Electroactivator for Pesticide Solution

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Abstract. Based on the analysis, it was found that it is necessary to develop electroactivators with adjustable parameters. The analysis showed that there are no analytical expressions connecting the degree of activation of solutions, electrical conductivity, temperature and geometrical parameters of the electroactivator. The article presents a mathematical model that allows describing the parameters of electroactivated water operating mode of the electroactivator.

1. Introduction
Today many kinds of pesticides are produced. Spraying is the most effective way of using pesticides. Water is an important element when using any pesticides, it delivers the drug to the leaves and plant stem. Water quality is a major factor in the effectiveness of pesticides. It is known that the decomposition of herbicides occurs faster in environments with a low pH. Recent studies show that the effectiveness of certain pesticides is increased if they dissolve in water with pH = 4-5. This is explained by the presence of free hydroxonium ions in an acid medium, which accelerate the hydrolytic processes, forming hydrolysis products. If the pH is high, the pesticides precipitate, and their effectiveness decreases. As a consequence, it is required to increase the dose or repeat the use, and this is the cause of pollution of soils, groundwater, deterioration in product quality.

2. Topicality
A solution to the problem of water quality is the electroactivator [1]. The electric water activator is designed to produce activated water: anolyte and catholyte. Activated water has a high dissolving power due to different charge concentrations: positive anolyte and negative in the catholyte. Also as a result of anodic electrochemical treatment, the surface tension and electrical conductivity decrease, the content of chlorine and oxygen decreases, the concentration of hydrogen and nitrogen decreases, and the water structure changes [2,3,4,5,6].

3. Theoretical part
To create a mathematical model, we will compile the system. The initial parameters for the system are the water parameters: initial water temperature (t_in), initial water mineralization (C_in), pH, productivity (Q_in) and electrical energy parameters: electric current (I_in) and voltage at the device terminals (U_in). General view of the system can be represented:
where, $C_{\text{out}}$ is the water concentration at the outlet, mol / m$^3$; $Y$ - concentration of water at the inlet, mol / m$^3$; $\alpha$ - coefficient of desalination; $t_{\text{out}}$ - anolyte temperature at the outlet, °C; $X$ - Anolyte conductivity, S / m; $I$ - current, A; $S$ - electrode area, m$^2$; $L$ - length of the channel, m; $pH_{\text{an}}$ - hydrogen anolyte index; $Q_{\text{an}}$ - productivity of anolyte, m$^3$ / s; $P_{\text{an}}$ - electric power of the anode chamber, W; $R_{\text{an}}$ - resistance of the anode chamber, Ohm; $W_{\text{an}}$ - Electricity consumption W h / m$^3$.

Mineralization of water at the outlet can be calculated by the formula [1]:

$$C_{\text{out}} = C_{\text{in}} \cdot Y$$  \hspace{1cm} (2)

In water, the electrical conductivity can be determined from the mineral composition. To calculate the electrical conductivity, we apply the formula [1]:

$$X_{\text{in}} = \frac{C_{\text{in}}^{\beta}}{\theta}$$  \hspace{1cm} (3)

where is $X_{\text{in}}$ the electrical conductivity of the solution at a temperature of 18 °C; $\beta$ - coefficient of salt content; $\theta$ is the coefficient of electrical conductivity (5300) [5].

Calculate the mineralization at the outlet from the anode chamber is determined by the formula:

$$C_{\text{can}} = C_{\text{in}} \cdot Y \cdot \frac{1-Y}{\log F_Y}$$  \hspace{1cm} (4)

As a result of process, the temperature of the liquid increases, and the calculation of the specific electrical conductivity of the anolyte must be carried out taking into account the correction for temperature changes. Equation (3) for anolyte:

$$X_{\text{outan}} = \frac{C_{\text{out}}}{\theta} \cdot [1 + \kappa_{\text{t}} \cdot (t_{\text{out}} - 18)]$$  \hspace{1cm} (5)

where is $t_{\text{out}}$ the temperature of the solution at the outlet of the chamber; $\kappa_{\text{t}}$ - temperature coefficient, 0.02 1/°C.

The temperature of the solution at the outlet from the chamber can be determined by the formula:

$$t_{\text{out}} = t_{\text{in}} + \Delta t_x$$  \hspace{1cm} (6)
where $\Delta T_t$ is the temperature shift.

