Potential of ultraviolet germicidal irradiation for maintaining better indoor air quality in smart cities of India

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Abstract - The Government of India has an ambitious project of developing 100 smart cities across the country with a mission of making them sustainable and user friendly. One of the critical factors in planning a smart city is to understand the importance of good indoor air quality (IAQ) in a city's built environment. It is thus evident to understand the role of IAQ products in maintaining and enhancing IAQ in smart cities of India. Ultraviolet germicidal irradiation (UVGI) is one of the effective tools used predominantly to disinfect air in commercial and residential air conditioning systems. This paper discusses the potential of UVGI in maintaining better IAQ in smart cities of India. The aim of this paper is to review the development of UVGI systems, feasibility of UVGI systems, current best practices, current and future applications of UVGI systems and design guidelines for UVGI system. The article also reviews some key elements such as strategies, awareness and real-world system conditions. This paper provides the research directions needed for comprehensive understanding of UVGI system from the perspective of smart cities in India. The present study assumes significance with increasing urbanization in India.

Keywords: Smart cities, Indoor air quality, UVGI

I. INTRODUCTION

Ultraviolet germicidal irradiation (UVGI) has been used successfully for many years for controlling airborne contaminants. It is often observed that the patients are at increased risk towards infections in hospitals, especially when continuously exposed to these environments. In majority of the cases, the antibiotics are ineffective to control or kill bacteria. Ultraviolet (UV) light is seen as a promising method towards significant reduction in infections associated with healthcare facilities [1]. Several authors have studied the benefits of UVGI systems in deactivating biological growth as well as energy savings in air handling units [2, 3, 4, 5, 6]. The present study investigates the potential of UVGI systems for maintaining better IAQ in smart cities of India. The aim of this study is to review the development of UVGI systems, feasibility of UVGI systems, current best practices and future applications of UVGI systems.

II. DESIGN GUIDELINES

ASHRAE [7] has summarized the general ranking of susceptibility of microorganisms to ultraviolet radiation (Refer Fig. 1).

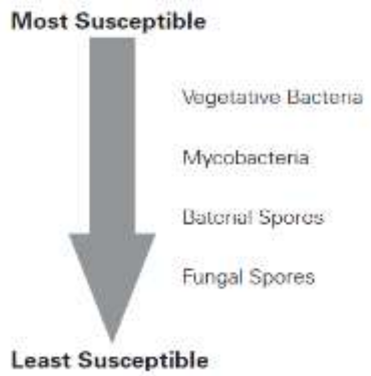

Fig. 1: Susceptibility of microorganisms to UVGI [7]

Kowalski [8] has made a comprehensive study on UV technology and its applications. The author has classified the UVGI guidelines and standards into four major categories viz., Electrical standards, Measurement and Testing standards, Application guidelines and UV safety guidelines. ASHRAE [7] has addressed three types of UVGI systems viz., Induct airstream disinfection, air handler surface disinfection, and Upper-air systems.

Use of UVGI systems is one of the strategies recommended by ASHRAE [9], to control moisture and contaminants related to mechanical systems. Though UVGI systems have widespread use, the need for consensus standards for design, application and testing were emphasized by

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Kowalski and Bahnfleth [10]. For smart cities in India, it also becomes inherent to develop standards and guidelines for UVGI systems for different applications, with respect to Indian conditions.

III. EXPERIMENTAL AND FIELD STUDIES ON UVGI SYSTEMS

This section reviews the experimental and field studies on UVGI systems.

Kowalski [11] demonstrated a methodology for calculating the effectiveness of UVGI systems. This method also enables the evaluation of UVGI rate constants from airborne laboratory tests.

Lau et al. [12] utilized ray tracing computer model to determine the fluence distribution in UVGI devices with different surface reflectivities and lamp configurations.

Levetin et al. [13] found UVGI systems as a promising approach for reducing fungal contamination within air handling units.

In addition to controlling contaminants, UVGI system is a superior alternative to periodic cleaning of cooling coils. Table 1 [14] demonstrates the energy conservation at M/s Persistent Systems Ltd., Pune with the use of UVGI system.

