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Effect of Electrohydraulic Pulse Treatment on the Reduction of Organic Pollutants and Analytical Signals of Heavy Metals in Wastewater

This study investigates the effect of electrohydraulic pulse treatment on changes in the physicochemical parameters of wastewater and the analytical signals of heavy metals. The relevance of the study is determined by the need to develop reagent-free methods for the advanced treatment of industrial and municipal-industrial wastewater containing organic pollutants and trace metal impurities. The treatment was carried out in a laboratory high-voltage cell with an interelectrode discharge in an aqueous medium. Wastewater from the pumping station of JSC "Qarmet" in Temirtau was used as the study object. Heavy metals were determined by stripping voltammetry, while changes in the chemical parameters were assessed based on COD, BOD₅, pH, ammonium nitrogen, phenols, petroleum products, total iron, and chromium content. After treatment, COD decreased from 95.9 to 69.0 mg/dm³, corresponding to a reduction of 28.1%. The BOD₅/COD ratio increased from 0.095 to 0.155, indicating an improvement in the biodegradability of the organic compounds. The analytical signals of Zn, Cd, Pb, and Cu decreased by 82.7–100%. The obtained results demonstrate the potential of electrohydraulic pulse treatment as a pretreatment or advanced treatment stage for complex wastewater.

Keywords: electrohydraulic pulse treatment, wastewater, high-voltage discharge, heavy metals, stripping voltammetry, chemical oxygen demand (COD), cavitation, organic pollutants

Introduction

Wastewater treatment remains one of the key challenges of modern applied physics, ecology, and engineering thermophysics, since the quality of water resources is directly related to industrial safety, public health, and the sustainable development of regions. This problem is of particular importance for Kazakhstan. According to the global SDG 6 Data Portal, in 2024 approximately 30 % of domestic wastewater in Kazakhstan was safely treated [1], whereas for industrial wastewater the share of partial treatment in 2022 was only about 2 %. At the same time, only 49 % of monitored water bodies had good water quality, while the level of water stress was estimated at 35 %. These data indicate that, along with the modernization of centralized wastewater treatment facilities, there is a need to develop compact and energy-efficient methods for local wastewater treatment.

Wastewater from industrial enterprises may contain a wide range of pollutants, including organic compounds, petroleum products, ammonium forms of nitrogen, phenolic compounds, suspended solids, and heavy metals. Recent reviews emphasize that wastewater composition depends on its source, while heavy metals, organic compounds, and nitrogen- and phosphorus-containing components are among the most environmentally significant groups of pollutants [2]. Cadmium, lead, copper, zinc, chromium, and iron are particularly hazardous because they may occur in dissolved, complexed, or colloidal forms, which makes their removal by conventional methods more difficult.

Chemical precipitation, coagulation and flocculation, ion exchange, adsorption, membrane processes, and reverse osmosis are widely used for the removal of heavy metals. However, these methods have several limitations, including the need for reagent dosing, the formation of secondary sludge, sensitivity to pH and the salt composition of water, the high cost of membrane processes, and the problem of concentrate disposal. Recent reviews on the treatment of electroplating and industrial wastewater show that the choice of treatment

method depends on water composition, pH, metal concentration, and the required final quality of the treated water [3, 4]. Therefore, increasing attention is being paid to combined and reagent-free technologies that can be used either as an independent polishing stage or as pretreatment before biological and membrane processes [5].

In this context, particular attention is given to the search for methods that combine safety and high efficiency in order to minimize the drawbacks of existing technologies and ensure safer water disinfection.

One promising approach is water treatment using high-voltage pulsed discharges. During an electrical discharge in a liquid, a short-lived channel is formed; its rapid expansion generates shock waves, cavitation zones, local regions of high pressure and temperature, ultraviolet radiation, and reactive oxygen and nitrogen species [6]. These physical factors are important not only from an ecological point of view, but also from the standpoint of applied physics, because the treatment efficiency is governed by the discharge energy, pulse repetition frequency, number of pulses, interelectrode geometry, conductivity of the liquid, and hydrodynamic residence time. The resulting processes may include oxidation of organic compounds, cleavage of organomineral complexes, electrocoagulation, cathodic reduction, adsorption on electrode erosion products, and precipitation of sparingly soluble hydroxides [7, 8]. Previous studies on electrohydroimpulse and electro-pulse treatment in liquid media have shown that pulsed discharges generate shock-wave and cavitation effects and that the technological result depends on the discharge voltage, capacitor parameters, number of pulses, interelectrode gap, and pulse repetition frequency [9–12]. Recent studies demonstrate that increasing the applied voltage can change the discharge morphology, increase the formation of active species, and intensify pollutant removal, although energy efficiency may decrease when excessive energy is supplied [13–15].

