International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

March 2014	Issue 18	Volume 6	Number 1	Pages 34-38

ENVIRONMENTALLY CLEAR METHODS OF WATER DISINFECTION

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Abstract- In this article the water disinfection process by high voltage pulse electric discharges is considered. Using of high voltage microsecond pulses in "pin-plane" (PE-PL) non-uniform electrode system in water cause the simultaneous proceeding of some physical processes, such as, electrolysis, formation of atomic oxygen and ozone, photo ionization, UV-radiation, thermo ionization, formation of shock waves, and micro explosions, effectively disinfected the water medium. High electrical fields directly affect on bacteria structure and cause their death. Consideration the heating and electrical processes in water is shown the dependence of discharge parameters, such as, delay time and speed of leaders from tension polarity of potential "pin" electrode, construction of electrode systems, amplitude of tension and electrical field intensity. This technology can be used as a basis on developed industrial installations in different stages of purification of drinking water and wastewater instead of ecologically dangerous and toxic chemical oxidizers.

Keywords: Disinfection, Water, Wastewater, Ecology, Pulse, Generator, UV-Radiation, Leader Channels, Potential Electrode, Pin-Plane System, Discharge, Coliform and Thermo Tolerant Bacteria, Colifaqs.

I. INTRODUCTION

Transition from the less economic and polluting environment technologies to more power effective and environmentally clean ones in all spheres of national economy and industry is now observed [1]. In this regard, the new ways and methods for successful solution of the more ecology problems, caused a big loss to environment, are researched, and elaborated. The ecological aspect is also seriously concerned the water supply systems. The continuous increase in water consumption at limited world reserves of drinking water and pollution of reservoirs by industrial and municipal-domestic wastes is one of the main environmental problems of the present.

The rivers, lakes, and seas by sewage of industrial and agro industrial enterprises are polluted. The fast development of chemical industries, formation of the sewage significant value, polluted by various chemicals, an increase of drinking water and cleared sewage requirements, causes of large application of various cleaning methods. Using of the chemical reagents strong oxidizers in water supply and sewage treatment systems and the subsequent formation of residual complexes, dangerous to activity, is the reason of distributions of the dangerous diseases, demanding the immediate decision.

The current trends in the field of water treatment are focused on combination of various methods of disinfecting for creation of multiple barriers and minimization of byproducts after disinfection process [2]. Application of UV lamps instead of chlorination process is well proved owing to absence of the by-products [3-5]. In this regard, the carrying out of the further researches on development of power effective and environmentally clear methods of water purification causes a huge practical interest. The present article to methods of disinfection of drinking water and wastewater by influence of high voltage pulsed discharges is devoted.

II. MATERIALS AND METHODS

In article the effects happened in water by influence of the high electric fields, are considered. It is possible to create the high intensities of electric field (10^5 V/cm and more) only in a pulse mode in non-uniform electric field. The desirable cluster structure and the transparent movement of dissolved salts ions by change of electrical field intensity, pulse duration, and frequency of the followed pulses are possible achieved.

Transformer with the maximum output tension up to 140 kV, as a high voltage source was used. The general scheme of experimental installation is given in Figure 1. The high voltage pulsed generator by Arkadiyev-Marx scheme on capacitor energy stores and output tension up to 40 kV was assembled. The pulse front was about 0.15 μsec. The river water and municipal domestic wastewater with available coliform, thermo tolerant bacteria, and colifaqs, as objects of research, are explored.

The discharge chamber from Plexiglas material, allowed visually observe the plasma processes inside, by sizes 140×140×140 cm^3 was done. The asymmetrical pin-plane (PE-PL) electrode system for creation of non-uniform electric field inside of chamber was designed. The electrodes place inside water and potential electrode by rubber insulation is separated from water besides of the edge of pin's end for prevention of surface energy dissipation. Experiments in tap water by conductivity $\sigma = (2.5 - 4)\times10^{-4}$ $Om^{-1}cm^{-1}$ were done. The chamber with explored water, exposed to influence of pulse electric discharges by amplitude 15-40 kV with frequency of followed pulses 100 Hz, was filled.

The chemical and bacteriological analyses of water, before and after experiments, at the Central laboratory of "Azersu" Open Joint Stock Company (OJSC) were done. At non-uniform electric field in water the partial discharges around the potential electrode, reminding the crown discharge in air, are arisen. At the crown discharge in water the polarity effect, influencing on distribution speed of the leader (plasma) channels in inter-electrode distance and on leader's delay time, is strong expressed.

