Method for water disinfecting by a single spatial electromagnetic field

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Abstract. The paper presents the results of a comparative analysis without reagent methods of water disinfection by a pulsed electromagnetic field. An improved design of the device for control systems of a single spatial electromagnetic field is proposed. The aim of the work is to develop and study the disinfection of water by a single spatial electromagnetic field, which improves the energy performance of the device, improves the technique, economic and operational characteristics with wide possibilities for its practical application. The theory of a unified spatial field assumes the interaction of four fields: pulsed electromagnetic, pulsed electric, permanent magnetic and gravitational. The theory of a unified spatial field is substantiated, which allows considering the issues of effective disinfection, desalination and purification of water, as well as studying the influence of electric, magnetic fields and electromagnetic waves on physical, chemical and biological processes occurring in liquids. Based on the theory presented in the work, the following conclusions can be drawn: a single spatial field allows you to disinfect and purify water; pulsed electric and magnetic fields allow saturating water with oxygen ions; the spatial field allows you to remove heavy metals from the water. According to the results of the analysis of power impulse systems, the ways of developing the device of a single spatial field are determined.

1 Introduction

New railway lines have been built and are being built in Uzbekistan, which run through desert and semi-desert areas. In this regard, there is a problem of providing service personnel, the population with drinking water. Railway transport is also a consumer of water, in particular, water is used in many production processes, such as cooling diesel engine compressors of locomotives and other equipment, steam generation, refueling passenger cars, rheostat testing of locomotives, etc. Therefore, this requires the preparation of process water for locomotive facilities and other services. In this regard, the issue of disinfection and water purification is of particular interest [1].

A known method of processing liquids and fluid products, including the treatment of water by a pulsed electromagnetic field with a pulse duration of 10-5÷10-7 μs and an instantaneous pulse power of 50÷1000mW [2; 3; 4].

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The disadvantages of this method: low degree of water disinfection, low productivity, high specific energy consumption.

Another, close in terms of technical capabilities, is the method of disinfecting water with an electromagnetic pulse, based on treating water with an electromagnetic field with an induction of 7 ÷ 8T (tesla), a pulse repetition rate of 10 ÷ 15 Hz, a pulse duration of 10 ÷ 15 mS and a power consumption of 4.0 ÷ 4.5 kW [3] .

The disadvantage of this method is the difficulty of achieving the required values of the magnetic field induction and the high cost of electricity.

The paper [5] considers methods for treating wastewater with a high concentration of organic pollutants by the method of methane fermentation and electro plasma discharges, the device of which is very complex.

In works [6; 7] proposes the treatment of water by the electromagnetic field of a special generator operating in the frequency range from 10 to 20 kHz, which is an inefficient method of wastewater treatment and the device is very complex.

The work [8] considers the technology of water treatment in rural settlements using a complex electric and magnetic effect on underground drinking water.

The closest in technical essence to the proposed method is a method of disinfecting water with an electromagnetic pulse, based on the treatment of water with an electromagnetic field with an induction of 7÷8 mT (millitesla), a pulse repetition rate of 10÷15Hz, a pulse duration of 10÷15ms and a current pulse amplitude of 200÷ 300A [2].

The disadvantage of this method is the low influence of the electromagnetic field on water molecules, since the field lines of force are directed along the liquid flow, and not perpendicularly, which gives a low degree of water disinfection.

The device [9] consists of a water treatment reactor and an electrode system.

The disadvantages of this method are the complexity of the device, the low service life of the insulation of electrode systems and electrodes, the use of high-voltage pulses equal to 1000 pulses/sec, the use of filters with sand and gravel loading to clarify water.

The aim of the work is to develop and study the disinfection of water by a single spatial electromagnetic field.

2 Main part

A solution to the problem is proposed by the influence of an electromagnetic field on the treated water, the use of a transverse magnetic field, the lines of force of which are directed perpendicular to the directions of the liquid flow, as well as a vortex electric field created by a rod located inside and in the middle of a dielectric pipe. Under the action of a magnetic field, additional pressure is created, which entails an increase in the distance between water molecules. Bubbles with a high density of microbes are formed inside the water. After the termination of the voltage pulse, due to a change in pressure, the bubble bursts, and the microbes die. To separate pure water from impurities, a vortex electric field is used, under the influence of which oxygen ions of water move along a helical path, twisting around the rod, and all impurities settle to the bottom of the pipe.