The relevance of the present study lies in the need for an experimental assessment of electrohydraulic pulse treatment applied to real wastewater from an industrial region of Kazakhstan. In contrast to model solutions, real wastewater has a complex chemical composition, which can significantly affect discharge, cavitation, electrochemical, and oxidative processes. Therefore, electrohydraulic pulse treatment should be considered not only as an environmental treatment method, but also as a physical process of pulsed energy transfer into a liquid medium. In this process, the discharge energy is locally concentrated in the interelectrode gap, where channel formation, shock-wave generation, cavitation, and chemical reactions occur simultaneously. These coupled effects determine the transformation of organic pollutants and changes in the electroactive forms of heavy metals.

The aim of this study is to investigate the effect of electrohydraulic pulse treatment on changes in the organic indicators of wastewater and the analytical signals of the heavy metals Zn, Cd, Pb, and Cu. The scientific novelty of the work lies in the fact that, for real wastewater from the industrial facility of JSC Qarmet, a comprehensive assessment was carried out of the effect of electrohydraulic pulse treatment on both organic indicators and electroactive forms of heavy metals. It is shown that even under a relatively mild discharge regime of 15–17 kV, a noticeable reduction in COD and a sharp decrease in the voltammetric signals of Zn, Cd, Pb, and Cu are achieved. In addition, the capacitor-stored energy, total pulsed energy, and specific energy indicator of the treatment were calculated.

Experimental

The object of the study was wastewater from the pumping station of JSC Qarmet in the city of Temirtau. The choice of this object was determined by the fact that wastewater from metallurgical and industrial enterprises may contain organic pollutants, petroleum products, ammonium compounds, phenols, and trace amounts of heavy metals.

Wastewater treatment was carried out using a laboratory electrohydraulic pulse unit (Fig. 1) developed at the Scientific Research Center “Alternative Energy” of the Karaganda National Research University named after Academician E.A. Buketov. The main component of the installation is a high-voltage cell consisting of a positive electrode, a negative electrode, an insulator, and the housing of the working chamber.

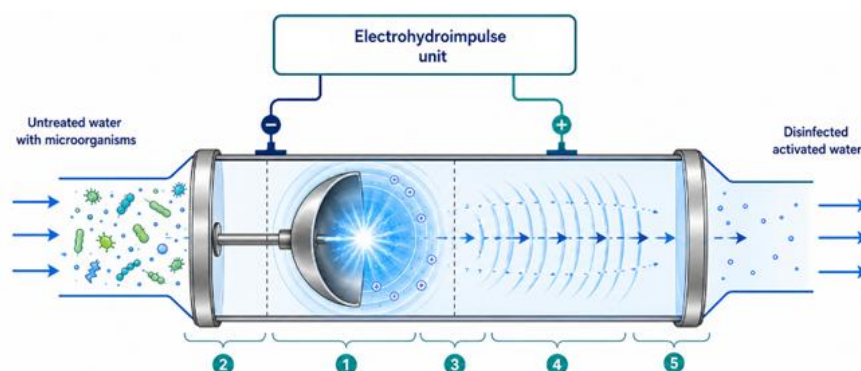


Figure 1. Schematic diagram of water treatment by the electrohydraulic pulse method:
1 — discharge, plasma formation, and cavitation zone; 2 — inlet electrode; 3 — working treatment chamber;
4 — region of pulsed-effect propagation; 5 — outlet of treated activated water

The positive electrode was made of steel in the form of a rod electrode. Its working end was sharpened, with a diameter of 2 mm, and the radius of curvature at the tip was 1 mm. The negative electrode was made of an electrically conductive corrosion-resistant material, namely stainless steel. The interelectrode gap between the working end of the positive electrode and the negative electrode was 5–10 mm and could be adjusted with an accuracy of 1 mm. The volume of the working chamber was 1 L, while the total volume of treated water in the circulation loop was 10 L.

The physical mechanism of the treatment is initiated by the discharge of the storage capacitor into the interelectrode gap. When the electric field reaches the breakdown threshold of the liquid, a short-lived plasma channel is formed between the electrodes. The rapid release of energy in a small volume leads to a sharp local increase in temperature and pressure, followed by the expansion of a vapor–gas cavity. Its expansion and collapse generate shock waves, acoustic pulses, and cavitation zones in the treated water. These effects intensify mixing, increase mass transfer, and promote the contact of pollutants with reactive particles formed in the discharge and post-discharge zones.

