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Impact of Surface Irrigation on the Intensity of Irrigation Erosion

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Abstract

Nowadays, in the world preference is given to the method of surface furrow irrigation. When using this method, compliance with the ecological balance of the environment and obtaining a designed crop yield are complicated, if the irrigation water is not regulated with taking into account an additional factors. Particularly, Irrigation should be carried out in such a way that there would not be a "transfer" of the surface flow, seepage of water deeper than the moisturizing designed project layer, etc., i.e. compliance with irrigation rates and hydromodule values should be realized, taking into consideration the surface and seepage-infiltration losses. In the given article, among the received equations for calculation of irrigation rate, the irrigation rate is directly proportional to the volume of water supplied and depends on the length of the stream, i.e. the length of the strip of irrigation furrow, and physical and mechanical properties of soil.

Key words: surface irrigation; irrigation erosion; irrigation rate; seepage; infiltration.

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1. Introduction

Among the factors responsible for irrigation soil erosion, the main role is assigned to the amount of water supplied to the irrigated areas, since the influence of hydro-mechanical force of flow determines the statistical and dynamic forms of equilibrium of irrigation earthen canals. As it is known, the relationship between soil and flow is integrally reflected in the formation of erosion processes of varying intensity. In this regard, among irrigation technologies, the most optimal is considered subsoil capillary water supply - "natural automation", because It prevents disturbance of soil structure, reduces water loss, facilitates regulation of water and air regime in the active soil layer, ensures normal growth and development of plants, etc. It should be noted that due to the complexity of implementation of this irrigation technology and its high cost, for today, in the world preference is given to the method of surface furrow irrigation. In a case of surface irrigation, observance of the ecological balance of the environment and obtaining a designed crop yield are complicated if irrigation water regulation does not take into account including additional factors. Particularly, Irrigation should be carried out in such a way that there would not be a "transfer" of the surface flow, seepage of water deeper than the moisturizing designed project layer, etc., i.e. compliance with irrigation rates and hydro-module values should be realized, avoiding the surface and seepage-infiltration losses [1].

2. Materials and methods

For today, a reliable forecast of infiltration processes, dynamics of the hydrological regime and a reserve of productive water in the active soil layer is based on the integral seepage and capillary characteristics of water permeability, i.e. the accuracy of the calculation of the seepage coefficient, which expresses the variability of the seepage and capillary potential in the soil, on the basis of which, the water supply schedule and the irrigation rate can be adjusted during any time of crop growing and development stages [2]. In the process of calculating these parameters, ignoring certain factors leads to such negative results as the emergence of progressive irrigation erosion centers, rise of intensive groundwater level, etc. Nowadays, many mathematical models have been obtained, whereby a picture of the dynamics of seepage and infiltration of water into the soil is described. Above mentioned models are mainly based on the theory of mass and heat exchange and are a complex system of hyperbolic type equations with a partial arbitrariness, the solution of which clearly indicates the need for an accurate determination of the seepage coefficient taking into consideration the pressure gradient [3]. During the strip irrigation a certain part of the irrigation water flows over the surface, and the second part seeps into the soil. The velocity of the seepage flow, according to Darcy's Linear Law, can be expressed by the following equation:

$$V = KI = K\frac{h+z+h_k-h_p}{z}, \qquad (1)$$

Where: K is seepage coefficient;

I - pressure gradient;

h - width of water layer on the soil surface;

h_k - height of capillary pressure;

h_p	-	Pneumatic air pressure clogged in the pores of the soil
z	-	Coordinate of the movement of water front at the soil depth.

During incomplete filling of the soil with water, which is characterized by the pre-irrigated period, the dynamics of the velocity of water absorption is expressed by the following equation [4]:

$$V_a = K_t I_t = \frac{K_0}{t^{\alpha}}, \qquad (2)$$

Where:	V_a	is	water absorption velocity at any point of time;
	K_t	-	coefficient of water conductivity;
	I_t	-	pressure gradient;
	K_0	-	ccoefficient of water conductivity during the first unit of time;
	α	-	exponent which is selected within 0,3-0,8;
	t	-	absorption time.

