

Studies and Researches Regarding the Efficiency of Romanian Disinfection Prototype using Ultraviolet Radiation to Wastewater Treatment

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This paper presents studies and research conducted on a prototype installation of ultraviolet disinfection on pathogens present in wastewater. To validate the prototype were carried out a series of physical, chemical and microbiological analysis on a number of wastewater samples before and after their ultraviolet irradiation using different times of irradiation. Elimination of pathogenic microorganisms was found after a certain time of irradiation, and physico-chemical parameters have not changed. Romanian prototype also has the same efficiency in destroying microorganisms as most of such facilities of this type from in the U.S. and UK market.

Keywords: prototype, microorganisms, ultraviolet radiation, wastewater

Wastewater from municipal treatment plants before being discharged into the emissary, must meet certain quality standards laid down in standards as physico-chemical (especially heavy metal content) and microbiological terms [1]. Quality standards values in terms of contamination with pathogens are provided by using wastewater treatment with different chemical substances, but a great importance has the using of ultraviolet radiation.

Treating water with UV represents a physical process that can apply to both drinking and wastewater, water types which are sensitive to chemical disinfectants. Ultraviolet radiation does not affect water quality from chemical point of view and does not remove particles in suspension, heavy metals or minerals such as calcium or magnesium salts.

The wastewater which will be treated with ultraviolet radiation must not contain suspensions (clear appearance without opalescent), because suspended particles can block ultraviolet rays allowing microorganisms to passage.

According to literature data [2 - 5] ultraviolet radiations having characteristic wavelengths and radiant energy causes inactivation of pathogenic strains currently present in wastewater while the microorganisms are bombarded by UV radiation, being destroyed by its effect. Ultraviolet radiation alters the DNA of viruses, bacteria or parasites so that microorganisms can not reproduce and are considered inactive.

Currently the irradiation process of water is used on a large scale and the devices are usually made in United States, Germany or Austria, according to their national standard methods [6, 7]. Generally, the installations used at UV irradiation process for disinfection [8-10] include one or more UV lamps protected by sheaths transparent quartz immersed in water flow. UV lamp emits a certain energy, which penetrates the fluid circulating through the installation.

As is known in Romania were not treated so far reactor blocks or elimination of microbiological agents in drinking water or wastewater purified with UV radiation.

For this reason it have not issued formal requirements, engineering design and technology and have not imported

these requirements and technologies, so we proposed to design and made the installation of disinfection under basic requirements, by adaptation to local opportunities for the type which we want to assimilate (at a rate of 5 L / s) on the Romanian market.

A condition imposed on the installation of radiation to be provided by UV germicidal lamps, or at least 1260 mWs/cm² (minimum level of radiation to destroy microorganisms) and a water flow of 15 m³ / h.

In terms of operation the plant meets the standards SR EN 60335-2-35: 2000, EN 60068-2-1+A1+A2:96, STAS 8393/4-81, STAS 6854 - 90 and SR EN 60529:95.

Materials and methods

Prototype irradiation facility used for the irradiation of two sets of wastewater samples, was made by Tehnoton Iasi, and contains three germicidal UV lamp Philips type TUV 55WHO - G13, arranged so that between two successive lamps should be an angle of 120 degrees, which emit ultraviolet type UV-C wavelength of 253.7 nm radiation power of 16.5 W having a radiant energy of 49500 mWs/cm².

The irradiation process includes the following phases:

- lamps calibration;
- start installation;
- maintaining the facility in operation until 2 h until is reached 80% of the reference level.

Before placing the waste water into the device irradiation, all the samples were filtered through membrane filters, to achieve a degree of turbidity of 1.16 and 1.04 NTU respectively. Wastewater samples were kept in the device under irradiation 5-900 s.

In order to determine the efficiency of ultraviolet radiation device on microorganisms in wastewater there have been made series of physico-chemical and microbiological analyses for the two sets of wastewater samples before and after completion of irradiation.

