# Development and Improvement of an Efficient Ozone Air and Surface Disinfection System in Hospitals

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***Abstract-*** Environmental spaces are important sources of pollutants that can expose the public to a risk of infection through the transmission of nosocomial pathogens that are localized on contaminated surfaces. It is therefore very important to reduce the risk of contamination, hence the need for reliable and effective air disinfection techniques. Ozone disinfection has been used and proven effective as an alternative sanitation technology to conventional disinfectants in reducing microbial contamination. In this paper, the disinfection capacity of $O_3$ gas is studied in the tramway train by 30 G and 60 G ozone generators by analyzing the reduction of bacterial colonies after ozonation on different points of the tramway.
The objective of our work is to carry out an experimental study to determine the capacities of ozone generator disinfection with using microbiological analysis.The results obtained showed a high disinfection efficiency with rates rates between 60 and 84%.

**Keywords -** Efficient Ozone, Disinfection System, ozone generators, Hospitals.

## I. INTRODUCTION

Microorganisms can be found everywhere on earth [1], certain areas such as hospitals are the most sensitive because contaminated surfaces can play an important role in the transmission of pathogens by causing nosocomial infections [2] which are considered to be a major problem in the hospital world. In order to prevent further transmission, it is therefore essential that they are properly cleaned and disinfected.
Furthermore, many studies underlined the disinfection validity of room surfaces and air using various devices/ methods, including ventilation system, ultraviolet lamps (UV), filtration, however, irradiation and plasma can burn the skin and eyes of personnel [3].
Chemical disinfectants could also be used for air disinfection, usually by means of vaporizing or spraying tels que l'oxyde d'éthylène (C2H4O) ou hydrogen peroxide vapor (fumigation), chlorine dioxide , However, these chemical disinfectants are usually difficult to decompose, leaving toxic chemical residues that are hazardous to human health [4].
Therefore, due to the several problems of such traditional methods for disinfection of public environments [5], other techniques are preferred to search for novel decontamination methods that are also ''environmentally friendly''. In recent years, there has been interest in the use of gas-based disinfectants for the inactivation of viruses present on surfaces and spaces in rooms. Among the gaseous disinfectants chloride dioxides ($ClO_2$) and cold plasma. There has been some recent interest in gaseous phase treatment techniques including the use of ozone, which has gained special attention in various fields for medical applications such as sterilization, surface disinfection, operating room disinfection, and in the food sector.
Ozone (O3) is a well-known powerful oxidant and disinfectant, which can be produced locally by several methods of which three are currently commercially available, dielectric barrier discharge DBD, ultraviolet light and electrolysis [6]; the most commercially important and effective method is ozone generation by DBD [7]. Ozone is an unstable gas that can be broken down to oxygen gas (O2) and oxygen atoms (O). Oxygen atoms, being strong oxidizers, appear to be a good agent for disinfection as well as the environmental control of pathogenic micro-organisms [8-9].
In this context, air and space disinfection with ozone has grown significantly in recent years. Numerous research works aiming at evaluating its efficiency for viral decontamination of spaces

have been carried out in order to reduce the transmission of nosocomial infections in hospitals and other indoor public spaces (health care facilities, dental offices, hotels and transport sector...) [10].

The objective of the work carried out in this paper is the development of a new installation for the disinfection of air and surfaces with ozone in the hospital environment in the department of legal medicine (autopsy room).

## II. MATERIALS AND METHODS

### Ozone generator

Two ozone generator were developed in the laboratory with ozone output of and 60 g/h (60 G) that were build up based on the ozone ceramic plate modules (Fig. 1). Each module omprises 3 flat rectangular shape ceramic plates with dimensions 100x40 $mm^2$ comprising a hexagonal cell electrode on one side and a flat electrode represented by a metallic aluminum layer on the other side. The two electrodes are separated by a ceramic dielectric layer with a thickness of 1 mm acting as a dielectric barrier. The 3 ceramic plates are powered by a high voltage transformer and produce a total concentration equal to 15 g/h. The generator 60 G comprises 4 modules and one air blower of flow rate 900 m3/h. The ozone concentration in airwas measured using an ozone analyzer with a measurement range [0-400 ppm].