It is easy to observe that there is a complete analogy between (1) and (2) equations, since in (1) equation the gradient is a function of z, however z is a function of time.The general nature of the variability of the velocity of water absorption can be represented by an approximate curve (see fig. 1):

$$V_a = V_\infty + (V_0 - V_\infty)e^{-\alpha t} \qquad (3)$$

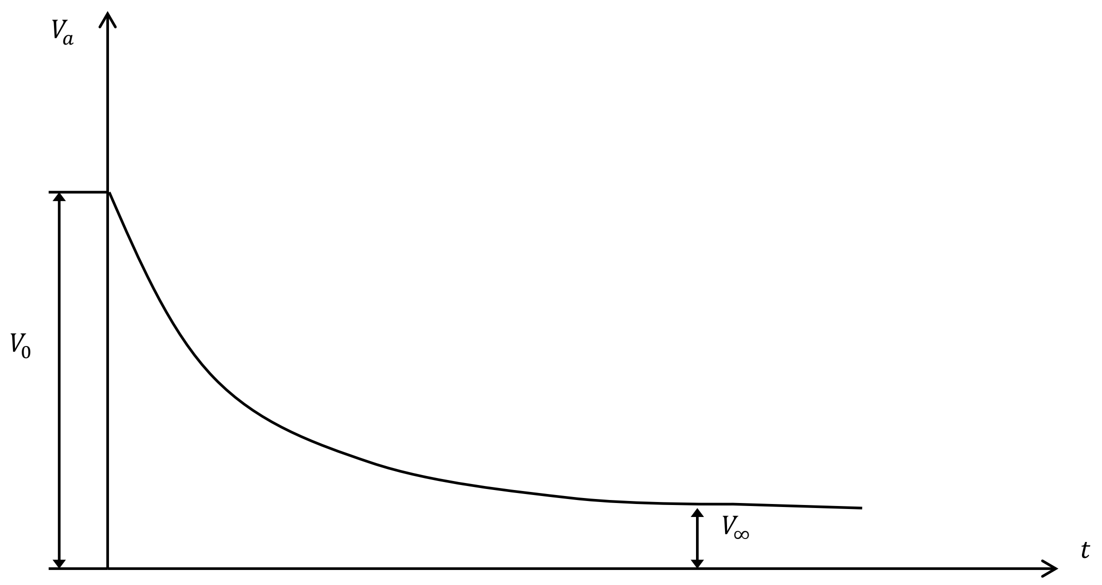

Figure 1: Curve illustrating the dynamics of water conductivity

Equation (3) satisfies the following boundary conditions: $t = 0$; $V_a = V_0$; $t = \infty$; $V_a = V_\infty$. $t = \infty$ is the time when the tangents at the given point of the curve are collinear to the $t$axis. Despite these remarks, in order to perform the comparison, we use the equation (2). According to this, the average percolation rate is determined as [5]:

$$V_a = \frac{1}{t}\int_0^t \frac{K_0}{t^\alpha} dt = \frac{1}{1-\alpha}\frac{K_0}{t^\alpha}. \quad (4)$$

According to the equation (4), the average value of the infiltration coefficient in a given time interval will be equal to:

$$\overline{K} = \frac{K_0}{1-\alpha}. \quad (5)$$

The K_0 coefficient and a exponent are determined according to the experiments, under the conditions of an undisturbed structure and full water saturation of the presented soil. Within the framework of the task set by us, towards the accountant of the variability of certain parameters and their probabilistic-statistical support is not given special significance. It evenly affects upon the results of the use of existing and recently obtained mathematical models. A necessary condition for excluding water erosion of the soil, based on the refinement of some parameters, requires the correction of the mathematical model. Theoretical study of strip irrigation provides an opportunity to determine the duration of irrigation and the selection of the technological scheme, which will ensure the maximum effect of irrigation and complete exclusion of the soil water erosion. In the mathematical models, non-uniform and often unsteady motion of water is replaced by equal resistance expressed by the well-known Law of Chezy.In this case, non-hydraulic formulas for the motion of a variable mass on the path are used, and the most common mathematical model is the conservation of the law of constant mass.

