Krypton chlorine excilamp for escherichia coli inactivation in aqueous media

Bouabdellah RAHMANI¹, El roumaissàa RAHMANI², Georges ZISSIS³, Svetlana Avtaeva⁴, B. Saghi¹

¹University of science and technology, Oran, Algeria, rahmani.bouabdellah@yahoo.fr
²Saliege- 3 rue Bernanos. BP 33130-31131-Balma-Cedex, erahmani@saliege.fr
³Université de Toulouse 3; UPS, INPT; LAPLACE (Laboratoire Plasma et Conversion d'Energie); georges.zissis@laplace.univ-tlse.fr
⁴Kyrgyz-Russian Slavic University, Bishkek, Kyrgyz Republic, s_avtaeva@krsu.edu.kg

1. Introduction

Excilamps can be considered as attractive alternatives to mercury lamps and lasers for applications in microbial-control technologies because of the absence of elemental mercury, long lifetime, geometric freedom, high photon flux and moderate operating temperatures [1]. The ultraviolet excimer sources have been developed [2-5] for inactivation of microorganisms [6-9] depending on their wavelength and their intensity. The inactivation is caused by changing absorption degrees of different biomolecules such as DNA, membranes or proteins. According to the kind of chemical bond between the elements of biomolecule, the UV light energy is absorbed by the element at different wavelength in a selective way. The low pressure (LP) mercury lamp emitted at 254 nm is traditionally used for inactivation of microorganisms [8]. This lamp emits near the DNA peak absorption coefficient at 265 nm [10]. This absorption causes damage to DNA by altering nucleotide base paring, especially 6-4 photoproducts and thymine dimers formation [11]. If the damage remains not repaired, the transcription and the replication of DNA are blocked. These processes lead to cell death. The proteins show a strong absorption coefficient at 220 nm [12, 13], which is an alternative way to reduce the photoreactivation mechanism. This mechanism uses a single enzyme called photolyase to repair UV-induced damage in the DNA [14]. The photoreactivation causes problems especially for large scale UV inactivation of microorganisms when processing treated wastewater, drinking water and sewage are exposed to sunlight. In contrast our excilamp krypton-chlorine shows a relatively sharp emission spectrum with a peak at 222 nm targeting the proteins of microorganism. The aim of this work was to examine the inactivation efficiency of the pulsed dielectric barrier discharge excilamp KrCl² against the E. coli bacteria which is commonly used as a biological indicator for disinfection efficiency in water systems.

2 Materials and methods
2.1 Bacterial strains and incubation conditions

The basic solution of the E. coli was obtained by incubating a few colonies (2 to 3) of the strain E. coli (O157:H7) in 5ml of the liquid LB (Luria Bertani) nutrient under the incubation conditions at 30°C and for 20 hours. The pH of this solution was adjusted at 7.2 by NaOH. A volume of 1ml taken from this solution was diluted with 9% of saline until 10⁶ for an easy visual counting of the E. coli. The initial density was estimated by taking 10l from the diluted solution at 10⁶ in a steriled circular Petri dish under the same incubation condition cited above. Its value of 34.10⁶ CFU/l was obtained by averaging three values receiving the same dose. A volume of 10 l taken from the basic solution for the aqueous media was irradiated in an open Petri dish. We add 2 ml of the liquid LB nutrient to the irradiated aqueous media before its incubation phase. The Petri dishes were covered by the aluminium foil just after irradiation to avoid the photoreactivation mechanism.

2.2 UV excilamp

The pulsed DBD excilamp krypton chlorine [5] was used for the inactivation of the Escherichia coli bacteria. The spectrum of this excilamp shows an intense peak at 222 nm (KrCl²*) and a weak one at 258 nm (ClCl⁰*). The excilamp was oriented horizontally on the opened glass Petri dish with a diameter of 40 mm and a height of 10 mm.

2.3 Irradiation and evaluation of the results

The E. coli has been irradiated in two different medias at the distance of 30 mm and 26 mm from the UV wall source [5], respectively. We use irradiation in the aqueous and on the surface medias. This distance was chosen for reducing the excilamp thermal effect on the E. coli bacteria during the irradiation. We used nine doses for each media. The photoreactivation mechanism was minimized by covering each irradiated Petri dish with the aluminum foil before and after the UV irradiation. The UV dose expressed in mJ/cm² is the result of the product of an irradiating time in s and the excilamp irradiance in mW/cm². The logarithmic reduction factor log (N/N₀) of the E. coli was calculated by averaging the values of three Petri dishes.
receiving the same dose. The *E. coli* population *N*₀ and *N* in CFU/l denotes their density values before and after the UV irradiation, respectively.

### 3 Results and discussion

The results on the inactivation of the *Escherichia coli* in the aqueous media are presented in figure 1. It shows a logarithmic reduction factor of 5.1 log in concentrations of the *E. coli* within irradiation time of 30 s at the dose of 180 mJ/cm². That means only 268 CFU/l of the *E. coli* are resistant at the wavelength 222 nm as shown in table 1.

![Figure 1: Logarithmic reduction factor of *E. coli* on dose at 222 nm in aqueous media](image)

The tailing plateau in aqueous media is observed between irradiation times from 180 s to 240 s in the dose range from 1080 mJ/cm² to 1440 mJ/cm² and its logarithmic reduction factor is around 5.4 log. At the high dose of 2880 mJ/cm², the logarithmic reduction factor has reached 5.5 log as shown in figure 1, corresponding to the survival *E. coli* density of 102 CFU/l in Table 1. Our results show tailing plateaus in the aqueous media. The tailing plateau observed in this media was due to the high initial density of the *E. coli*, as was reported by Muranyi et al.[15] and by Matafonova et al.[6].

#### Table 1: Survival *E. coli* density on dose in aqueous media.

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Dose (mJ/cm²)</th>
<th>Survival <em>E. coli</em> density (CFU/l)</th>
</tr>
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<tbody>
<tr>
<td>30</td>
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</tr>
<tr>
<td>480</td>
<td>2880</td>
<td>102</td>
</tr>
</tbody>
</table>

### References


[7] Marcus Clauß and Norbert Grotjohann,

“Comparative mutagenesis of *Escherichia coli* strains with different repair deficiencies irradiated with 222-nm and 254-nm ultraviolet light”, *Mutation*


