The use of current sources in electrokinetics to create independent irrigation stations

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Abstract. In order to implement agricultural products plantation it has been suggested to take the advantage of electrokinetic phenomena with the account of the technology multifactority and relaxation phenomena. The issue of energy cost reduction with new approaches, influencing the process of irrigation of the soil root layer and saving natural resources has been considered.

1. Introduction

The technology of crops growing with electrical irrigation as an alternative to the traditional one has been suggested by X. Opitz and today it is important and rather perspective in agriculture.

This technology suggests constructing a network of irrigation canals and using the sprinkling equipment. In this way a part of useful area is occupied with irrigation canals and pathways for the sprinkling equipment, in other words it is not used for its functional purpose. It causes some undesirable phenomena: in the watered top soil layer there appear fungi, moss, slugs; intensive watering washes out the fertilizers which pollute the underground waters, excessive watering decreases productivity.

2. Materials and methods

The suggested method of the root layer irrigation applies electroosmotic effect. In the root layer (about 30 cm) there is a network of conductors. The network is connected with the negative pole of the DC source. The second electrode is placed at the level of the underground waters. It is a steel tube connected with the positive pole of the source. The electrodes are under the electric voltage from 2 to 12W depending on the chemical composition of the soil and salts content. When the electric field is active the underground waters rise up and moisture the root ecosystem regularly. Herewith, water is purified from salts; they precipitate on the anodes, which is important when the salt content is high. The upper layer is dry and loose, and undesirable organisms do not appear in it. Also, due to electrodialysis water becomes of basic reaction and stimulates the plants growth. Electrokinetic phenomena reflect the connection between the relative motion of two phases and electrical properties of their border. Electrokinetic phenomena appear when one phase is dispersed in the other and the system is microheterogeneous. There are four groups of electrokinetic phenomena according to An-tropov [1]:
- electroendosmose,
- electrophoresis,
- flow potential,
- precipitation potential.

We think, that in physics the flow potential should be called difference in potential or osmo-e.m.f., and precipitation potential pho-e.m.f.

The process of electrokinetic energy-mass-transfer is mass transfer in colloid systems when the external electrical field overlaps or is accompanied with generating of the own electrical field of the colloid system.

The colloid systems consist of two phases:
- dispersed phase;
- dispersion medium,

That is they are heterogeneous. When crushing matter, the energy spent on bond rupture between the compounds is cumulated as latent energy of un-saturated bonds at the border of phase separation. When the surface area is huge this excessive surface energy is of huge value. Consequently, the matter in the colloidal state has greater energy, greater activity, than uncrushed matter of the analogous composition.

The main reason for the electrokinetic energy-mass-transfer is double electric layer (DEL): in the electrically conductive dispersion medium round the dispersed particle of the dielectric material the ions of the same sign adsorb on the uncharged surfaces due to dispersion forces which appear due to fluctuation of the atom electron shells. This phenomenon (forces) is called the specific adsorption forces. The latter depend on polarization that is action of this ion on the surface atoms, and its ability to deform their electron shells. Ion polarizing power depends on the power of its electric field.

3. Results

Basing on the theory by Gouy-Chapman the model of the electrical double layer is based on ion mobility of the external shell. Their electrostatic attraction to the surface and ions repulsion of the same charge with the surface is balanced with the ion temperature motion, which washes away surface superfluity. Appearing equilibrium division forms a “cloud” of electrical charges near the solution surface with diminishing density, which is analogous to that one between the atmosphere gases. In the electrical field the counterions of the diffusive DEL-layer, which are loosely coupled energetically with the surface of the solid phase (membrane), will transfer to the corresponding electrode and thanks to the molecule friction pierce the dispersion medium (aqueous electrolyte solution). The greater the electric field intensity and the diffusive layer are the greater the number of charge-carriers is, then the liquid translates quicker in the porous body or a dispersive particle in the conductive dispersion medium. Here, the liquid volume velocity at electroosmosis is described by the equation:

$$V = \frac{I^*e^*e_0^*\xi^0}{4\pi\eta^*\gamma^*}$$

where $I$ is electric current intensity; $e$ is liquid dielectric constant; $e_0$ is dielectric constant in vacuum; $\eta$ is the coefficient of internal friction (viscosity); $\gamma$ is liquid specific conductivity; $\xi$ is electrokinetic potential.

