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PUBLICATION

TECHNICAL PAPER

UV LAMPS IN LAMINAR FLOW AND BIOLOGICAL SAFETY CABINETS

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Introduction

Ultraviolet light is part of the electromagnetic (EM) spectrum, and is divided into 3 wavelength ranges: UV-C, from 100 nanometers (nm) to 280 nm; UV-B, from 280 nm to 315 nm; and UV-A, from 315 nm to 400 nm.

The germicidal ultraviolet lamp emits high intensity ultraviolet radiation concentrated around the wavelength of 253.7nm (i.e. "UV-C radiation"). 95% of the radiation emitted by germicidal lamps is at this wavelength which also happens to be in the region of maximum germicidal effectiveness.

Before laminar flow cabinets were developed in the 1960s and 1970s, biologists in the laboratory used dead air boxes constructed of plastics with nothing more than an UV lamp in them to keep the interior of the box sterile. The UV lamp would be turned on to decontaminate the interior of the box, switched off, leaving the box ready for use. Of course we have come a long way since then - the dead air box system was rudimentary and without any positive pressure airflow (from inside the box to the outside) contaminated room air could easily have been induced into the box again.

Naturally as the use of laminar flow cabinets become increasingly popular UV lamps were also incorporated on these new clean air devices for their germicidal properties. Typically in a laminar flow or biological safety cabinet the UV lamp is activated while the cabinet is not in use to keep the interior of the work zone clean and decontaminated (for example throughout the night until the user returns the next day to use the cabinet again). Modern cabinets have also improved on this feature and some have UV timers to allow the user to control the decontamination cycle (for example to turn the lamp on for a few hours, then shut it down, instead of leaving it on the entire night) in order to conserve lamp life (these lamps have a rated lifespan after which effectiveness rapidly deteriorates).

However, in the late 1970s and 1980s as the use of laminar flow and biological safety cabinets became increasingly prevalent, manufacturers became increasingly aware of the detrimental effects of the UV lamp when used on these cabinets. It is the purpose of this technical paper to discuss the negative effects of using UV lamps in modern laminar flow and biological safety cabinets, in the hope that this will educate users, purchasers, and anyone involved in laminar flow or biological safety cabinet technology, to ensure better safety all for laboratory users.

1. The use of the UV lamp in laminar flow and biological safety cabinets is explicitly discouraged in all major international standards and recommendations. May we refer the reader to the following references:

a. NSF Standard 49 for Class II Biohazard Safety Cabinetry

"UV lighting is not recommended in Class II (laminar flow) biosafety cabinetry. If requested by the purchaser, it shall be installed in such a manner that it does not reduce the required performance (of the cabinet) ... UV irradiation can cause erythema of skin and eye damage." (Section 5.25.2)

b. European Standard EN12469:2000 for Microbiological Safety Cabinets

"Ultraviolet (UV) radiation is not recommended for use in safety cabinets. However, if requested, it should be installed in such a manner that it does not affect the airflow and containment performance of the cabinet." (Annex A Section 2)

c. Australian Standard AS1386.5 for Clean Workstations (Laminar Flow Cabinets)

"It is recommended that the use of UV-lamps be avoided. The need for UV-lamps should first be established by the user. Special safety precautions need to be in use for protection of personnel, products and materials. There is a potential for misuse of UV-lamps with resulting injuries and deleterious effects of pharmaceutical products." (Section 5.12)

d. Australian Standard AS2252.1 for Class I Biological Safety Cabinets
"Installation of UV lamps is not recommended ..." (Section 4.7)

e. Australian Standard AS2252.2 for Class II Biological Safety Cabinets
"Installation of UV lamps is not recommended ..." (Section 4.7)

f. Australian Standard AS2567 for Laminar Flow Cytotoxic Drug Safety Cabinets
"Installation of UV lamps is not recommended ..." (Section 4.7)

g. American CDC Publication "Primary Containment for Biohazards: Selection, Installation and Use of Biological Safety Cabinets"

"Ultraviolet (UV) lamps are not required in BSCs" (Page 26)

2. Personnel safety issues

a. Exposure to UV radiation can cause erythema of skin and eye damage.

b. In addition the cabinet needs to be properly equipped with UV-filtering materials (front / side covers) and proper interlocking mechanism to prevent exposure, which increases the overall cost and complexity of the cabinet. When one considers all this additional extra precautions need to be taken, plus the facts concerning the ineffectiveness of the UV lamp (see below), clearly the reasons for not using the UV lamp are compelling.

c. Some UV lamps also contain mercury and breaking the lamp can result in undesirable exposure to this toxic compound.

d. UV radiation is also reflected off some surfaces like stainless steel, which means additional safety precautions need to be taken as well. A front cover / night door must always be utilised on a cabinet when UV is employed to prevent UV exposure of other personnel in the laboratory when the UV lamp is activated.

e. One of the problems in working with UV radiation is that the symptoms of overexposure are not immediately felt so that persons exposed do not realize the hazard until after the damage is done.

f. Germicidal UV lamps produce ozone which can also be toxic in high concentrations.

3. Performance degradation of the cabinet

a. Ultraviolet radiation can potentially degrade materials in the cabinet such as certain plastics (when they may be used) and sealant (such as RTV / silicone) used to ensure joints / seams are airtight. In the most extreme / dangerous situation for biological safety cabinets, this could cause critical joints to degrade, in turn resulting in other performance issues: loss of pressure tightness integrity (potentially allowing biological hazards to escape through these seams), or allowing contamination to accumulate in these joints posing a cleanability / decontamination problem.

