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*Ecology*

# Impact of Irrigation Water on the Irrigation Mode Considering Rheological Indices

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**Ongoing seepage process in the soil body is a function of hydro-physical processes. According to the assessment mechanism it is equally relevant for both arid and wetland areas. The granular-porous body according to the modern view of scientists represents the soil, which is selected to produce various types of agricultural crops. According to the hollowness, its body is traced in a labyrinth, and between the particles of the solid component, formation of different types of water categories is taken place. The regularity of water seepage in the labyrinth system does not obey the resistance law, which is typical for Newtonian fluids. The complete representation of the events taking place in soil's body, while adapting the models to the real process, relates to the necessity of developing in fundamentally different methodology. The chemical potential of ground water formed in the pore space by the forces of energy fields is diametrically different from the liquid in a free state. Dispersion of the solid part of the soil for the purpose of energy balance is necessary to proceed independently of temperature and chemical processes. During the selection of calculation models, the boundary layer is unchanged during the movement of fluid in the soil. The initial resistance to the shift represents the abnormality of the layer formed during the solution of engineering tasks. Based on the model proposed in the paper, the possibilities of porosity variation and its maximum value are established. Considering the layer of water supplied for irrigation, the velocity formula is derived for the case of seepage.** *© 2024 Bull. Georg. Natl. Acad. Sci.*

rheology, irrigation water, seepage, porosity, viscosity

The management of natural resources and its rationalization in the direction of agriculture is especially important from the point of view of sustainable development.

The use of water as a scarce resource in irrigation-drainage or overcoming its excess is related to soil potential, crop water needs and migration capabilities.

The movement of water in the soil labyrinths is recorded after the pressure gradient exceeds the threshold value. The possibility of flow initiation by surrounding the bound water on the soil constituent particles and forming apses on the surface can be explained.

Taking into consideration the presented category of water formed on the surface of soil particles is interesting from the point of view that it is radically different from the usual one, it is formed by energy of different nature, and it is characterized by the properties of a quasi-solid body and initial resistance to displacement.

## Main Part

From physical and chemical points of view, creation of seepage-capillary models of soil aggregation and derivation of the calculated dependence of operating agents are associated with the dispersion of the constituent aggregates of the solid part, processes occurring in the plane of dividing surfaces, dynamics of changes in humidity due to anomalies of seepage-capillary processes and microbiological characteristics [1,2].

The determining criteria for the movement of water in the soil are the intensity of the acting forces, the axonometry of the porous space and the relevant rheological characteristics of the concentration. In the growth and development of the plant, along with the mentioned, the role of the films surrounded by particles is important on the water consumption capacity of the plant, irrigation and drainage flow, estimation of irrigation and draining rate, when considering porous models on the hydraulics of water movement, capillary processes, soil water permeability and the formation and nature of the initial gradient. A special interest of the research is the axonometry of the pore space during water supply to the plant from the irrigation area, which is difficult to modify with the analogue of the quasi-solid body properties model [3,4].

Natural hydrological resources play a special role in irrigation. Management of the irrigation regime in such case is a function of the change of soil characteristics, the water demand of agricultural crops, and the interaction of water with the soil. Fluid movement in the structural body of the soil often does not follow the law of resistance characteristic of Newtonian fluids. Therefore, Darcy's law – the expansion of the boundaries – considering the contact of water on a part of the soil, remains an actual issue.

In order to determine the dynamic parameters of water movement in the soil, various types of models have been proposed, according to which the porous system of the soil is modelled with a tube. The movement of fluid in an individual tube of a tubular soil system is adapted to the model of fluid moving along with gradient layer and core. Therefore, several features represent the movement of liquid in the pipeline [5].

The concentration of water on the inner surface of the pipe gives it quasi-solid properties. In order to set it in motion, it is necessary to have a corresponding gradient layer. Therefore, displacement due to high density can have several peculiarities.