Due to the fact that the speed of the electromagnetic wave in water is 5×105m/s, and the speed of the liquid is 1.5÷2m/s, that is, many times higher, multiple cleaning occurs. This ensures the required collie index and the required number of microbes in a gram-molecule of water. The cleaning time does not depend on the geometric dimensions of the pipe and the speed of the liquid.

A method has been developed for water disinfection by a pulsed electromagnetic field with transverse force lines directed perpendicular to the water flow, created by an inductance, as well as a vortex electric field.

The inductance is outside the dielectric tube, the rod is inside (in the middle) of the dielectric tube.

The water disinfection device is a solenoid with a total length of lc=2m, wound over a non-metallic pipe (for isolation from water) with a diameter of d=159mm and placed inside a metal pipe to prevent external damage. The solenoid must provide induction within 7÷10mT. Water, passing through the solenoid at a speed of V=1m/s, serves as a natural heat sink for it. Thus, passing through a solenoid with a length of lc=2m, water is processed for a time T equal to Te = lc/V=2c.

The solenoid is powered by a transformer connected to a 220V AC network through a control thyristor. The thyristor itself is controlled by a pulse generator control device, since the thyristor and transformer are a pulse generator. When control pulses are applied to the thyristor, it either opens or closes, applying a pulsed voltage to the solenoid. To control the pulse generator, pulses with a repetition rate of 10÷15Hz and a duration of 10÷15ms are required.

This requires a power supply supplying one vibrator, a frequency divider, and a square-wave power amplifier [10–16].

There is no information to determine the parameters of the device and the working body, taking into account the performance of the water source and its initial contamination. At the same time, the presence of such obvious advantages of an electromagnetic device as the possibility of concentrating and issuing significant energy at low powers of the devices themselves with a control system, compactness, reliability and controllability of the process predetermine their use for water disinfection with wide areas of its application.

It was found that the existing devices and methods for disinfecting water with a pulsed electromagnetic field, based on the treatment of water with an electromagnetic field with the above parameters, have a relatively low efficiency, a small effect of the electromagnetic field on water molecules, since the field lines of force are directed along the liquid flow, and not perpendicular, which gives a low degree of water disinfection.

By a comparative analysis of existing methods and devices for water disinfection, the ways of solving the task of increasing the impact of an electromagnetic field on treated water by using a transverse magnetic field, the lines of force of which are directed perpendicular to the direction of the liquid flow, as well as a vortex electric field created by a rod located inside and in the middle of the dielectric pipes.

The proposed improved device [17;18] of control systems for a single spatial electromagnetic field is shown in Fig.1.

It is required to improve the technique, economic and operational characteristics with wide possibilities of its practical application.

Based on this, the following task was set: to increase the scope of possible application with improved energy performance and reliability.

This problem is solved by improving the designs of devices for control systems of a single spatial electromagnetic field - SPEP.

A schematic representation of the experimental sample of the developed device with a control system and the design of the installation is shown in Fig.1.

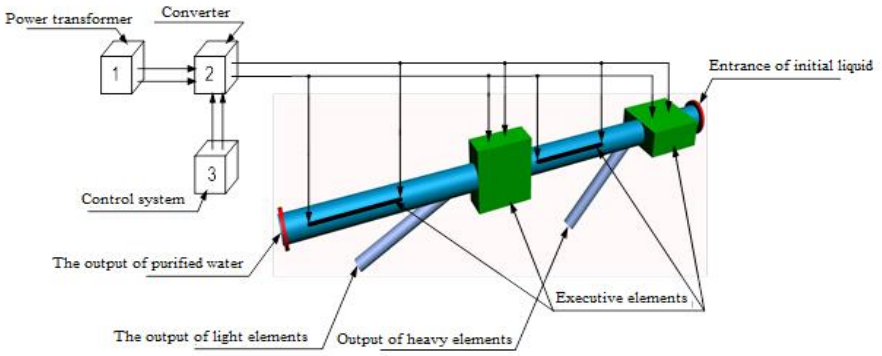

Fig.1. Schematic representation of an experimental sample of the developed device with a control system. 1 - Power transformer; 2-Converter; 3-Control system.