Monthly, from June to November 2009, there were taken samples of wastewater from sewage treatment plants,

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Table 1
EQUIPMENT USED IN THE DETERMINATIONS OF PHYSICAL, CHEMICAL
AND MICROBIOLOGICAL PARAMETERS

Parameter	Equipment	Method
pH	WTW 82362 pH-meter	Potentiometry
Turbidity	555i WTW Turbidimeter	Nephelometry
Electrical conductivity	WTW 82362 Conductometer	Potentiometry
Total phosphorus / phosphates	Kit Aquaquant 14445.0001 (Merck)	Colorimetry
Chlorides	Kit Aquaquant 14445.0001 (Merck)	Colorimetry
Nitrates	Kit Aquamerck114408.0001 (Merck)	Colorimetry
Nitrites	Kit Aquamerck 111170.0001(Merck)	Colorimetry
Total dissolved salts	Consort C561 Multiparameter	Potentiometry
Sulphides	Kit Aquaquant 14416.0001 (Merck)	Colorimetry
Sulfates	Kit Aquaquant 14411.0001 (Merck)	Colorimetry
Ammonium	Kit Aquaquant 14428.0001 (Merck)	Colorimetry
Total coliform detection	Merck Incubator	Incubation at, 37°C
Total coliform counting	Kit Envirocheck Contact C, E, YM(R)	Incubation at, 37°C

according to relevant standards [11]. For water sampling have been used polyethylene containers with glass stopper, hermetically sealed and sterile.

Encoding:

- Sample 1 - average values recorded for samples of wastewater during June-August 2009;

- Sample 2 - average values recorded for samples of wastewater during September-November 2009.

Equipment and methods used in the determinations of physical, chemical and microbiological parameters for

irradiated and not irradiated wastewater samples are presented in table 1.

Microbiological analysis were carried out immediately after sampling process, samples were not preserved. This type of analysis was applied to wastewater samples before and after the irradiation process.

In order to characterize wastewater samples from microbiological point of view, it has been analyzed the detection and the counting of the number of colonies for Total Coliforms (*Enterobacteriaceae*), *Enterococci*,

Parameter	Allowable limits, according to [1]	Sample 1	Sample 2
pH (units of pH)	6.5-8.5	7.12	7.43
Electrical conductivity (mV)	-	+2	1.13
Turbidity before filtration (NTU)	-	8.71	10.47
Turbidity after filtration (NTU)	-	1.04	1.16
Total phosphorus (mg/L)	1.0	> 0.14	>0.12
PO ₄ ³⁻ (mg/L)	4.0	> 0.43	>0.40
Cl ⁻ (mg/L)	500.0	> 300	> 300
NO ₃ ⁻ (mg/L)	25.0	25 - 50	20-50
NO ₂ ⁻ (mg/L)	1.0	absent	absent
S ²⁻ (mg/L)	0.1	absent	absent
SO ₄ ²⁻ (mg/L)	600.0	> 400	> 400
NH ₄ ⁺ (mg/L)	2.0	> 0.4	>0.2
Total NH ₄ ⁺ - N (mg/L)	10.0	> 0.5	> 0.7
Total dissolved salts (mg/L)	-	647	815
Al ³⁺ (mg/L)	8.0	10	6
Fe ²⁺ (mg/L)	5.0	absent	absent
Co ²⁺ (mg/L)	1.0	absent	absent
Ni ²⁺ (mg/L)	0.1	0.02	0.05
Pb ²⁺ (mg/L)	0.2	absent	absent
Cu ²⁺ (mg/L)	0.1	absent	absent
Zn ²⁺ (mg/L)	0.5	absent	absent
Cr ³⁺ (mg/L)	1.0	absent	absent
K ⁺ (mg/L)	-	absent	absent
Ca ²⁺ (mg/L)	300	> 40	> 30

