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Model of water-salt balance in the new irrigation territory of the karshin steppe

Abstract

The article presents a methodology for the development of a model of salt transfer in the conditions of a stationary water-salt regime of soil-grounds, caused by furrow irrigation of cotton.

Keywords: salt transfer, mathematical model, priming, lysimeter, tensiometer, mode, equations, aeration zones

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Introduction

The objects of research are the irrigated field, observation wells, as well as the created lysimetric and tensiometric complexes on the territory of the new irrigation of the Karshi steppe. The reliability of solving the problems of predicting the salt regime of soils largely depends on the accuracy of determining the parameters of salt transfer. The choice of a mathematical model of salt transfer, which satisfactorily describes the phenomena under study, is of great importance. Qualitative and quantitative changes in the salt content under the conditions of a stationary water-salt regime are predicted using analytical methods. Analytical methods are based on the use of solutions of the equation of water-salt balance, written in differential form for specific design schemes. Of practical interest is the forecasting of desalinization and secondary salinization of the soil aeration zone as a result of prolonged irrigation and a rise in the groundwater level. When forecasting, it is necessary to know in advance the parameters of the salt transfer model during furrow irrigation of cotton. When analyzing the theory of salt transfer during water filtration in soils, it was shown that the main parameters characterizing the transfer of dissolved salts are the parameters of convective diffusion, which should be determined from the data of special field and laboratory experiments. Finding them is reduced to solving an inverse problem of mathematical physics, in which, according to the known solution of a boundary value problem, it is required to find the parameters of differential equations.

A method has been developed for determining the parameters of salt transfer under the conditions of a stationary salt regime of soils in the aeration zone based on the average salinity of soils of a given thickness, before and after furrow irrigation of cotton, according to the data of lysimetric experiments. Based on the solution of the salt transfer model, which describes the process under the conditions of a stationary water-salt regime of soils in the aeration zone, it is possible to determine the convective diffusion parameter from the average soil salinity both in the absence and in the presence of transpiration. The main advantage of the method is the simplification of the computational procedure and the reliability of the values of the convective diffusion parameter, since the initial information on the salt content on the soil surface, which is difficult to determine in reclamation practice, is not used in the calculations.

The reliability of solving the problems of predicting the salt regime of soils largely depends on the accuracy of determining the parameters of salt transfer. It is also important here to choose a mathematical model of salt transfer, which gives a satisfactory description of the phenomena under study. The use of rough ideas can lead to uncontrollable errors, which will negatively affect the quality of forecasting the salt regime of irrigated areas. Therefore, the establishment of the parameters of salt transfer is extremely important and is one of the most important tasks of experimental and theoretical research. These parameters should be determined based on the results of special field and lysimetric experiments. Their finding is reduced to solving the inverse problem of salt transfer. Methods for solving such problems are described in detail, when the required parameters of the salt transfer model are found, according to the salinity data, at individual points of the calculated soil thickness at a fixed time.

Integral methods are more reliable when the parameters are found using experimental data on the process for a certain period of time at some points of the porous medium or information in the entire considered area of space for a certain period of time. However, in practice, it is not always possible to obtain information about the process in such a volume because of the complexity, laboriousness and high cost of the corresponding experiment. As a result of research on this topic, it turned out that the existing methods for determining the parameters,[1–3] especially for the conditions of a non-stationary regime, have not been sufficiently developed. According to the research results, it was proved that it is necessary to develop a methodology to determine the parameters of the salt transfer model based on the average salinity of the washed soil strata before and after cotton irrigation, which are more accurate. The rationale for these methods mainly lies in the fact that the average values of the distribution of salts in the strata, which were integral values, are determined with great accuracy and are more informative than the salt content at any point in the soil.

The proposed method for determining the parameters of salt transfer under the conditions of a stationary water-salt regime of soils, according to the data of both field and laboratory experiments, takes into account the above features. To illustrate the proposed method for calculating the parameter of the convective diffusion coefficient D_a and the hydrodynamic dispersion λ, the dependence is used. The data of field experiments at the lysimetric complex were taken as the initial information.

Components of water balance in the absence of transpiration:

Precipitation: $v_n = 170,2mm / year = 466,301 \cdot 10^{-4} m / day$;

Evaporation: $w_p = 232,8mm / year = 637,808 \cdot 10^{-4} m / day$

Then for the dimensionless velocity we have:

$V = w_p / v_n = 1,3678$; Distribution of salts along the profile:

Concentration of irrigation water: $C_{Ï} = 2g / l$

Groundwater concentration: $C_{ãð} = 16g / l$

Concentration of salts on the soil surface: $C(0) = 328g / l$

The average content of salts in the soil layer: $S(l) = 108g / l$

The depth of groundwater: l = 2.14 m.

