

Disinfecting room air with upper-room (UR) germicidal UV (GUV) systems



FIGURE 1 Naturally ventilated outpatient department waiting room equipped with ceiling fans and upper-room GUV fixtures. National Institute of Tuberculosis and Respiratory Diseases, New Delhi, India.

What are UR GUV systems?

UR GUV (also referred to as ultraviolet germicidal irradiation or UVGI) systems combine the safe usage of GUV energy in the upper room with mechanical air mixing to disinfect large volumes of room air. (See Figure 1).

Why is UR GUV needed?

UR GUV is an affordable, effective and sustainable environmental control for reducing TB transmission in high TB transmission risk settings.

Are UR GUV systems recommended by WHO?

Yes, the updated WHO TB infection prevention and control guidelines¹ state “Upper-room germicidal ultraviolet (GUV) systems are recommended to reduce *M. tuberculosis* transmission to health workers, persons attending health care facilities or other persons in settings with high risk transmission.” (Recommendation 5).

Studies on the effectiveness of GUV in two TB wards (one in Peru, the other in South Africa), found the reduction in risk of TB transmission was 70-80%.^{2,3}

Other studies show the varying levels of effectiveness of GUV in preventing airborne transmission of measles and other airborne pathogens.^{4,5}

How do we know if UR GUV systems are right for us?

Every facility should conduct a comprehensive airborne infection prevention and control (IPC) risk assessment by a trained facility IPC Team. This should be followed by development of a feasible and sustainable IPC plan to address and minimize the risks. Administrative controls must be given first priority, before considering other measures including UR GUV Systems.⁶

Should UR GUV systems be prioritized over other environmental IPC measures?

Depending on local conditions and sustainable resources (utilities, finances, and technical skills), UR GUV may be used to augment environmental IPC measures. Natural ventilation is often used in resource-limited settings as the only measure to dilute concentrations of airborne pathogens. Micro-environment differences such as seasonal variations in temperature (hot and cold), humidity, rainy seasons; pollution, and security measures, however, may greatly reduce effectiveness of natural

ventilation in poorly designed buildings and/or when windows and doors are closed. High humidity will reduce the effectiveness of UR GUV while lack of good air mixing may greatly or possibly completely eliminate the effectiveness of UR GUV. UR GUV is an effective air disinfectant when used in such situations to augment natural ventilation. *UR GUV is not a replacement for ventilation.* Ventilation is still required to control odor and to reduce the buildup of carbon dioxide. UR GUV can complement all ventilation strategies whether mechanical, natural or mixed mode.



UR GUV is not a replacement for ventilation.



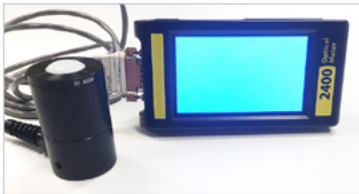
How should UR GUV systems be used?

UR GUV systems are used in settings with a high risk of TB transmission (e.g., crowded OPDs, TB wards, general medical wards, emergency departments, special respiratory procedure areas, X-ray rooms, operating theaters, mortuaries, correctional facilities, cancer infusion centers, *et al.*). Priorities for use of UR GUV should come from the facility IPC Team. While this is not a high-tech solution, selection of UR GUV fixtures should be done in collaboration with the facility engineers and maintenance team. Care needs to be taken to obtain quality UR GUV fixtures, ensure adequate room air mixing, develop a professional design/layout of the fixtures, install properly, document performance (high GUV irradiance levels in the upper room and low GUV irradiance levels in the occupied space), and guarantee funded budget plans for maintenance and operation.

ETTI has developed a guide on UR GUV maintenance in English, Spanish, Russian and Chinese which is available at: <http://www.stoptb.org/wg/ett/resources.asp>.⁵ Some companies offer UR GUV systems inclusive of professional design/layout, proper installation, and documentation of performance and maintenance, through a multi-year contract (recommend minimum of five years). A facility will need in-house staff who, at a minimum, have a handheld GUV radiometer to periodically check the function of the units for performance (output) and safety. Procurement should therefore be done with guidance from engineers and maintenance teams.