Table 2
PHYSICO-CHEMICAL PARAMETERS
DETERMINED FOR WASTE WATER

No. Det	Exposure time [sec]	Number of total Coliform [UFC/cm ²]	Presence of <i>Escherichia coli</i>	Presence of Enterococi	Presence of <i>Salmonella</i>	Presence of <i>Klebsiella</i>	Presence of <i>Shigella</i>	log(Nt/N0)
1	0	120000	positive	positive	positive	positive	positive	0
2	0	115000	positive	positive	positive	positive	positive	0
3	0	120000	positive	positive	positive	positive	positive	0.0184834
4	5	5000	positive	positive	positive	positive	positive	-1.3617278
5	5	5000	positive	positive	positive	positive	positive	-1.3617278
6	5	4500	positive	positive	positive	positive	positive	-1.4074853
7	10	3000	positive	positive	positive	positive	positive	-1.5835765
8	10	3000	positive	positive	positive	positive	positive	-1.5835765
9	10	3000	positive	positive	positive	positive	positive	-1.5835765
10	15	1000	positive	positive	positive	positive	positive	-2.060697
11	15	900	positive	positive	positive	positive	positive	-2.1064553
12	20	450	positive	positive	positive	positive	positive	-2.4074853
13	20	400	positive	positive	negative	negative	negative	-2.4586378
14	20	400	positive	positive	negative	negative	negative	-2.4586378
15	30	250	positive	positive	negative	negative	negative	-2.6627578
16	30	220	positive	positive	negative	negative	negative	-2.7182751
17	30	200	positive	positive	negative	negative	negative	-2.7596678
18	35	200	positive	positive	negative	negative	negative	-2.7596678

Table 3
EXPERIMENTAL VALUES FOR MICROBIOLOGICAL ANALYSES FOR SAMPLE 1

Escherichia coli, *Shigella*, *Klebsiella* using membrane filtration, method which provides quantitative and qualitative analysis of the types of pathogens and multiple tube method providing data for evaluation of the most probable number of microorganisms [12].

It was performed reference standard test and rapid test for counting by incubation at 37°C on selective medium with membrane biochemical characterization under typical sequence of positive colonies. Both tests led to the detection and enumeration of Total Coliforms after 48 h and then after five days.

Results and discussions

Physico-chemical analysis of wastewater

For waste water samples were carried out a series of physico-chemical analyses in accordance with standard methods for determination. In table 2 are presented the main values of physico-chemical parameters determined for waste water.

There are not observed values of parameters higher than the allowable limit for anions and cations content in waste water samples, excepting the Al ions concentration for sample 1.

Microbiological analyses for waste water

Before the irradiation process, for the two waste water samples it has been determined the medium number for total coliforms of 120000 UFC/cm² (sample 1) and 300000 UFC/cm² (sample 2), also the presence of *Escherichia coli*, *Enterococci*, *Salmonella*, *Klebsiella* and *Shigella* by obtaining a positive answer at the treatment of waste water with special microbiological reagents.

Further, waste water samples were irradiated with UV radiation, the time ranging from 5 to 30 s for the first set of samples.

After exposure to UV radiation, bacterial load was determined by the same methods. It has been obtained a

No. Det	Exposure time [sec]	Number of total Coliform [UFC/cm ²]	presence of <i>Escherichia coli</i>	presence of Enterococi	presence of <i>Salmonella</i>	presence of <i>Klebsiella</i>	presence of <i>Shigella</i>	log(Nt/N0)
1	0	300000	positive	positive	positive	positive	positive	0
2	0	300000	positive	positive	positive	positive	positive	0
3	20	400	positive	positive	positive	positive	positive	-2.8750612
4	30	200	positive	positive	positive	negative	negative	-3.1760912
5	35	200	positive	positive	positive	negative	negative	-3.1760912
6	60	100	positive	positive	negative	negative	negative	-3.4771212
7	70	100	positive	negative	negative	negative	negative	-3.4771212
8	80	50	positive	negative	negative	negative	negative	-3.7781512
9	300	0	negative	negative	negative	negative	negative	-
10	360	0	negative	negative	negative	negative	negative	-
11	600	0	negative	negative	negative	negative	negative	-
12	900	0	negative	negative	negative	negative	negative	-

log(Nt/N0) Represents the survival rate of pathogen agents
Nt Represents the number of coliform for irradiated sample
N0 Represents the number of coliform for not irradiated sample