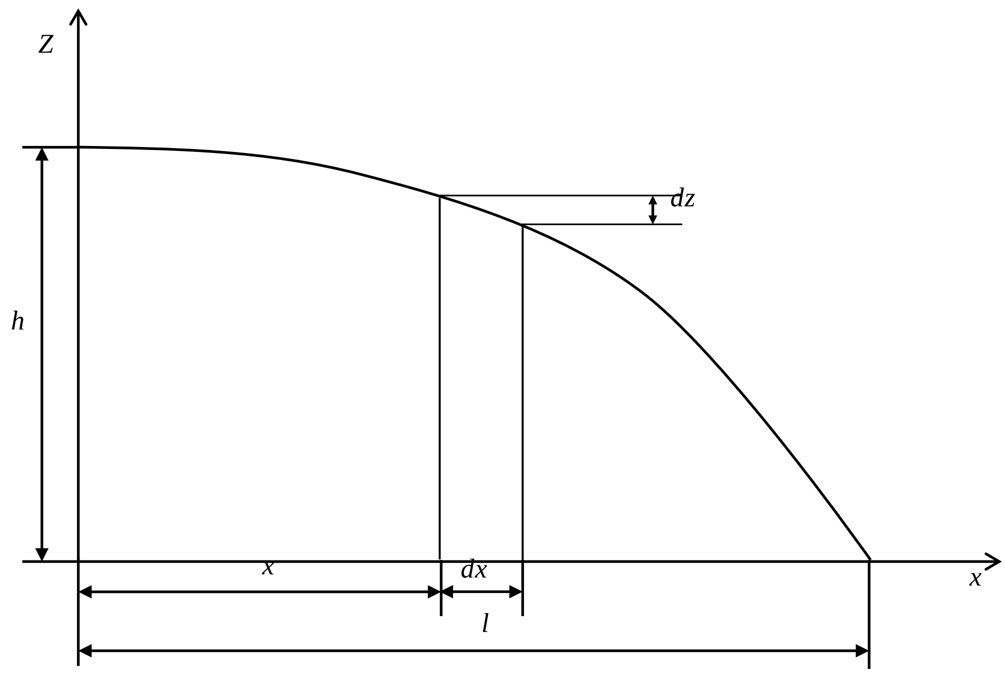

Figure 2: The design scheme of the free flow surface

According to the design scheme shown on the fig. 2, it is considered that a layer of water that has a $h$depth at the beginning of the irrigation strip, for a certain period of $t$time, is completely absorbed by the soil on a certain length$l$.According to the presented slope and the coefficient of water absorption, it is necessary to determine the shape of the curve of the free flow surface. The average velocity of a flat flow outlying at x distance from the head of an irrigation strip will be:

$$V_x = \frac{87\sqrt{z}}{\delta+\sqrt{z}} \cdot \sqrt{zi}, \quad (6)$$

Where: δ - coefficient of rroughness of the surface of irrigation area, which is taken within 1,4-4,0;

i - slope of the surface or irrigation area.

The water depth practically varies within the (1,4-4,0)10^{-2} m, therefore, it is relatively unmatched and may be ignored. Specific water flow in the x section:

$$q_x = \frac{87\sqrt{z}}{\delta}\sqrt{zi} \cdot z = az^2, \quad (7)$$

Where: $a = \frac{87\sqrt{i}}{\delta}$.

The difference between the water flows in sections with z and z_1 flow depths will be:

$$\Delta q = az^2 - a(z-dz)^2 = 2azdz. \quad (8)$$

Δq–The percolation of water at dx distance and its accumulation on the surface determine the specific flow rate. The greater the specific flow q at the head and the smaller the surface roughness and slope, the greater the amount of accumulated water at x length of the irrigation strip. The ratio β between the amounts of accumulated and percolated water is directly proportional to the flow rate q, and is inversely proportional to the slope i.The average rate of percolation of water into the soil at a certain distance x in the time interval t will be $\beta K_0/t^{\alpha}$, and the equation of the water balance will take the following form:

$$2azdz + \beta\frac{K_0}{t^{\alpha}}dx = 0. \quad (9)$$

Integration of this equation and the use of boundary conditions x=0; z=h, gives us:

$$a(h^2 - z^2) = \frac{\beta K_0}{t^{\alpha}}x. \quad (10)$$

If the x distance is taken as the distance of the decrease of the flow for the time t when irrigation is completed, when z=0, then according to the equation (10), we will get:

$$ah^2 = q = \frac{\beta K_0}{t^\alpha} x, \tag{11}$$

According to which it is easy to determine the distance x of the flow run:

$$x = \frac{q}{\beta K_0} t^\alpha. \tag{12}$$

3. Results

In the balance equation (9) of water run-off, the gradient of the seepage head, the value of which varies from infinity to unity, does not participate explicitly.If we take into account the change in the gradient in the form of a linear function I=1+$a_0 z$, then the differentiated equation takes the following form [6]:

$$2azdz = \frac{\beta K_0}{t^\alpha}(1 + a_0 z)dz. \tag{13}$$

When integrating (13) equation, with respect to the equation q=ah^2, we obtain:

$$x = \frac{q}{\beta K_0} t^\alpha \frac{2}{(a_0 h)^2}\left[a_0(h - z) + ln\frac{1+a_0 z}{1+a_0 h}\right]. \tag{14}$$