According to the degree of water filling of the pipeline, the active porosity of the soil can be represented by a mathematical model [6,7]:

$$m = \frac{\pi r^2 - \pi \left(r - r_0\right)^2}{\pi r^2}, \qquad (1)$$

where $r_0$ is the radius of the fluid moving in the pipeline; $r$ – the inner radius of the pipeline, and $\left(r - r_0\right) = r_1$ is the thickness of the water concentration on the wall of the pipeline.

In the case of the solution of the first equation to the $r_1 / r$:

$$\frac{r_1}{r} = 1 - \sqrt{1 - m}\,. \qquad (2)$$

The degree of filling of the cross-section of the pipeline with water is equal to:

$$r_0 / r = \sqrt{1 - m}\,. \qquad (3)$$

The maximum porosity can be determined by the point of intersection of equations (2) and (3) or graphically.

An illustration of the graphical intersection point of the equations is given in Fig. 1.

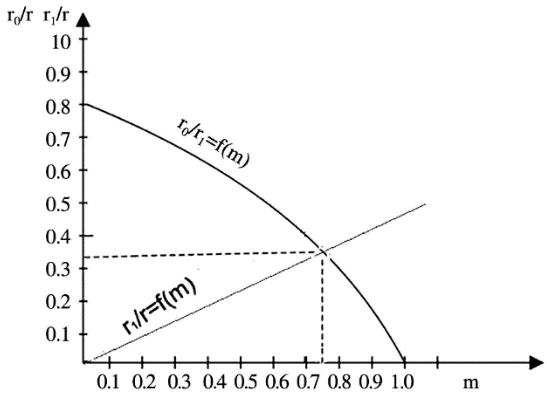


**Fig. 1.** Relation Graph $\frac{r_0}{r_1} = f\left(m\right)$ and $\frac{r_1}{r} = f\left(m\right)$.

The point of intersection of the graphs corresponds to the porosity value – m=3/4=0,75.

Irrigation water is often delivered through the soil on the reclamation draining or irrigated area with or without head pressure. In the case of pressurized (pressure head) movement, when water flows through a system of pipelines with radius $r$ in the soil and it is represented by a system of parallel axes, the fluid to be transported is characterized by a kinematic coefficient different from water. Corresponding equivalent values of the viscosity are represented by depth $h_0$ or radius $r_0$. The local velocity change in the pipeline section is represented by the $u$ magnitude and the pressure variation in the selected sections is represented by the $P_1$ and $P_2$ values. The distance between the sections is equal to $\ell$ and the movement of a fluid can be represented by the following model [8,9]:

$$-\mu\frac{du}{dz}=\frac{p_1-p_2}{2\ell}\left(r_1-r_0\right)\psi, \tag{4}$$

where $\mu$ is the coefficient of viscosity of the mud (Ns/cm[4]); $U_x$ – the value of the local velocity in the gradient layer (m/s); $r$ – radius of the flow in the pipeline and its maximum value (m); $P_1$ and $P_2$ are head pressures acting in the initial and final sections of the pipeline (N/m[2]); $\ell$ – the length of the pressure pipeline (m); $r_0$ – the size of the centre of the moving stream (m); $\psi$ – a coefficient, which depends on the angle $\varphi$ of internal friction $\psi=\tan^2\left(45°-\frac{\varphi}{2}\right)$.

Average velocity in the case of head motion:

$$V=\frac{\gamma u^2}{3\mu}\psi^2\left[0.5+-\frac{r_0}{r}\left(1.25\frac{r_0}{r_1}-1\right)\right]. \tag{5}$$

Average velocity during the head-free motion:

$$V=\frac{\gamma u^2}{3\mu}\psi^2\left[1-\frac{h_0}{h}\left(1.5-0.5\frac{h_0}{h_1}\right)\right]. \tag{6}$$

In order to obtain the calculation relation of seepage during the soil represented by the tubular system, in the case of the coefficient of hydraulic resistance λ, length, radius $r$, hydraulic radius $R$ and average velocity of the pipeline $u$, the magnitude of the head loss [10]:

$$h=\lambda\frac{l}{4R}\frac{u^2}{2g}. \tag{7}$$

Based on the representation of the Reynolds number with a functional relationship with the value of the hydraulic radius and by marking the complex of dimensionless quantities with $\pi$, we will get:

$$I=\frac{h}{l}=\frac{\lambda}{4R}\frac{V^2}{\left[f\left(\beta\right)\right]^2}\frac{1}{2g}. \tag{8}$$