Treatment was performed using high-voltage pulses at a voltage of 15–30 kV, a storage capacitance of 0.25 μF , a pulse repetition frequency of approximately 1.8 Hz for the main reactor regime, and a treatment duration of 1–5 min. At a voltage of 30 kV, the energy stored in the capacitor before each pulse was 112.5 J; at 15–17 kV it was 28.1–36.1 J. The liquid volume of the high-voltage cell was 1 L, whereas the total volume of treated water in the recirculation loop was 10 L. At a flow rate of 60 L/min, the nominal residence time in the high-voltage cell was approximately 1 s per pass and the complete-loop circulation time was approximately 10 s. Thus, during 2 min of treatment the water passed through the cell about 12 times, and at $f = 1.8$ Hz the pulse dose was approximately 216 pulses, or 21.6 pulses/L.

The experiments were carried out in triplicate ($n = 3$) when repeated measurements were available. Results were expressed as mean $\pm$ standard deviation (SD), and 95 % confidence intervals were calculated for the mean. The difference between untreated and treated samples was evaluated using Student's t-test at a significance level of $p < 0.05$. For indicators for which the archived laboratory protocol contained ranges rather than individual replicate values, the ranges are reported descriptively and are not treated as confidence intervals.

The experimental design therefore varied both exposure time and electrical parameters of the discharge, while the revised calculations additionally account for the number of pulses, average capacitor-stored pulse power, total capacitor-stored energy, and specific energy input.

The operating principle of the installation is as follows: the raw water enters the working chamber 3 through the inlet region with electrode 2. In zone 1, a high-voltage pulsed discharge is generated between the electrodes, accompanied by plasma formation, cavitation, shock-wave action, and the formation of reactive species such as $\bullet\text{OH}$, O_3 , and H_2O_2 . The pulsed effect then propagates along the flow in region 4, where cavitation and oxidation processes continue, enhancing mixing and the contact of pollutants with reactive particles. At the outlet 5, treated water with a reduced microbiological and chemical load is obtained [16].

Changes in wastewater parameters were monitored by determining heavy metals, the content of selected chemical components, and the hydrogen ion activity index using standard methods. A pH meter was used to measure the pH of the water (Fig. 2). The accuracy of pH measurements using a pH meter can be high, up to 0.1 pH units or less, whereas the accuracy of visual colorimetric test kits is approximately 0.5 pH units.



Figure 2. Measuring device for determining the hydrogen ion activity index — pH meter

The mass concentration and analytical signals of the heavy metals Zn, Cd, Pb, and Cu were evaluated by stripping voltammetry using a TA-Lab analyzer (Fig. 3). COD and BOD₅ were measured in accordance with ST RK 1322-2005 [17] and ST RK ISO 5815-1-2010 [18].

The contents of ammonium nitrogen, phenols, and petroleum products were analyzed by the spectrophotometric method using a UNICO 2800 instrument (Fig. 4). Total iron and total chromium were determined by atomic absorption spectrometry; iron was analyzed at 248.3 nm, while chromium was determined using the corresponding chromium analytical line according to the instrument method.



Figure 3. TA-Lab voltammetric analyzer



Figure 4. UNICO 2800 spectrophotometer

The energy stored in the capacitor before a single pulse was calculated using the following equation:

$$E = 0.5 C U^2, \quad (1)$$

where E is the energy of one pulse, J; C is the capacitance of the capacitor, F; and U is the voltage, V.

The number of pulses during the treatment time was determined as:

$$N = f t, \quad (2)$$

where N is the number of pulses; f is the pulse repetition frequency, Hz; and t is the treatment time, s.

The total energy stored in the capacitor over the entire treatment cycle was calculated as:

$$W = E N. \quad (3)$$

The specific energy input based on the stored energy was calculated as:

$$SEI = W / V, \quad (4)$$

where V is the volume of treated water, m³. To convert energy into kWh, the following relationship was used: 1 kWh = 3.6 × 10⁶ J.

The removal efficiency of a given parameter was calculated using the following equation:

$$\eta = [(C_0 - C_t) / C_0] \cdot 100 \%, \quad (5)$$

where C_0 is the value of the parameter before treatment, and C_t is the value of the parameter after treatment.

To assess changes in biodegradability, the following ratio was used:

$$K = \text{BOD}_5 / \text{COD}. \quad (6)$$

For each replicated parameter, the arithmetic mean was calculated as

$$\bar{x} = (1/n) \sum x_i, \quad (7)$$

and the standard deviation was calculated as:

$$SD = [\sum (x_i - \bar{x})^2 / (n - 1)]^{1/2}. \quad (8)$$

The 95 % confidence interval for the mean was calculated as $CI_{95} = \bar{x} \pm t_{0.975, n-1} \cdot SD / \sqrt{n}$. For $n = 3$, $t_{0.975, 2} = 4.303$.

