

## ADVANCED TECHNOLOGIES FOR WASTEWATER TREATMENT BY UV – A REVIEW–

ZĂBAVĂ B.ȘT.<sup>1)</sup>, VOICU GH.<sup>1)</sup>, VLĂDUȚ V.<sup>2)</sup>, UNGUREANU N.<sup>1)</sup>, DINCĂ M.<sup>1)</sup>,  
FERDEȘ M.<sup>1)</sup>, IPATE G.<sup>1)</sup>

<sup>1)</sup>U.P. Bucharest / Romania; <sup>2)</sup>INMA Bucharest;  
E-mail: [bianca.dragoiu@yahoo.com](mailto:bianca.dragoiu@yahoo.com)

**Keywords:** *disinfection, advanced technologies, ultraviolet.*

### ABSTRACT

*Reclamation and reuse of wastewater is one of the most effective ways to alleviate water resource scarcity. Disinfection plays a key role in reuse of wastewater for eliminating infectious diseases. Water disinfection using ultraviolet light is a newer process that currently has a limited use area.*

*Ultraviolet(UV) disinfection is now widely implemented as a tertiary treatment for wastewater reclamation.*

*The purpose of this paper is to present the most representative studies on the use of ultraviolet in wastewater treatment.*

### INTRODUCTION

Reclamation and reuse of wastewater is one of the most effective ways to alleviate water resource scarcity. Disinfection plays a key role in reuse of wastewater for eliminating infectious diseases. Hazardous chlorination by-products restricted the use of chlorine for the disinfection of water and wastewater [5]. Chlorination is the conventional wastewater disinfection method used around the world because chlorine is an effective disinfectant against many enteric bacteria, but it has lower efficiency against viruses, bacterial spore-formers, and protozoan cysts [8]. In recent years, the use of chlorination has been decreasing, mainly due to toxic, mutagenic, and/or carcinogenic disinfection by-products (DBPs) formed in the disinfection process and chlorine residuals [7]. Thus, a number of alternative disinfectants have been researched and implemented, such as ozone and ultraviolet (UV) light [2].

Ozonation and UV have lately emerged as a viable alternative by virtue of their operational costs and accurate maintenance operation. Water disinfection

using ultraviolet light is a newer process that currently has a limited use area.

Ultraviolet(UV) disinfection is now widely implemented as a tertiary treatment for wastewater reclamation. Ultraviolet (UV) disinfection is a well established, cost-competitive technology. In the late 1800's researchers first discovered the germicidal effects of sunlight, and systems based on fluorescent tube technology have been operating since the 1950's. More recently, UV disinfection has been attracting a lot of attention due to the discovery of chlorinated Disinfection Byproducts (DBP), and new measurements confirming the effectiveness of UV to inactivate *Cryptosporidium* [3].

Ultraviolet (UV) sanitizing units are used in many water purification systems to control bacteria and have certain applications in animal drinking water systems. UV units can be effective water treatment tools, but it is important to recognize what UV can do, what its limitations are, and what maintenance is required [9].

Certain contaminants in water can reduce the transmission of UV light through the water, which reduces the UV dose that reaches the bacteria. These UV absorbing contaminants include turbidity, iron, and humic and fulvic acid, common to surface water supplies. Suspended

particles are a problem because microorganisms buried within particles are shielded from the UV light and pass through the unit unaffected. UV disinfection is most effective for treating high-clarity purified reverse osmosis or distilled water [4].

## MATERIAL AND METHOD

Ultraviolet or UV energy is found in the electromagnetic spectrum between visible light and x-rays and can best be described as invisible radiation. In order to kill microorganisms, the UV rays must actually strike the cell. UV energy penetrates the outer cell membrane, passes through the cell body and disrupts its DNA preventing reproduction. UV treatment does not alter water chemically; nothing is being added except energy. The sterilized microorganisms are not removed from the water. UV disinfection does not remove dissolved organics, inorganics or particles in the water. Generally, UV is simple to install

and requires little supervision, maintenance, or space. Improved safety, minimum service time, low operation and maintenance costs, and the absence of a chemical smell or taste in finished water are primary factors for selecting UV technology rather than traditional disinfection technologies [8].

A special lamp generates the radiation that creates UV light by striking an electric arc through low-pressure mercury vapor – fig.1. This lamp emits a broad spectrum of radiation with intense peaks at UV wavelengths of 253.7 nanometers (nm) and a lesser peak at 184.9 nm.

