ULTRAVIOLET GERMICIDAL IRRADIATON (UVGI) INDOOR AIR PURIFIER – AN UPDATE

HEALTH TECHNOLOGY ASSESSMENT SECTION
MEDICAL DEVELOPMENT DIVISION
MINISTRY OF HEALTH MALAYSIA

002/2013

DISCLAIMER

Technology review is a brief report, prepared on an urgent basis, which draws on restricted reviews from analysis of pertinent literature, on expert opinion and / or regulatory status where appropriate. It has not been subjected to an external review process. While effort has been made to do so, this document may not fully reflect all scientific research available. Additionally, other relevant scientific findings may have been reported since completion of this review.

Please contact: htamalaysia@moh.gov.my, if you would like further information.

Health Technology Assessment Section (MaHTAS),
Medical Development Division
Ministry of Health Malaysia
Level 4, Block E1, Precinct 1
Government Office Complex
62590 Putrajaya

Tel : +603 8883 1246

Fax : +603 8883 1230

Available at the following website: http://www.moh.gov.my

Prepared by:
Dr. Hanin Farhana Kamaruzaman
Assistant Director
Health Technology Assessment Section (MaHTAS)
Ministry of Health Malaysia

Reviewed by:
Datin Dr Rugayah Bakri
Deputy Director
Health Technology Assessment Section (MaHTAS)
Ministry of Health Malaysia

DISCLOSURE

The author of this report has no competing interest in this subject and the preparation of this report is totally funded by the Ministry of Health, Malaysia.

EXECUTIVE SUMMARY

Introduction

Ultraviolet germicidal irradiation (UVGI) is an established means of disinfection and can be used to prevent the spread of certain infectious diseases. UVGI can be used to disinfect air, water and surfaces, although surface disinfection is limited by microshadows and absorptive protective layers. Air disinfection is accomplished via several methods: irradiating the upper-room air only, irradiating the full room (when the room is not occupied or protective clothing is worn) and irradiating air as it passes through enclosed air-circulation and heating, ventilation and air-conditioning (HVAC) systems.

The purpose of this technology review is to update on UVGI air purification system. This technology review was requested by the Director of Planning and Development Division, Ministry of Health Malaysia.

Objective/aim

To assess the effectiveness, cost-effectiveness and safety of [redacted] ultraviolet germicidal irradiation indoor air purifier.

Results and conclusions

There was one retrievable evidence on [redacted] indoor air purifier via Pubmed. Two full text articles were provided by the manufacturer, [redacted] Technologies Inc.. There were also two local technology reviews conducted by MaHTAS which assessed ultraviolet germicidal irradiation air purifier system. There was no retrievable evidence on the cost-effectiveness of [redacted] UVGI indoor air purifiers or other types of UVGI. As for safety issues, there was no recent retrievable evidence related to the adverse events of UVGI systems.

Based on the above review, there were few scientific evidences to support the effectiveness and safety of [redacted] UVGI indoor air purifier systems. As for other air disinfectant using UVGI, the technology may have potential benefit for airborne pathogen irradiation; however, more research is warranted. UVGI is feasible in its application and the adverse events can be avoided with proper precaution and maintenance.

Methods

Electronic databases were searched through the MEDLINE(R) In-process and other Non-Indexed Citations and Ovid MEDLINE(R) 1948 to present, EBM Reviews - Cochrane Central Register of Controlled Trials and EBM Reviews - Health Technology Assessment. Other database was PubMed, Cochrane Library, Australia & New Zealand Horizon Scanning Network (ANZHSN) and US Food & Drugs Administration (US FDA).

1. INTRODUCTION

Indoor air quality is a term which refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants. It can be affected by gases, particulates, microbial contaminants or any mass or energy stressors that can induce adverse health conditions. Source control, filtration and the use of ventilation technologies are the primary methods for improving indoor air quality in most buildings.