If we assume that:

$$r = \frac{2}{(a_0 h)^2}\left[a_0(h - z) + ln\frac{1+a_0 z}{1+a_0 h}\right],$$

We will get:

$$x = \frac{q}{\beta K_0} t^\alpha r. \tag{15}$$

This equation according to the parameter r differs from the equation (12), which in turn is a function of z and takes into account the variability of the gradient of the seepage head according to the depth of infiltration.To compare (14) and (12) equations, for the purposes of illustration, for a specific example, a calculation is carried out when $a_0 h$=1,72, gives us, that r=0,5, which means that the length of flow run according to the (12)equation is twice the value obtained by equation (14). This result indicates how significant the gradient is taken into account when determining the mean flow run, which is one of the main elements of irrigation technique. Obviously, other elements of surface irrigation, calculated with the help of the equations obtained by us, can be subjected to appropriate adjustments.

The depth of surface runoff, according to the equation (10), when q=ah^2, is calculated by the following equation:

$$z = h\sqrt{1 - \frac{\beta K_0}{q t^{\alpha}} x}. \tag{3.16}$$

From this equation it is obvious that with increasing t, the depth of the flow in a fixed section gradually grows and approaches the depth h, which is schematically illustrated on the figure 3 by means of the curves presenting the variability of the depth of the surface flow.

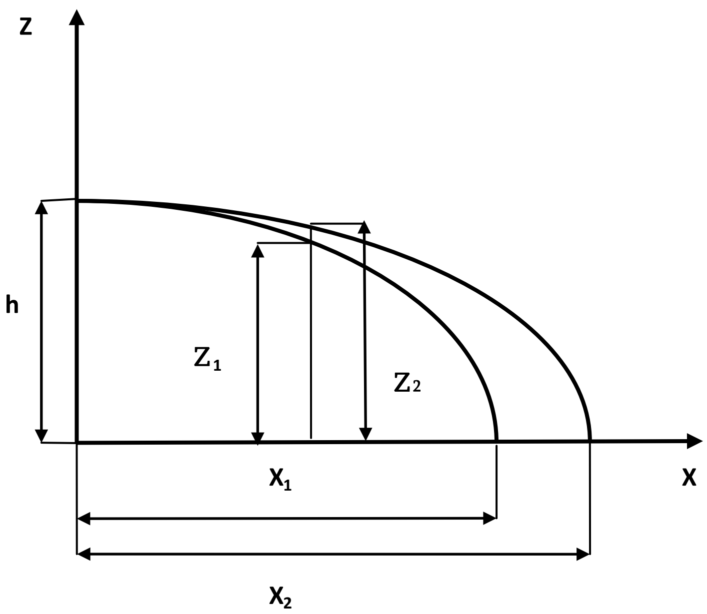

Figure 3: The curve for the variability of the free flow surface. $z = f(x);\ \ x = \varphi(t)$

The specific flow of transferred water for the moment *t* is calculated:

$$q_x = q \cdot \left(1 - \frac{\beta K_0}{q t^{\alpha}}\right). \tag{17}$$

The proportion of water transferred will be the greater, the higher the flow at the beginning of irrigation strip, the smaller the length of the strip and the low possibility of water absorption. Also, the specific proportion of the transit flow increases proportionally to the duration of irrigation. The distribution of moisture over the entire length of the irrigation strip depends on the duration of the irrigation period. During of a period of time *t*, a surface runoff occurs at the end of the irrigation strip, which varies from the zero flow value to a certain value, which eventually decreases to zero. The total amount of water that drains at the end of the irrigation strip can be determined according to the following equation:

$$W = qt = \frac{mx}{1-\sigma}, \tag{18}$$

Where: m Is an irrigation rate;

σ - Ratio between run-off and supplied water.

The equations obtained above make it possible to determine the elements of gravity furrow irrigation x, t, q , which, in particular soil and relief conditions, will satisfy the uniform moistening of the soil, the planned supply of the required amount of irrigation water, and provide minimum seepage losses and other boundary requirements.

4. Conclusion

Proceeding from the abovementioned, according to the transformation of the formula (18) obtained above, the equation for calculation of irrigation rate will be looks like:

$$m = \frac{W(1-\sigma)}{X}(m^3) \tag{19}$$

From this equation it is obvious that the irrigation rate is proportional to the volume of water supplied and depends on the length of flow run, i.e. on the length of the irrigation strip and the physical and mechanical properties of the soil.

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