Sustainable Environment Research 26 (2016) 191–195

Contents lists available at ScienceDirect

Sustainable Environment Research

journal homepage: www.journals.elsevier.com/sustainable-environment-research/

Technical note

Evaluation of disinfection efficiency in pet's hospital by using chlorine dioxide

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ARTICLE INFO

Article history:
Received 1 June 2015
Received in revised form
19 August 2015
Accepted 19 October 2015
Available online 22 April 2016

Keywords:
Pet's hospital
Chlorine dioxide
Disinfection

ABSTRACT

Microbial aerosols could cause various human and animal health problems and their control is becoming a significant scientific and technological topic for consideration. The main objectives of this study were to monitor bioaerosol levels of the pet's hospital and then to perform disinfection efficiency by applying chlorine dioxide. The air quality within these pet's hospitals should satisfy the guidelines specified by the Taiwan Environmental Protection Administration (TEPA). Accordingly, this study performed an experimental investigation into the efficiency of two different gaseous chlorine dioxide (0.3 mg m^{-3}) treatments in disinfecting a local pet's hospital, namely a single, one-off application and a multiple-daily application. In both cases, the ClO_2 was applied using strategically-placed aerosol devices. The air quality before and after disinfection was evaluated by measuring the bioaerosol levels of bacteria and fungi. The experimental results found that the average background levels of bacteria and fungi prior to ClO_2 disinfection were found to be 2014 ± 1350 and 1002 ± 669 CFU m^{-3}, respectively. A single ClO_2 application was found to total disinfected bacteria and fungi concentration levels by as much as 57.3 and 57.6%. By contrast, a multiple-daily ClO_2 application was found to total disinfected bacteria and fungi concentration levels by as much as 65.1 and 57.6%. Among the two disinfection methods, the multiple-daily ClO_2 application method was found to yield a higher disinfection efficiency for bacteria, i.e., 16.28 ± 0.92%. Thus, using a ClO_2 disinfectant to maintain the air quality is of great importance to reduce infectious diseases in the pet's hospital. Therefore, the results suggest that the air quality guidelines prescribed by the TEPA for pet's hospital and other animal facilities can best be achieved by applying chlorine dioxide at regular intervals. The ClO_2 aerosol devices can effectively restrain or disinfect airborne bacteria to improve the indoor air quality. Thus, it can be applied in pet's cosmetology institutions, hospitals, and other public areas, where bioaerosols are of great concern.
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1. Introduction

Particles of biological origin account for approximately 24% of the total concentration of airborne particles [1]. Deterioration of indoor air quality due to the airborne bacterial consortia is a widespread environmental problem. The indoor environment can potentially cause greater risks to human occupants than the outside environment, because enclosed spaces can confine and accumulate aerosols to levels that cause health hazards. Additionally, average persons spend most of their time indoors. Microbial contamination of air has become of interest in the past two decades because of the correlation of sick building syndrome (SBS) with indoor air pollution [2]. In fact, the onset of SBS, which comprises a series of symptoms such as eye irritation, airways dryness, headache, sleepiness, and skin rash and itch, seems to be related to the presence of microbes or their components in indoor air [3,4]. Biocontamination has the same harmful effects as chemical pollutants on the health of individuals [5]. In the past few decades, the problem of microbial contamination of indoor air has become a subject of interest for many researchers; both for the possible effects on health and for the control measures to limit these effects [6,7]. Exposure to microbial pollutants is in fact related to many negative consequences, such as infectious diseases, toxic effects, allergies, and asthma [3].

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Peer review under responsibility of Chinese Institute of Environmental Engineering.

http://dx.doi.org/10.1016/j.serj.2016.04.009
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Bioaerosols may be suspended in the air, attached to indoor surfaces, or present in the dust accumulated within a building or any of its internal parts or operating systems (e.g., the inside walls, air-conditioning units, ducts, among others). Given favorable conditions, bioaerosols are able to grow and propagate rapidly through enclosed indoor environments, resulting in significant indoor air pollution [2]. Research has shown that long-term exposure to bioaerosols in indoor environments may lead to infectious disease, SBS, or organic dust toxic syndrome [8]. Furthermore, elevated levels of particulate air pollution are associated with decreased lung function, increased respiratory problems, and enhanced rates of chronic obstructive pulmonary disease, cardiovascular disease and lung cancer [9]. As a result, exposure to bioaerosols in public spaces has emerged as a matter of growing concern in recent years [1,10,11]. In general, the concentration and size distribution of indoor bioaerosols depend on a wide range of biotic and abiotic factors. For example, previous studies have shown that the moisture content of building materials, the relative humidity and temperature of the local environment, the air exchange rate, the presence of human activities, and the number of people and pets all significantly affect the concentration level of indoor bioaerosols [12–14]. In non-industrial indoor environments, airborne bacteria are generated mainly by the presence of humans and related activities such as talking, sneezing, coughing, walking, washing, toilet flushing, and so forth [15]. Thus, while indoor environments are supposed to be protective, they can in fact become contaminated with particles which present different and sometimes more serious risks than those in outdoor environments if their concentration levels exceed recommended safety limits.