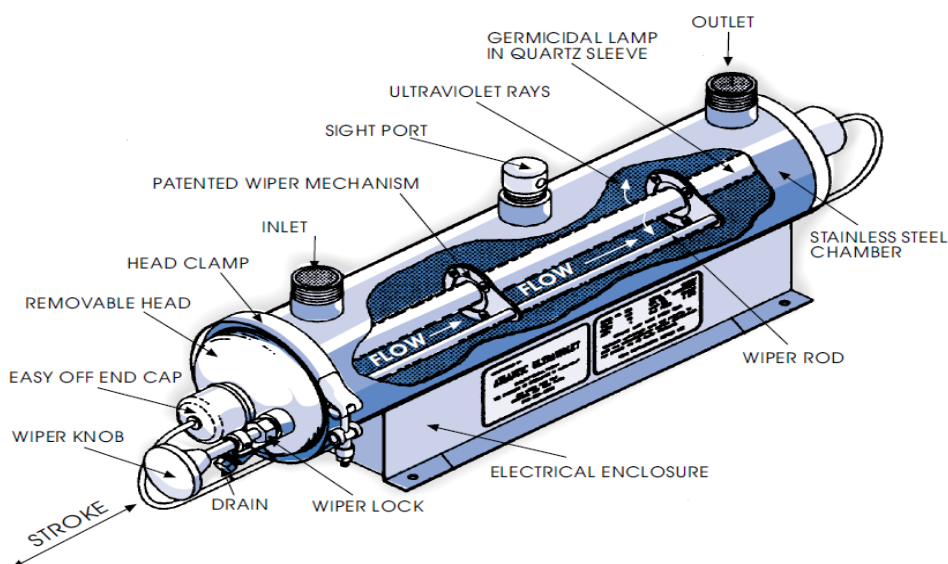


Figure 1 - Schematic of typical UV Reactor [10]

The optimum wavelength to effectively inactivate microorganisms is in the range of 250 to 270 nm. The intensity of the radiation emitted by the lamp dissipates as the distance from the lamp increases. Low-pressure lamps emit

essentially monochromatic light at a wavelength of 253.7 nm.

Standard lengths of the low-pressure lamps are 0.75 and 1.5 meters with diameters of 1.5-2.0 cm. The ideal lamp wall temperature is between 95 and 122 °F [11].

## RESULTS AND DISCUSSIONS

Research over the years have identified ultraviolet (UV) sterilizers as probably the most cost effective and efficient alternative technology available to home owners to eliminate a wide range of biological contaminants from their water supply. According to this, numerous studies have been carried out, the most representative of these are presented in this paper.

Adegbola A.A. and Olaoye R.A have investigated the effectiveness of ultraviolet water purification as replacement of chlorine disinfection in domestic water supply.

Water from an established contaminated well in Ogbomoso, Nigeria, were subjected, simultaneously and in parallel, to chlorine dosing and contact with UV light, over a period of seven days without pre-filtration, and additional seven days with pre-filtration. Pre-filtration was accomplished by the use of a calibrated pressure filter. Effluent water samples were taken daily for the two scenarios to the laboratory for physical, chemical and biological analyses. Figure 2 shows the schematic diagram of the photovoltaic system used to power the ultrasound sterilizer.

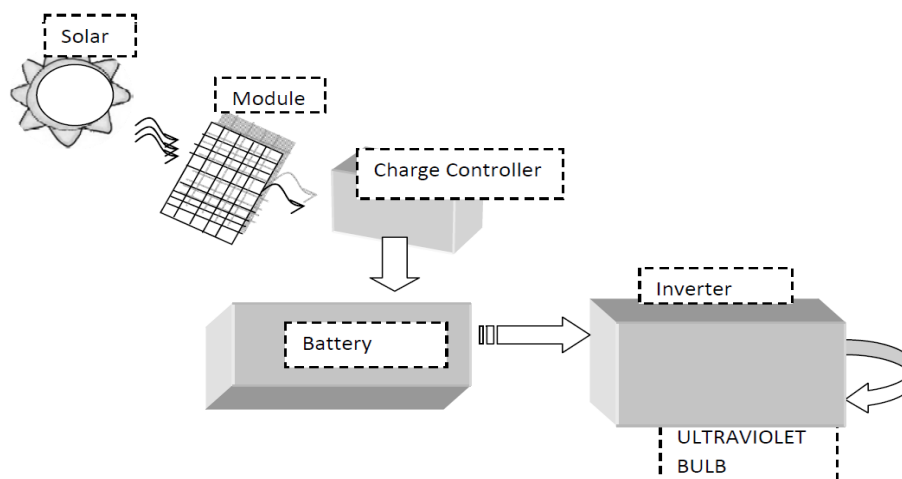


Figure 2–Schematic Diagram of a Photovoltaic System [2]

The experimental results showed that the ultraviolet water purification method was more effective only when the raw water pre-filtration process was introduced. In this case, the number of colonies, coliforms and E. coli organisms recorded mean values in seven of 1 and 0. In both cases, it was confirmed that the UV method did not produce bi-products and did not alter the taste, or other water properties, in contradiction with the chlorine disinfection method.