◆ **FIGURE 2** Gigahertz-Optik X11 radiometer with UV-3725 detector (Puchheim, Germany)



◆ **FIGURE 3** International Light Technologies 2400 radiometer with SED240/NS254/TD detector (Peabody, Massachusetts, USA)



◆ **FIGURE 4** GUV meter with sensor mounted at eye height

How do I know if UR GUV is effective?

The only way to determine if the GUV lamp is emitting the correct wavelength and designed output over time is to have a radiometer equipped with a GUV detector calibrated to 254 nm. The radiometer should be able to read from 0.01-2,000 $\mu\text{W}/\text{cm}^2$. GUV lamp manufacturers can provide GUV irradiance output and length of use (operating hours before needing to be changed).⁵

How are UR GUV systems maintained?

UR GUV fixtures can vary in output and distribution of the GUV rays emitted from the fixture; therefore, installed UR GUV fixtures should be maintained by a trained maintenance engineer or technician for best output.

Maintenance engineers and technicians should test UR GUV equipment both for the total emitted GUV as well as how it is distributed as well as clean the GUV lamp, reflector(s), and louvres (if present). Dust may be “brushed” off surfaces with something as simple as a dry paintbrush. Surfaces should then be cleaned with a lint-free cloth soaked with $\geq 70\%$ alcohol (ethanol or isopropanol). Once dry and streak free, turn the UR GUV fixtures on and re-take the measurements to ensure all are working properly. In addition, ensure air mixing (exchange of air from the occupied portion of the room to the UR) using smoke or other visual means. The frequency of cleaning will depend on your microenvironment and should be based/adjusted on your GUV irradiance measurements.

Details of how to maintain UR GUV fixtures are provided in the ETTI document *Maintenance of upper-room germicidal ultraviolet (GUV) air disinfection systems for TB transmission control* which is available at: <http://www.stoptb.org/wg/ett/resources.asp>.⁶

Costs related to owning and operating UR GUV systems


The cost of owning and operating UR GUV systems is much more than just the initial purchase price of an UR GUV fixture! It depends, on whether the system is to be owned or leased, provided as a service by a manufacturer or some combination of these. At a minimum a facility with a GUV system must be trained on safety, performance, and have one working and maintained radiometer with a GUV detector calibrated for 254 nm. This will allow the facility engineers to check the operation and safety of the system. The facility will require a method of ensuring air-mixing either through ceiling fans, wall fans or mechanical ventilation. Most naturally ventilated spaces have some form of air mixing; however, if it not present, it will need to be added. The table below provides estimates based on best practice of costs that could be incurred. Local labor and electrical costs will vary as well as custom duties on imported equipment. If a manufacturer is providing a quote for a project to be included in a proposal, having an independent review of the proposal by a GUV consultant would be advisable. A GUV consultant can also provide a brief for bidding.

TABLE 1

UR GUV costs

(all costs presented in USD)

	Estimated unit cost	EXAMPLE			
		Unit cost	Lifecycle cost: 1 unit	Lifecycle cost: 10 units	Lifecycle cost: 50 units
Initial costs UR GUV fixture(s): This price will vary depending on the volume of purchased units and taxes. Efforts are underway to develop negotiated prices through the GDF along with listing of pre-qualified fixtures (10% discount ≥ 10 units; 20% discount ≥ 50 units)	200 – 2,000 USD	1,000 USD	1,000 USD	9,000 USD	40,000 USD
Shipping, customs, taxes: The price will vary by country depending on the volume purchased and local taxes.	0 – 100% of unit price	200 USD (20%)	200 USD	1,800 USD	8,000 USD
Air Mixing system (fans, etc.): a method of air-mixing is required. In naturally ventilated space, either ceiling or wall fans can provide this function.	20 – 100 USD	30 USD	30 USD	300 USD	1,500 USD
Layout design: Includes site visits, GUV fixture selection and specification, architectural, mechanical & electrical drawings showing GUV fixture locations and model number.	0 – 50 USD	0 USD	0 USD	0 USD	0 USD
Installation (fixture, fans, electrical, etc.): Electrical conduit to each fixture location. Individual electrical switch per location. Electric panel(s) & circuit breakers as required. Added facility electric capacity as necessary. UV fixture mounting & electric hookup at each location specified.	10 – 40% of unit price	200 USD (20%)	200 USD	1,800 USD	8,000 USD
Acceptance testing (UR GUV performance): Each installed GUV unit is assessed for functionality, placement & orientation. UV radiometric evaluation is performed to ensure each unit is both safe and effective (that adequate germicidal UV is present in the irradiated zone above room occupants and that only safe levels of UV are present in the occupied area near the unit). UV output adjustment as required. Prepare and document acceptance report.	5 – 10% of unit price	75 USD (7.5%)	75 USD	675 USD	3,000 USD
GUV Meter: at least one UV radiometer with a 254 nm detector is required for operating and maintaining a GUV system. If a facility has over 100 units it may require an additional meter as a backup. (for lifecycle cost, the cost will be divided by the total number of fixtures purchased)	1,500 – 2,500 USD	2,000 USD	2,000 USD	2,000 USD	2,000 USD
Total initial costs			3,505 USD	15,575 USD	62,500 USD