Ultraviolet germicidal irradiation (UVGI) is an established means of disinfection and can be used to prevent the spread of certain infectious diseases.[1] The UV spectrum is commonly divided into UVA (wavelengths of 400 nm to 315nm), UVB (315nm to 280nm) and UVC (280nm to 200nm). The entire UV spectrum can kill or inactivate many microorganisms, but UVC energy provides the most germicidal effect, with 265 nm being the optimum wavelength.[2]

UVGI can be used to disinfect air, water and surfaces, although surface disinfection is limited by microshadows and absorptive protective layers. Air disinfection is accomplished via several methods: irradiating the upper-room air only, irradiating the full room (when the room is not occupied or protective clothing is worn) and irradiating air as it passes through enclosed air-circulation and heating, ventilation and air-conditioning (HVAC) systems.[1]

Two technology review reports related with UVGI indoor air purifier system hs been prepared by Malaysia Health Technology Assessment Section (MaHTAS), namely Upper Room Ultraviolet Germicidal Irradiation Eliminator An Update (2006) and Sterybox Air Disinfectant (2008). The purpose of this technology review is to update on UVGI air purification system. This technology review was requested by the Director of Planning and Development Division, Ministry of Health Malaysia.

2. OBJECTIVE/AIM

To assess the safety and effectiveness of [redacted] ultraviolet germicidal irradiation indoor air purifier.

3. TECHNICAL FEATURES

[redacted] Technologies Inc. is established in 1995 and their systems are used around the world in residential, commercial, institutional, medical and military installations. [redacted] is one of the leading manufacturers of UV air purification systems and several research and clinical trials have been conducted on their products.[3]

There are mainly two types of [redacted] system, which are air sterilization system and coil sterilization system. This review will discuss on air sterilization system of [redacted] as proposed by the requestor.

3.1. Mechanism of Action of Air Purifier System

The aim of air purifier system is to improve indoor air quality by inactivation of microorganisms with or without filters. There are several factors influencing the effectiveness of UVGI air sterilization system.[4] They are:-

i. **UVGI irradiance, dose and time of exposure**
- the sensitivity of the microorganisms to UVGI and the dose of UVGI received by a microorganism or population of microorganisms. The more time that the contaminant is exposed to the UV light, the higher the UV dosages it receives and the greater the killing rate.

ii. **Mechanical ventilation**
- as the mechanical ventilation rate in a room or space is increased, the total number of microorganisms removed from the room or space via this system is increased.

iii. **Air mixing**
- ventilation systems should be designed to provide optimal airflow patterns within rooms and prevent air stagnation. If areas of air stagnation are present, air mixing should be improved by adding fan or repositioning the supply diffusers and/or exhaust grills.

iv. **Humidity**
- a number of studies indicated that the effectiveness of upper-room UVGI systems decreases as humidity increases.

v. **Air temperature**
- the combined effect of air temperature and velocity on UV lamp temperature can cause significant variation in lamp output and ultimately UV dose.[2]

There are three types of UV air purification systems by Sanuvox. The widely used systems are :

a. In-duct UV systems
   - eg: UV Bio-Wall In-Duct Air Sterilization System

b. Coil-clean UV systems
   - eg: UV CoilClean Commercial

c. Stand-alone UV systems
   - eg: S300FX-GX Medical HEPA/UV Sterilization, P900GX Portable UV Sterilization

3.2. Mechanism of Action of UVGI

Ultraviolet can be separated into various ranges, with short range UV-C considered as germicidal. At certain wavelengths, in the other hand, UV is mutagenic to bacteria, viruses and fungal. At a wavelength of 254 nm, UV will break the molecular bonds within the DNA of microorganisms, producing thymine dimers in their DNA thereby destroying them, rendering them harmless or prohibiting growth and reproduction. Microorganisms have less protection from UV and cannot survive prolonged exposure to the UV light.

Ultraviolet treatment equipment does not replace other types of indoor air quality products but rather complement other air enhancement systems.[5] Healthcare facilities are where most UVGI systems are installed. The rationale of application in the upper part of occupied spaces is that germicidal irradiation will safely and effectively interrupt transmission of certain airborne human infections when vigorous upflow of air rapidly bring infectious particles into the upper room.[4] Maintenance of the UVGI system consists of replacing the UV lamps and parts, disinfecting the duct system as well as replacement of defective or worn out fixtures.