The pulse generator consists of the following functional blocks: single vibrator, frequency divider, power amplifier, thyristor power supply, matching transformer. The installation is fixed on a mobile device, i.e. can work anywhere.

To reduce losses, the contacts are made in the form of tires, long wires run in pipes to exclude the influence of the electromagnetic field on them. The degree of water disinfection is regulated by the frequency of the pulses generated by the pulse generator.

In a water disinfection plant, four energy-intensive elements can be distinguished: a power transformer, inductors (dry transformer), a control system and a rod, which are most closely connected with each other.

The power transformer feeds a system of two inductors connected to each other in parallel, opposite and in series with them-kernel. A pulse is supplied from the control system, which opens the thyristor and a current of 120A flows through the inductors. Water flows through the pipe at a speed of 0.2÷0.4m/s.

Inductors create a transverse electromagnetic field.

A force acts from the side of the field, which creates additional pressure. Under the action of this pressure, the distance between water molecules increases, an area is formed into which microbes and microorganisms enter. The water then enters the vortex electric field generated by the rod. The electric field slams the area, the microbes die, and the water, supplied with oxygen ions, winds up on this rod, while larger particles settle down and are ejected through a nozzle located at an angle of 450 to the main pipe. The intensity of cleaning can be changed by changing the pulse repetition rate, and by changing the diameter of the holes in the pipe.

For this purpose, the inlet and outlet of the pipe are equipped with adapters that allow you to change the inlet and outlet diameters of the pipe. The current amplitude can be changed using a power autotransformer.

3 Theoretical part

Let us consider the principle of disinfection using the provisions of the electromagnetic field theory [19–23].

The pulsed current in the coil forms a magnetic field, the electromotive force of which is equal to:

$$e = L\frac{di}{dt}, \tag{1}$$

where L is the inductance of the coil.
At the same time, the electromotive force is:

$$e = \frac{\partial \Phi}{\partial t} = \frac{s \partial \text{в}}{\partial t}, \tag{2}$$

where Φ– magnetic field flux; S– the surface area through which the magnetic flux flows. The relationship between the current and the magnetic field excited by it in a vacuum can be expressed in differential form as follows:

$$dB = \frac{\mu_0 \left[\overline{\delta l_R}\right] \overline{s}\, a}{4\pi R^2} \, \overline{l}_R, \tag{3}$$

where $\overline{\delta}$ – coil current density; $\overline{s}$ –coil cross-sectional area; R– distance to the point at which the $\overline{B}$; $\mu_0 = 4\pi 10^{-7}$–магнитная постоянная; $\overline{l}_R$ – unit vector. With the help of treated water in a pulsed magnetic field, the latter will affect moving charged microorganisms according to Ampère's law:

$$d\overline{F} = I\left[d\bar{l} \cdot \overline{B}\right], \tag{4}$$

where $\overline{F}$ – force acting on a linear current element.

To enhance the effects of a magnetic field on organic pollutants in water, it is necessary to increase the field induction or increase the current amplitude. Therefore, in practical devices, the current amplitude reaches several hundred amperes [24–29].

The main factor determining the effectiveness of disinfection is the energy of the magnetic field. The greater the energy of the magnetic field, the stronger the effect of water disinfection. For the energy of the magnetic field of the circuit with current, we can write:

$$W_{mfe} = \int_s \frac{\overline{B^2}}{2\mu_0} l \, d\, S, \tag{5}$$

where W_{mfe}– magnetic field energy.

We propose a method for disinfection and purification of water, based on the theory of a single spatial field.

The theory of a unified spatial field provides for a nonlinear dependence of the mechanical equivalent on the field energy (Fig. 2).

