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Study of ozone disinfection in the hospital environment

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Abstract

Hundreds of millions of patients are affected by health care-associated infections worldwide each year. In the hospitals, contaminated surfaces and air may play an important role in the transmission of respiratory pathogens. Recently, ozone disinfection is employed and shows the effectiveness as an alternative sanitizing technology to conventional disinfectants in reducing the microbial contamination in air as well as in the surfaces of the functional rooms of the hospitals. In this paper, the disinfection capacity of ozone gas is investigated by means of analysing the CFU reduction during ozonation of an operative theatre in Ha Dong polyclinic hospital (Hanoi, Vietnam). The full removal of the microorganisms and fungi in the operative theatre during ozonation was achieved by using ozone of 5 ppm concentration and exposure time of 40-60 min.

Keywords. Hospital-acquired infection, ozone disinfection, operative theatre, agar dish, CFU.

1. INTRODUCTION

Hospital-acquried infection is a frequent adverse problem around the world. Hundreds of millions of patients are affected by health care-associated infections worldwide each year, leading to significant mortality and financial losses for health systems. Infection is spread to the susceptible patients in clinical settings by various means. Health care staff also spread infection. For the case of hospital infection, surfaces may play an important role in the transmission of respiratory pathogens. The most commonly contaminated surfaces were the bed sheet and the towels. In air dissemination can be either airborne droplet nuclei (small-particle of evaporated droplets containing microorganisms that remain suspended in the air for long periods of time) or dust particles containing the infectious agent. Therefore, there is a need for reliable and efficient air disinfection techniques to decontaminate the hospital area.

There are various methods for air disinfection. The common air disinfection method is using ultraviolet radiation of short wave length (UV-C). However, UV radiation could only disinfect air close to the lamps as UV light has a limited penetration capacity. Another well-known air cleaning method is to employ High Efficiency Particulate Air (HEPA) filter.[1] Chemical disinfectants could also be used for air disinfection, usually by means of vaporizing or spraying. However, these chemical disinfectants are usually difficult to decompose, leaving toxic chemical residues that are hazardous to human health.[1]

Ozone is a well-known powerful oxidizer which can be used for air disinfection. Ozone gas has high oxidation potential of about 2.05 V, remarkably higher than chlorine (1.36 V) so ozone is a strongest oxidant which is widely used for water and air disinfection. As a strong oxidant, ozone has a rapid reaction rate in the disinfecting process. It leads to the effect of low-dose gaseous ozone on pathogenic bacteria. Besides, ozone molecule (O_3) is chemically unstable and it is easily broken down into the oxygen. So, ozone is considered to be an environment-friendly disinfectant that leaves no residual or by-products after the disinfecting process. Ozone is also a safe sanitizer with no need for chemical storage, handling or related safety issues.

As mentioned above, ozone is a powerful oxidizer. Ozone with concentration higher than 1 ppm has adverse effects on human health and the use of ozone for air disinfections generally is not recommended if people are around. Therefore, air disinfection using ozone should be restricted to unoccupied room only.[1-4]

2. MATERIALS AND METHODS

Experiments were performed in a 30 sq. meter operative theatre (room) in The Ha Dong polyclinic hospital. The ozonation was carried out periodically or a few hours before operation when the room is unoccupied. An ozone generator of 25 grams ozone per hour is installed in the room. The feed gas for ozone generator is oxygen rich gas produced by a PSA oxygen generator. The ozone concentration is limited to be 5 ppm. The ozonation time is in the range from 20 up to 60 min. A system of ventilators supports the identical distribution of ozone in the room. Ozone concentration in the room is controlled by ozone monitors and electronics.

The technical procedure applied to ozonation process of the room is as follows: First experiment (static variant): ozone generator provides the ozone level of 5 ppm in the room for disinfection. This level will be kept for 20 minutes and more (up to 60 minutes). After that, the ozone generator will be turned off. Ozone in the room begins spontaneously (thermal) decomposite up to level less than 1 ppm. Then Petri dishes were put in the room and kept there for 10 minutes.

Second experiment (dynamic variant): The thermal decomposition process is going slowly. In order to quickly reduce the ozone level to the safe level for humans working in the room (~0.1 ppm) after ozonation, an amount of fresh air is added to the room through a HEPA filter as substitutes for the highly ozonated air. After that, Petri dishes were put and kept for 10 minutes in the room. In this variant, the HEPA filter for air disinfection and surface disinfection by ozone may play an important role.

When the ozone concentration became less than 1 ppm, ten Petri dishes (blood and sabouraud agar) were placed in room; the distance between the dishes is nearly 1.6 m. Petri dishes were kept for 10 minutes in ozone treated room. Then, the dishes were transferred to the biological Lab where it was kept warmed at 37 °C for 24 hours in the CO_2 rich air. Then the Petri dishes were checked by observing with naked eye to count the number of colonies. The CFU was calculated according to the formula of 26/QD-BYT.[5]

$$X = \frac{A.100\,x100}{S.k}$$

where X: CFU/m^3, A: number of colonies, S: area (cm^2) of the Petri dish, k: coefficient = 2 (Samples were kept in the room for 10 min).

3. RESULTS AND DISCUSSION

Disinfection capacity of ozone gas is investigated by means of analyzing the CFU reduction during air ozonation. Figure 1 shows both sabouraud agar (left) and blood agar dishes before and after ozonation with various exposure time from 20 to 60 minutes (for the static experiment).

The significant reduction of CFU in the dishes can be seen easily. Fungi in sabouraud dishes strongly decreased after 30 min of treatment (Figure 1, *left*, 1, 2 photos). No fungi (probably mycelium) are seen in the sample after 60 min of treatment (photo 3, *left*). For the blood agar dishes, the microbes, probably Gram (+) decreased and fully disapreared after 60 min of treatment.