To safeguard public health, the National Institute of Occupational Safety and Health in America and the American Conference of Governmental Industrial Health (ACGIH) have ruled that the total number of bioaerosol particles in indoor environments should not exceed 1000 CFU m^{-3}, while the total culturable count for bacteria should be no higher than 500 CFU m^{-3} [16]. Furthermore, the Taiwan Environmental Protection Administration (TEPA) Taiwan has stated that for indoor public spaces, the bacteria concentration should be no higher than 1500 CFU m^{-3}, while the concentration of fungi should not exceed 1000 CFU m^{-3} [17].

Taiwan lies in a subtropical zone, and is usually warm and humid throughout the entire year. As a result, the local climate is highly conductive to the growth of bioaerosols [18]. According to the results of one long-term monitoring study, the concentration of biological contamination in Taiwan is much higher than the value of 1000 CFU m^{-3} recommended by the WHO [19]. Thus, to satisfy the TEPA guidelines for the air quality in indoor environments, effective disinfection treatments are required.

Pet shops and pet hospitals are two potential workplaces associated with the possibility of being exposed to bioaerosols, since pets are known as a potential source for indoor bioaerosols [14,20,21]. As a result, stringent disinfection protocols are required to ensure the health and general well-being of the cafeteria's consumers. The gaseous chlorine dioxide (ClO_2) is one of several techniques used for the remediation of structures impacted by microbial growth [6]. ClO_2 can destroy all manner of microorganisms, including bacteria, spores, fungi, viruses and even protozoans [22,23]. ClO_2 dissolves readily in water, forming a stable state of small particles. Under room temperature conditions, the ClO_2 content within the water evaporates and propagates naturally through the local environment, providing a disinfection function. Being in gaseous form, the ClO_2 molecules have the ability to penetrate into building cavities, wall cavities and other hard-to-access areas, and therefore provide an extremely thorough disinfection function [24]. Moreover, ClO_2 also exhibits a good degree of fungicidal activity when applied in solution form [25,26]. This study has been carried out on the ClO_2 disinfection of airborne bacteria in polluted indoor air due to its great potential to protect public health.

In a study performed by the US EPA, it was shown that ClO_2 results in no physiologically relevant alterations in human health provided that it is present only in low concentrations [27]. Accordingly, the present study with two different ClO_2 ultrasonic aerosol procedures were performed, namely single and multiple ClO_2 application. The air quality in the pet's hospital before and after ClO_2 disinfection was evaluated in terms of the bioaerosol levels of bacteria and fungi. The air quality results were then analyzed in order to determine the relative disinfection efficiencies of the two different methods.

2. Materials and methods

The study was conducted in the pet's hospital in Taiwan. Prior to disinfection, air samples were collected and analyzed in order to determine the background concentration levels of bacteria and fungi. ClO_2 disinfection was then carried out using two different application procedures. On each sampling day, air samples were collected over a 5-h period in order to evaluate the reduction in the bacteria and fungi concentration levels. The ClO_2 disinfection process for each mode was executed triple. The details of the experimental procedure are described in the sections below.

2.1. Study area and sampling time

Fig. 1 presents the floor plan of the pet's hospital considered in the present study. Sampling was conducted in four different areas of pet's hospital. The air samples were collected in accordance with the NIEA (National Institute of Environmental Analysis) guidelines specified by the TEPA. On each sampling day, indoor air samples for determining the biological and nonbiological contaminants in the pet's hospital were collected between the hours of 10:00 am and

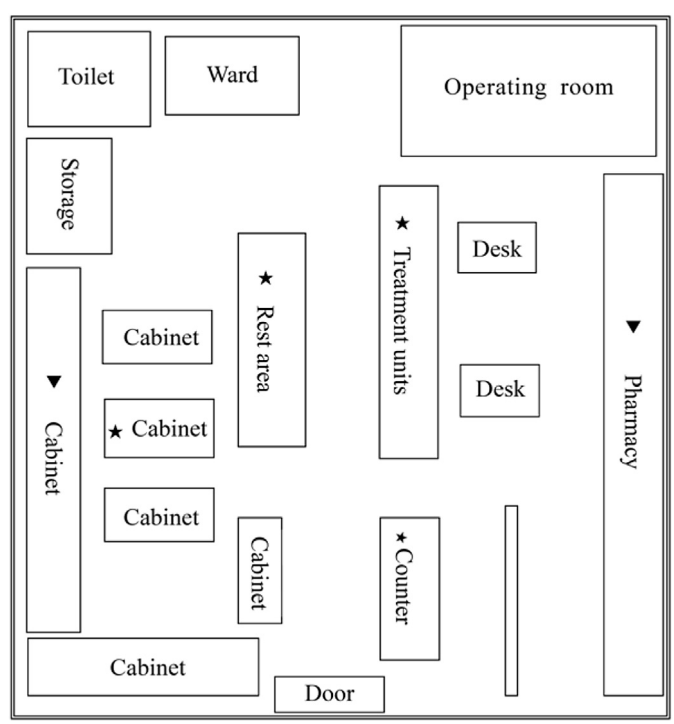

Fig. 1. Floor plan of pet's hospital (★ = sample collection location; ▲ = location of ultrasonic aerosol devices).

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