Starting from the point "a", the mechanical energy W_M increases sharply with increasing field energy W_P. As a result, under the action of the received energy, mechanical work is performed. From the side of the field, a force acts, which is determined by the relation:\

$$\bar{F} = grad W_M, \tag{6}$$

where $W_M = W_{me}$ – mechanical energy; $\overline{F}$ – force acting from a single spatial field.

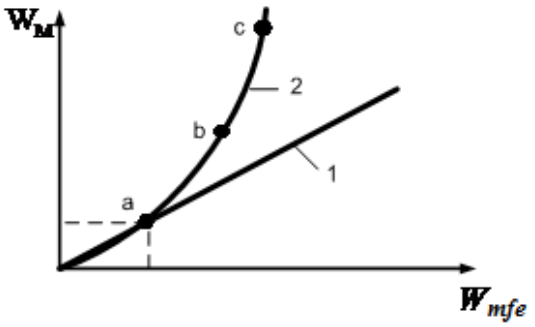

Fig.2. Dependence of the mechanical equivalent on the field energy mfe.

Formula (6) allows calculating all known interactions: electromagnetic, gravitational, strong and weak. To do this, it is necessary to know the level of the main energy concentrated in space and the differences in this energy from this type of interaction. The picture of the field is represented not by equipotential surfaces and force lines of tension, but by equip-energy lines and lines of direction of the force acting from the field.

The gravitational interaction, like the electromagnetic one, has an infinitely large radius of action, therefore, for example, bodies located on the surface of the Earth are affected by gravitational attraction from all the atoms that make up the Earth.

According to the concept of the field, the particles participating in the interaction create a special state at each point of the space surrounding them - a field of forces, which manifests itself in the force effect on other particles placed at any point in this space.

In a system of interacting particles, the force acting at a given moment of time on any particle of the system is not determined by the location of another particle at the same moment of time, that is, a change in the position of one particle affects the other particle not immediately, but after a certain period of time,

Thus, the interaction of particles can only be described in terms of the fields they create. The theory of a unified spatial field involves the interaction of four fields: pulsed electromagnetic, pulsed electric, permanent magnetic and gravitational.

The theory of a unified spatial field allows us to consider the issues of effective disinfection, desalination and purification of water, as well as to study the influence of electric, magnetic fields and electromagnetic waves on the physical, chemical and biological processes occurring in liquids.

In an arbitrary section of a pipe with a flowing liquid, the center of gravity of which is located at a height h from the zero reference level, the following relationship must be satisfied (Bernoulli's Law):

$$p + \rho g h + \frac{\rho \upsilon^2}{2} = const\ , \tag{7}$$

where p– external pressure; υ– speed of movement through a given section; ρ– liquid density. From an energy point of view, pressure is the work done by external forces on a unit volume of liquid

$$W = \rho g\ h + \frac{\rho \upsilon^2}{2}\ . \tag{8}$$

For two arbitrary sections of the liquid flow, the law of conservation of energy for the flowing liquid is observed:

$$p_1 + \rho g h_1 + \frac{\rho \upsilon_1^2}{2} = p_2 + \rho g h_2 + \frac{\rho \upsilon_2^2}{2}. \quad (9)$$

Water, being in a closed space (non-conductive pipe), experiences pressure from a single spatial field, which is determined by the force coming per unit of the outer surface [30]:

$$F = \int_0^{\tau} \mu_0 H J dx = \mu_0 H_0^2 \int_0^{\tau} \frac{\tau - x}{\tau^2} dx = \frac{\mu_0 H_0^2}{2}, \quad (10)$$

where F– force acting from a single spatial field; H– field strength; J– conduction current; τ– thin layer length.On the other side:

$$F = \frac{\mu_0 i^2}{8\pi^2 a^2}, \quad (11)$$

where a – pipe radius.

However, Maxwell's idea of the field pressure seems too formal, it is easier and clearer to imagine the origin of such pressure as the interaction of a single spatial field and the current of moving charges.

