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Automatic System for Irrigation Water Treatment with a Set Mineralization for Regions with High Salt Content

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ABSTRACT: The high salinity of water negatively affects soil fertility up to the loss of yield. In regions with high salinity using classical methods and devices to reduce the level of mineralization, which is a costly process and extensive. This article discusses the development of an automatic decision-making system for a device aimed at reducing the level of mineralization by diffusion mixing. The created construction is capable of filtering water to the irrigation level, 3 grams per/ litter, and extending the life of the reverse osmosis filter. The article aimed at disclosing the issue of preserving the specified volume of salinity of the structure by automatically controlling the salt concentration and the level of irrigation water salinity. The article presents a mathematical justification, models of technological process control, technical implementation of the control concept and research results in an experimental prototype.

KEYWORDS: automation, irrigation, water treatment, programming, electronics, automatic control, mathematic model**.**

I. INTRODUCTION

Half of the irrigated lands in Uzbekistan to one degree or another has 50% salinity, of which 31.3% is weak, 15% average and 3.3% strong.
The yield per hectare of irrigated land depends mainly on the increase in the concentration of toxic salts, the chemical composition of the soil [1].

Most urban and rural settlements are located in the middle of irrigated land or near water sources. Highly saline soils found mainly in the Republic of Karakalpakstan, Khorezm and Bukhara regions. The share of irrigated land in the Republic of Karakalpakstan is highly saline: 11.8% in 2007, 10.5% in 2012 and 9.8% in 2019.In Khorezm region - 14.1%, 13.1% and 11.25%, in Navoi - 5.7%, 4.3% and 3.8% in Bukhara - on average 4.6% [2].

In Uzbekistan, from year to year, the economic and demographic pressure on land, especially for agricultural purposes, is increasing. Of the 17.8 million hectares representing the total area of agricultural land in the republic, only 25% is arable land [3].

Over the past 16 years, the area of agricultural land has decreased by more than 5%, and per capita - by 22%. Over the past 30 years, the area of irrigated land per capita has decreased by about 25%, i.e. from 0.23 hectares to 0.16 hectares. Naturally, the above data suggest that farmers are reducing the area for work and thus their incomes crushed. The process of anthropogenic desertification, that is, associated with human activity. The processes of soil erosion and soil salinization continue.

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More than 3 million hectares of land suffer from water erosion — during the season, the average loss of the fertile layer, for this reason, reaches 80 tons per hectare [4].

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A. Problem statement and proposed solution

There is various methods and devices for reducing the salt content in water. To eliminate such problems, one of them is a device based on diffusion mixing method. This method allows the use of water with high salinity and does not require additional mixing resources due to internal recirculation, which reproduced using a reverse osmotic filter.

However, the disadvantage of this method is the creation of a certain volume of water with the required concentration; unfortunately, this technical process cannot performed in the absence of accompanying automatic control methods. This article presents an automatic system that can implement this method with high accuracy. A literature review on this issue showed that Uzbekistan lacks any practical solution. At the same time, there are recommendations of the authors A. Karimov and S. Mirzaev, who work on exclusively ameliorative content, on the possibility of mixing drainage and natural waters [5].

Accounting of data on the ongoing technological process with the help of measuring modules and sensors.

The technical side of the implementation of the automatic system based on the integration of modules, sensors, actuators and a programmable logic controller.

The operation of the system verified by using the developed mathematical model for controlling two streams of different water quality.

The design used for water purification has its own specifics and requires an individual approach to the development of an automatic control system, which described by a specific model [6].

II. OBJECT OF RESEARCH

The object of the study is the method of batch mixing in which water of high concentration is mixing with water of low order of mineralization in the practice of irrigation, it is necessary to obtain water with a certain content of minerals. It is achieving by mixing water with a low amount of minerals with some water of high mineralization [5]. This process schematically (see Figure 1).

This figure shows the scheme of water intake numbered; through Q, C with the corresponding indices indicate the flow of water and the concentration of minerals. For concreteness, we have $C_1<C_2$. It is obvious that the concentration of minerals in the resulting mixture satisfies the condition $C_1 \le C \le C_2$.

Fig.1. Mixing process**.**

III. RESULTS OF RESEARCH

It is necessary to build a control system that provides and maintains some required values of the mineral concentration $C=C_T$ at the mixer outlet.