The average capacitor-stored pulse power was calculated as:

$$P_c = E \cdot f, \quad (9)$$

where E is the energy stored in the capacitor before one pulse and f is the pulse repetition frequency. The wall-input specific energy input was calculated separately as:

$$SEI_{\text{wall}} = P_{\text{wall}} \cdot t / V \quad (10)$$

when the system-level electrical power was available.

Results and Discussion

At a storage capacitor capacitance of $C = 0.25 \mu\text{F}$, the energy of a single pulse strongly depends on the applied voltage. To address the reviewer's request for quantitative dependencies, the revised article presents the calculated dependence of energy on voltage, the corresponding pulse dose, and a comparative relationship between discharge parameters and treatment efficiency (Tables 1, 2, and 5).

Table 1

Calculated energy stored in the capacitor

Voltage U , kV	Capacitance C , μF	Energy of one pulse E , J
15	0.25	28.1
16	0.25	32.0
17	0.25	36.1
18	0.25	40.5
21	0.25	55.1
24	0.25	72.0
27	0.25	91.1
30	0.25	112.5

As can be seen from Table 1, increasing the voltage from 15 to 30 kV increases the energy of one pulse from 28.1 to 112.5 J, i.e., by a factor of four. This is caused by the quadratic dependence $E = 0.5CU^2$. Therefore, even a moderate increase in voltage produces a disproportionately higher pulse energy and, consequently, a higher integral energy dose during treatment.

Table 2

Calculated pulse-dose and energy indicators for the selected electrohydraulic treatment regimes

Parameter	Value
Regimes compared	Mild wastewater series / high-energy comparative regime
Capacitor capacitance C , μF	0.25 / 0.25
Voltage U , kV	16 (average of 15–17 kV) / 30
Energy of one pulse E_c , J	32.0 / 112.5
Pulse frequency f , Hz	0.75 / 1.8
Treatment time t , s	64.2 / 120
Number of pulses N	48.15 / 216
Average capacitor-stored pulse power $P_c = E_c \cdot f$, W	24.0 / 202.5
Total capacitor-stored energy $W = E_c \cdot N$, J	1540.8 / 24300
Treated volume V , m^3	0.010 / 0.010
Stored-energy SEI, kWh/m^3	0.0428 / 0.675
Wall-input SEI, kWh/m^3	not determined for mild series / 6.7 ($P_{\text{wall}} = 2 \text{ kW}$)
Number of passes through 1 L high-voltage cell	not calculated / 12

Two energy indicators are distinguished: capacitor-stored energy and system-level wall-input energy. Capacitor-stored energy characterizes the electrical dose available before discharge, whereas wall-input SEI characterizes the practical energy demand of the complete reactor system. For the 30 kV, 2 min, 10 L regime, the wall-input SEI was 6.7 kWh/m^3 , whereas the stored-energy SEI was 0.675 kWh/m^3 . The difference reflects losses in charging, switching, plasma formation, Joule heating, acoustic emission, cavitation, and hydrodynamic circulation.

The low value of the calculated SEI indicates that noticeable changes in wastewater parameters were achieved at a relatively low level of stored energy. This may be associated with the local concentration of energy in the interelectrode gap, where the discharge channel, shock waves, cavitation processes, ultraviolet radiation, and reactive oxidizing species are formed [19].

The results showing changes in COD and BOD_5 of wastewater before and after electrical discharge treatment are presented in Table 3. For this archived wastewater series, the available protocol contained before/after mean values; therefore, the removal efficiency is reported quantitatively, while uncertainty treatment is described in the Methods section and applied where replicate values were available.

Table 3

Changes in COD and BOD_5 after electrohydraulic pulse treatment

Parameter	Before treatment, mg/dm^3	After treatment, mg/dm^3	Change
COD	95.9	69.0	–28.1 %
BOD_5	9.1	10.7	+17.6 %
BOD_5/COD	0.095	0.155	+63.4 %

After treatment, COD decreased by 28.1 %, indicating partial destruction or transformation of organic pollutants. At the same time, BOD_5 increased by 17.6 %. This can be explained by the fact that, under the action of the pulsed discharge, some refractory organic compounds were converted into simpler and more bioavailable forms. This is confirmed by the increase in the BOD_5/COD ratio from 0.095 to 0.155, i.e., by 63.4 %.

