MICROBIAL CONTAMINATED TAP WATER DISINFECTION BY PULSED HIGH VOLTAGE DISCHARGE.

A.M.Anpilov[1], E.M.Barkhudarov[1], N.Christofi[2]*, V.A.Kopiev[1], *I.A.Kossyi[1]*, M.I.Taktakishvili[1], and Yu.Zadiraka[3]
.[1]General Physics Institute
Vavilov Street 38, 119991Moscow, Russia.
[2]Pollution Research Unit, School of Life Sciences, Napier University
10 Colinton Road, Edinburgh, EH105DT, Scotland.
[3]SPLITS Technologies Ltd.
8 Marchfield Park, Edinburgh EH4 5HW, Scotland.

In pulsed electric discharges, researchers have considered a number of processes and products involved in the microbiocidal action. These include the production of chemically active substances including ozone, hydrogen peroxide, and, hydroxyl and superoxide free radicals; UV radiation generated by the discharge itself, and, acoustic and shock waves.

Among the different means of electric discharge, a novel method involves multielectrode slipping surface discharges [2] which may have some advantages over two electrode systems most generally used at the present time [3,4]. Recent studies utilising multielectrode discharge systems have been performed where measurements of generated UV radiation as well as production of ozone and hydrogen peroxide have been made [1]. The results indicated that multielectrode discharge could be effective in the destruction of microorganisms in liquids.

This study provides data on the effectiveness of the disinfection action of SSD in liquids containing *E. coli* and its viruses (coliphages).

Treatment System. The apparatus used to treat liquids is schematically shown in Figure 1. The basic components are a chamber filled with water (5), a multielectrode system for exciting the SSD (1) and a high voltage power supply (6). The multielectrode discharge system (1) is similar in design to that previously described [2,5]. The use of the system is described in [1]. The multispark discharge system consists of a set of annular electrodes mounted on a dielectric tube surrounding a back-current conductor. A gas (air, argon, oxygen) is injected through a set of holes into water between the electrodes, producing fine gas bubbles (7).

The principal advantage of the multi-electrode system lies in the decrease in the discharge load on each electrode (thereby enhancing the erosion resistance of the system as a whole), which ultimately increases the lifetime of the system substantially. The discharge gaps are distributed in such a way as to increase the efficiency of the discharge action on liquids, in particular, by focusing shock-waves and radiation flux [6].

The discharge device (1) is situated in the treatment chamber (5) through which water contaminated with microorganisms is pumped. Water contaminated with *E. coli* or viruses (somatic coliphages) can be used to test killing efficiencies of the discharge system. Samples of water for microbiological analyses are taken via a sampling port (4). Triplicate samples in 10 ml sterile bottles are removed for analysis.

The experiments were conducted using the high-voltage multichannel generator (6) with the following parameters: high voltage pulse amplitude $U \leq 20$kV, pulse repetition frequency $f \leq 100$ Hz, capacitive storage energy of one channel $W \leq 2$ J, pulse duration $\tau \approx 5$ μs. The circuit of the output stage of each channel is shown in Fig. 2. Each multielectrode system was powered from one channel of a multichannel generator.

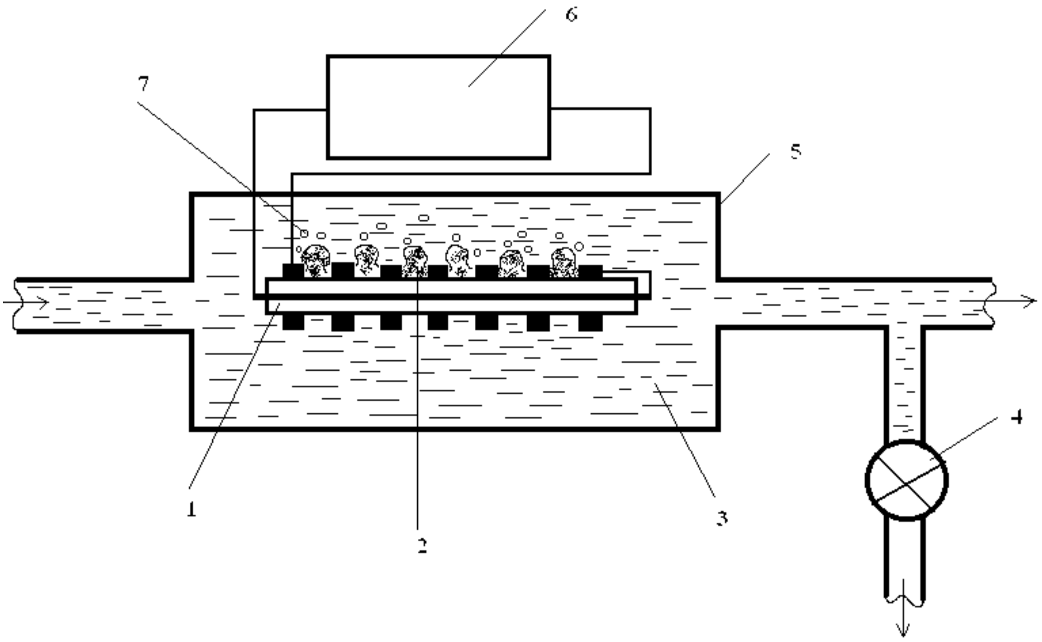

Fig. 1. Schematic representation of the discharge chamber.

Microbiology. *Escherichia coli* (NCIMB 86; ATCC 4157) was grown overnight in nutrient broth (Oxoid) at 37°C. The cultures were diluted to population densities of ~ 10^6 CFU ml^{-1} with tap water and placed in treatment chambers containing the pulsed plasma SSD system. Somatic coliphage was supplied by East of Scotland Water, Edinburgh, who also carried out the analyses of population changes.

