

UV excilamp inactivation of helminth eggs in wastewater

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Abstract. The inactivation of *Opisthorchis felineus* eggs in the wastewater was demonstrated. The wastewater samples were taken at the bio-filter outlet of district wastewater treatment plant of settlement “Airport” of rural settlement “Mirnenskoe” of Tomsk district of Tomsk region. The UV irradiation of wastewater samples was performed by the combined exposure of UV excilamps at 282 and 222 nm. There was less than 15% of the initial count of *Opisthorchis felineus* eggs in the wastewater after the UV treatment at the total surface dose of 25 mJ/cm². At the same time, 85% of the eggs lost the shell integrity and destroyed. It is proposed to use UV irradiation by excilamps to wastewater deworming on wastewater treatment plants of small capacity up to 200 m³/day.

1. Introduction

District wastewater treatment plants designed and built in Soviet times to clean the drains of residential areas, settlements and neighborhoods located outside the city limits and having a population of 10 thousand people, as a rule, do not perform their design functions. The budgets of rural settlements and districts cannot cope with the timely reconstruction of treatment plants. Across the country, there are thousands of district wastewater treatment plants, which are pollution sources of water bodies by pathogens and helminthes eggs.

The main reason for poor performance of wastewater treatment plants is the presence in the drains of high concentrations of detergents and petroleum products that disrupt the estimated job of bio-filters. The solution may be the ultraviolet (UV) disinfection of wastewater at the outlet of the bio-filters.

The use of mercury UV lamps for wastewater purification may be dangerous to the environment in the event of bulb failure and requires special measures for the disposal of waste emitters. In addition, radiation in atomic line at 254 nm of mercury vapors (see. Figure 1) ineffectively destroying helminthes egg shell.

Alternative sources of spontaneous UV radiation are barrier discharge excilamps (see Figure 2), which emit in the molecular bands with maxima at wavelengths of 222 and 282 nm (see Figure 1). They do not contain mercury, effectively destroy the shell of helminthes eggs (KrCl, 222 nm), such as *Opisthorchis felineus* and *Diphyllbothrium latum* [1], provide disinfecting wastewater from thermotolerant coliform bacteria (XeBr, 282 nm), including bacteria of the *Proteus* genus [2].

The use of excilamps as light sources in the UV disinfection units at the output of bio-filters of district wastewater treatment plants producing the water release in the rivers of Ob basin can provide disinfection of wastewater from eggs of *O. felineus* and *D. latum*. In the long term of 20–30 years, it



could reduce the intensity of the natural epidemiology centers of such diseases as opisthorchiasis and diphyllorhynchiasis.

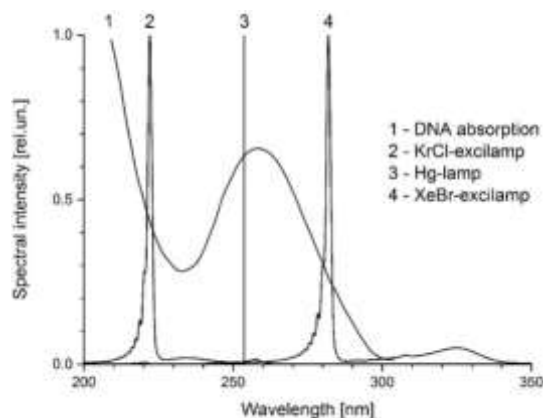


Figure 1. Absorption and emission spectra: the total absorption spectrum of DNA (1), the emission spectrum of barrier discharge KrCl-excilamp with a maximum at 222 nm (2); the atomic line of a mercury lamp at 253.7 nm (3); the emission spectrum of barrier discharge XeBr-excilamp with a maximum at 282 nm (4).