Table 4
EXPERIMENTAL VALUES FOR MICROBIOLOGICAL ANALYSES FOR SAMPLE 2

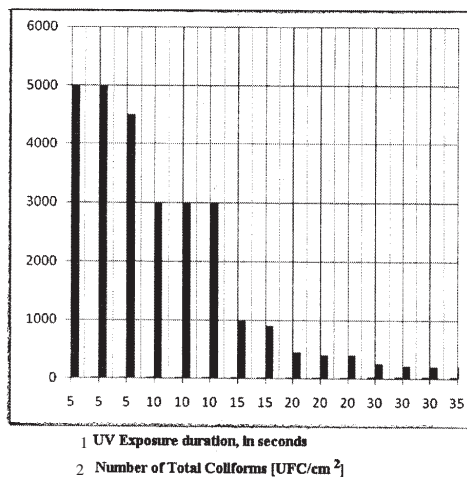


Fig.1. Variation of total coliform number depending on the exposure time for the first set of samples

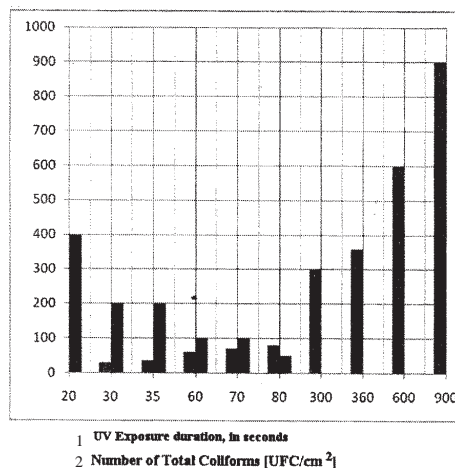


Fig.2. Variation of Total Coliform number depending on the exposure time for the second set of samples

series of positive and negative responses of microbiological cultures, as presented in table 3.

For the same samples, after irradiation was obtained negative response (absence) for strains of *Salmonella*, *Klebsiella*, *Shigella*, if the exposure time was 20, 30 and 35 s.

The second set of wastewater samples was exposed to UV radiation a long time between 20 and 900 seconds.

Experimental values for microbiological analyses (sample 2) are presented in table 4.

In this case, for different time of exposure was experimentally found that for a radiant energy of 49500 mWs/cm², *Shigella* and *Klebsiella* strains were annihilated after 35 s, *Salmonella* and *Enterococci* 70 after s and Total Coliforms and *E. coli* after 300 s. Microbiological characterization of irradiated water after 300 s of irradiation shows that the water did not reported the presence of pathogens detected at the beginning of the process.

To underline the efficiency of ultraviolet irradiation prototype plant on pathogens existing in the wastewater, it was graphically represented the dependence of the Total Coliforms in water depending on the duration of irradiation, for two sets of wastewater samples (figs.1 and 2).

Conclusions

Currently, there are not irradiation devices made in Romania used for wastewater treatment, all the devices being from UK, Canada or USA.

For this reason, our purpose is to make a unit that can be used for wastewater treatment which consist in 3 lamps type TUV 55WHO-G13 from Philips that have UV-C light with 253.7 nm wavelength and irradiation power of 16.5 W each.

This irradiation device is a prototype, which is in trade mark process of authorization at OSIM (National Organization on Trademark), made according to European and Romanian standards.

Physico-chemical and microbiological experiments conducted on wastewater confirmed the viability of original installation, for disinfection of water, but the time of exposure must be correlated with the microbiological degree of contamination for wastewater. It can be concluded that after 20 s at radiant energy of 49500 mWs/cm² given by prototype facility, *Shigella* and *Klebsiella* pathogenic strains were annihilated. All strains of pathogens were inactivated by an irradiation time of 300 seconds.

This method is one of the safest methods of disinfecting water, micro-type bacteria and parasites are destroyed in

the rate of 99.97%, unlike the ultraviolet lamp, where physico - chemical properties of water remains unchanged.

Also it has been demonstrated the efficiency of prototype facility, in terms of microbiological inactivation strains existing in wastewater samples.

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