Based on the simplification and transformation of relation (8), in the case of linear laminar seepage, when $n$=1:

$$V=\frac{8gI}{A}f\left(\beta\right)^2\frac{R^2}{\alpha}. \tag{9}$$

In the (9)-the relation $\frac{8R^2}{A}$ according to the seepage theory, it is known as the coefficient of water permeability and has the dimension of are:

$$K^1=\frac{8R^2}{A}. \tag{10}$$

Considering (10) in (9):

$$V=\frac{K^1 gIf\left(\beta\right)^2}{\alpha}. \tag{11}$$

Because the kinematic coefficient of viscosity ν=μ/ρ, we will get:

$$V=\frac{\gamma}{\mu}K^1If\left(\beta\right)^2. \tag{12}$$

When the water permeability in a case of $m$ porosity is equal to $K^1=\frac{k_0}{m}$, then the value of the average seepage rate $V_f^n$, when the product $mV=V_f$ and $\frac{K_0\gamma}{\mu}=K$,

$$V_{\text{з}}^{\text{б}}=V_{\text{з}}f\left(\beta\right)^2. \tag{13}$$

In the case of laminar filtration, when the pressure gradient exceeds a certain value, i.e. the value corresponding to the critical pressure, the value of which can be considered as the initial value of the gradient, and the functional

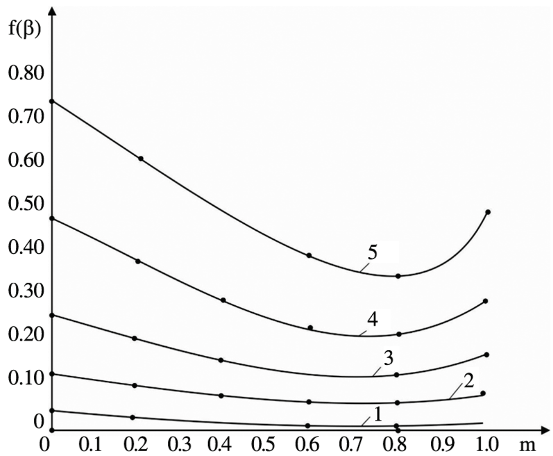


**Fig. 2.** Graph of relationship $f(\beta) = f(m)$;
$1.\psi = 0.2$; $2.\psi = 0.4$; $3.\psi = 0.6$; $4.\psi = 0.8$; $5.\psi = 1.0$.

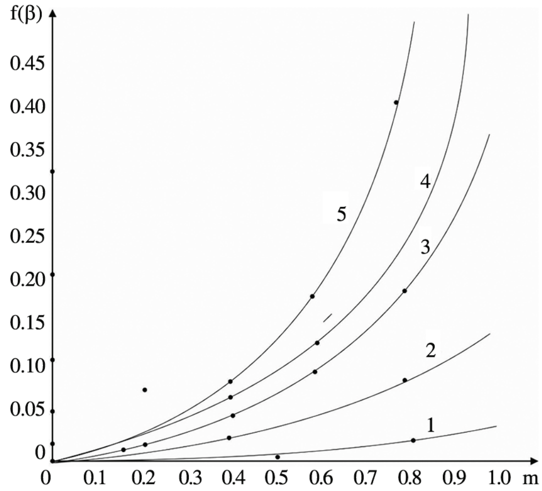


**Fig. 3.** Graph of relationship $f(\beta) = f(m)$;
$1.\psi = 0.2$; $2.\psi = 0.4$; $3.\psi = 0.6$; $4.\psi = 0.8$; $5.\psi = 1.0$.

relationship between the water seepage velocity and the gradient is represented by the equation $V = KI - KI_0 = KI\left(1 - \frac{I_0}{I}\right)$, then the value of filtration rate for irrigation water is equal to:

$$\frac{V_{з}^{б}}{V_{з}} = KI\left(I - \frac{I_0}{I}\right) f(\beta)^2. \quad (14)$$