The temperature shift is determined by the formula:

$$\Delta T_t = \frac{d \cdot (1 - Y)}{(K_c - 1)}$$

(7)

$d$ - dimensionless ratio of anolyte consumption to catholyte consumption; $\kappa_c$ - coefficient of concentration of calcium and sulfate ions in water, calculated by the method [4].

Then expression (6) takes the form:

$$t_{out} = t_{in} + \frac{d \cdot (1 - Y)}{(K_c - 1)} \rightarrow t_{out} = t_{in} + \frac{Q_{out} \cdot (1 - Y)}{(K_c - 1)}$$

(8)

Substituting (8) into (5) we obtain:

$$X_{out} = \frac{C_{out}}{\theta} \cdot [1 + \kappa_c \cdot (t_{in} + \frac{Q_{out} \cdot (1 - Y)}{(K_c - 1)} - 18)]$$

(9)

Knowing the electrical conductivity of water in the chambers, we calculate the electric current for the device.

$$I = \frac{F \cdot (C_{in} - C_{out}) \cdot Q_{out}}{n \cdot \eta}$$

(10)

where $F$ is the Faraday number, 26.8 A $\cdot$ h / mol; $n$ - number of cells in the electroactivator; $\eta$ is the current output (0.85-0.98). Based on the Kuban SAU research, the minimum mineralization was 0.05 g / l.

We take into account the coefficient of gas filling. Calculation of the coefficient is carried out according to the formula [4]:

$$k_{x} = \frac{V_{x}}{V_{e}}$$

(13)

where $V_{x}$ the volume of the electro activator chamber, m$^3$; $V_{e}$ - volume of gas released in the chambers, m$^3$.

Taking into account (13), equations 8 and 9 take the form:

$$t_{out} = (t_{in} + \frac{Q_{out} \cdot (1 - Y)}{(K_c - 1)}) \cdot k_{x}$$

(14)
\[ X_{\text{out}} = \frac{C_{\text{out}}}{\theta} \cdot \left[ 1 + \frac{Q_{\text{out}} \cdot (1 - Y)}{Q_{\text{out}} \cdot (t_{\text{out}} + \frac{C_{\text{out}}}{(K_i - 1)}) \cdot k_y} - 18 \right] \] (15)

For the anodic and cathodic parts, the formula for determining the resistivity can be:

\[ \rho_{\text{out}} = \frac{1}{X_{\text{out}}} \quad \rightarrow \quad \rho_{\text{out}} = \frac{\theta}{C_{\text{out}} \cdot [1 + k_y \cdot (t_{\text{out}} - 18)]} \] (16)

Knowing the value of the resistivity, an expression can be obtained for calculating the resistance of the anode and cathode parts (Ohm):

\[ R_{\text{an}} = \frac{\theta \cdot L}{C_{\text{out}} \cdot [1 + k_y \cdot (t_{\text{out}} - 18)] \cdot S} \] (17)

\[ R_{\text{an}} = \frac{\rho_{\text{out}} \cdot L}{S} \] (18)

The power consumption of the chamber is determined by the formula, taking into account equation (19), the capacity of the anode chamber is determined by the expression:

\[ P_{\text{an}} = \frac{I^2 \cdot \theta \cdot K_y}{C_{\text{out}} \cdot [1 + k_y \cdot (t_{\text{out}} - 18)]} \] (19)

To determine the resistance of the diaphragm, we determine the voltage drop [2]:

\[ U_o = \frac{X_o \cdot S_o \cdot \delta}{\Delta_l \cdot e^2} \] (20)

where: \( X_o \) - specific electroconductivity of the electrolyte; \( S_o \) is the area of the diaphragm, \( \text{m}^2 \); \( \delta \) - coefficient of material quality; \( \Delta_l \) - thickness of the diaphragm, \( \text{m} \); \( e \) is the aperture factor.