Having the above initial data, we first calculate the values of the Peclet parameters, dispersion and diffusion coefficient according to the existing (1) or (2) formulas:

$$\lambda = \frac{w_p l}{2Pe(w_p - v_n)} 1$$

$$D_a = \lambda\left(w_p - v_n\right) 2;$$

$$Pe = \frac{1,3678.(20,5-1)}{2.6,75(1,3678-1)+0,125} = \frac{26,6721}{5,2153} = 5,1142;$$

$$\lambda = \frac{w_p l}{2Pe(w_p - v_n)} = \frac{498,1920}{640,2978} = 0,7781\text{m};$$

$$D_a = \lambda\left(w_p - v_n\right) = 0,778.1,715.10^{-4} = 1,3343.10^{-4}\,\text{m}^2 / day$$

Further, the calculation according to the proposed formula is carried out by the selection method η with known values of S (l) and ω. For the above initial data, we have:

$$\bar{S}(l) = \frac{108}{16} = 6,75; \bar{C}_n = \frac{C_n}{C_{ãð}} = \frac{2}{16} = 0,125; \bar{V} = \frac{w_p}{v_n} = \frac{232,8}{170,2} = 1,3678 > 1$$

$$\omega = \frac{\bar{C}_n}{\bar{V}-1} = \frac{0,125}{0,3678} = 0,3399; \psi_{ex} = \frac{\bar{S}(l)+\omega}{1+\omega} = \frac{6,75+0,3399}{1+0,3399} = 5,2914$$

Since: $w_n / v_n = 1,3678 > 1$, then according to the found value $\psi_{ex} = 5,2914$ and according to equation, that is $f_1(\eta) = (\;^{\eta} - 1) / \eta$, according to the selection method on computer or graph-1, we find the value $\eta^* = 2,7411$ and then determine the value of the parameter λ and the coefficient of convective diffusion D_a:

$$\lambda = \frac{l}{\eta} = \frac{2,14}{2,7411} 0,7807\text{m};$$

$$D_a = \lambda\left(w_p - v_n\right) = 0,7807.1,715.10^{-4} = 1,3389.10^{-4}\,\text{m}^2 / day$$

From a comparison of the values of the variance parameters λ, calculated according to the existing (1) or (2) and the proposed formulas , it can be seen that the obtained values of λ are of the same order of accuracy, and the use of formula greatly simplifies the method of calculating λ, in which knowledge of information about the content of salts on the soil surface C(0) is excessive. The average relative error is Figure 1:

$$\lambda_{sushest} = 0,7781ì\,; \lambda_{offers} = 0,7807m \Rightarrow \Delta = \left|\frac{0,7781-0,7807}{0,7807}\right|.100\% = 0,33\%$$

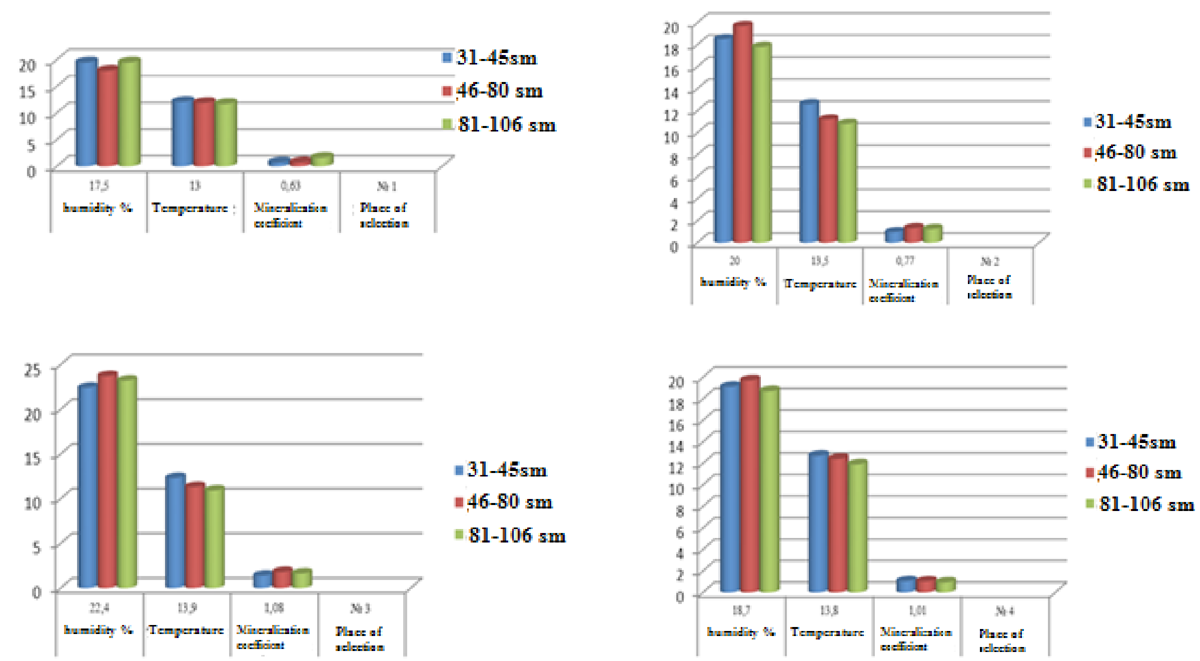

Figure 1 Diagrams of the results of calculating the water-salt balance of the study area.

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Conclusions

A method has been developed for determining the parameters of salt transfer under the conditions of furrow irrigation of cotton based on the average salinity of soils of a given thickness, before and after irrigation, according to the data of field experiments on the lysimetric complex. Based on the solution of the salt transfer model, which describes the process under the conditions of a stationary water-salt regime of the soil-soil of the aeration zone, it is possible to determine the parameter of convective diffusion from the average soil salinity, both in the absence and in the presence of transpiration. The main advantage of the method is the simplification of the computational procedure and the reliability of the values of the convective diffusion parameter, since the initial information on the salt content on the soil surface, which is difficult to determine in reclamation practice, is not used in the calculations.

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Conflict of interest

The authors declare, that there is no conflict of interest.

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