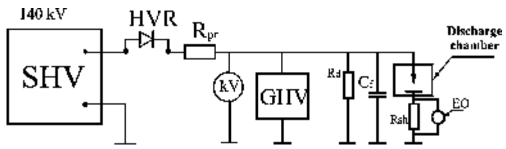
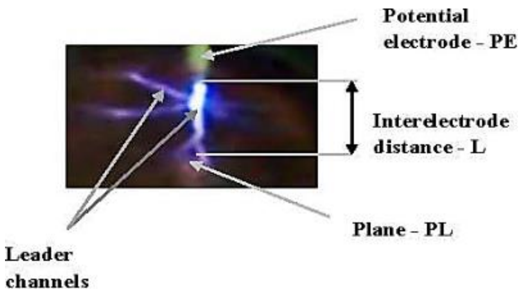
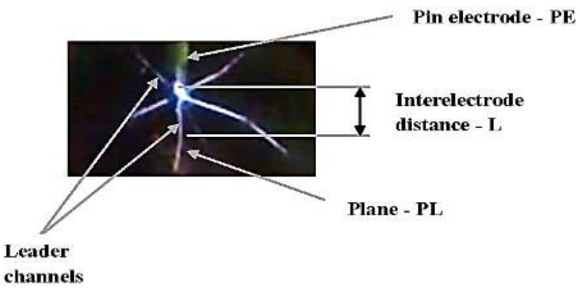


Figure 1. General scheme of the pilot installation, SHV (Source of High Voltage), HVR (High Voltage Rectifier) R_{pr} (Current Limiting Resistance), kV (kilo Voltmeter), GHV (High Voltage Generator), EO (Electronic Oscillograph)

However, at both polarities around potential electrode up to tension 16 kV, the same thermal processes, i.e. liquid boiling and formation of gas cavities are taken place. In Figure 2 the pin-plane discharge gap luminescence digital photos at positive (a) and negative (b) polarities on Potential Electrode (PE) at the fixed inter-electrode distance (L) are given.



(a)



(b)

Figure 2. Digital luminescence photos, (a) + PE – PL, L = 2.5 cm, U = 40 kV, (b) - PE + PL, L = 2.0 cm, U = 40 kV

At both polarities the gas cavities gradually move ahead towards to an opposite electrode. Inside of them the high conductivity leader channels are appeared. Temperature and pressure are grown inside of cavities. They are extended and pressure inside of them is falling. When pressure becomes less hydrostatic one they are collapsed and the process is resumed. So, there are fluctuations of the cavities and as a result the weak shock waves are formed.

With increase of tension the number of leaders and their ramifications increases and their speed to ~ 2×10^4 cm/sec value is reached. At a small tension around the pin-electrode the crown discharge is arisen. By increase of tension up to 40 kV and at positive polarity on potential electrode the distribution speed of the leader channels achieves 20 mm/μsec (higher than sound speed in water) and as a result, the spark discharge in inter-electrode distance is observed.

On positive polarity of potential electrode and tension more 20 kV, leader's formation time is reduced (no more 5 μs) and only leader channels move ahead towards to opposite electrode. Their speed up to 5×10^6 cm/sec is reached (is more than sound speed in water). Temperature and pressure inside of plasma channels reaches $(3\text{-}4)\times10^4$ K and $(2\text{-}3)\times10^4$ atm., respectively. They also are collapsed and resumed like in crown discharge.

As a result the powerful shock waves are formed and finally the leader channels cross all inter-electrode distance and we observe the spark discharge. Comparing the experimental data, we chose pin-plane electrode system with a positive polarity (+ PE – PL), as an optimal in any cases, that is confirmed by volts-second characteristics [6].

III. RESULTS AND DISCUSSION

As it was mentioned above, the high electric fields influence on the river water, intended for drink, and wastewater with maximum concentration of coliform and thermo tolerant bacteria and colifaqs: 3000 KOE/100 ml coliform and thermo tolerant bacteria in surface water and 260000 KOE/100 ml in wastewater, 800 BOE/100 ml colifaqs in surface water and 320 BOE/100 ml in wastewater. Indicators of raw water pollution, COD (Chemical Oxygen Demand) and BOD (Biology Oxygen Demand) were 130 mg/l and 30 mg/l respectively.

