ISSN NO: 2770-4491
November 2025

Study of the Influence of Electro-Impulse Technology Parameters on Microorganisms in Wastewater

Aytbaev Nurlan Tashkent State Technical University named after Islam Karimov. Uzbekistan Tashkent City University Street 2,
aytbaev.nurlan@mail.ru https://orcid.org/0000-0002-3880-0893
Abdurahim Berdishev "Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" Branch in Almaty Republic of Kazakhstan 050010, Abay Avenue 8.
berdyshev@mail.ru https://orcid.org/0000-0002-1174-8028

Abstract: This paper examines the physical processes accompanying the occurrence of an electric discharge in an aqueous medium, which is a key element of electrohydraulic technologies. Special attention is given to the mechanisms of discharge initiation, the influence of medium parameters (pressure and conductivity), and the characteristics of high-voltage pulses. The study aims to determine the optimal conditions for effective discharge formation and the generation of shock waves used in technological processes of material destruction, treatment, and purification. Experimental data are presented, and the prospects for applying the obtained results in engineering practice are discussed..
Keywords: electric discharge, aqueous medium, electrohydraulic effect, discharge initiation, pulsed voltage, plasma formation, shock wave, liquid breakdown, cavitation, and high-voltage technologies.

Introduction. The development of effective methods for influencing liquids by means of electrical energy represents one of the urgent tasks of modern science and technology. Electrohydraulic technologies, based on the use of electric discharge in an aqueous medium, have found wide application in such fields as material processing, wastewater treatment, rock destruction, and even in medicine [1].

The rapid development of industry necessitates the prevention of the negative impact of industrial wastewater on natural water bodies. Many modern technological processes are associated with the discharge of wastewater into aquatic environments. Due to the extreme diversity in the composition, properties, and flow rates of industrial wastewater, it is essential to apply specific methods and facilities for their local, preliminary, and complete treatment [2, 3].

The process of electric discharge in water is a complex physical phenomenon that includes local dielectric breakdown of the medium, ionization, plasma formation, and the generation of shock waves. Understanding the mechanisms of discharge initiation and development in an aqueous medium is key to optimizing the parameters of electrohydraulic systems.

The purpose of this study is to investigate the processes of electric discharge formation in an aqueous medium, analyze the influencing factors, and determine the conditions under which the discharge is effectively initiated and can be utilized in engineering applications.

Principle of Operation of the Installation: The installation designed to produce the electrohydraulic effect (electro-impulse technology) consists of two circuits: a charging circuit and a discharge circuit.

The charging circuit includes a high-voltage transformer equipped with a rectifier.

The discharge circuit consists of a capacitor, a forming gap (FG), and a working gap (WG) immersed in liquid.

The system operates as follows: the transformer converts the mains voltage into high voltage. When the voltage across the capacitor C reaches a predetermined threshold, a breakdown occurs in the forming gap (FG). As a result, the stored energy in the capacitor is released in the form of a pulse and transmitted to the working gap (WG), causing dielectric breakdown of the liquid in which the WG is placed.

This rapid discharge creates a plasma channel and generates a powerful shock wave, which is the essence of the electrohydraulic effect used for material destruction, water purification, or microorganism inactivation. The electrohydraulic effect is observed in the working chamber (Fig. 1).

During this process, an electrohydraulic shock occurs, which performs mechanical work. The cycle is repeated at a certain frequency depending on the transformer power and the capacitor charging rate, which in turn is determined by this power.

ISSN NO: 2770-4491
November 2025

In the working gap, the water behaves as a conductor before breakdown, maintaining an equal potential across the right part of the circuit (beyond the forming gap). At the moment of the forming gap breakdown, the liquid ions do not have time to move from one electrode to another, and the liquid instantly becomes a dielectric.
At this instant, a streamer of a specific polarity grows from one electrode of the working gap to the other (both immersed in the liquid). The entire energy accumulated in the circuit is concentrated in the working gap, leading to the formation of a plasma channel and the generation of a powerful shock wave - the core of the electrohydraulic effect [7].