In the experiment, it is noteworthy that certain factors, namely: chemical and biological films that develop on the surface of the UV lamp, color, turbidity and short-circuiting in the water flowing

through the UV sterilizer could negatively affect the effectiveness of UV disinfection [2].

In another study, [5], was undertaken to characterize the efficacy of flow-through pulsed UV light for inactivation of Escherichia coli and Bacillus subtilis spores in synthetic (SMWE) and real municipal wastewater effluent (RMWE).

Microbial inactivation experiments were performed on a laboratory scale using the UV pulse system using a SteriPulse®-RS4000 pulsed light sterilization system. The system consisted of a controller, the camera including the lamp and the power supply (figure 3).

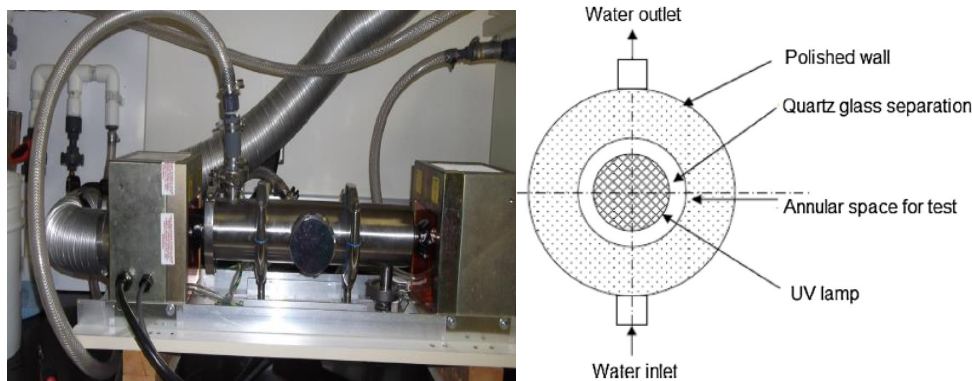


Figure 3 - Picture and schematic diagram of the flow-through pulsed uv chamber[5]

The disinfection efficiency was evaluated at various flow rates (2–20 L/min) and number of passes in a flow-through pulsed UV light chamber using *E. coli* and *B. subtilis* spores in SMWE. Using a single pass, complete inactivation, was observed until 10 L/min flow rate for *E. coli* and 5 L/min flow rate for *B. subtilis* spores (fig. 4). In this study, the effects of UV disinfection on chemical oxygen demand (COD), total organic carbon (TOC), total solid suspensions (TSS) and turbidity (figures 5-6) were also analyzed.

According to the graphical representation, the experimental results showed a decrease of the solid suspension content from 25.3 to 7.3% for *E. coli* inoculum (10 L / min) and 20.3 to 5.2% for *B. subtilis* (6 L / min). The reduction in chemical oxygen demand ranged from 32.05 to 9.72% for the initial microbial population of *E. coli* and from 31.86 to 7.78% for the *B. subtilis* initial microbial population.

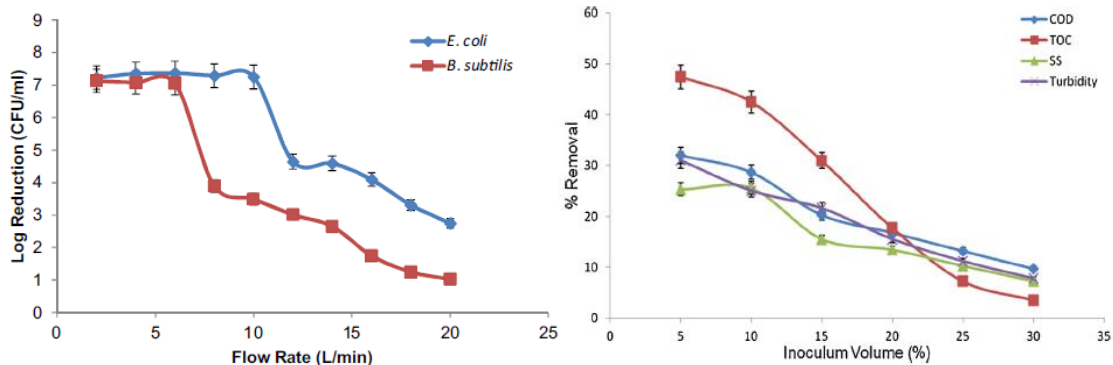


Figure 4 - Log reduction profiles of *E. coli* and *B. subtilis* spores [5]