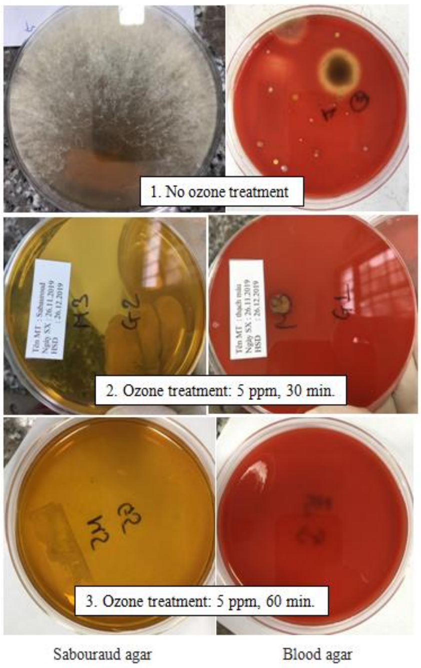

Figure 1: Reduction of fungi in sabourand petri agar dishes (left) and Gram(+) - right in blood dishes during ozone treatment. After ozonation (60 min, at 5 ppm), fungi and Gram microbes are not seen in both petri dishes

Figure 2 shows the dependence of CFU on exposure time for the static experiment (No adding fresh air to the room after ozonation, i.e. no use of HEPA filter). The number of colonies decreases from near 500 CFU (t = 0 min. i.e. before ozone treatment) to nearly zero (t = 60 min) after 60 min. of ozonation at level of 5 ppm of ozone. For 30 min of ozone treatment, CFU decreased by 16 times, from ~500 to ~30 CFU/m^3 (See chart 2).

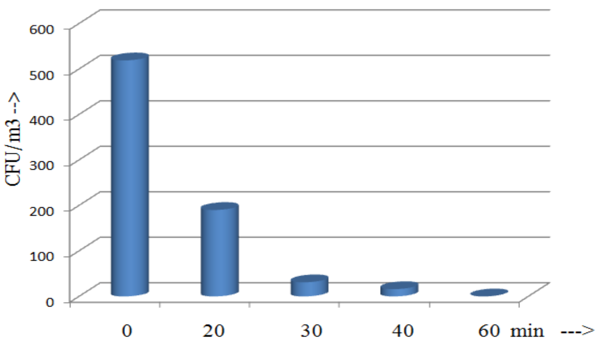

Figure 2: Time dependence of colonies (CFU/m^3) during ozonation at 5 ppm

The chart showing the reduction of CFU during ozonation in the second experiment (Dynamic variant, Fresh air was added after ozonation) has the same shape as shown in figure 2 but the data in it. In this chart the effect of CFU reduction is observed clearly (This chart is not shown here). But there is remarkable difference in CFU reduction between the static and dynamic experiments. In the dynamic experiment (with addition of fresh air after ozonation), for 30 min of ozone treatment at level ozone at 5 ppm, CFU decreased by 8 times only, from near 500 to ~64 CFU/m^3 (normalized data) in the same time this ratio is 16 for the static experiment. This fact shows that, static variant of disinfection has higher effectiveness in removing microorganisms in comparison with dynamic one.

Note that, ozone gas has capacity to kill not only the airborne microorganisms but also the microorganisms in the surfaces of the room's walls, the ceiling and the floor of the room as well as microbes in the surfaces of equipment. Total area of the room is large enough, more than 100 sq. meters so it is a large source for the transmission of respiratory pathogens to air.

The different effectiveness of ozonation for the static and dynamic experiments can be explained as follows. For the first experiment (static variant, no use of HEPA filter, no addition of fresh air to the room after ozonation), both airborne microbes and microbes slung to the surfaces have been killed by ozone. In contrast, in the second experiment (second variant), fresh air added to the room though a HEPA filter may contain an amount of microbes because the HEPA filter could not trap microbes of small size. Ozone treatment carried out before adding fresh air to the room may kill only microbes slung on the surfaces of the room to prevent the transmission of microbes from the large area of the ceiling, the walls and the floor of the room to air. This is the reason why the disinfection effect in the first experiment (no addition of air after ozonation, no use of HEPA filter) is higher than the second experiment (fresh air was pumped though a HEPA filter to the room after ozonation).

The results shown on figures 1 and 2 indicate the effectiveness of ozone (gaseous) treatment as an alternative sanitizing technology to conventional disinfectants in reducing the microbial contamination in air as well as in the surfaces of the room. The investigation of air ozonation process in the baby's room was also carried out and the microbiological reduction was observed, similar to the case of the ozone treatment at the operative theatre mentioned above. The removal of the residual ozone after ozonation was realized by use of an exhauster to pump air to the ambient atmosphere, where the ozone concentration became less than 0.1 ppm.

4. CONCLUSIONS

1. The observing of bacteria in the Petri dishes indicates the full removal of the microorganisms and fungi in the operative theatre after ozonation with ozone concentration of 5 ppm and exposure time of 30-60 min.

2. In the process of air disinfection, ozone kills not only the airborne microorganisms but also the microorganisms slung in the surfaces of the room's walls, the ceiling and the floor of the room as well as microoganisms in the surfaces of equipments which is the source of the transmission of microorganisms to air.

3. In certain cases, in the ozonation process, the HEPA filters can be employed while adding fresh air to the room after ozonation to quickly decrease the ozone level to the safe level for human. Ozone gas used in combination with the HEPA filters is considered to be air disinfection method of high efficiency.

4. The effectiveness of air ozone treatment without addition of fresh air is higher than those of adding fresh air with use of HEPA filter.

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Conflict of Interest. *The authors declare that they have no conflict of interest.*

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