Figure 1: UV Bio-Wall In-Duct Air Purifier creates a "barrier wall" of UV energy which destroying biological and chemical contaminants. It is mounted parallel to the airstream in order to maximize the contaminant's contact time with the UV energy. (courtesy from [redacted] Technologies Inc.)

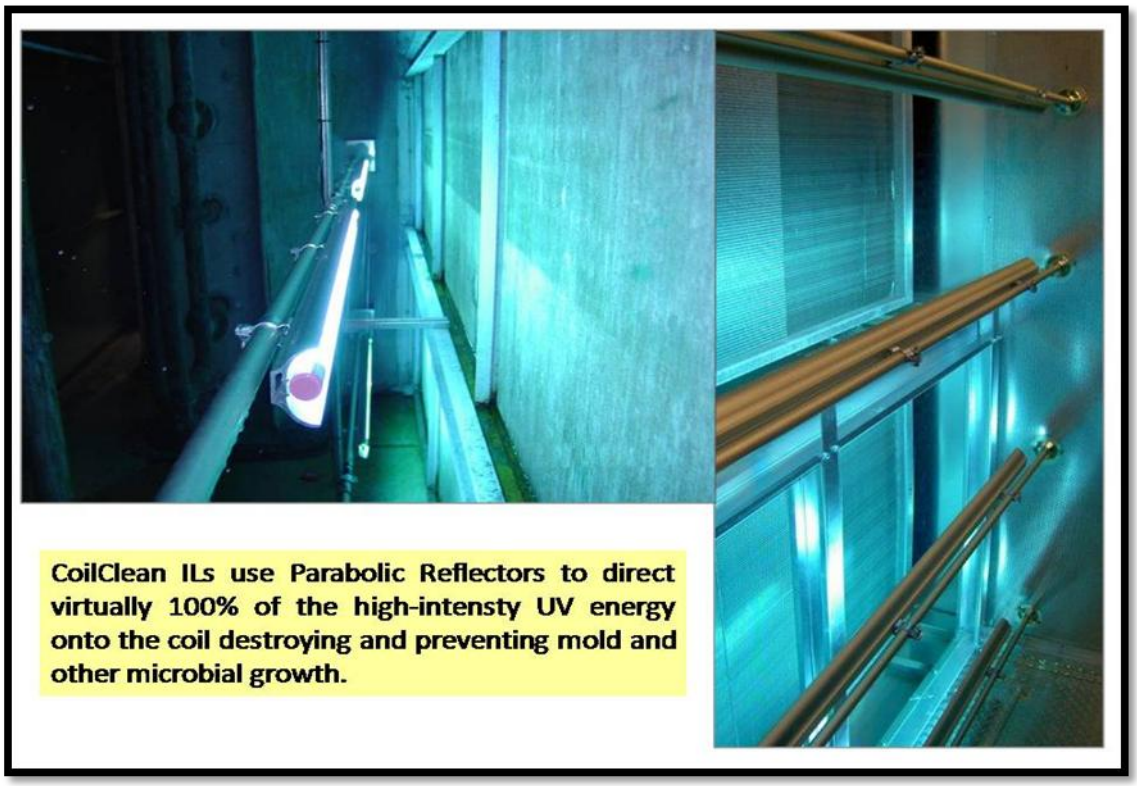

Figure 2: UV CoilClean Commercial
(courtesy from [redacted] Technologies Inc.)

Figure 3: S300FX-GX Medical HEPA / UV Sterilization System
(courtesy from [redacted] Technologies Inc.)