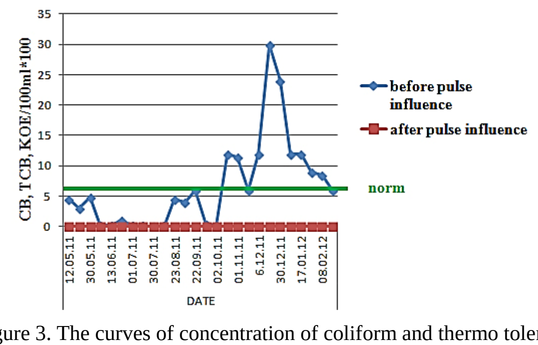


Figure 3. The curves of concentration of coliform and thermo tolerant coliform bacteria in surface water before and after pulsed treatment

The curves with results of experiments are given in Figures 3 to 6. Analyzing these curves we see, that the general concentration of the coliform and thermo tolerant bacteria and colifaqs in river water and municipal, domestic wastewater after high-voltage pulsed treatment is reduced up to units KOE/100 ml and BOE/100 ml, respectively. COD and BOD indicators are become 0 mg/l, which are much lower normal value. Results of experiments testify to a positive effect of pulsed influence on bacteriological cleaning of polluted water within the international standards.

Analyzing the obtained experimental data, the process of water disinfecting can be presented as follows. During high voltage pulse influence on water the gas cavities around the potential electrode, as a result of water boiling up and electrolysis, are formed. The water heating by hydrogen allocation at the cathode and oxygen at the anode is accompanied. The volume of appeared gas cavities is more at the cathode, than at the anode. Existence of gas inclusions causes the sharp increase of heterogeneity of electrical field.

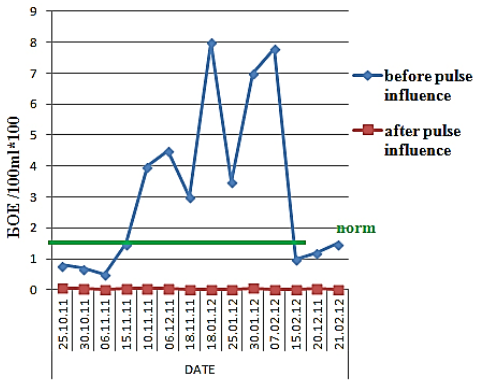


Figure 4. The curves of colifaq's concentration in surface water before and after pulsed treatment

The difference in the size of gas inclusions at the anode and cathode, possibly causes sharper increase of electrical intensity around the cathode. By this we can explain small delay time of leader channels in - PE + PL electrode system in comparison with + PE - PL one. Intensity of electrical field inside of gas cavity is more than in liquid. Therefore, the gas cavity is warming up and, as a result, it turns into well conducted inclusion. Besides, gas inclusion with discharge in it becomes a source of free electrons.

There are possible the avalanche processes in liquids and formation of leaders, as a result of increase of electrical intensity near the gas cavity and appearance of free electrons. The leader's delay time depends from polarity and amplitude of tension, the maximum intensity of electrical field, and also from the water conductivity. At initial intensities E = 36 - 45 kV/cm this time is close to necessary time for water heating up to boiling temperature. By increase of intensity the leader's delay time is reduced.

The average speed of leader's development also depends from polarity and amplitude of tension. The leader's delay time on negative polarity is less (up to the tension 25 kB), than in positive one. It, probably, connects with difference in the size and volume of the gas inclusions, which are forming around potential electrode, as a result of, electrolysis process. Speeds of negative and positive leaders are little differed up to the tension ~25 kV. Smaller speeds of leaders, than 5×10^3 cm/s, aren't observed. Speed of leader's increases by increase of tension, and the speed of positive leaders grows quicker.

At a tension 90-100 kV the speed of positive leaders is 2 orders more in comparison with negative ones. The different physical processes, like shock ionization, photoionization and thermo ionization inside of them, are taken place. The high conductivity leader (plasma) channels, moved to opposite electrode with various speed (subsonic or supersonic), depending on amplitude and polarity of tension on sharp electrode, are appeared. Near the non-uniform electrode with high electrical intensities, formation of atomic oxygen and ozone, including also theirs negative ions, are formed.