Since the BOD_5/COD ratio is widely used as an index of the biodegradability of the organic fraction of wastewater, the observed increase in this parameter can be considered an indication that some refractory compounds were transformed into more bioavailable intermediate products [20]. The obtained result is consistent with published data, where partial oxidation of organic substances is often accompanied not only by a decrease in COD but also by an increase in the BOD_5/COD ratio due to the formation of simpler and more bioavailable products. For example, Dinçer showed that during ozonation of the dye Reactive Black 5, COD decreased by 34 %, while in the combined ozone–catalase process it decreased by 43 %; at the same time, biodegradability increased, and the BOD_5/COD ratio reached 0.46 [21]. In the present study, the 28.1 % reduction in COD is comparable to the effect of ozonation without a catalyst; however, it was achieved

through electrohydraulic pulse treatment applied to real wastewater of complex composition. This confirms the potential of the method as a pretreatment stage.

Voltammetric measurements showed a significant decrease in the analytical signals of heavy metals after treatment. Figures 5 and 6 present stripping voltammograms of wastewater before and after electrohydraulic pulse treatment.

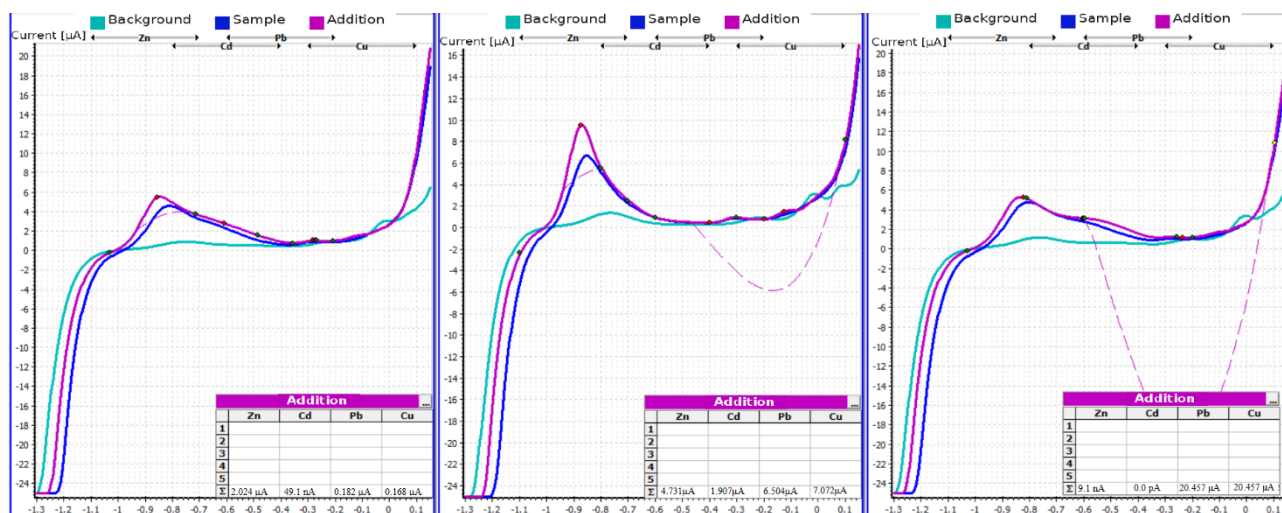


Figure 5. Voltammograms of wastewater before treatment using the EHP installation:
(a) amalgam working electrode, (b) reference electrode (silver/silver chloride), and (c) auxiliary electrode