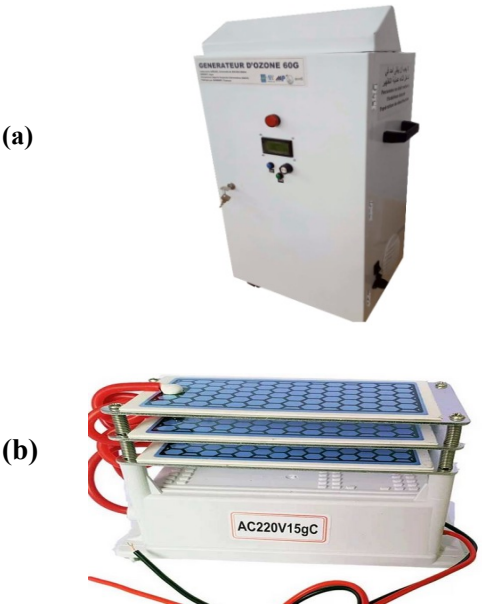


**Fig. 1.** Ozone generator used : (a) Photograph of the generator ; (b) Ozone generator kit with fan.

### Electrical characterization of the ozone ceramic plates modules

The electrical characterization of the ozone plate module was carried out as shown in Fig. 2. The applied voltage V was measured by using a digital scope (Picoscope 6-26403A) with band-pass of 350 MHz connected to a computer using a high voltage probe (Tektronix P6015A), while the current I was estimated by a Hall effect sensor (Pearson current monitor, model 410) with band-pass of 20 MHz. The current and voltage waveforms were recorded in two different channels of the picoscope over several periods with a total of 100000 points. A 22 nF capacitor placed between the metal electrode and the ground was also used to measure the transported charges. The power is then evaluated using Lissajous figure by plotting the electric charge on the Y-axis and applied the voltage on the X-axis [11-12].

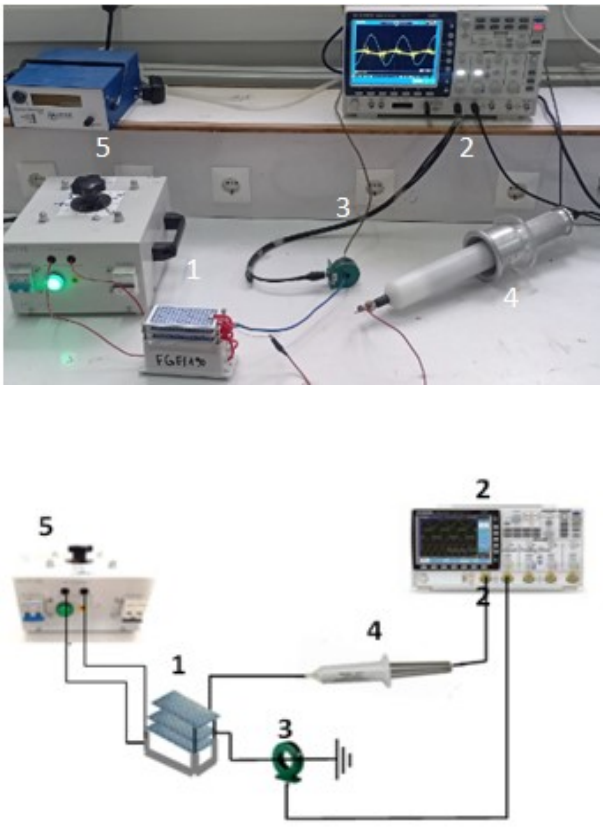


**Fig. 2.** Experimental setup used for the electrical characterization of the ozone module.
**(1)** Ozone module composed of 3 ceramic plates, **(2)** Digital scope, **(3)** Current sensor, **(4)** high voltage probe, **(5)** Autotransformer

### Bacteriological analysis

The experiments were carried out at the level of : Service of legal medicine of the University Hospital ABDELKADER HASSANI (Sidi Bel Abbés): Autopsy room.
We have carried out surface sampling targeting the various sensitive points of the autopsy room. The tests were conducted by measuring the antimicrobial effect of ozone on the total flora for 3 different ozonation durations (1h, 1h30 minutes and 2 hours), in five different sampling locations: stainless steel table (1), sink (2), chair (3), door handle (4), instrument cart (5) using the 60 G generator.