The relationship can be used to calculate the value $f(\beta)^2$ during the pressurized motion of irrigation water:

$$f(\beta)^2 = \psi^2\left[0,5 + \sqrt{1-m}\left(1,25\sqrt{1-m} - 1\right)\right]^2, \quad (15)$$

and during non-pressurized motion:

$$f(\beta) = \psi^2\left[1 - \sqrt{1-m}\left(1,5 - 0,5(1-m)\right)\right]^2. \quad (16)$$

The values of the $f(\beta)$, when determining the filtration rate of irrigation water, are presented in the form of graphs (Figs. 2, 3).

## Conclusion

The soil, which is represented by micro- and macro-sized particles of various orders, according to the modern opinion, is considered as a dispersed-hydrophilic porous system. Between its solid particles, different categories of water are arranged differently. Since microcapillary dimensions represent the pores of the soil, water migrating through its body acquires specific properties. Considering the specific surface of the water-permeable pores and other main indicators, new equations have been obtained, which are used to calculate the seepage rates of irrigation water. Taking into account the influence of water on seepage processes, the impact of rheological indices on the irrigation process is obtained.

*ეკოლოგია*

# მორწყვის რეჟიმზე სარწყავი წყლის გავლენა რეოლოგიური ინდექსების გათვალისწინებით

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ნიადაგ-გრუნტის ტანში მიმდინარე ფილტრაცია წარმოადგენს ჰიდრო-ფიზიკური პროცესების ფუნქციას. შესაბამისად, შეფასების მექანიზმი თანაბრად აქტუალურია როგორც არიდული, ისე დაჭაობებული ზონებისათვის. ნიადაგი, რომელიც სხვადასხვა სახის სასოფლო-სამეურნეო კულტურათა წარმოების მიზნითაა შერჩეული, მეცნიერთა თანამედროვე შეხედულებით მარცვლოვან-ფოროვან სხეულს წარმოადგენს. სიცარიელის მიხედვით მისი ტანი დაქსელილია ლაბირინთულად და მყარი შემადგენლის ნაწილაკებს შორის ადგილი აქვს სხვადასხვა სახის წყლის კატეგორიების ფორმირებას. ლაბირინთულ სისტემაში წყლის ფილტრაციის კანონზომიერება არ ემორჩილება ნიუტონური სითხეებისათვის დამახასიათებელ წინააღმდეგობის კანონს. მის ტანში მიმდინარე მოვლენების სრულად წარმოჩენა, მოდელების რეალურ პროცესთან ადაპტაციის დროს, პრინციპულად განსხვავებული მეთოდოლოგიის შემუშავების აუცილებლობასთან არის დაკავშირებული. ენერგეტიკული ველების ძალებით ფოროვანი სივრცის არეში ფორმირებული გრუნტის წყალი ქიმიური პოტენციალით დიამეტრულად განსხვავებულია თავისუფალ მდგომარეობაში მყოფი სითხისაგან. ნიადაგის მყარი ნაწილის დისპერსია ენერგეტიკული წონასწორობის მიზნით აუცილებელია მიმდინარეობდეს ტემპერატურული და ქიმიური პროცესებისაგან დამოუკიდებლად. საანგარიშო მოდელების შერჩევის დროს ნიადაგ-გრუნტში სითხის მოძრაობის დროს სასაზღვრო შრე არის უცვლელი. საინჟინრო ამოცანების გადაწყვეტის დროს ფორმირებული შრის ანომალურობა ძვრისადმი საწყისი წინააღმდეგობითაა გამოსახული. ნაშრომში შემოთავაზებული მოდელის საფუძველზე დადგენილია ფორიანობის ცვალებადობის შესაძლებლობები და მისი მაქსიმალური სიდიდე. სარწყავად მიწოდებული წყლის ფენის გათვალისწინებით, ფილტრაციის შემთხვევისათვის გამოყვანილია სიჩქარის საანგარიშო დამოკიდებულება.

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