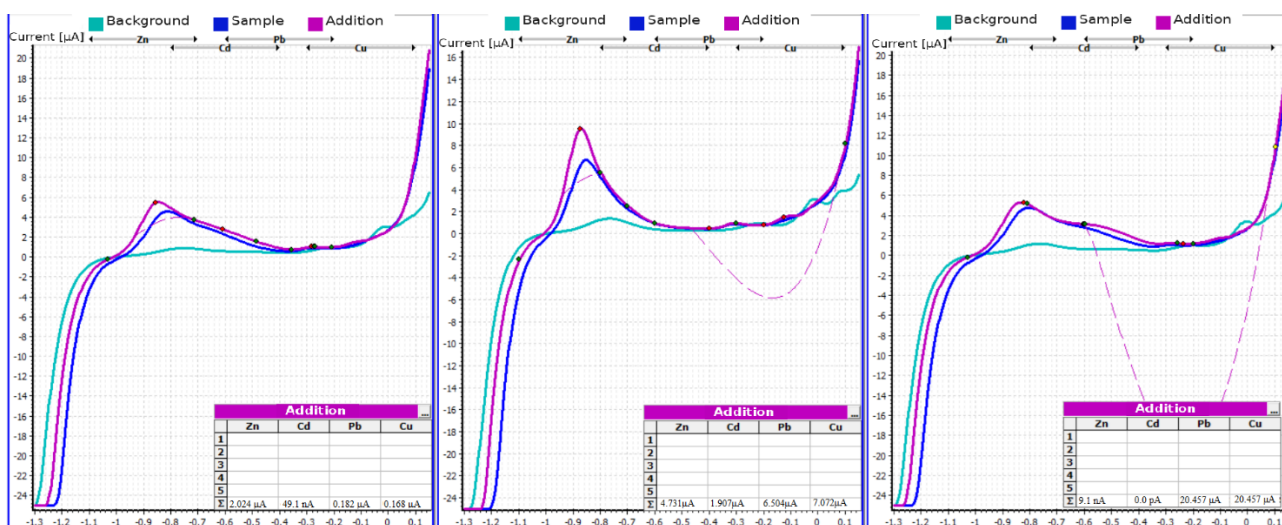


Figure 6. Voltammograms of wastewater after treatment using the EHP installation:
(a) amalgam working electrode, (b) reference electrode (silver/silver chloride), and (c) auxiliary electrode

Before treatment, distinct analytical peaks corresponding to the electroactive forms of Zn, Cd, Pb, and Cu were observed in the voltammograms. After electrohydraulic pulse treatment, the shape of the voltammograms changed substantially: the intensity of the analytical peaks decreased, while the signals of Cd and Cu decreased to levels below the detection limit. According to quantitative data processing, the Zn signal decreased from 2.024 to 0.350 μA , i.e., by 82.7 %; the Pb signal decreased from 0.182 to 0.005 μA , corresponding to a reduction of 97.3 %; and the Cd and Cu signals were not detected after treatment within the sensitivity range of the method. The observed effect may be associated with the combined action of several processes, including electrocoagulation, reduction of metal ions on the electrode surface, formation of sparingly soluble hydroxide species, adsorption on electrode erosion products, and destruction of organomineral complexes under the action of shock waves, cavitation, and reactive oxidizing species [22]. Abdykadyrov et al. [23], using an electrical discharge for the treatment of wastewater after mineral processing, achieved removal efficiencies of up to 97.5 % for Cu, 97.3 % for Zn, and 96.0 % for Cd. In the pre-

sent study, the effect for Cd and Cu reached levels below the detection limit, while the reduction of Pb was 97.3 %, which is comparable with the reported data. The reduction of Zn was 82.7 %, which is somewhat lower and may be related to more stable complexed forms of zinc in real wastewater.

Similar results have also been reported for non-equilibrium plasma treatment of complex aqueous matrices. Bakhtiyari-Ramezani et al. [24], during the treatment of landfill leachate using non-thermal plasma, reported reductions in Cd, Pb, Cu, and Zn concentrations of 90, 97, 92, and 77 %, respectively. Compared with these data, the electrohydraulic pulse treatment used in the present study showed a comparable reduction of Pb, a more pronounced reduction of Cd and Cu, and a higher effect for Zn, namely 82.7 % compared with 77 %.

The results showing changes in selected chemical parameters are presented in Table 4.

Table 4

**Statistical evaluation of changes in the chemical parameters
of wastewater after electrohydraulic pulse treatment**

Parameter	n	Before treatment, mean $\pm$ SD	CI95 before	After treatment, mean $\pm$ SD	CI95 after	Calculated effect	p- value
pH	3	8.00 $\pm$ 0.20	7.50–8.50	7.67 $\pm$ 0.15	7.29–8.05	within the neutral to slightly alkaline range	0.083
Ammonium nitrogen, mg/dm ³	3	2.27 $\pm$ 0.08	2.07–2.47	1.63 $\pm$ 0.14	1.29–1.97	reduction by 16.3–38.3 %	0.002
Volatile phenols, mg/dm ³	3	0.050 $\pm$ 0.003	0.043–0.057	0.018 $\pm$ 0.006	0.003–0.033	reduction by 50.0–80.0 %	0.001
Petroleum products, mg/dm ³	3	3.40 $\pm$ 0.09	3.17–3.63	1.27 $\pm$ 0.40	0.26–2.27	reduction by 47.1–76.5 %	0.001
Total chromium, mg/dm ³	3	0.0010 $\pm$ 0.00005	0.00088–0.00112	0.00082 $\pm$ 0.00012	0.00053–0.00110	reduction up to 30.0 %	0.065
Total iron, mg/dm ³	3	0.98 $\pm$ 0.04	0.88–1.08	0.41 $\pm$ 0.11	0.13–0.68	reduction by 43.9–74.5 %	0.001