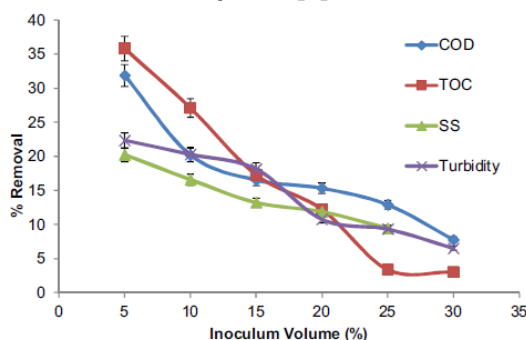


Figure 5 - Effect of flow-through pulsed UV treatment for *E. Coli* [5]

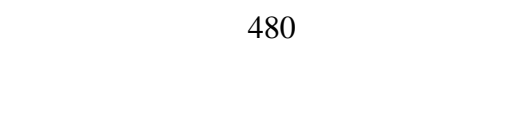


Figure 6 - Effect of flow-through pulsed UV treatment with 6 L/min flow rate on COD, TOC, SS, and turbidity for *B. Subtilis* [5]

Recorded values for total organic carbon also showed a reduction after UV treatment, with a reduction of over 45%, and the degree of elimination of turbidity decreased with the increase in microbial inoculum. The results clearly show the potential of pulsed UV light in the sewage treatment process. In conclusion, UV light has a great potential to disinfect residual water or other liquid waste with added potential in improving quality [5].

Naddeo V. et colab., in study [6] have investigated the wastewater advanced treatment by simultaneous combination of UV and US in terms of bacteria inactivation (Total coliform and Escherichia coli) at pilot-scale.

The pilot plant was composed of two reactors: US–UV reactor and UV reactor – fig. 7.

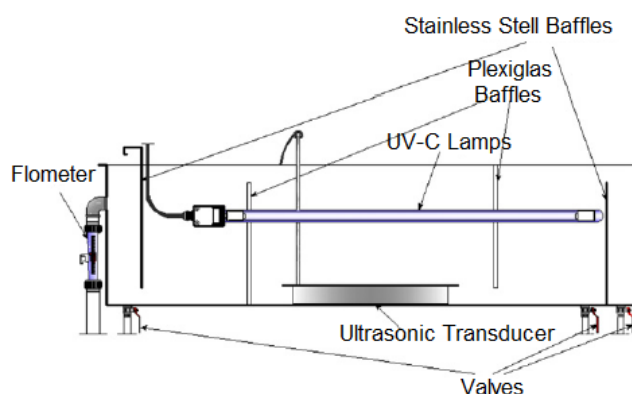


Figure 7 - Schematic longitudinal section of the US–UV reactor [6]

The influence of different reaction times, respective US and UV dose and synergistic effect was tested and discussed for two different kinds of municipal wastewater.

The tests were carried out at two wastewater streams having different characteristics; one of these with a very high pathogen concentration (Type-B), both with a very low transmittance. The

tests with a Type-A influent, carried out in reactor 1, are performed at 2, 5, 10, 15 and 30 min of retention times with both disinfection technologies turned on. The tests with a Type-B influent, carried out in both reactors, were performed at around 30 min of retention times in both UV and US–UV disinfection, guaranteeing a constant flow by the employment of valves and flowmeters.

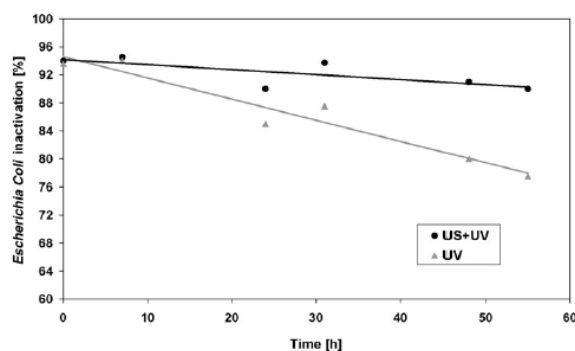


Figure 8 - Escherichia coli inactivation versus length of the test in “sun” condition [6]

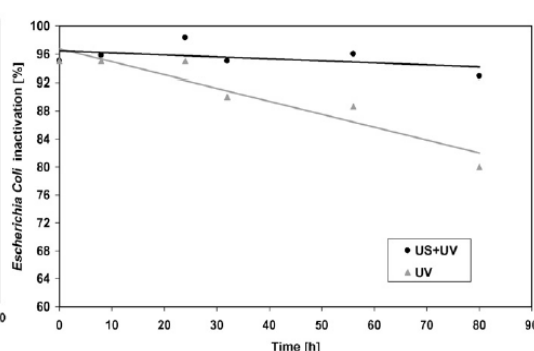


Figure 9 - Escherichia coli inactivation versus length of the test in “dark” condition [6]

The results obtained with Type-A influent show that the disinfection

efficiency by UV increased from 30% to 98% as retention time increased from 2 to

15 min respectively. The tests with a Type-B influent were carried out for consecutive three days with a retention time of 30 min.