The required mineral concentration value also satisfies the inequality:

$$C_1 \le C \le C_2 \qquad (1)$$

If m_{1w}, m_{2w} were the masses of pure water; μ_1, μ_2 be the masses of minerals contained in the water.

Degree of mineralization in the first pipe:

$$k_1 = \frac{\mu_1}{m_1} = \frac{\mu_1}{m_{1w} + \mu_1} = \frac{1}{\frac{m_{1w}}{\mu_1} + 1} \qquad (2)$$

In second pipe it will be:

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$$k_2 = \frac{\mu_2}{m_2} = \frac{\mu_2}{m_{2w} + \mu_2} = \frac{1}{\frac{m_{2w}}{\mu_2} + 1} \quad (3)$$

For the degree of mineralization of the prepared water, we have:

$$k = \frac{k_1 m_1 + k_2 m_2}{m_1 + m_2} = \frac{m_1}{m} k_1 + \frac{m_2}{m} k_2 \quad (4)$$

There is a ratio between mass and volume:

$$m = \rho Q \quad (5)$$

In equation 5 ρ- density; Q-volumetric flow.

It's obvious that

$$Q = Q_1 + Q_2 \quad (6)$$

In taking into account the last two expressions, it is easy to obtain from expression (4):

$$k = \frac{\rho_1 Q_1}{\rho_1 Q_1 + \rho_2 Q_2} k_1 + \frac{\rho_2 Q_2}{\rho_1 Q_1 + \rho_2 Q_2} k_2 \quad (7)$$

The concentration of minerals is defined as the ratio of their mass to the volume of the solution, that is:

$$c = \frac{\mu}{Q} \quad (8)$$

In result we get the output stream we get:

$$c = \frac{c_1 Q_1 + c_2 Q_2}{Q_1 + Q_2} \quad (9)$$

$$c = \frac{k_1 \rho_1 Q_1 + k_2 \rho_2 Q_2}{Q_1 + Q_2} \quad (10)$$

Comparison of expressions (9) and (10) yields the relation and has following form (11)

$$c = xp \quad (11)$$

Possible technological schemes. The following variants of the schemes for the formation of water with the required concentration of minerals are possible:

a) by regulating the flow of highly mineralized water Q_2 (pic. 2 a)
b) regulation of low-salinity water flow Q_1 (pic. 2 b)
c) regulation of both streams (pic. 2 c).

Technological schemes corresponding to the listed options are shown in Fig. 2. Q_{10}, Q_{20} - maximum possible water discharge, respectively, through channels 1 and 2;

Z_1,Z_2 setting signals of automated gates for the corresponding channels. The change in technological variables in time is described through a set of operator relations. Also, for option:

a) work on principal $Q_1(t) = Q_{10}(t)$, and b works on $Q_2(t) = Q_{20}(t)$ equalition

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When using option (a) of the technological scheme, the required concentration can be set only in accordance with the following inequality:

$$c_1 \le c_T \le \frac{c_1 Q_{10} + c_2 Q_{20}}{Q_{10} + Q_{20}} < c_2 \quad (12)$$

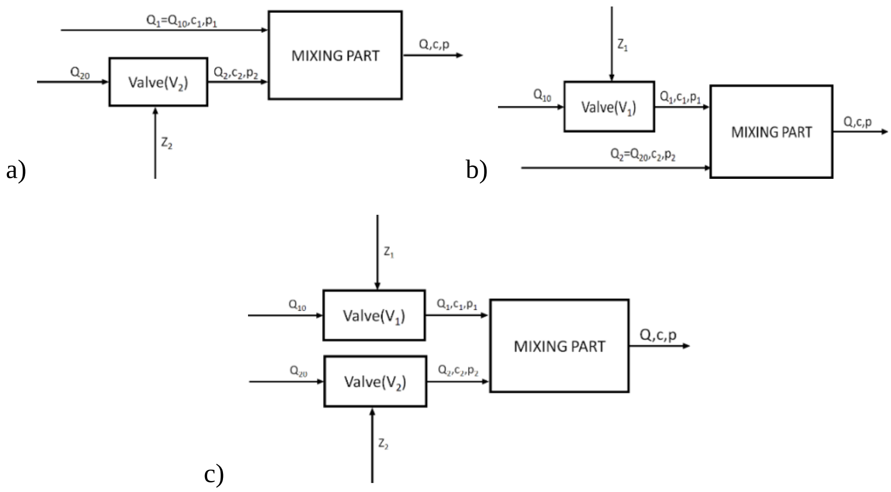

Fig. 2. Technological schemes of concentration formation minerals in water

Option (b) also does not provide the ability to control the volume of the output stream. In this case, the input stream is unmanaged. Q_2 . Input stream Q_1 satisfies the inequality:

$$0 \le Q_1(t) \le Q_{10}(t)$$

Possible limits of changes in the concentration of minerals in the outlet stream, for this option, are determined by the inequality:

$$C_1 < \frac{C_1 Q_{10} + C_2 Q_{20}}{Q_{10} + Q_{20}} \le C_T \le C_2 \quad (13)$$

The volume of the output stream will lie within:

$$Q_{20} \le Q \le Q_{10} + Q_{20}$$

In the case of using option (c) it becomes possible and necessary to control not only the concentration of minerals, but also the volume of the output flow Q_1. Required concentration C_T can be specified within inequality (1). Let us find out the permissible range of setting the output volumetric flow Q_T. From relations (6) and (9) you can get:

$$\left.\begin{aligned} Q_1 &= \frac{C_2 - C_T}{C_2 - C_1} Q_T; \\ Q_2 &= \frac{C_T - C_1}{C_2 - C_1} Q_T; \end{aligned}\right\}$$

Where (13) equalizes:

$$\frac{Q_1}{Q_2} = \frac{C_2 - C_T}{C_2 - C_1} \quad (14)$$

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Considering that the inequalities must be satisfied: $Q_1 \le Q_{10}$, $Q_2 \le Q_{20}$

$$\left.\begin{array}{l} Q_T \le \dfrac{C_2 - C_1}{C_2 - C_T} Q_{10} \\ Q_T \le \dfrac{C_2 - C_1}{C_T - C_1} Q_{20} \end{array}\right\}$$

Whence we finally have

$$0 \le Q_T \le \min\left\{\frac{C_2 - C_1}{C_2 - C_T} Q_{10} > \frac{C_2 - C_1}{C_T - C_1} Q_{20}\right\} \qquad (15)$$

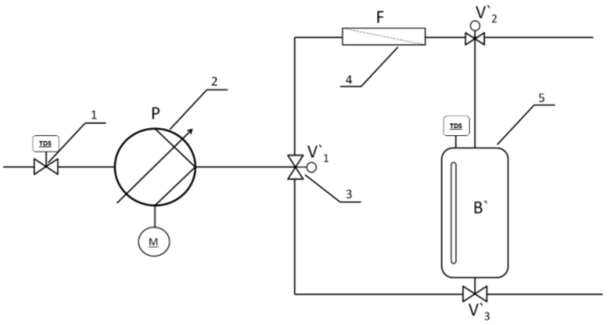
Thus, the possible volume of the output flow, in the case of accepting option (c) depends on the value of the required concentration.

Construction for a selective selection of purification or direct water supply to the mixing capsule implements the logic of operation based on equations (14) and (15).

The main principle of the proposed design is to create the required concentration of water with an acceptable salt content inside the tank and then transfer it for irrigation.

The device consists of 5 parts; 1- a measuring sensor that will be installed in the water source to determine the salt content in the source, 2- centrifugal pump for pumping water, 3- solenoid valves for water distribution, 4- reverse osmosis to lower the salt level in the water - 5 capsules for collection water (see Figure 3) [6].

The principle of operation of the design is that the electromagnetic control valve $V`_1$ distributes water for cleaning using reverse osmosis, valve $V`_2$ is used to supply purified water to the capsule, valve $V`_3$ is used to supply mixed water for irrigation. Valve response time and volume of water flow distribution for cleaning and direct transfer to the capsule, depending on the salinity of the water source. The data that is transmitted from the 1st sensor goes to the controller, after which the controller, based on the built-in algorithm, sets the operating time of the on-off valves. The level of reverse osmosis load depends on the salinity of the water source and, thus, it is possible to extend the level of the reverse osmosis by creating an individual mode depending on the degree of salinity of the water.



1-conductivity sensor; 2-pump unit; 3- two position solenoid valve; 4- reverse osmosis;
5- tank of diffusion mixer.

Fig.3. Scheme of construction of diffusion mixing system.

On base of (15) equalizing logic developed PLC program for CFC (continues functional chart) for IEC standard technology. The program includes triggers of the leading and trailing edges of inclusion and the move module for the implementation of signal counting and determination of limits (see Figure-4) [7].