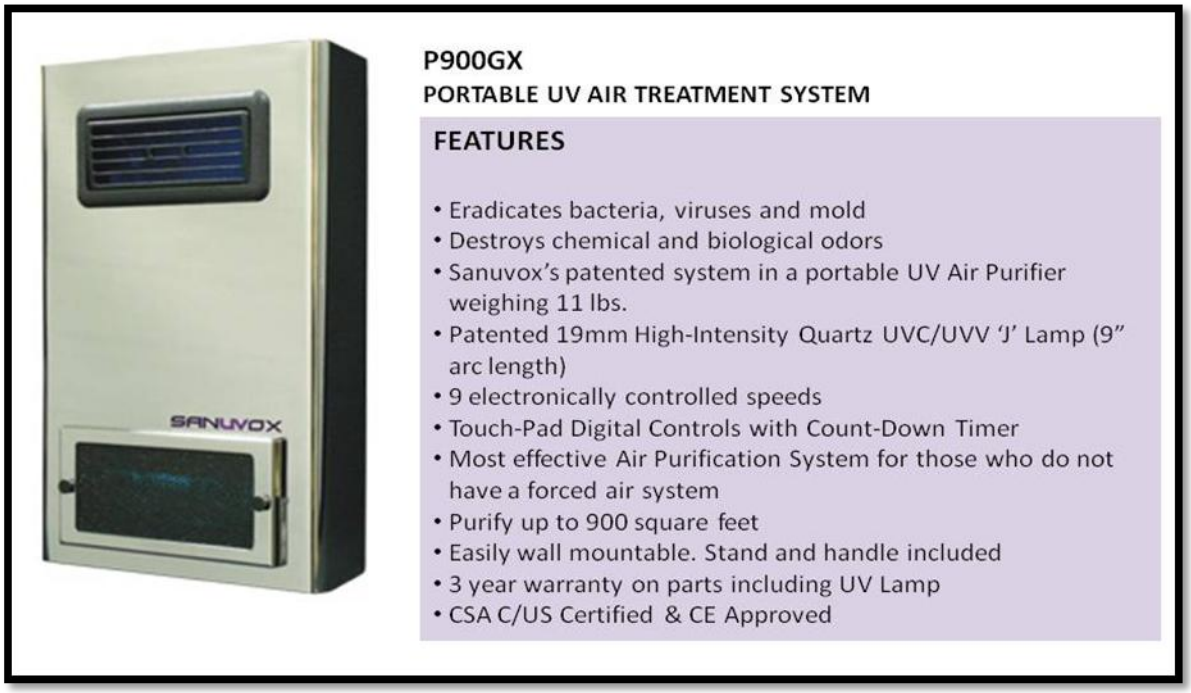

Figure 4: P900GX Portable UV Air Treatment System - previously known as P800GX
(courtesy from [redacted] Technologies Inc.)

4. METHODS

4.1. Searching

Electronic databases were searched through the MEDLINE(R) In-process and other Non-Indexed Citations and Ovid MEDLINE(R) 1948 to present, EBM Reviews - Cochrane Central Register of Controlled Trials and EBM Reviews - Health Technology Assessment. Other database was PubMed, Cochrane Library, Australia & New Zealand Horizon Scanning Network (ANZHSN) and US Food & Drugs Administration (US FDA). The search terms used can be referred in Appendix 1.

4.2. Selection

A reviewer screened the titles and abstracts against the inclusion and exclusion criteria and then evaluated the selected full-text articles for final article selection. The inclusion and exclusion criteria were:

Inclusion criteria

Population	Indoor air pollution, indoor air quality, indoor airborne infection, indoor airborne disinfectant
Interventions	[redacted] ultraviolet germicidal irradiation, UVGI, indoor air purifier system
Comparators	-
Outcomes	Effectiveness, cost-effectiveness and safety of UVGI
Study design	Randomized control trials, systematic reviews, meta-analysis, case control, cohort and descriptive studies
Type of publication	English
Limit	Articles published from 2008 to 3rd week of February 2013 (applied on online database)

Exclusion criteria

Study design	Abstract, animal study
Type of publication	Other language than English

Relevant articles were critically appraised using Critical Appraisal Skills Programme (CASP) and evidence graded according to the US / Canadian Preventive Services Task Force (Appendix 2).