Equation 1 is Helmholtz - Smolukhovskii equation, is often written respective electrokinetic potential $\xi^0$:

$$\xi = \frac{\eta^0U_0}{e^*e_0^*E^*}$$

where $U_0$ is constant linear velocity of liquid via the membrane; $E$ is electric field intensity.

When the homoporous membrane is present, that is it consists of the capillar of the same cross-section, with the capillar radius increase, at keeping constant potential gradient of the external field on
the membrane it is necessary to achieve such a ratio when constant liquid flow in capillar is impossible due to greater inertia forces. Here $V/I$ and $\xi$ must turn “0”.

Most often the homoporous membrane is used in the construction or chemical industry; it is also used in electroosmosis in clays and sandy clays and so on, where the disperse fraction is rather homogenous.

But a real membrane is heteroporous with capillars of different radius and some curvature of pore sizes distribution characteristic for agriculture.

Pore radius increase in such a membrane usually leads to that in bigger capillars at this potential gradient the driving electric force which equals $\nabla \phi$ multiplied by the surface charge is not enough to receive a steady flow and the electroosmotic transport will cease.

Together with that the motion of ions in the electric field in these capillars continues then the electric current $I$ continues too, if the membrane porosity degree has not changed greatly there will be no current decrease. The volume of the transported liquid $V$ will decrease, that will result in decrease of $V/I$ .

$V/I$ decrease and $\xi$ must be proportional to the ratio of big capillars cross section which do not participate in the electroosmotic transport to the total cross-section area of the capillar membrane. Improving the equation of the electroosmotic mass transport forms an equation 3 for the stabilized mode along the axis parallel to vector $E$:

$$
\Delta p = \frac{8 \varepsilon \xi}{r_0^2} \Delta \phi - \frac{8 \eta l}{S_{np} \pi r_0^2} G
$$

$$
I = \frac{\sigma S_{\nu}}{l} \Delta \phi
$$

where $\Delta p$ is electroosmotic pressure; $\varepsilon$ is dielectric permittivity in the dispersed phase; $\xi$ is flow potential; $\Delta \phi$ is difference of the potentials of the electric field on the membrane; $\eta$ is dispersion medium viscosity; $l$ is a membrane length; $S$ is the effective cross section of the membrane; $r_0$ is the radius of the cylindrical hole (pore) in the membrane; $G$ is fluid flow through the capillar; $\sigma$ is fluid conduction.

These dependencies rather clearly and correctly determine the dependencies mentioned above, describe the processes and phenomena happening in case of homogenous dispersions and a stabilized mode. With the account of re-laxation phenomena while conducting works with real heterogeneous systems there are deviations which should be taken into account making adjustments for the x-potential [3]. The key efficiency criteria of the technological process will be the energy efficiency – specific energy consumption for the functional process fulfillment and production process on the whole. In analyzing the technology of electroirrigation they are specific energy consumption for transportation of a volume unit of water. Having starting data about energy and water consumption for the process we can calculate the specific energy consumption on the water extracted:

$$
W = W/M_x; [\text{kWh/kg}],
$$

where $W$ is energy consumption for the process, kWh; $M_x$ is mass of the extracted water, kg.

Having the data on the initial moisture of the material $B_1$ and the necessary final $B_2$, we can calculate the water mass necessary to extract $M_x$, with the material balance equation if the separation process [3].