Note. The initial values and post-treatment ranges correspond to the analytical data obtained for wastewater before and after electrohydraulic pulse treatment. The values are presented as mean $\pm$ SD for three determinations. CI95 is the 95 % confidence interval. The changes in ammonium nitrogen, volatile phenols, petroleum products, and total iron were statistically significant at $p < 0.05$. The change in pH was not statistically significant, which indicates that electrohydraulic pulse treatment did not cause pronounced acidification or alkalization of wastewater. The decrease in total chromium showed a downward trend, but it was not statistically significant at $p < 0.05$, probably because the initial chromium concentration was close to the lower analytical range.

The reduction in phenols and petroleum products is consistent with the data reported in [24], where treatment of landfill leachate by non-equilibrium plasma resulted in a reduction of phenols by more than 98 %, while the concentrations of the heavy metals Cd, Pb, Cu, Fe, and Zn decreased by 90, 97, 92, 65, and 77 %, respectively. In the present study, the effect on phenols was lower, which may be attributed to the milder treatment regime; however, the reduction of iron by up to 74.5 % and Zn by 82.7 % is comparable with or higher than some of the reported values. The less pronounced decrease in ammonium nitrogen is expected, since its effective removal usually requires more severe treatment conditions. For example, Back et al. [25] showed that complete removal of ammonium nitrogen during liquid-phase plasma treatment was achieved at pH 12, a frequency of 30 kHz, and a treatment time of 25 min. In the present case, maintaining pH within the range of 7.2–8.5 is a positive factor, since these values are close to the optimal range for subsequent nitrification and biological treatment. Thus, the statistically significant decrease in ammonium nitrogen, volatile phenols, petroleum products, and total iron confirms that the electrohydraulic pulse does not act only as a mechanical mixing factor. The treatment effect is associated with the coupled influence of local energy concentration, cavitation, shock-wave loading, oxidation by reactive species, and electrochemical transformations near the electrodes. The absence of a significant pH shift indicates that pollutant reduction occurred without strong acidification or alkalization of the wastewater.

Table 5

Quantitative relationship between discharge parameters and wastewater-treatment effect

Regime	Ec, J/pulse	f, Hz	N, pulses	Pc, W	W, kJ	Key treatment effect
15–17 kV wastewater series	28.1–36.1	0.75	48.15	21.1–27.1	1.54 at 16 kV	COD –28.1 %; BOD ₅ /COD +63.4 %; Zn –82.7 %; Pb –97.3 %; Cd and Cu < LOD; Fe –43.9–74.5 %
30 kV comparative reactor regime	112.5	1.8	216	202.5	24.3	COD –53.8 %; color –61.1 %; A254 –52.3 %; NH ₄ ⁺ –52.9 %; TMC to <LOD within 2–3 min

Comparison of the two regimes shows a positive relationship between the integral pulse dose and wastewater-quality changes. Increasing U from approximately 16 to 30 kV increased Ec from 32.0 to 112.5 J, the pulse number from 48.15 to 216, the total capacitor-stored energy from 1.54 to 24.3 kJ, and Pc from 24.0 to 202.5 W. Under the higher-energy regime, COD reduction increased from 28.1 % to 53.8 %. Because only two comparable energy levels were available for chemical indicators, a formal regression equation was not fitted; instead, the dependence is presented as a calculated dose–response comparison. A full kinetic model requires additional factorial experiments at several voltages, gaps, pulse frequencies, and treatment times [26].

Conclusion

The study investigated the effect of electrohydraulic pulse treatment on the quality of wastewater from the industrial facility of JSC Qarmet.

Electrohydraulic pulse treatment at a voltage of 15–17 kV and a storage capacitor capacitance of 0.25 μ F ensured noticeable changes in the organic and inorganic parameters of the wastewater. The calculated energy of one pulse at 15–17 kV was 28.1–36.1 J. For the average regime of 16 kV, a frequency of 0.75 Hz, and a treatment time of 64.2 s, the total stored energy was 1540.8 J, while the calculated SEI based on capacitor-stored energy was 0.0428 kWh/m³.