5. RESULTS AND DISCUSSION

There was one retrievable evidence on [redacted] indoor air purifier via Pubmed. Two full text articles were provided by the manufacturer, [redacted] Technologies Inc.. There were also two local technology reviews conducted by MaHTAS which assessed ultraviolet germicidal irradiation air purifier system. A guidelines on basic upper-room UVGI for healthcare settings in environmental control for tuberculosis produced by US Centers of Disease Control and Prevention (CDC) and National Institute for Occupational Safety and Health (NIOSH) was also included in this review.

There was no retrievable evidence on the cost-effectiveness of [redacted] UVGI indoor air purifiers or other types of UVGI.

As for safety issues, there was no recent retrievable evidence related to the adverse events of UVGI systems.

5.1 EFFICACY / EFFECTIVENESS OF UVGI AIR PURIFIER SYSTEM

There were one technology evaluation report and a double-blind multiple cross-over trial discussing on the effectiveness of different [redacted] UVGI indoor air purifier systems.

The US Environmental Protection Agency's (EPA's) National Homeland Security Research Center (NHSRC) Technology Testing and Evaluation Program (TTEP) evaluated the performance of the [redacted] Technologies Inc. Bio-Wall 50 Outwardly Projecting Air Purifier. The objective of testing the device was to evaluate its bioaerosol inactivation efficiency as a heating, ventilation and air-conditioning (HVAC) in-duct ultraviolet light system. The product was tested using a test plan approved by EPA. The tests were conducted using three organisms, two bacteria (*Bacillus atropheus* and *Serratia marcescens*) and one bacterial virus (MS2). These organisms were selected because their sizes, shapes and susceptibility to UV inactivation make them reasonable surrogates for biological warfare agents (BWA). Generally, vegetative bacteria are readily killed and bacterial spores are more difficult. To model use in an HVAC system, EPA used a test duct designed for testing filtration and inactivation efficiencies of aerosol, bioaerosol and chemical challenges. The system had five lamps that were burned in for 100 hours prior to measurement. From the tests, the bioaerosol inactivation efficiencies calculated for the three organisms were 93% for *B. atropheus*, 99.9% for *S. marcescens* and 99% for MS2. It was concluded that the spore form of the bacteria *B. atropheus* is more resistant to being killed by UV than the vegetative bacteria *S. marcescens*.[6, level III]

In an article published in The Lancet Medical Journal, McGill University scientists conducted a double blind, multiple cross-over trial to investigate whether the use of UVGI lights in office ventilation systems would reduce surface microbial contamination and occupants' work-related symptoms. Three office buildings in Montreal, with sealed windows, mechanical ventilation and air conditioning were selected and a total of 771 occupants of the offices participated in the trial. [redacted] UV CoilCleaners which applied UVGI systems were installed in the ventilation systems of the buildings. In every building, the UVGI lights were turned on for 4 consecutive weeks, then alternately turned off for 12 consecutive weeks, which provided sufficient time to decontaminate and then recontaminate. Primary outcomes of self-reported work-related symptoms and secondary outcomes of endotoxin and viable microbial concentrations in air and on surfaces were measured six times along the 48-weeks study. From the trial, the use of UVGI was associated with significantly fewer work-related symptoms overall (adjusted OR=0.8, 95% CI: 0.7 to 0.99) as well as respiratory (adjusted OR=0.6, 95% CI: 0.4 to 0.9) and mucosal symptoms (adjusted OR=0.7, 95% CI: 0.6 to 0.9) symptoms than was non-use period. Operation of UVGI also resulted in 99% reduction of microbial and endotoxin concentrations on irradiated surfaces within the ventilation systems. The author concluded that installation of UVGI technologies in office building could resolve work-related symptoms that caused by microbial contamination of HVAC systems.[7, level II-3]

In 1997, US Centers of Disease Control and Prevention (CDC) and National Institute for Occupational Safety and Health (NIOSH) awarded a contract to the University of Colorado to evaluate the ability of a well-designed and thoroughly characterized upper-room UVGI system to kill or inactivate airborne mycobacteria. The completed research indicates that an appropriately designed and maintained upper-room UVGI system may kill or inactivate airborne TB bacteria and increase the protection afforded to healthcare workers while maintaining a safe level of UVGI in the occupied lower portion of the room. CDC and NIOSH produced a guidelines which was designed to provide information to healthcare managers, facility designers, engineers and industrial hygienists on the parameters necessary to install and maintain an effective upper-room UVGI system.[4]