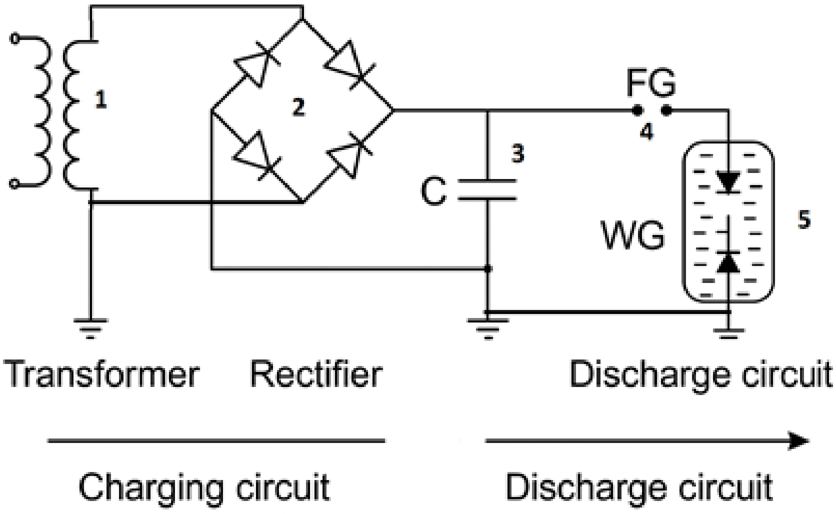


Fig. 1. Diagram for generating the electrohydraulic effect:
1 – Transformer; 2 – Rectifier; 3 – Capacitor; 4 – Forming Gap (FG); 5 – Working Gap (WG).

Then, a rapid expansion of the spark discharge channel occurs, leading to the formation of a cavity accompanied by a primary shock pulse. After the discharge process is completed, the cavity begins to collapse, and the speed of its compression reaches the speed of sound. This process is accompanied by a cavitation impact.
The resulting pressure depends on the discharge energy — it increases with the growth of power and decreases with the increase in pulse duration [4, 5].
Based on the diagram shown in Fig. 1, block diagram of the electrohydraulic effect technology has been developed. The purpose of this installation is the disinfection of wastewater and drinking water (Fig. 2).

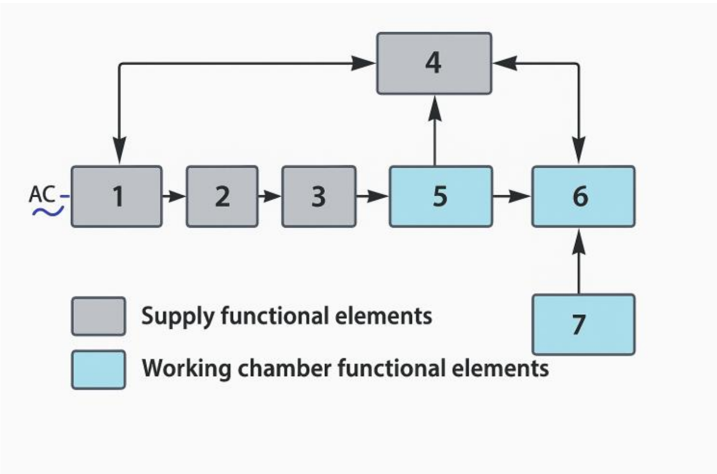
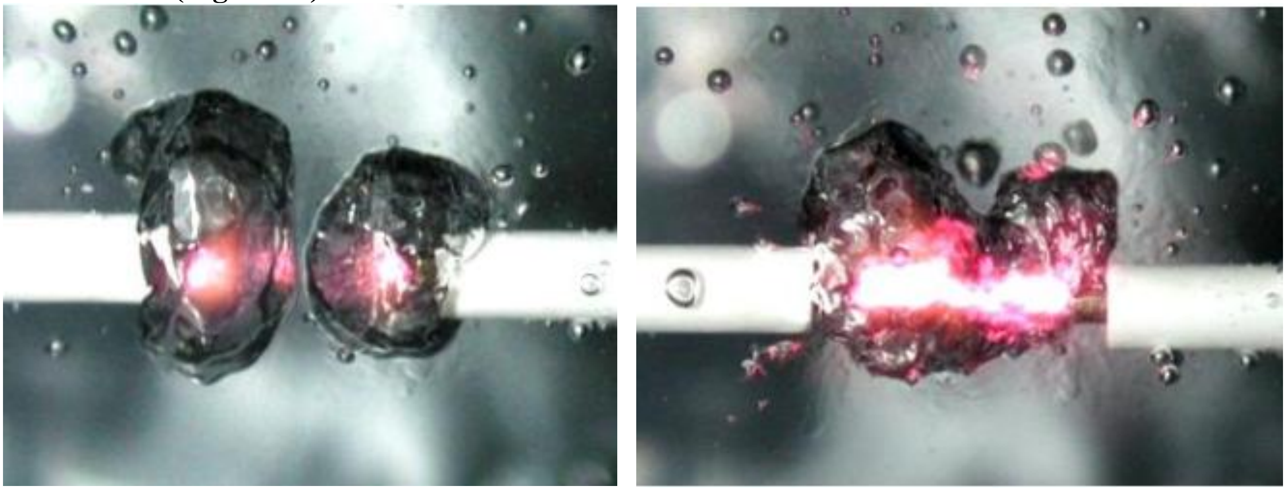