The formula for calculating the resistance of the diaphragm takes the form:

\[ P_o = \frac{I \cdot X_o \cdot S_o \cdot \delta}{\Delta_l \cdot e^2} \] (21)

The voltage drop in the electrolyte (anolyte, catholyte) is determined by the formula:

\[ U_a = \frac{D_a \cdot \Delta l}{X_a} \] (22)

where is \( D_a \) the specific current density between the electrodes, \( \text{A} / \text{m}^2 \); \( \Delta l \) - specific electrical conductivity, \( \text{(Ohm} \cdot \text{m})^{-1} \); \( X_a \) - distance between electrodes, \( \text{m} \);

The power of the electroactivator is calculated:

\[ P = P_o + P_k + P_d \] (23)
After the transformations, we get:

\[ P = I \cdot \frac{X_a \cdot S_a \cdot \delta}{\Delta \theta \cdot e^2} + \frac{I \cdot \theta \cdot K_a}{[1 + k_a \cdot (t_{\text{out}} - 18)]} \left( \frac{1}{C_{\text{out}} + \frac{1}{C_{\text{out}}} \right) (25) \]

To determine the specific energy consumption \((W \cdot \text{h} / \text{l})\) in the electroactivator, we use the formula with allowance for the expression (25):

\[ W = \frac{I}{Q} \cdot \frac{X_a \cdot S_a \cdot \delta}{\Delta \theta \cdot e^2} + \frac{I \cdot \theta \cdot K_a}{[1 + k_a \cdot (t_{\text{out}} - 18)]} \left( \frac{1}{C_{\text{out}} + \frac{1}{C_{\text{out}}} \right) (26) \]

The \(pH\) of the water is calculated on the basis of regression dependence. This mathematical model makes it possible to estimate the influence of productivity and current intensity on the acidity of the anolyte [3]:

\[ pH_a = (pH_{in} - 7,5) + \left(6,32 + 0,025Q - 0,1735I + 0,0023 QI - 0,0017Q^2 - 0,0068I^2\right) \] (27)

After all transformations, the system (1) takes the form (28).

As a result of the research, a system of equations (28) is obtained that describe the parameters of water in the electroactivator and its operating mode.

\[
\left\{
\begin{align*}
Y &= \frac{C_{\text{out}}}{C_{\text{in}}} \\
\tau_{\text{out}} &= (t_{\text{in}} + \frac{Q_{\text{in}}}{Q_{\text{out}} \cdot (K - 1)}) \cdot \frac{V_x}{V_x} \\
K_x &= 1,0223 \cdot \exp[5,523 - 0,413 \cdot (\ln C_{\text{Cl}}^+) + \ln C_{\text{SO}_4^2-}] - \\
&\quad 0,31 \cdot \ln((C_{\text{Cl}}^+ + C_{\text{Mg}^2+} + C_{\text{SO}_4^2-} + 0,5 \cdot C_{\text{Na}^+} + C_{\text{HCO}_3^-} + C_{\text{Cl}^-}) \cdot 10^{-3}) \\
pH_a &= (pH_{in} - 7,5) + (6,32 + 0,025Q - 0,1735I + 0,0023 QI - 0,0017Q^2 - 0,0068I^2) \\
I &= \frac{F \cdot (C_{\text{in}} - C_{\text{out}}) \cdot Q_{\text{in}}}{n \cdot \eta} \\
P_{\text{m}} &= \frac{I^2 \cdot \theta \cdot L}{C_{\text{out}} \cdot [1 + k_a \cdot (t_{\text{out}} - 18)] \cdot S} \\
W &= \frac{I}{Q} \cdot \frac{X_a \cdot S_a \cdot \delta}{\Delta \theta \cdot e^2} + \frac{I \cdot \theta \cdot K_a}{[1 + k_a \cdot (t_{\text{out}} - 18)]} \left( \frac{1}{C_{\text{out}} + \frac{1}{C_{\text{out}}} \right) (28)
\end{align*}
\right.
\]

4. Practical importance

Studies were conducted to identify the error of the theoretical model. To do this, a model of an electroactivator is made.

Plots of the dependence of the parameters of the electroactivator are constructed (Fig. 1, 2). The analysis of the graphs indicates the reliability of calculations of the hydrogen index, mineralization and temperature in the mathematical model for this type of electroactivator at a capacity of 75 l/h.
5. Conclusions
The result of comparing the temperature readings during the experiment and obtained theoretically indicates the reliability of calculation of the mathematical model. For the operating mode of the electroactivator adopted in the experiment, the calculated value of the critical current was 9.38 A. Analysis of the obtained data allows us to conclude that it is possible to calculate the structural and regime parameters of the electroactivator from the obtained mathematical model. The error in the calculations does not exceed 10%.

6. References
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