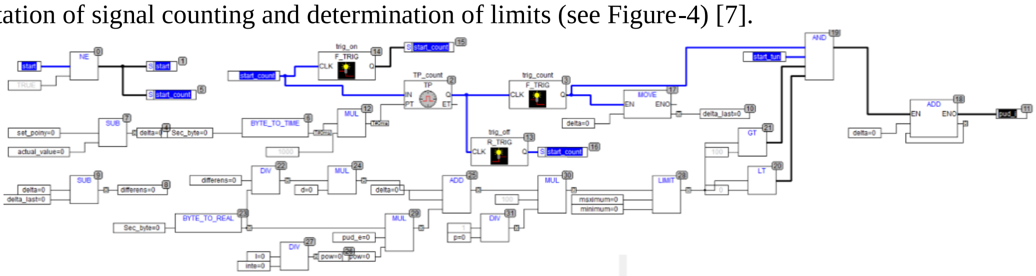


Fig.4. Structure of a CFC program.

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Based on the signal indicators, buttons for visual impact on the signal operation cycle were attached, which made it possible to monitor the volume of water and turn on / off the pump unit remotely by software shells based on Codesys (see Figure-5).

The program can include a shutdown process installed by a water flow control display on-off control valve and a notification about the state of the osmotic filter. when the pump unit is turned on and off, there is a color indication of the pump unit operation.

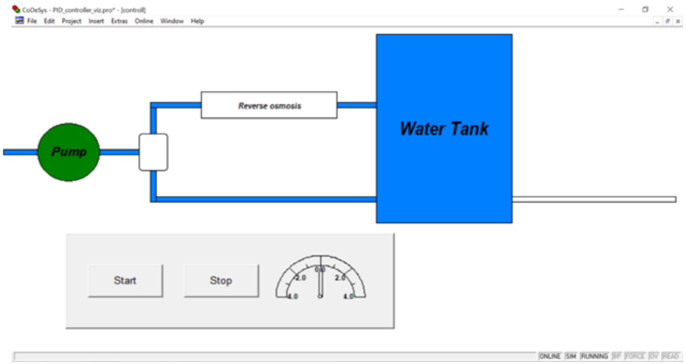

Fig.5. Workflow of work loaded programs into the controller.

A. RESULTS AND DISCUSSIONS.

Based on the above data, a batch-mixing prototype of Figure -3 was constructed. The volume of the capsule for mixing is 250 liters per hour. TDS sensor used to determine the salt content of the source and the mixing capsule. Considering the fact that the water concentration based on the volume and operating time of the valves, an electrode type water level sensor installed in the inner part of the capsule, can been (see figure 4).

This experimental construction based on the aforementioned schematic diagram of figure 1.

Siemens S7-1200 to control the water flow. The volume of water for filtration depends on the salinity of the water, the opening and closing times of the valve are determined according to salinity of water in source(see figure-4).

Fig. 4. Experimental prototype

During the experiment, the ratio of the valve operation time for filtration with the volume of salt in water was determined, which presented in table-1.

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Table 1. Parameters of work solenoid manifolds according to salt value

Water classification	Total dissolved solids	Opening time of valve $v`_1$ to filter
Brackish water:	10,000 mg/l	*25 minutes*
Saline water:	35,000 mg/l	*45 minutes*
Hypersaline	50,000 mg/l	*60 minutes*

A process control board has been designed on the architecture which shown on fig.3. When the device is working, it shows that 3 grams of salt are in the liquid, which is the normative indicator for irrigation.[8]

IV. CONCLUSION

The created program in the simulation model showed its high quality of response to the sensor signal, and the response of the system is less than 5% of the error. Visual programs when connected to a controller they have a lag and are fully synchronized.

When studying the work of the program, the following shortcomings and prospects for further work identified.

1. Critical point notification works and automatic shutdown in this program, this function is not provide.

2. Local control capability with controller connection via Ethernet is the only real-time monitoring control capability, indicating that cloud remote control function or connection via GPRS module most considered.

3. Control of two-position valves in an emergency system, this function not provided in the program.

4. Further scientific work will consider these three aspects for the development of this program and it was also considered that this programming language is much more compact and safer than other text editors along with c ++ and Python.

5. Algorithm on base of (14) and (15) functional adequately to construction.

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