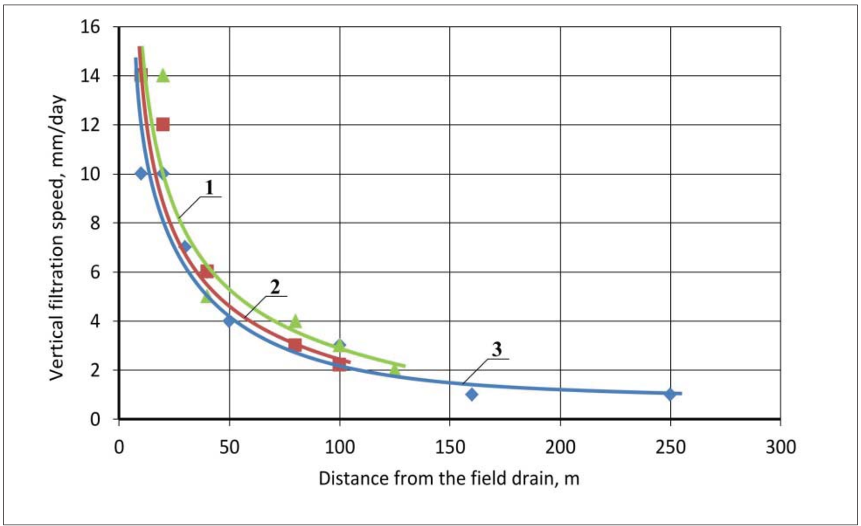

Fig. 2. Vertical filtration speed at field drains на картах-чеках by distance between drain canals: 1-B=200m; 2- B=250m; 3 – B=500m

According to the accepted practice and experience, a solution for such a complicated problem of the existing RIS, which are – in their essence – are complex natural-technical and ecological-economic systems with respective change of the entire methodology, technical and technological strategy of their creation and functioning, requires application of respective complex and systemic solutions, based on principles of systemic optimization of operational, technological and constructional solutions and their parameters. For the existing RIS systemic optimisation envisages ecological-economical optimisation of natural-meliorative regime parameters, technology of water management and constructional solutions for their application.

Optimization of project parameters of the RIS and, first of all, those of the drainage and water discharge network, given the necessity to create and maintain a percolative water regime on irrigated salty soils as the main factor in ensuring their favorable ecological and land reclamation status, as well as increase of the overall rice system technical, technological, economic and the ecological efficiency can ultimately be limited to optimization of the filtration speed after surface irrigation of the leading rice crop owing to the respective correlation between water supply and discharge under appropriate irrigation mode. It is the filtration regime which is created on irrigation rice field drains during the presence of the water layer as well as further on in the rice post-vegetation period that determines their overall ecological and land reclamation status and allows to assess the technological efficiency of the drainage network during different periods of RIS functioning.

According to [6], as an economic criterion and condition for optimization of the project and parameters of the RIS drainage during the project, we consider it expedient to consider the indicator of adjusted costs ZP_i taking into account the weather-climatic risk R_i and bearing in mind the deviation of the water regime of the rice field from the optimal in the post-vegetation, autumn-spring period as well as in the vegetation period of the system functioning to implement the appropriate variants of project solutions (PS) of the aggregate $\{i\}$, $i = \overline{1, n_i}$

$$ZP_i = Z_i \cdot k_{Z_i}^V = \left[(C_i + E_n K_i) + R_i \right] / V_i, \quad i = \overline{1, n_i}, \qquad (1)$$

where $k_{Z_i}^V$ – is a coefficient of expression of the adjusted costs by volume (value) V_i of the received products as per variants of operational, technological and technical solutions of the aggregate $\{i\}$, $i = \overline{1, n_i}$, which is determined by the inverse relationship $1/V_i$;

C_i – current expenses for the production under options of the PS;

$E_н$ – normative coefficient of economic efficiency of capital investments in the respective variants of the PS;

R_i – weather-climatic risk as per the respective PS.

Weather-climatic risk is the possibility of loss or decrease of profit as a result of the influence of adverse factors on the economic activity, or the probability of unforeseen losses due to the accidental change in the conditions of economic activity or due to impact of adverse circumstances, etc. It is determined by formula:

$$\overline{R_i} = \sqrt{\sum_{j=1}^{m} (W_{ij} - \bar{W}_{пм})^2 \cdot \alpha_{pj}} = \sqrt{\sum_{j=1}^{m} R_{ij}^2 \cdot \alpha_{pj}}, \quad i = \overline{1, n}, \qquad (2)$$

where W_{ij} – the value of gross output by the actual yield of cultivated crops, obtained by i-variant of the PS, UAH/ha;

$\bar{W}_{пм}$ – value of gross output for potentially possible yield on the site, UAH/ha.