5.2 COST-EFFECTIVENESS OF UVGI AIR PURIFIER SYSTEM

There was no retrievable evidence on the cost-effectiveness of [redacted] UVGI technologies, as well as other types of UVGI air purifiers. However, according to the manufacturer, the cost of [redacted] products varies depending on the types of the technologies. The cost for P900GX portable UV air purifier is approximately RM [redacted] per unit, while the Bio-Wall In-Duct

Air Purifier system may reach RM [redacted] to RM [redacted] per floor, depending on the area and in-duct system.

5.3 SAFETY OF UVGI AIR PURIFIER SYSTEM

There was no retrievable evidence to show that [redacted] UVGI indoor air purifier systems obtained US FDA approval.

In a technology review prepared by MaHTAS in 2008, it was mentioned that safety may be much more difficult to achieve in UV fixtures used for upper-room irradiation because it present in rooms rather than hidden in ducts. Thus, UVGI should be installed and maintained properly to prevent complications.[5]

No recent major adverse events were reported in relation to any UVGI air purifier systems, as most of the complications were tackled by improving the system itself. For example, the issue of direct exposure to UV light resulting in kerato-conjunctivitis has been prevented by installing the fixtures within the ventilation systems or also know as in-duct irradiation.[8]

5.4 LIMITATIONS

This technology review has several limitations. The selection of studies was done by one reviewer. Although there was no restriction in language during the search but only English full text articles were included in this report. Any abstracts without a full text articles were also excluded.

6. CONCLUSION

Based on the above review, there were few scientific evidences to support the effectiveness and safety of [redacted] UVGI indoor air purifier systems. As for other air disinfectant using UVGI, the technology may have potential benefit for airborne pathogen irradiation; however, more research is warranted. UVGI is feasible in its application and the adverse events can be avoided with proper precaution and maintenance.

7. REFERENCES

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8. APPENDIX

8.1. Appendix 1: LITERATURE SEARCH STRATEGY

Ovid MEDLINE® In-process & other Non-Indexed citations and OvidMEDLINE® 1948 to present

1. Indoor air pollution/
2. indoor air quality.tw.
3. indoor airborne infection.tw.
4. indoor airborne disinfectant.tw.
5. 1 or 2 or 3 or 4
6. ultraviolet germicidal irradiation.tw.
7. UVGI.tw.
8. sanuvox.tw.
9. indoor air purifier system.tw.
10. 6 or 7 or 8 or 9
11. 5 AND 10

OTHER DATABASES	
EBM Reviews - Cochrane Central Register of Controlled Trials	Same MeSH, keywords, limits used as per MEDLINE search
EBM Reviews - Database of Abstracts of Review of Effects	
EBM Reviews - Cochrane database of systematic reviews	
EBM Reviews - Health Technology Assessment	
PubMed	
NHS economic evaluation database	
INAHTA	
FDA	

8.2. Appendix 2

HIERARCHY OF EVIDENCE FOR EFFECTIVENESS STUDIES

DESIGNATION OF LEVELS OF EVIDENCE

I Evidence obtained from at least one properly designed randomized controlled trial.

II-I Evidence obtained from well-designed controlled trials without randomization.

II-2 Evidence obtained from well-designed cohort or case-control analytic studies, preferably from more than one centre or research group.

II-3 Evidence obtained from multiple time series with or without the intervention. Dramatic results in uncontrolled experiments (such as the results of the introduction of penicillin treatment in the 1940s) could also be regarded as this type of evidence.

III Opinions or respected authorities, based on clinical experience; descriptive studies and case reports; or reports of expert committees.

SOURCE: US/CANADIAN PREVENTIVE SERVICES TASK FORCE (Harris 2001)