Fig. 2. Block diagram of the electrohydraulic effect technology.
1. Voltage regulator (autotransformer), 2. High-voltage transformer, 3. Capacitor banks and rectifiers, 4. Control system, 5. Discharge unit with auxiliary air gap (FG), 6. Working chamber, 7. Water inlet to the installation.

ISSN NO: 2770-4491
November 2025

Around the spark discharge channel, a high-pressure region is formed, consisting of several concentric zones (Fig. 3.a.b).



a) b)

The diameter of the disintegration (neutralization) zone is proportional to the impulse power. The impulse power, in turn, depends on the discharge steepness. Discharge steepness is explained as the rate at which the maximum pressure is generated within the liquid over a very short time. It is a physico-technical parameter that represents how quickly the voltage or current changes with time during the electrical discharge process. In other words, it shows how rapidly the discharge begins or how sharply the leading edge (front) of the signal rises.

The extent of damage to the cell's outer membrane is determined by the value of this very parameter of the electrical discharge (Figure 4). The effect of pulsed electrical discharge on the cell's outer membrane — that is, the plasma membrane — is an important concept in biology and is known as electroporation. The cell's outer membrane, or plasma membrane, consists of a bilayer of phospholipids that separates the cell from the external environment and serves as a control point for substance exchange.

Through the pressure wave (shock wave) generated in the water medium by a pulsed electrical discharge, the outer membrane of the cell becomes damaged.

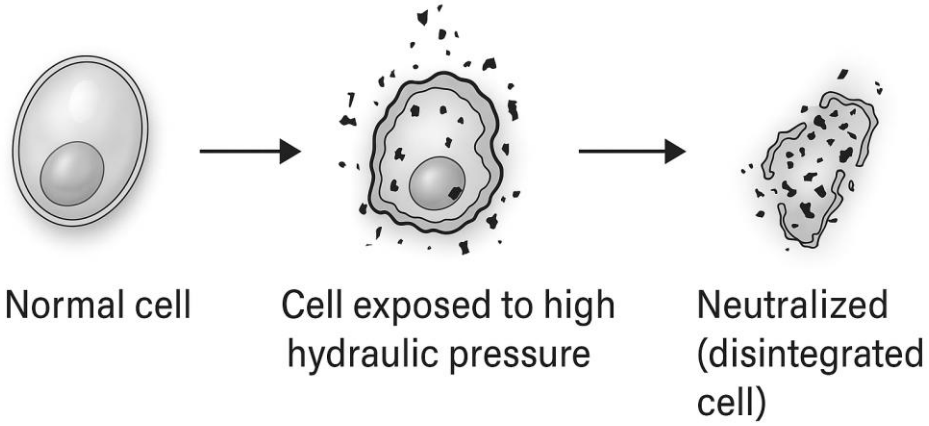


Figure 4. Damage to the cell membrane caused by pressure generated in the water medium through a pulsed electrical discharge.

An electrical discharge in water generates a pressure wave through the following stages:

Pulsed electrical discharge → strong energy is transferred into the water.

This energy creates plasma at the discharge point.

Due to the plasma, the water expands rapidly → forming a cavitation bubble (void).

This bubble quickly collapses, generating a high-pressure (10–100 MPa) shock wave [6].

ISSN NO: 2770-4491
November 2025

Based on scientific sources, the pressure levels required to damage the outer membrane of a cell through shock waves generated in a water medium as a result of pulsed electrical discharges have been evaluated [8; pp. 41–52] (Table 1).