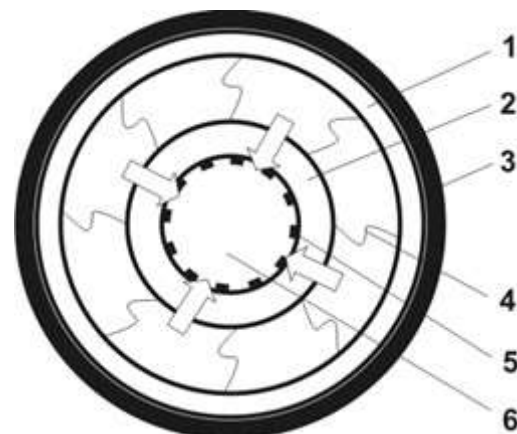


Figure 2. The cross section of the coaxial barrier discharge excilamp: quartz tubes, forming the outer and inner walls of excilamp (1, 2); the external reflective electrode (3); the discharge zone between quartz tubes (4); the inner translucent electrode (5); the inner irradiation cavity (6). White arrows indicate the concentrated UV radiation direction.

We report on the use of UV radiation of KrCl(222 nm)- and XeBr(282 nm)-excilamps for wastewater treatment in the laboratory. The water samples were taken at the bio-filter outlet of district wastewater treatment plant of settlement “Airport” of rural settlement “Mirnenskoe” of Tomsk district of Tomsk region. At the surface dose of 25 mJ/cm², it was achieved reduction in 6 times the count of viable eggs of *O. felineus*. Now the work is underway on the design and pre-production of prototype of UV wastewater disinfection unit based on KrCl- and XeBr-excilamps.

2. The action of UV excilamps on eggs of *O. felineus* and *D. latum*

Previously it has been shown [1] that the inactivation of *O. felineus* eggs by KrCl-excilamp radiation is more effective than the XeBr-excilamp radiation. The average power of KrCl-excilamp radiation was 2 times less than that of XeBr-excilamp. However, after irradiation by KrCl-excilamp, there were the viable eggs of *O. felineus* (survived after irradiation) less at 40–70% than in the case of XeBr-excilamp irradiation (see Figure 3). The spectral maximum of KrCl-excilamp band corresponds to photon energy of 5.6 eV, which is much higher than the photon energy of XeBr-excilamp (4.4 eV). We assume that the photons with higher energy destroy or embrittle efficiently the shell eggs of *O. felineus*. Under the conditions of experiments, the proportion of *O. felineus* eggs, surviving after irradiation at 222 nm, was 15–30% at surface radiation doses of 5.1–0.3 mJ/cm². Upon irradiation at 282 nm, the proportion of surviving *O. felineus* eggs was 70–90% at surface radiation doses of 116–4 mJ/cm².

For one of water samples containing the *O. felineus* eggs, after exposure to radiation at 222 nm at the surface dose of 8.5 mJ/cm², there was complete absence of eggs in the sample. The linear approximation (excluding zero experimental value at 8.5 mJ/cm²) allows us to estimate the surface dose of 15.6 mJ/cm² required for complete inactivation of *O. felineus* eggs by radiation at 222 nm.

Irradiation of water samples containing *D. latum* eggs showed less effective disinfection by radiation at 222 nm than for samples containing *O. felineus* eggs. Under conditions of the experiments, the proportion of *D. latum* eggs surviving after irradiation at 222 nm was 44–68% at the surface radiation doses of 5.1–0.5 mJ/cm².

Differences in the inactivation levels of eggs of *O. felineus* and *D. latum*, achieved at 222 nm irradiation, may be associated with greater resistance of protective shells of *D. latum* eggs to incident photons.

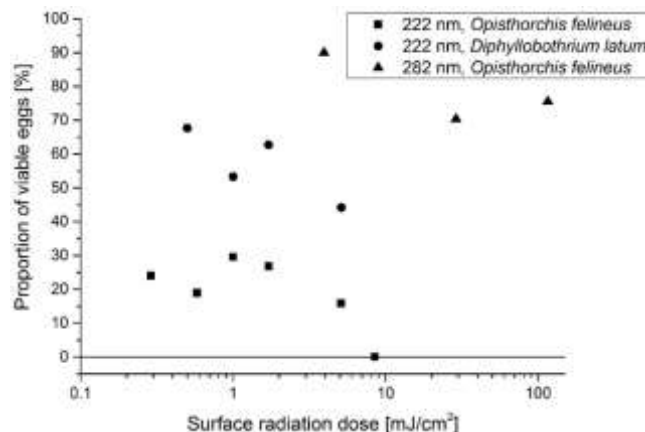


Figure 3. Dependence of the proportion of eggs count after exposure to the eggs count before exposure from the surface dose of radiation of KrCl- and XeBr-excilamps.