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		EXAMPLE			
Annual recurring costs	Estimated unit cost	Unit cost	Lifecycle cost: 1 unit	Lifecycle cost: 10 units	Lifecycle cost: 50 units
Annual maintenance costs: <ul style="list-style-type: none"> ■ Cleaning lamp, reflector, & fixture (at least quarterly) ■ Lamp replacement & disposal/recycling (~annually) ■ UR GUV performance measurement ■ Replacement of serviceable parts as needed (e.g., ballasts, sockets, reflectors, etc.) ■ 10% discount for ≥10 units and 20% discount for ≥50 units 	5 – 15% of unit price	100 USD (10%)	100 USD	900 USD	4,000 USD
Annual operating electricity kW-h * local rate (kW-h = nominal watts * 24 h * 365 days / 1000W/kW)	0.10 – 0.60 USD/kW-hr	66 USD (30W, 0.25 USD/kW-h)	66 USD	660 USD	3,300 USD
Calibration of GUV meter every 1 – 2 years (may have to be done outside of country)	200 – 600 USD	500 USD (annually)	500 USD	500 USD	500 USD
Total annual recurring costs			666 USD	2,060 USD	7,800 USD
Total lifecycle cost (15 years of life) ¹			13,495 USD	46,475 USD	179,500 USD
Lifecycle cost per unit (15 years of life) ²			13,495 USD	4,648 USD	3,590 USD

1 Total lifecycle cost = Initial cost plus Annual recurring costs *times* 15 years.

1 unit: 3,505 + (666 * 15) = 13,495 USD
 10 units: 15,575 + (2,060 * 15) = 46,475 USD
 50 units: 62,500 + (7,800 * 15) = 179,500 USD

2 Lifecycle cost per unit = Total lifecycle cost *divided by* number of fixtures.

1 unit: 13,495 / 1 = 13,495 USD
 10 units: 46,475 / 10 = 4,648 USD
 50 units: 179,500 / 50 = 3,590 USD

How do we procure UR GUV systems of known performance?

It is expected that a limited number of UR GUV fixtures will be available for procurement through the Global Drug Facility (GDF) in early 2020. With proper planning and advocacy, The Global Fund, World Bank, PEPFAR, USAID and other partners could be potential funding sources of these and other UR GUV fixtures in the future.

What should be included in the IPC program on UR GUV?

UR GUV systems implementation should be based on sound administrative measures. Implement TB IPC assessment, facility risk zoning, staff and patient training, choosing UR GUV fixture models, installation planning, procurement GUV lamps for replacement, fixture maintenance, operation, and monitoring and evaluation.⁷

Where do I find further information on UR GUV equipment testing and application?

ETTI is developing further technical bulletins for engineers and architects which will go into greater detail with examples and cases studies. Additionally, ETTI has GUV experts who can provide assistance. Queries may be sent to ETTInitiative@gmail.com.

References

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Further reading

WHO Infection prevention and control assessment framework:

<https://www.who.int/infection-prevention/tools/core-components/IPCAF-facility.PDF>

2019 ASHRAE Handbook — HVAC Applications: Chapter 62 Ultraviolet Air and Surface Treatment. ASHRAE, Georgia: USA.



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