Results and Discussion. Figure 2 shows the effect of electric discharges on microorganisms (*E. coli* and coliphages) in the water. The fraction of survived bacteria and viruses (N/N_0) is plotted versus the energy density (J cm^{-3}) released in water. Each point in the plot represents the mean of three measurements. Deviation from the mean did not exceed 15%. It is evident from Fig.3 that the viruses are killed using a lower energy input to the liquid. *E. coli* requires an energy of 0.3 J cm^{-3} (or ~ 10^{-4} kW h l^{-1}) to reduce the population by a factor of 10 (1 log reduction). Coliphages required an energy input of 0.15 J cm^{-3} for the same result.

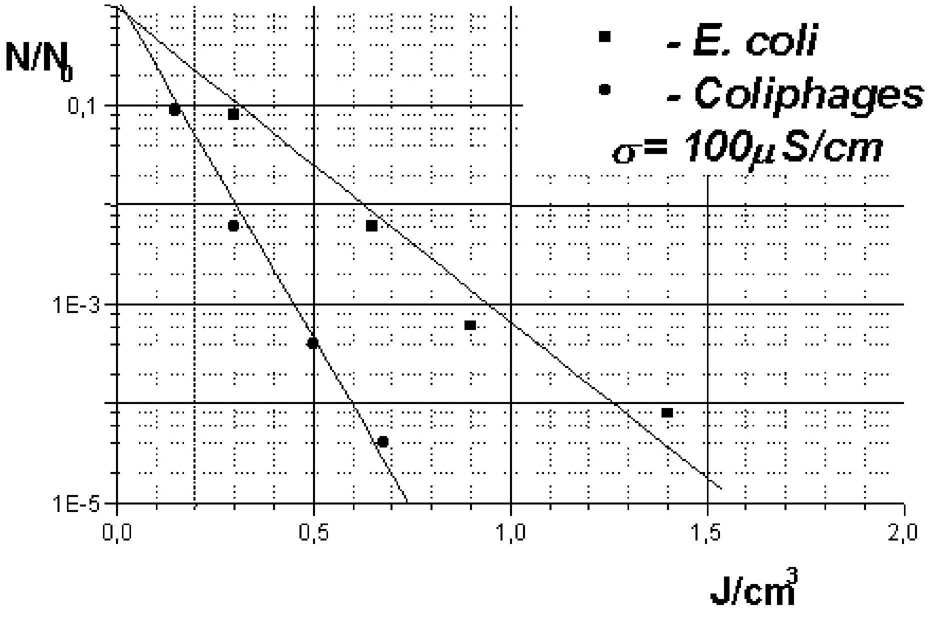

Fig. 2. Changes in populations of *E. coli* and viruses (N) in treated water relative to the initial populations (N_0) as a function of specific energy release (J cm^{-3}) during the treatment.

The electric discharge regimes used in this work are identical with the SSD regime previously investigated [1] where an examination was made on the generation of biologically active UV radiation, ozone, hydrogen peroxide and other active species. Measurements carried out during the present study allow calculation of energy costs of the disinfection action using electric discharges, and these are as low as 10^{-4} kW h l^{-1} for bacteria.

The possibility that disinfection using electric discharges may lead to the production of toxic by-products was tested by the input of energy as high as ~ 1 J cm^{-3} into water. Water samples were analysed for a range of substances including physical appearance by the Certification Control-Analytical Center in Moscow State University. The water was tested for colour, turbidity, pH, ammonium, Fe, Pb, Cr, fluoride, chlorite, nitrate and sulphate. The quality of treated water fulfilled the necessary standards in the European Union (Council Directives on the quality of water intended for human consumption 80/778/EEC and the new drinking water Directive 98/83/EC adopted by the Council on 3 November 1998). In addition, we carried out incubations of SSD treated water with microorganisms to test whether killing action continued. This could be due to persistence of oxidising species produced by the SSD but these are rapidly quenched within the system following treatment. There was no increased effects on *E. coli* added to systems containing tap water treated compared to SSD untreated tap water. This is contrary to results obtained with bielectrode discharges [4].

It would be interesting to investigate possibilities of using the SSD system described to treat industrial and domestic waste water prior to discharge to receiving waters. The first endeavor of such application was carried out by [5].

REFERENCES

1. Anpilov A.M., Barkhudarov, E.M., Bark, Yu.B., Zadiraka, Yu.V., Christofi, N., Kozlov, Yu.N., Kossyi, I.A., Kop'ev, V.A., Silakov, V.P., Taktakishvili, M.I. and Temchin., S.M. (2001) Journal of Physics D: Applied Physics V. 34, P. 993.

2. PCT (1999) Treatment of Liquid. International Patent Application, No: PCT/GB99/00755.

3. Kul'skii, L.A., Savchuk, O.S. and Deinega, E. Yu. (1980) Influence of Electric Field on Process of Water Sterilization (Kiev: Nauk. Dumka), P. 125, (in Russian).

4. Goryachev V.L., Rutberg, F.G. and Fedyukovich, V.N. (1998) Izv. RAN, Applied Energy, Russian Journal of Fuel Power and Heat Systems, V. 36, P.35.

5. Barkhudarov E.M., Kossyi, I.A., Taktakishvili, M.I., Christofi, N. and Zadiraka, Yu.V. (2000). Proceedings of XIII International Conference on Gas Discharges and their Applications, V. 2, P. 680. Strathclyde University, Glasgow, UK.

6. Barkhudarov, E.M., Kossyi, I.A. and Taktakishvili, M.I. (2000) Proceedings of XIII International Conference on Gas Discharges and their Applications, V. 2, P. 340. Strathclyde University, Glasgow, UK.