The water molecule has a large dipole moment (P_e=6,1•10^{-30} *Кл• м.*), as a result, at distances having the order of the distance between molecules in liquids (r = 1^{0}A = 10^{-10} m),a strong electric field arises around it according to:

$$E = \frac{\varphi_1 - \varphi_2}{d}, \quad (12)$$

where:

$$\varphi \approx \frac{P_e}{4\pi\varepsilon_0 r^2} \approx \frac{6 \cdot 10^{-30} \cdot 36 \cdot \pi \cdot 10^9}{4 \cdot \pi \cdot 10^{-20}} \approx 6V. \quad (13)$$

This is the cause of electrical dissociation.

Consequently, a unified spatial field enhances the process of dissociation in water, and the orbital electrons of two hydrogen atoms and one oxygen atom of water create a strong inhomogeneous electric field around them, which leads to the separation of water and the compounds it contains into elements.

If the liquid moves at a speed υ across the field lines with induction B, then an electromotive force of induction is induced in the liquid volume:

$$\varepsilon = \upsilon \cdot B \cdot l, \quad (14)$$

where l– length of liquid section in a pipe. Fluid section resistance:

$$R = \frac{l}{\gamma \cdot l}, \quad (15)$$

where γ– fluid conductivity.

Induced current in liquid:

$$i_{\text{ind.}} = \frac{\varepsilon}{R} = \gamma \cdot \upsilon \cdot B \cdot l^2 . \tag{16}$$

According to Lenz's rule, the induced current interacts with the field in such a way that the resulting interaction force prevents the movement of water.

Thus, in addition to the usual hydrodynamic forces, electromagnetic forces also act in the liquid.

Magnetic field induction of induced currents:

$$B_{\text{ind}} = \mu_0 \cdot H_{\text{ind}} \approx \frac{\mu_0 \cdot i_{\text{ind}}}{l} \approx \mu_0 \gamma \upsilon B l . \tag{17}$$

The force acting from the magnetic field:

$$F_a = \gamma \upsilon B^2 l^3 . \tag{18}$$

This force can be compared to the force of friction:

$$F_{frik} = \eta \cdot l \cdot \upsilon , \tag{19}$$

where, η – fluid viscosity coefficient. Pressure resistance force:

$$F_{\text{press.}} \approx p \cdot \upsilon^2 \cdot l^2 . \tag{20}$$

The ratio of the Ampere force to the pressure resistance force is called the Stewart criterion:

$$N = \frac{F_A}{R} = \frac{\gamma \cdot B^2 \cdot l}{\rho \cdot \upsilon} . \tag{21}$$

Comparison of the Ampere force (18) with the pressure resistance force (20) gives us the Hartmann criterion:

$$M = \sqrt{\frac{F_A}{F_{fric.forte}}} = Bl\sqrt{\frac{\gamma}{\eta}} \cdot \tag{22}$$

If a liquid flows through a pipe across a single spatial field, then at low Hartmann or Stewart numbers, the field has little effect on the nature of the flow, and resistance to movement arises mainly due to the viscosity of the liquid.

At large Hartmann or Stewart numbers, the viscosity of the fluid recedes into the background, the resistance to movement arises mainly due to the interaction of the fluid with a single spatial field. As a result, the water is saturated with negatively charged oxygen ions, that is, it is pure. Positive charges of hydrogen are detrimental to a living organism.

4 Conclusion

1. The study of the issues of comparative analysis of power electromagnetic pulse systems and power electromagnetic devices of control systems of a pulsed electromagnetic field showed that the device of control systems for an actuating element, based on the use of a pulsed electromagnetic field and a vortex electric field, meets the requirements most fully.

2. According to the results of the analysis of power impulse systems, the ways of developing the device of a single spatial field are determined.

3. It has been established that the control device for a single spatial electromagnetic field has extended functionality.

4. Based on the stated theory, the following conclusions can be drawn:

a) a single spatial field allows you to disinfect and purify water;

b) pulsed electric and magnetic fields make it possible to saturate water with oxygen ions;

c) the spatial field makes it possible to remove heavy metals from the water;

d) with the help of pulsed electromagnetic fields, it is possible to carry out reagent less water disinfection, destroy viruses, sterilize milk and juices, heat liquids by increasing internal energy, create environmentally friendly devices with a high efficiency;

e) the use of a single spatial field in the development of technology and technological means for disinfection and purification of water can significantly save energy and material resources in desert and semi-desert conditions.

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