Determination of environmentally acceptable variants of project solutions for the rice field and the system as a whole in general can be presented as necessary conditions and restrictions for the determined, substantiated and accepted for consideration a number of physical indicators (criteria) for assessing the water, salt and general natural-meliorative regime of rice fields and systems: by the regime of groundwater level in the non-vegetation period (Hg); the duration of its standing below the critical depth (T); the intensity of the filtration processes under the flooded rice field (V), the degree of salting of the active soil layer (S); irrigation rate (M); mineralization of groundwater (G), etc.

$$Z_{jks} = (Hg_{ks}, T_{ks}, V_{ks}, S_{ks}, M_{ks}, G_{ks}), \quad j = \overline{1, n_j}, \; k = \overline{1, n_k}, \; s = \overline{1, n_s}. \qquad (3)$$

By such indicators, namely by their limit values in accordance with the specific soil-meliorative conditions of the object, it is possible to predict the direction of the processes occurring in the rice field and the system as a whole and to assess the ecological effect of the implementation of meliorative measures.

An assessment of the environmental reliability of PS variants in respect of the parameters of vertical filtration speed on a rice field drain, which simultaneously reflects operational and technological aspects of water management of the RIS, is given in Table 1.

Optimization of drainage parameters included optimal parameters of vertical filtration speed on the rice field drain, which simultaneously reflects operational and technological aspects of water management of the RIS, as well

Table 1

Assessment of the ecological reliability of PS variants depending on vertical filtration speed at rice field drains

Vertical filtration speed, V,mm/day	Component Hz by Hg	Component Hz by T	Component Hz by S	Component Hz by G	Component Hz by M	Ecological reliability coefficient, kn
0,5	0,80	0,82	0,51	0,43	0.24	0,56
1,0	0,95	0,98	0,55	0,50	0,28	0,65
2,0	1,00	1,00	0,67	0,60	0,33	0,72
4,0	0,93	0,93	0,73	0,75	0,50	0,77
6,0	0,87	0,89	0,80	0,86	0,61	0,80
8,0	**0,80**	**0,93**	**0,89**	**1,00**	**0,74**	**0,87**
10,0	0,67	0,86	1,00	0,83	0,77	0,83
12,0	0,70	0,86	1,00	0,73	0,77	0,81
14,0	0,65	0,86	0,75	0,67	0,83	0,75
16,0	0,59	0,82	0,63	0,50	0,96	0,70
18,0	0,50	0,79	0,50	0,33	0,91	0,61

as the established optimal parameter of rice share of 50-60% in crop rotation cycle.

According to the results of the forecast-optimization calculations, the optimal and economically advantageous option of the project decision as per the estimated distance between the drainage and escape channels and projected closed drainage collectors projected for the Danube RIS conditions is the variant with a distance of 100 m. This drain spacing, unlike the existing one with 200-500 m, ensures the creation and existence of a percolative water regime on the rice field with an optimal speed of vertical filtration of 6-8 mm/day. The economic optimization criterion is ZPo=0,74.

Conclusion

In order to improve the ecological and meliorative state of the RIS lands, increase the rice yield, create favorable conditions for redox processes and eliminate the prerequisites for secondary soil salting, it is necessary to increase infiltration under the rice field and ensure uniformity of its distribution along the entire surface of the rice field. The task of rice system drainage as a unified way of regulating their water and salt regimes is the soil unsalting during the rice cultivation period, creation of optimal water filtration speed in the soil throughout the vegetation season and ensuring the rapid drying of field drains in the post-irrigation period.

According to the received calculations of the distance between drainage and water discharge canals for the conditions of the Danube RIS, favorable water-and-air regime of the soil can be achieved by completing the drainage network in the form of open field drains by individual closed drain collectors, which should be arranged along the field drains, maintaining the calculated distance.

Improvement of the project of the drainage and water discharge network makes it possible to extend the period with favourable level of ground waters during the irrigation interval by 30-100 days and bring its total duration to 200-220 days. This creates conditions for the complete oxidation of all recoverable toxic products before the start of the new irrigation season.

The proposed project of the irrigation field check enables reconstruction of existing rice systems with minor investments, since it does not require the installation of systematic drainage, will significantly increase the efficiency of the intra-field drainage network and will enable drainage process management in different phases of agricultural crops cultivation.

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