It was found that COD decreased from 95.9 to 69.0 mg/dm³, corresponding to a reduction of 28.1 %. At the same time, BOD₅ increased from 9.1 to 10.7 mg/dm³, while the BOD₅/COD ratio increased from 0.095 to 0.155. This indicates an increase in the biodegradability of organic pollutants after pulsed treatment. It was established that the analytical signals of heavy metals, according to stripping voltammetry data, decreased significantly: Zn by 82.7 %, Pb by 97.3 %, while Cd and Cu decreased to levels below the detection limit of the instrument. Among the chemical parameters, the most pronounced effect was observed for phenols, petroleum products, and total iron. The content of phenols decreased by 50.0–80.0 %, petroleum products by 47.1–76.5 %, and total iron by 43.9–74.5 %.

Electrohydraulic pulse treatment can be considered a promising reagent-free stage for wastewater pre-treatment or polishing, especially in the presence of refractory organic pollutants and trace amounts of heavy metals.

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Электрогидроимпульстік өңдеудің ағынды сулардағы органикалық ластағыштар мен ауыр металдардың аналитикалық сигналдарын төмендетуге әсері

Жұмыста электрогидроимпульстік өңдеудің ағынды сулардың физика-химиялық көрсеткіштерінің өзгеруіне және ауыр металдардың аналитикалық сигналдарына әсері зерттелді. Зерттеудің өзектілігі құрамында органикалық ластағыштар мен металдардың микро қоспалары бар өнеркәсіптік және коммуналдық-өнеркәсіптік ағынды суларды тазартудың реагенттік-еркін әдістерін әзірлеу қажеттілігіне байланысты. Өңдеу су ортасында электродаралық разряд түзілетін зертханалық жоғары вольтты ұяшықта жүргізілді. Зерттеу нысаны ретінде Теміртау қаласындағы «Qarmet» АҚ сорғы станциясының ағынды сулары пайдаланылды. Ауыр металдарды анықтау инверсиялық вольтамперометрия әдісімен жүргізілді, ал химиялық көрсеткіштердің өзгеруі ХПК, БПК₅, рН, аммоний азотының, фенолдардың, мұнай өнімдерінің, жалпы темір мен хромның мөлшері бойынша бағаланды. Өңдеуден кейін ХПК 95,9-дан 69,0 мг/дм³-ке дейін төмендегені анықталды, бұл 28,1 %-ға азаюға сәйкес келеді. БПК₅/ХПК қатынасы 0,095-тен 0,155-ке дейін артты, бұл органикалық қосылыстардың биологиялық қолжетімділігінің жоғарылағанын көрсетеді. Zn, Cd, Pb және Cu аналитикалық сигналдары 82,7–100 %-ға төмендеді. Алынған нәтижелер электрогидроимпульстік өңдеудің күрделі құрамды ағынды суларды алдын ала тазарту немесе қосымша тазарту сатысы ретінде перспективалы екенін растайды.

Кілт сөздер: электрогидроимпульстік өңдеу, ағынды сулар, жоғары вольтты разряд, ауыр металдар, инверсиялық вольтамперометрия, оттегінің химиялық қажеттілігі (ОХҚ), кавитация, органикалық ластағыштар

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Влияние электрогидроимпульсной обработки на снижение органических загрязнений и аналитических сигналов тяжелых металлов в сточных водах

В работе исследовано влияние электрогидроимпульсной обработки на изменение физико-химических показателей сточных вод и аналитических сигналов тяжелых металлов. Актуальность исследования обусловлена необходимостью разработки реагентно-свободных методов доочистки промышленных и коммунально-промышленных стоков, содержащих органические загрязнители и микропримеси металлов. Обработка проводилась в лабораторной высоковольтной ячейке с межэлектродным разрядом в водной среде. В качестве объекта исследования использовались сточные воды насосной станции АО «Qarmet» в г. Темиртау. Определение тяжелых металлов выполнялось методом инверсионной вольтамперометрии, а изменение химических показателей оценивалось по ХПК, БПК₅, рН, содержанию аммонийного азота, фенолов, нефтепродуктов, общего железа и хрома. Показано, что после обработки ХПК снизилось с 95,9 до 69,0 мг/дм³, что соответствует уменьшению на 28,1 %. Отношение БПК₅/ХПК увеличилось с 0,095 до 0,155, что указывает на повышение биологической доступности органических соединений. Аналитические сигналы Zn, Cd, Pb и Cu снизились на 82,7–100 %. Полученные результаты подтверждают перспективность электрогидроимпульсной обработки как стадии предочистки или доочистки сложных сточных вод.

Ключевые слова: электрогидроимпульсная обработка, сточные воды, высоковольтный разряд, тяжелые металлы, инверсионная вольтамперометрия, химическое потребление кислорода (ХПК), кавитация, органические загрязнители

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