Table 1: Comparison of energy consumption [14]

Months	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.
2008	-	-	-	2593	3041	2795	2200	1885	1845	1602	1602	1507
2009	1163	1368	1840	2108	2231	2287	1893	1667	1863	1810	1573	1354
2010	1235	1495	1769	1991	2069	1958	1774	1493	1635	1716	1520	-
Infrequent cleaning			Weekly cleaning			UVGI Installed						

A reduction of 25.8% and 8.3% in energy consumption over infrequent cleaning and weekly cleaning of cooling coils were reported due to use of UVGI systems.

In another investigation for hot and humid climate [15], the authors observed that the overall thermal conductance of coil increased by 10% and the pressure drop decreased by 13%, with the improvement being most rapid over the first month after UVGI intervention. Fan energy use was reduced by 9% over the ten months of UVGI operation. Savings in fan energy were 39% greater than the energy used by the UV lamps.

Menzies et al. [16] conducted a double blind, multiple crossover trial of 771 participants in Montreal, Canada. The UVGI system was alternately off for 12 weeks and then turned on for 4 weeks. This process was done for 3 times with UVGI on and three times with it off, for 48 consecutive weeks. The results of this study indicated that with UVGI systems on, the workers reported considerably fewer work related mucosal, respiratory and overall symptoms.

A significant reduction in the microbial count in the air was observed after installation of UVGI system. Table 2 [14] summarizes the results of the same, which were reported in an office building of major IT company in Pune.

Table 2: Reduction in bacteria count [14]

Location of air sample measurement	Pre - UVGI Installation Bacteria count	Post - UVGI Installation (10 days) Bacteria count	% reduction in Bacteria count
Return air duct (aggregate effect)	38	12	68 %
Work area full occupancy	35	6	83 %
Work area 30 % occupancy	15	9	40 %

IV. CURRENT BEST PRACTICES

4.1 In – Duct UVGI

Figure 2 [17] shows the installation of in-duct UVGI system with lamps mounted on the downstream of cooling coil and drain pan. It is necessary to use the in-duct UVGI system in combination with filters. The filtration helps in enhancing the air cleaning ability of UVGI system, by protecting them from dust particles.

Fig. 2: In – duct UVGI Installation [17]

4.2 Surface disinfection

Figure 3 [17] shows UVGI system used for surface disinfection. The reflectors help to direct the UV energy on the required surfaces. It is general practice to mount the UV lamps within 3 feet (0.9 m) and the operating of lamps is generally 24 hours per day and seven day per week.

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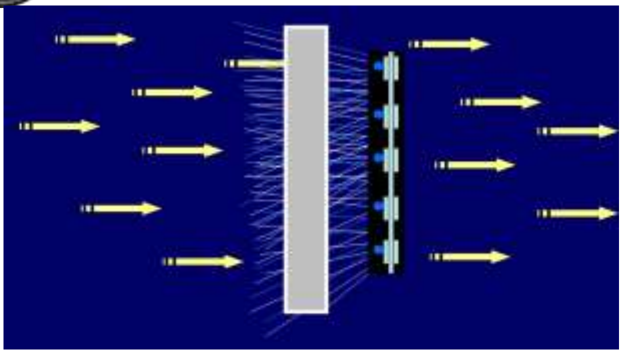

Fig. 3: UVGI system for surface disinfection [17]

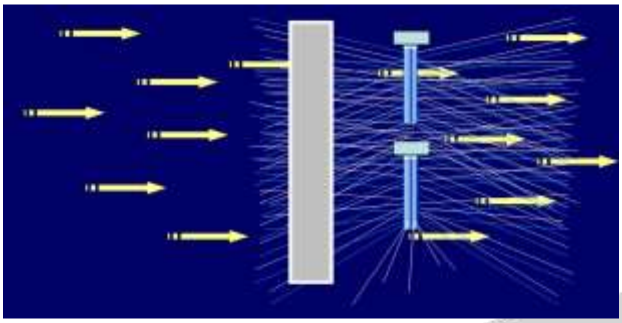

Fig. 4: In-duct UVGI installation for air disinfection [17].

Figure 4 shows the installation of UVGI system for air disinfection. In the absence of reflectors, the UV energy can be distributed throughout the air path. In these situations, the enhancement in the overall reflectivity of air handling unit or inside of the duct helps to reflect the UV energy back thereby increasing its effectiveness.