**Fig. 3.** Location of sampling points in the autopsy room.

We take a sample of the material used to confirm the presence of bacteria in its of bacteria in the initial state before the disinfection procedure.

The surface samples were taken by the swabbing method according to the following steps: To each swab tube, 1ml of diluent-neutralizer (saline) was added, and then we aseptically returned it to its tightly sealed bag before sampling. Once the sampling was completed, the swabs were put back into their tubes and immediately transferred to the laboratory for microbiological analysis.

In addition, air sampling was performed with Petri dishes containing nutrient agar medium (GN) inoculated with E. Coli; these open plates were then placed in different points of the ablution room. After a determined exposure time, the plates are immediately closed and incubated in an oven at a temperature of 37°C for a period of 24 hours..


**Fig. 4.** Location of petri dishes in the autopsy room.

The antimicrobial effect was evaluated using the "dilution/spreading" method, which quantifies the colonies of bacteria on the agar medium. The results are expressed as a percentage of inhibition calculated as follows:

$$\text{Inhibition } \% = \frac{\text{UFC Control} - \text{UF treated}}{\text{UFC Control}} \times 100 \qquad (1)$$

With :
CFU $_{\text{Control}}$: Untreated control sample.
CFU $_{\text{treated}}$ : Treated control sample.

## III. RESULTS AND DISCUSSION

The diagrams representing the current and the voltage waveforms are plotted in Fig. 5. According to the obtained results, the power consumed by one module was equal to 30 W, corresponding to a total power 120 W .

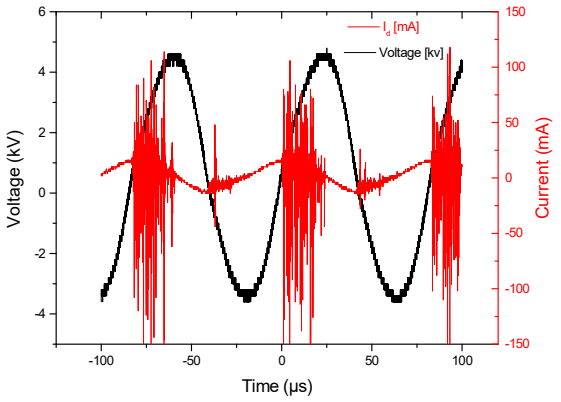


**Fig. 5.** Voltage and current waveforms.

## Ozone concentration evolution

After closing all windows and doors, the ozone generator was turned on by a device located inside to begin the ozonation process.
The concentration of ozone produced by the generator was measured directly in the sealed room, using an $O_3$ TECHNOLOGIES ozone analyzer with a measurement range of [0-400 ppm].After turning off the ozone generator, the ozone level began to drop as it decomposed into oxygen. Figure 6 shows the evolution of the ozone concentration as a function of the ozonation time, i.e. the time during which the ozone generator is running without and with the use of the fan.

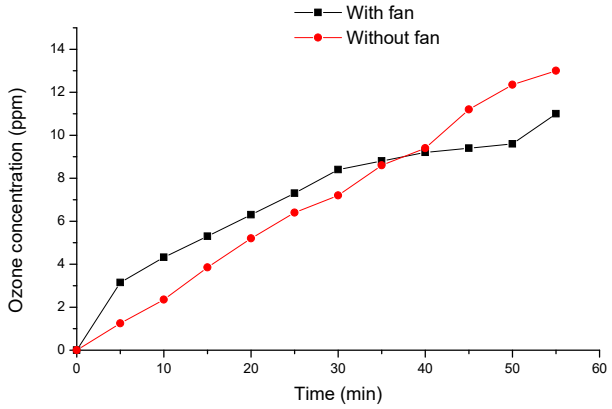


**Fig. 6.** Variation of ozone concentration with time for the case of the ozone generator 60 G in the autopsy room.

The use of the 60 G generator (autopsy room), the ozone concentration started to increase started to increase immediately when the generator was turned on, and increased linearly to a increased linearly to a level of about 8.5 ppm after 35 minutes without ventilation, and and 3 ppm in 5 minutes with ventilation, a maximum concentration was obtained for the for the volume of this room, 13 ppm without fan and about 11 ppm with fan only after 60 minutes ventilation only after 60 minutes (1h).