Pressure Range	Type of Effect	Explanation
10–30 bar (10^6–3×10^6 Pa)	Sublethal deformation	The shape of the cell changes, but it remains alive.
30–100 bar (3×10^6–10×10^6 Pa)	Membrane microperforations (poration)	Long-term permeabilization occurs.
100–300 bar (10×10^6–30×10^6 Pa)	Severe membrane damage	Cytoplasmic leakage occurs, leading to cell death.
>300 bar (>30×10^6 Pa)	Complete lysis (rupture)	The cell bursts, and DNA is released.

Let's examine how the pressure generated in water by a pulsed electrical discharge depends on voltage, capacitance, and processing time:

$$P = \frac{F}{S} = \frac{\frac{W}{l}}{S} = \frac{W}{S \cdot l} = \frac{W}{V_{ef}}$$

Here:
P — shock wave pressure (Pa),
W — supplied energy (J),
V_{ef} — effective volume of the bubble or shock zone (m^3).

To calibrate the formula for a real system, we add the coefficient k, which is a fitting (correction) factor.

$$P \approx k \cdot \frac{W}{V_{ef}}$$ supplied energy $$W = \frac{CU^2}{2} \rightarrow P \approx k \cdot \frac{CU^2}{2V_{ef}}$$

If the effect between the pulse duration t and the maximum pressure P is determined as a function of time:

$$P \approx k \cdot \frac{CU^2}{t2V_{ef}}$$

Electrohydraulic impulses formed in a liquid medium under the influence of high-voltage electrical discharges have a pronounced destructive effect on the microflora, leading to the death of microorganisms. This effect is caused by the combined influence of various factors — mechanical, thermal, and chemical. These include shock waves, cavitation processes, ultraviolet radiation, and the formation of active radicals capable of disrupting the integrity of cellular structures and impairing the vital activity of microorganisms [9].

 ISSN NO: 2770-4491
November 2025

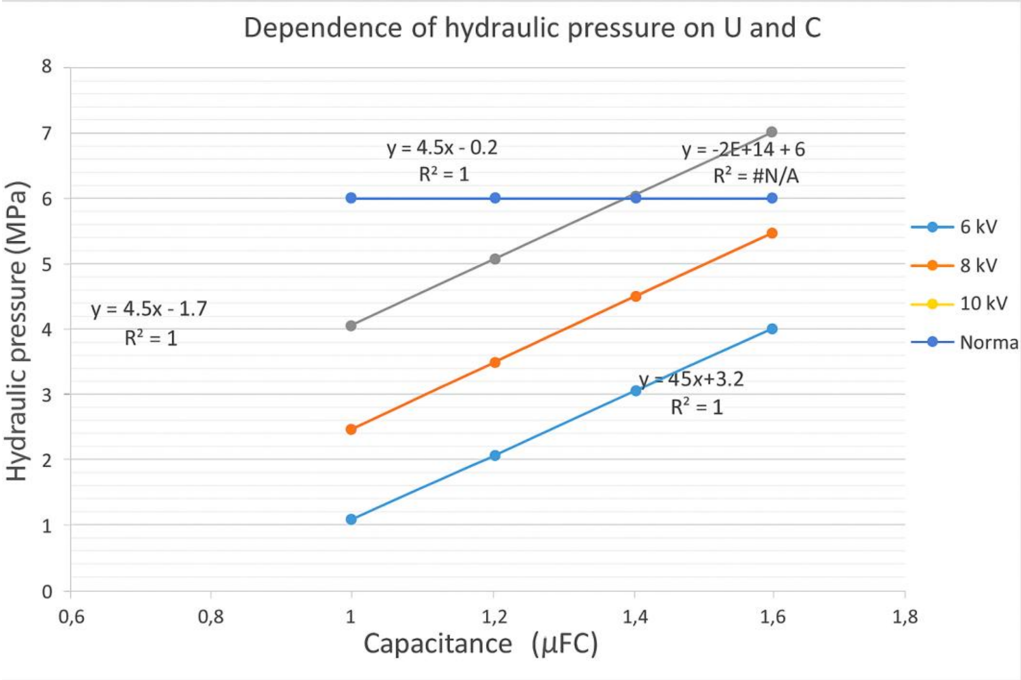


Figure 5. Dependence of Pressure Formed in Water by the Electrohydraulic Effect on the Capacitance of Capacitor Banks and Processing Voltage

Modern electrohydraulic systems mainly employ an electrothermal breakdown mechanism of the working gap. In this case, due to ionic conductivity, a significant volume of the solution between the electrodes is heated, leading to the formation of a vapor–gas medium within which the discharge channel develops.