4.3 Upper-air UVGI

Figure 5 shows the installation of upper – air UVGI system with fixture bottom at least 7 feet (2.1 m) above the floor. The installation must be such that the radiations are directed upward and outward to create an intense UV zone in the upper portion of the room (Figure 6) whereas protecting the occupied spaces from UV radiation.

Upper – air UVGI system provides an effective solution where in-duct UVGI is not feasible or where it is required to further reduce the airborne contaminants [32].

(a) Wall mounted (b) Ceiling mounted

Fig. 5: Upper – air UVGI system [17]

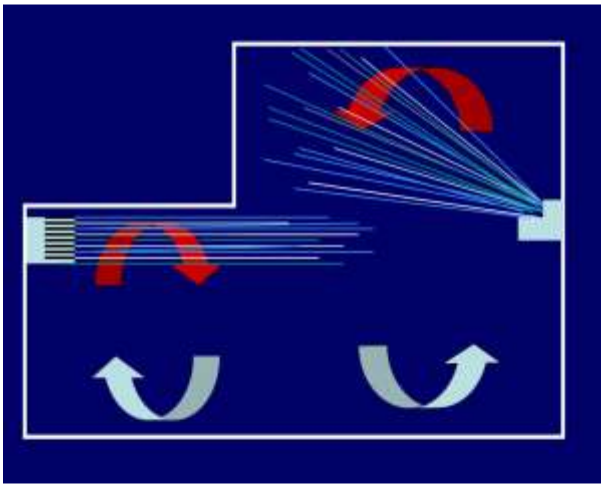

Fig. 6: Upper-air UVGI installation showing wall mounted fixtures [17]

V. MISSING LINKS

Though UVGI systems are in operation for many years, there is limited information available that provides comprehensive information on use of UVGI systems. Bahnfleth [18] has also commented on this issue and has insisted on further investigations on UVGI systems for wider range of operating conditions.

The missing links for UVGI systems can be summarized by following points.

1. The IAQ audit of UVGI systems integrated with fresh air needs to be investigated, particularly for ventilation systems. The IAQ results for UVGI systems along with air purifiers also need to be studied. This factor will prove beneficial for office applications and residential application.
2. There is enough information on UVGI systems for centralized air conditioning. However, the constraints and benefits of UVGI systems integrated with unitary air conditioning systems, needs to be studied. The improvement in IAQ due to this mechanism will prove as a vital source of information, especially in situations where unitary air conditioning is widely used.
3. A comprehensive understanding is necessary to study the effect of air temperatures, relative humidity and flow on the performance of UVGI systems.
4. One of the emphasizing parameter which is currently missing is the need of training and awareness programme on correct use of UVGI systems. Though ASHRAE [66] has specified the operation, maintenance and safety guidelines, the mandatory provision of personal safety training to facility personnel on UVGI systems will prevent the facility from unnecessary hazards.

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VI. Research directions for UVGI systems in smart cities of India

There lies tremendous potential in the use of UVGI system for maintaining better IAQ. The research directives include following specific questions. The comprehensive understanding of these questions with possible solutions will ensure appropriate use of UVGI systems in maintaining better IAQ in smart cities of India.

1. What is the understanding of Indian architects, engineers, contractors and end users about the use of UVGI systems especially for critical applications such as hospitals?
2. What is the public awareness in India, about use of UVGI systems for residential and commercial applications?
3. What is the mechanism for training the technician and engineers about installation, operation and maintenance of UVGI systems?
4. Are pilot studies available for use of UVGI systems in schools, hospitals and commercial buildings of Indian cities?
5. What is the framework for use of UVGI systems in smart cities in the world?
6. What must be the framework for use of UVGI systems in smart cities of India?
7. How will the performance of UVGI systems be monitored and controlled in a smart city?
8. What is the role of policy makers in promoting UVGI systems?
9. Which are the relevant Indian standards for UVGI systems? Do we need to develop them for Indian smart cities?
10. What are the mechanisms by the Government to promote UVGI systems for different segments especially hospitals?

VII. Conclusions

The several important aspects of UVGI system are addressed in this paper. The implementation of safety guidelines for UVGI system becomes the critical parameter in promoting its usage in smart cities of India. This paper provides the research directions needed for comprehensive understanding of UVGI system from the perspective of smart cities in India. The present study assumes significance with increasing urbanization in India.

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