## Bacteriological analysis

The effectiveness of the disinfection was evaluated by counting the colonies of bacteria before and after disinfection with the 60 G generator, for 3 different durations 60 min, 90 min and 120 minutes. The samples taken on the different surfaces allowed us to obtain the results shown in Figures 7, 8 and 9. Photos of the air samples taken after incubation at 37°C are shown in Fig.10.

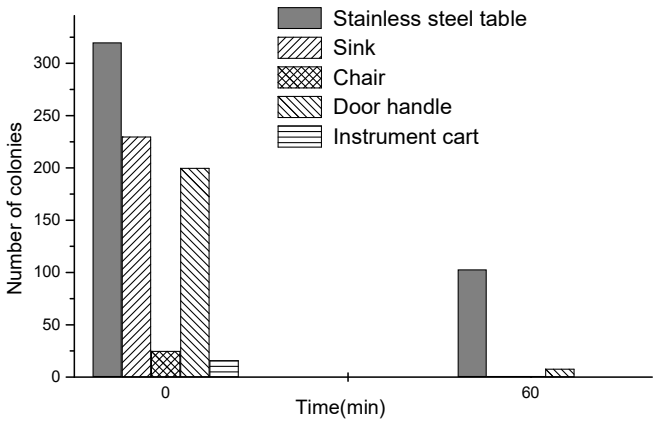


**Fig. 7.** Bacteria number evolution as a function of the ozonation time (60 min).

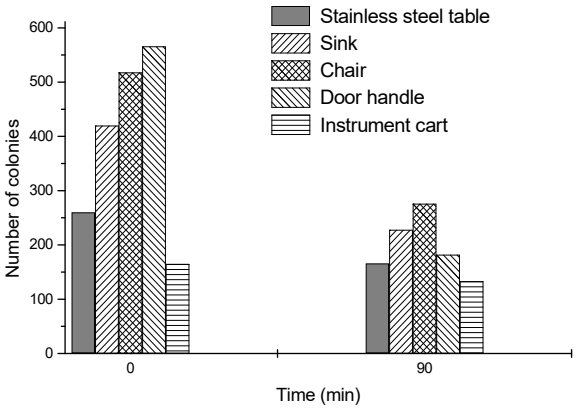


**Fig. 8.** Bacteria number evolution as a function of the ozonation time (90 min).

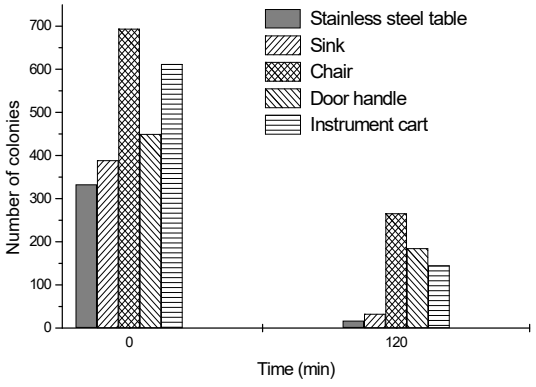


**Fig. 9.** Bacteria number evolution as a function of the ozonation time (120 min).

Almost complete removal was achieved after 1 hour of exposure to ozone, with rates [67-100%] with ventilation for the five sampling sites. A 90 minute treatment gave rates [19-67%] with ventilation. A decrease of the bacterial population was found between [58- 95%] for a 2h treatment. The results showed that disinfection of this room at 1 hour could be as effective as disinfection at 90 minutes.