3. The action of UV excilamp radiation on the wastewater from treatment plant

There were performed the comparative studies of the inactivation of microorganisms in the wastewater using the radiation of XeBr- and KrCl-excilamps [2]. It was shown that the simultaneously irradiation the wastewater by XeBr- and KrCl-excilamps had the greatest effect. The studies were conducted on the experimental setup, whose photo is shown in Figure 4.

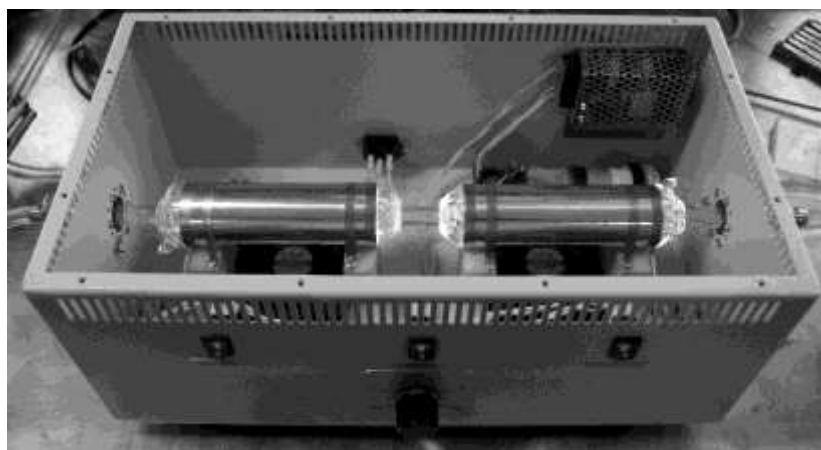


Figure 4. The photo of experimental setup.

The study of action of XeBr- and KrCl-excilamp irradiation on wastewater for the purpose of disinfection from *O. felineus* eggs was carried out on the same experimental setup. The setup provided the circulation of wastewater in the system: the original container, a quartz tube passing inside of coaxial KrCl- and XeBr-excilamps of barrier discharge, receiving container. The pumping rate through the system was 1.5 liter/min.

The wastewater for research was taken at the bio-filter outlet of district wastewater treatment plant in settlement “Airport” of rural settlement “Mirnenskoe” of Tomsk district of Tomsk region. For the studies there were taken three wastewater samples of 15 liters each. One of them was used for control. The wastewater from the two samples was subjected to simultaneous treatment by KrCl- and XeBr-

excilamps. The total surface dose of irradiation at two wavelengths (222 and 282 nm) was about of 250 mJ/cm².

The treated water is tested for compliance with SanPiN 2.1.5.980-00 "Hygienic requirements for surface water" [3] using the method of investigation MUK 4.2.1884-04 "Sanitary-microbiological and sanitary-parasitological analysis of water from surface water bodies" [4] in the bacteriological laboratory of Center of Hygiene and Epidemiology in the Tomsk region.

There were found eggs of *O. felineus* in the wastewater samples. The UV treatment results for wastewater samples are shown in table 1.

Table 1. Counts of *O. felineus* eggs in samples #1 and #2 and proportions of count of surviving eggs after irradiation to count of eggs in the control sample

Sample	Count	Proportion (%)
Control	59	-
# 1	9	15
#2	5	8

Thus, a moderate surface dose of UV radiation by KrCl- and XeBr-excilamps (about 25 mJ/cm²) can provide reduction of counts of *O. felineus* eggs in the wastewater to 6 or more times.

4. Conclusion

These encouraging results have allowed us to start the design and manufacture the prototype of industrial UV wastewater treatment setup for district wastewater treatment plants with productivity up to 200 m³/day. Testing and endurance testing of this setup will be carried out at district wastewater treatment plant at settlement "Airport", located in the rural settlement "Mirnenskoe" of Tomsk district of Tomsk region [5, 6]. In case of successful tests, it is supposed to patent and certificate the setup to achieve opportunities of industrial production of UV wastewater disinfection units.

Acknowledgments

The authors would like to appreciate the Administration of the Institute of High Current Electronics SB RAS, especially the Director of the institute N. A. Ratakhin and the Principal Director of Scientific Research I. Yu. Turchanovskiy for the organizing support of the work.

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