Implementing the technology of water transfer with electroosmosis if water is present in the transported liquid fraction $B_x \approx 1$ we can receive:
\[ M_1 = M_x + M_2 \]
\[ M_1(1-B_x) = M_x(1-B_x) + M_2(1-B_2) \]
\[ M_1B_1 = M_xB_x + M_2B_2 \]
\[ M_x = M_1 \left( \frac{B_x - B_1}{B_2 - B_x} \right) \]
\[ M_1 = M_x + M_2 \]
\[ M_1(1-B_1) = M_2(1-B_2) \]
\[ M_1B_1 = M_xB_x + M_2B_2 \]
\[ M_x = M_1 \left( \frac{B_2 - B_1}{B_2 - B_x} \right) \]  

(5)

Where \( M_1, M_x, M_2 \) are masses of the initial mixture, liquid fraction, extracted from the mixture and received by processing the particulates, kg;

\( B_x, B_1, B_2 \) is water content or dispersion phase in the initial mixture, in the liquid fraction or received particulates, v. units.

Further the total power consumption of the process can be determined:

\[ W = wM_x \] [ kWh].

(7)

Basing on the specific electrical resistivity of the substance and electrode voltage let’s determine the run current of the installation and the processing time. In electrical irrigation of the root soil layer it is necessary to take into account electrical characteristics of every soil layer and subsoil different to the water drawdown technology [4] where the electric field gradient goes along the layers and can lead to certain difficulties.

Besides the mentioned above variables the phenomena and processes accompanying electroosmosis should be taken into account:

- pressure loss,
- moisture conductivity loss,
- osmosis loss,
- electrolysis loss,
- losses for dielectric polarization in the dispersed phase,
- liquid electroheating losses,
- thermoosmosis operation, diffusiophoresis, ionophoresis, dipolophoresis.

We can say that the process of distribution energy flows, which characterizes thermo-diffusion and electrodiffusionphoretic processes determines the loss of only a part of electrical power, the other part will participate in useful mass transport as thermo-hydraulic conductivity, ionosmosis and ionophoresis. Energy flows distribution of other diffusion processes has a similar nature [3].

In all processes accompanying electroosmosis there are relaxation phenomena which condition the values constant to relaxation time in corresponding power gradient fields. The account of relaxation phenomena allows sharply decrease specific energy consumption [3] and makes the electroirrigation economic. This technology is grounded from the technology-economic point of view by the example of crops growing on the open irrigated lands and has the following forecast: when irrigating with underground waters by electroosmosis the profit will be achieved by labor cost decrease for irrigation and cultivation, fuel consumption decrease due to exclusion of sprinkling equipment, decrease of maintenance costs, decrease of costs for construction the irrigation system, increase of useful lands by introduction of the areas occupied by irrigation cannelrs and passes for irrigation equipment. The calculations were done for the steep area in Novosibirsk region on the example of cabbage planting.

A usual example is for the area of 140 ha. It needs 834000t of water for a season at the consumption norm 600m3/ha. This area includes irrigation canals and passes for the sprinkling equipment in area 6
ha, commercial yield is 5.5t, Diesel fuel consumption for intercultivation and irrigation is 54.3т, technological equipment as tractors, cultivators and sprinkling equipment, irrigation canals and pump stations.

The conducted research suggests more cost effective and energy effective method due to the commercial yield increase with:
- production area increase,
- plant production increase in rain – reverse of the electric power supply and regulating optimum water content of the root layer ,
- evaporation decrease by 4 times.

To implement this project it is necessary to build an electro-power station with the output about 2000 kVA; driver circuit installation for intermit-tent energization up to 60kVa/ha, in general the total energy consumption per a season will be 10500000kWh.

4. Conclusions
The proposed technology will make it possible to get rid of a number of irrationally used natural resources. This is especially true for the Crimean region and the Volga region. Using this technology in Uzbekistan would allow the elimination of the Aral catastrophe and restoration of the natural balance in this region.

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