At the same time inside of the gas cavities, as result of photo ionization process, a Ultra-Violet (UV) radiation is arisen. Because of high pressure in gas cavities, they are extended and at the moment, when the internal pressure is lower than the external hydrostatic one, they are collapsed. These processes are repeated again and, as a result, the shock waves and dispersing water streams are formed.

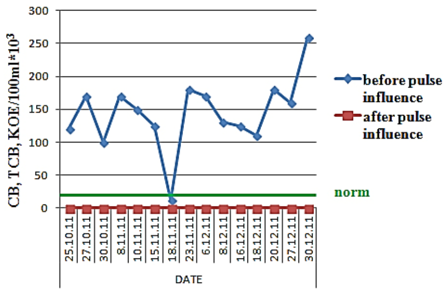


Figure 5. The curves of concentration of coliform and thermo tolerant coliform bacteria in wastewater before and after pulsed treatment

During water's pulsed influence the high electric fields affect perniciously directly on structure of pathogenic microorganisms. On the example of two-layer model of a bacterial cell with two dielectric membranes by several dielectric permeability's we can observe the distribution of electric field. From external area with a big dielectric permeability to membrane with less one, protected the nuclear of the cell. These membranes maintains the high intensity fields and electric breakdown of them can causes cell's death. Should be noted, that during the high voltage pulsed affect on water sodium, calcium and other metals ions are formed. On other hand, there are free channels on cell's membrane, transparented for above-mentioned ions.

By means of them at pulse influence the micro explosions inside of membrane are arisen, that causes the death of microorganisms. Finally the pulsed electrical fields penetrate into cytoplasm and inactivate its further development. All above described processes negatively influence on activity of microorganisms and cause their death, disinfecting the water medium [7]. Analyses of researches showed, that in all cases quantitative indicators of pathogenic microbes and bacteria in all above mentioned waters are lower than norm and corresponds to the international standards.

So, the water is disinfected. Summing up the above, we offer to apply our technology at different stages of water treatment. For bacterial purification of underground waters, where the high voltage pulse installation can be located directly at the exit of raw water from a well instead of chlorination process. For a surface water, this equipment can replace in whole or in part the chlorination process directly at the first stage of cleaning or completely replace chlorination process on the last site of cleaning before consumption.

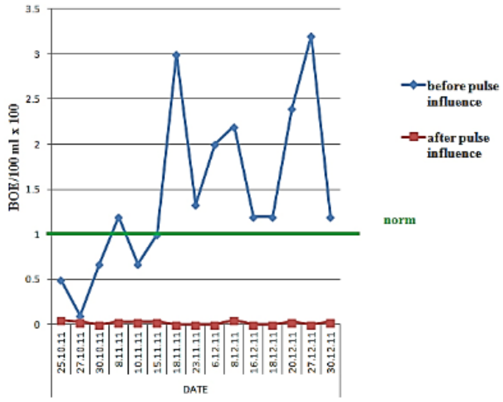


Figure 6. The curves of colifaq's concentration in wastewater before and after pulsed treatment

In surface water we can firstly estimate the water turbidity level at the beginning of purification, where chlorine as an oxidizer is usually used. We must note, that for ensuring an effective disinfecting the turbidity of raw water should be an average 2 mg/l (5.4 NTU, max to 5 mg/l (13.5 NTU)). At absence in initial water of the specific organic pollution demanding an application of oxidizing technologies, it is perspective to partially or completely replace of primary chlorination by high voltage pulsed discharges equipment.

Industrial tests showed that using of high voltage pulsed method at the first stage of water purification instead of chlorine the total microbe number practically in all tests after plasma treatment is less 100 KOE/100 ml. So, we observe an improvement of water quality after the high electrical fields affect already on an entrance to treatment facilities. For wastewater, the pulse technology can be located after biological cleaning, replaced with the chlorination process just before emission in an open reservoir.

The plasma processes in wastewater accompanies by decrease of follow indicators: chemical and biochemical demands for oxygen (COD and BOD). It should be noted, that varying parameters of the pulsed generator and a discharge circuit we can achieve the most effective purification of water. With small amplitudes of tension (up to 20 kV and field intensities 36-45 kV/cm) on potential electrode the polarity choice doesn't have an essential role, because at both polarities (+ and –) the plasma processes in water have the almost same formation time, as a result, of heat processes and electrolysis in water.