A substantial portion of the pulse energy is consumed in the creation of this medium, resulting in considerable energy losses during the preliminary stage.

These losses reduce the overall efficiency of the electrohydraulic effect and limit the potential of the technology in a number of practical applications.

Efficiency Evaluation

The electrohydraulic effect (EHE) represents a process of converting electrical energy into mechanical energy through a powerful pulsed discharge in a liquid. Its efficiency is determined by several factors that influence the transfer of energy to the target object and the minimization of energy losses.

The electrohydraulic effect that occurs during a powerful electrical discharge in a water medium represents an effective method for disinfecting both drinking and wastewater.

Its disinfecting action is due to the combined physicochemical impact on microorganisms, organic compounds, and contaminants.

Overall conclusion.

Evaluation of the efficiency of the Electrohydraulic Effect (EHE) requires a comprehensive approach that includes both energy parameters and the operational characteristics of the system. Efficiency can be improved through:

- optimization of the chamber design;
- selection of appropriate electrodes;
- application of methods for directed discharge initiation;
- optimal selection of voltage, capacitor capacitance, and processing time.

In the course of this study, the key physical processes accompanying the occurrence of an electrical discharge in a water medium were examined. Special attention was given to breakdown mechanisms, plasma channel formation, and the conditions for generating shock and cavitation waves that underlie the electrohydraulic effect.

ISSN NO: 2770-4491
November 2025

The obtained data confirm the high potential of electrohydraulic technologies for applications in material processing, liquid medium purification, and various engineering and environmental fields. Further research in this area should focus on improving the energy efficiency of the systems, enhancing electrode durability, and adapting the technology to specific conditions such as wells or aggressive environments.
Based on the analysis of the conducted experiments, the optimal parameters of the electrohydraulic effect device for wastewater disinfection and E. coli elimination were determined as follows:

- Processing voltage: 10 kV
- Capacitor bank capacitance: 1.4 µF
- Processing time (system productivity): 7.6 L/min

These parameters ensure the most effective microbial inactivation while maintaining energy efficiency of the electrohydraulic treatment process.

References

1. Yushkov A. Yu. Study of the Formation of Bored Piles by Pulsed Discharges / Abstract of the Dissertation for the Degree of Candidate of Technical Sciences. Tomsk – 2004.
2. Voronov, Yu. V., & Yakovlev, S. V. (2006). Wastewater Disposal and Treatment: A Textbook for Universities. Moscow: Association of Construction Universities Publishing House. – 704 p.
3. Karmanov, A. P., & Polina, I. N. (2015). Wastewater Treatment Technology. Saint Petersburg State Forest Technical University named after S. M. Kirov – 6 p.
4. Yutkin, L. A. (1986). The Electrohydraulic Effect and Its Application in Industry. Leningrad: Mashinostroenie Publishing House. – 253 p.
5. Bekaev, A. A., Sokovikov, V. K., Merzlikin, V. G., et al. (2010). Application of L. A. Yutkin's Effect in Electrohydraulic Devices. In Automobile and Tractor Engineering in Russia: Development Priorities and Personnel Training: Proceedings of the International Scientific and Technical Conference (Book 7, pp. 10–12). Moscow.
6. J.Phys. B.Chem. Impact of Shock-Induced Cavitation Bubble Collapse on the Damage of Cell Membranes with Different Lipid Peroxidation Levels. The Journal of Physical Chemistry B, 2021.
7. Aytbaev N. A., Berdishev A. S., Sheryazov S. K. Study of the Process of Electrical Discharge Initiation in a Water Medium during the Development of Electrohydraulic Technologies. Agro-Industrial Complex of Russia. Chelyabinsk 2025.
8. Lopez, J. Gomez, M. T. Circuit modeling and parameter dependence of pulsed power discharges in water. Journal of Electrostatics. 2014. 41-52 p.
9. N. A. Aitbayev, A. S. Berdishev, A. A. Turdibayev. Application of the Electrohydraulic Effect Method for Wastewater Disinfection // Economics and Society, No. 12(127), 2024.

Author:
Nurlan Aliyevich Aytbaev,
Senior Lecturer, Department of Electrical Power Stations, Networks, and Systems,
Tashkent State Technical University named after Islam Karimov

E-mail: aytbaev.nurlan@mail.ru

Phone: +998 95 982 93 23