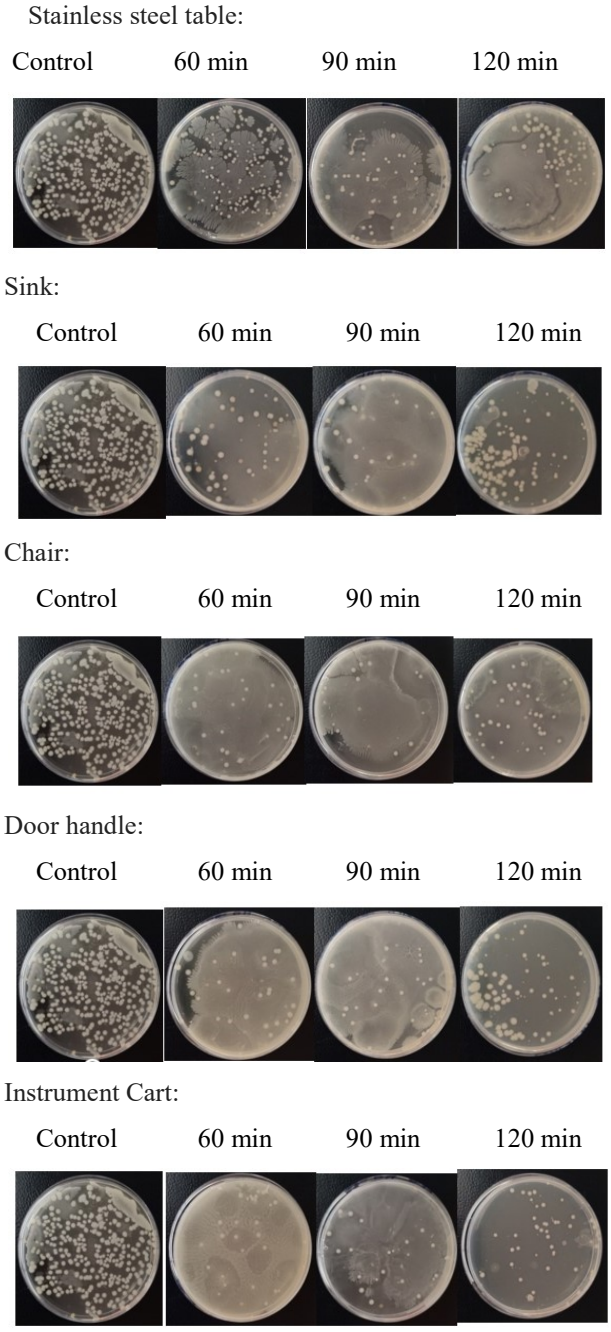


**Fig. 10.** Photos of the surface of Petri dishes showing E. Coli colonies exposed in air before and after treatment for different durations.

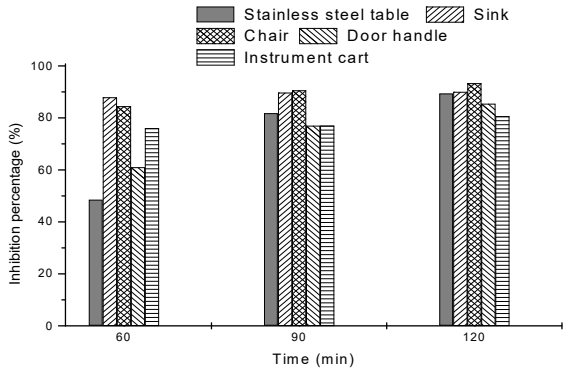


**Fig. 11.** Inhibition percentage evolution as a function of the ozone treatment time.

For the E. Coli study, the count results show that ozone is effective in reducing airborne bacteria. The higher the ozone level the higher the disinfection effect. A disinfection rate between 77% and 91% of airborne bacteria airborne bacteria could be reduced at an exposure time of 1h30 minutes. A increase of the exposure time to 2 hours results in a disinfection rate between 80% and between 80% and 94% does not have the beneficial effect on the reduction of airborne bacteria.For reasons of health and safety of people, too high an ozone concentration must be avoided. be avoided. The lowest $O_3$ concentration that can kill most microorganisms should be selected as should be selected as optimal. This depends on the level of contamination, a time of (1h-1h30min) of ozonation is sufficient for the disinfection of this room.

## IV. CONCLUSION

The experiments carried out in the forensic medicine service of university hospital centre (CHU) of Sidi-Bel-Abbes confirmed the efficiency of disinfection of surfaces with the dielectric barrier discharge ozone generator. Moreover, the disinfection using ozone generators have given reliable and really interesting results; the reduction of total flora is significant and reaches values of reduction rate higher than 80% between 1h30 min and 2 hours of exposure to ozone.

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