At the field intensities less 80 kV/cm it is desirable to apply the positive polarity on pin electrode, and, in few cases, the negative one. And, when the electrical field intensities are more, than 80 kV/cm, is better use the positive polarity on potential pin electrode, because in this case it is possible to achieve the small formation times of the leader channels and entirely the discharge processes in water. Also, it is necessary to note, that the offered technology is more power effective in comparison with applied chlorination process. This method of cleaning consumes the electric power several times less.

Thus, summarized the all experimental data, we recommend to use of this technology, owing to its energy efficiency and ecological purity, for application in industrial installations for disinfection of drinking water and wastewater.

IV. CONCLUSIONS

Thus, in present article the different physical processes in water, such as, electrolysis, water's boiling up, formation of atomic oxygen and ozone, UV-radiation, thermo ionization, formation of shock waves and micro explosions, as a result of influence of high voltage pulsed discharges, are considered. Is shown, that depending on conditions, processes in water can be thermal or electric. At initial electric field intensity less 36 kV/cm an electrical process in water isn't observed and liquid is boiling up in places with maximal electrical field intensities.

Discharge formation time in small tension amplitudes (until 20 kV) on potential electrode in (– PE + PL) electrode system is less, than in (+ PE – PL) one. It depends from volume of gas cavities around the potential electrode. Is shown, that on big tension amplitudes the (+ PE – PL) non-uniform electrode system is more effective for using in water purification. The high electrical fields directly influence on bacterial cell and cause their death. This method can be successfully used partially or entirely instead of chlorination process in different stages of surface water and entirely for wastewater disinfection.

REFERENCES

[1] M.E. Kuzmenko, O.V. Mitichkin, A.I. Bezlepkin, S.V. Kostyuchenko, N.N. Kudryavtsev, V.Y. Peterkin, "Experimental Exploration of the Low Pressure Amalgam Lamp at the Increased Power of the Discharge", TVT, Vol. 38, No. 3, pp. 510-513, Russia, 2000.

[2] N.A. Mammadov, B.B. Davudov, K.M. Dashdamirov, G.M. Sadikhzadeh, Sh.Sh. Alekberov, "Using of Ozone Technology During Biological and Chemical Processes and Polluted Water Purification", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 17, Vol. 5, No. 4, pp. 184-189, December 2013.

[3] V.M. Alshin, S.V. Volkov, A.Y. Gilbukh, A.I. Grechukhin, S.V. Kostyuchenko, N.N. Kudryavtsev, A.V. Yakimenko, "Advantages and Deficiencies of Industrial Methods of Water Disinfecting", Water Supply and Sanitary Equipment, No. 12, pp. 2-6, Russia, 1996.

[4] S.V. Kostyuchenko, "Ultra-Violet Radiation is the Modern Method of Water Disinfecting", Water Supply and Sanitary Equipment, Part 1, No. 12, pp. 21-22, Russia, 2005.

[5] S.V. Kostyuchenko, "The Current State of the Prospect of UV-Technology", Water Supply and Sanitary Equipment, No. 4, pp. 2-4, Russia, 2008.

[6] I.P. Kuzhekin, E.J. Kurbanov, "High Electric Fields and Pulsed Discharges in Water", Vestnik MEI, No. 2, pp. 33-36, Moscow, Russia, 2008.

[7] I.P. Kuzhekin, E.J. Kurbanov, "Pulse Discharge in Water", Power Engineering Problems, No. 1, pp. 103-105, Baku, Azerbaijan, 2008.

BIOGRAPHY

Elchin Jalal Gurbanov was born in 1963, Kurdamir, Azerbaijan. He graduated from school in Baku, Azerbaijan and entered to Moscow Power Engineering Institute on Faculty of Electronic Equipment, Moscow, Russia in 1980. He graduated in specialty of "Electronic Devices" and start to work in High Voltage Laboratory in Institute of Physics of Azerbaijan National Academy of Sciences, Baku, Azerbaijan in 1986. He defended from the Candidate Dissertation regarding High Voltage Treatment of Compositional Materials and received the Ph.D. degree in Physics and Mathematics Sciences in 1995. He studied in Doctorate in High Voltage Department of Moscow Power Engineering Institute (Technical University), Moscow, Russia during 2006 to 2010. From 2013 he works in Science Department of "Azersu" Open Joint Stock Company, Baku, Azerbaijan. He has above 60 scientific articles in different journals, 1 author certificate and 2 patents.