In these tests the *E. coli* inactivation, after some hours of treatment, was about 94% in both reactors. On the third day, after about 55 h of continuous treatment, while in the UV reactor the inactivation went down until 77%, in the US–UV reactor the disinfectant power was still up 90% (fig. 8). In the ‘dark’ tests the initial inactivation was about 97% in both reactors. At the fourth day, after about 80 h

of continuous treatment, the *E. coli* inactivation decreased to 80% in UV reactor, while in US–UV reactor the inactivation was still higher than 92% (fig. 9).

This innovative combined treatment is able to guarantee high performance of the wastewater treatment process with low transmittance.

An important increase in UV disinfection capacity was observed in the presence of ultrasounds [6].

## CONCLUSION

Ultraviolet (UV) disinfection is a well established, cost-competitive technology.

The purpose of this paper is to present the most representative studies on the use of ultraviolet in wastewater treatment. It is noteworthy that certain factors, could negatively affect the effectiveness of UV disinfection.

UV light has a great potential to disinfect residual water or other liquid waste with added potential in improving quality.

The innovative combined treatment is able to guarantee high performance of the wastewater treatment process with low transmittance.

## ACKNOWLEDGEMENT

This work was supported by a grant of the Romanian Ministry of Research and Innovation, CCCDI - UEFISCDI, project

number 27PCCDI/2018, entitled „Innovative technologies for crop irrigation in arid, semi-arid and sub-dry climate”, within PNCDI III.

## BIBLIOGRAPHY

1. **Adedayo, A., Olaoye, A., Adepate R.**, 2012- Investigating the Effectiveness of Ultraviolet (UV) Water Purification as Replacement of Chlorine Disinfection in Domestic Water Supply, *International Journal of Engineering Science and Technology (IJEST)*, ISSN : 0975-5462 Vol. 4 No.08,
2. **Bohrerova, Z., Shemer, H., Lantis R., Impellitteri, C.A., Linden, K.G.**, 2008- *Comparative disinfection efficiency of pulsed and continuous-wave UV irradiation technologies*, *Water Res.* 42 (2008) 2975–2982.
3. **Crawford, M.H., Banas, M.A., Ross, M. P., Douglas, S.R., Nelson, J.S., Boucher, R., Allerman, A.A.**, 2005- *Final LDRD Report: Ultraviolet Water Purification Systems for Rural Environments and Mobile Applications*, SANDIA REPORT SAND2005-7245.
4. **Eccleston, B.**, 1998 - *UV intensity levels affected by water quality*. *Water Technology* 21(5):61-68.
5. **Gulsad, U., Demircib, A., Regan, J.M.**, 2016 - Disinfection of synthetic and real municipal wastewater effluent byflow-through pulsed UV-light treatment system, *Journal of Water Process Engineering* 10 89–97.
6. **Naddeo, V., Landi, M., Belgiorno, V., Napoli, R.M.A.**, 2009 - Wastewater disinfection by combination of ultrasound and ultraviolet irradiation, *Journal of Hazardous Materials* 168 925–929.
7. **Oppenheimer, J.A., Jacangelo, J.G., Lanei, J.-M., Hoagland, J.E.**, 1997- *Testing the equivalency of ultraviolet light and chlorine for disinfection of wastewater to reclaim standards*, *Water Environ. Res.* 69 (1) 14–24.
8. **Veschetti, E., Cutillia, D., Bonadonna, L., Briancesco, R., Martini, C., Cecchini, G., Anastasi, P., Ottaviani, M.**, 2003- *Pilot-plant comparative study of peracetic acid and sodium hypochlorite wastewater disinfection*, *Water Res.* 3778–94.
9. \*\*\* Aquafine Corporation, “Ultraviolet Systems” brochure
10. \*\*\* *Tech Briefs*, 2000- A national drinking water clearinghouse fact sheet, Ultraviolet Disinfection.
11. \*\*\* *United States Environmental Protection Agency*, (1999) *Wastewater Technology Fact Sheet Ozone Disinfection*, EPA 832-F-99-063.