While Esco ensures that all materials in our cabinets are resistant to ultraviolet radiation, this may not be the case for other manufacturers. In addition, clearly by eliminating this extra performance variable (i.e. not using an ultraviolet light) especially after considering the other detrimental effects of the UV lamp, the long-term overall performance of the cabinet can be better ensured.

b. Airflow interference and turbulence. When UV lamps are installed as a permanent fixture in the work zone (which is usually the case for reasons of convenience) they cause unnecessary airflow turbulence which can in turn disrupt product and cross contamination protection. In other words the UV lamp causes turbulence which disrupts the laminar / unidirectional nature of the

air stream, which is critical to maintaining proper cabinet product / cross contamination performance.

As detailed in many of the international standards above, the cabinet is tested with the UV lamp in place in order to ensure that it does not degrade this performance aspect. Again, while Esco ensures this by conducting rigorous testing in our in-house research laboratory, this may not always be the case for other manufacturers.

In conclusion, while it is reasonable to say that the UV lamp largely has no effect on the product protection and cross contamination protection of the cabinet, it is also very reasonable to conclude that by eliminating this variable the overall performance of the cabinet can be increased - especially when the other factors in this document as considered as a whole.

4. Ineffectiveness of the UV lamp on modern laminar flow and biological safety cabinets

When considered in the modern perspective of laminar flow and biological safety cabinet technology, the ultraviolet lamp on the whole in generally ineffective for the following reasons:

a. The laminar flow or biological safety cabinet should be operated 24 hours a day (an economic possibility especially when some of Esco's latest energy efficient models are used) to ensure complete sterility, eliminate lengthy startup times, and keep the work zone ready to use at all times, prevent non-decontaminated biological hazards from escaping the work zone from the interior in the case of safety cabinets. When this recommendation is observed the ultraviolet lamp becomes irrelevant.

b. The ultraviolet lamp to a large extent has become largely a fallacy among users of laminar flow and biological safety cabinets today. Again when one considers the way in which these lamps are used this easily becomes apparent.

As mentioned above usually the operator will shut down the blower, install a front / night cover (when available), then turn on the UV lamp. The work zone is then "decontaminated" (or so the user believes) overnight, and the next day when he / she returns to the lab the UV lamp is turned off, and the lamps deactivated. Clearly since the front / night cover is not totally air-tight during this interval the cabinet could already be contaminated before the user has a chance to start the fans, thus rendering whatever "decontamination" that took place in the night useless.

In some extreme situations, UV lamps are used without front / night covers which not only poses a safety risk, but also makes the use of the lamp ridiculous. In other words the user turns the lamp on, exits the laboratory, returns the next day and shuts the lamp down. Even during the "decontamination" at night of the cabinet by the lamp the user did not realize that air in the room was already moving into the cabinet thus contaminating all exposed surfaces, thus negating the use of the lamp.

c. Presence of surface contamination in the work zone
During the period when the blowers are shut down, the front / night covers installed, and the UV lamp activated, clearly there is ample opportunity for contaminated room air to infiltrate and contaminate the work zone. UV lamps are ineffective as long as any surface contamination (dust particles etc.) is present as UV has limited penetrating power.

d. The lamp does not decontaminate all surfaces in the cabinet
On some cabinet designs, the placement and design of the lamp means that not all surfaces in the cabinet are exposed to UV radiation. This is especially the case for biological safety cabinets where the lamp on all cabinet designs does not decontaminate the critical contaminated air return plenum beneath the work surface.

In addition, occasionally some users (disregarding manufacturer recommendations) may store objects inside the cabinet. When this is the case the UV lamp is totally ineffective for these shadowed areas.

f. The lamp must be cleaned regularly (to remove surface dust on the glass surface of the lamp) for maximum effectiveness but this aspect is often ignored by users which therefore degrades the performance of the UV lamp.

5. The UV lamp encourages bad working practice

The lamp encourages bad working practice by giving users a "false sense of security". While manufacturers like Esco constantly emphasize that when the lamp is used it is ONLY an aid to surface decontamination, some users, lulled into a sense of security, may disregard usual surface decontamination practices

In other words before using the cabinet they believe the work zone is clean and do not wipe down with for example 70% alcohol. After using the cabinet they also disregard the wipe down process which is especially important on biological safety cabinets.

When one considers that the UV lamp, for the reasons stated above, is ineffective, this work habit (or the lack thereof) and false sense of security that the UV lamp encourages in users, is detrimental to the performance of the cabinet.

6. Lack of validation

a. UV lamps are not changed when they have to
As mentioned above, UV lamps have a specific life cycle and need to be changed after a certain number of hours to maintain effectiveness (radiation intensity). Unfortunately not many service companies have the capability to check the intensity of the UV lamp and consequently the user may persist in using a lamp which has already become ineffective.

b. The effectiveness of the UV lamp cannot be validated
There does not exist a single convenient technique that is widely employed for validating the effectiveness of the UV lamp after every decontamination cycle. The best option that exists is the use of a special decontamination paper "strip" that changes appearance after exposure to sufficient radiation, but this is not employed by many cabinet users.

c. Lack of consistency in validation technique
Even when the service company may check the intensity of the UV radiation, there exists a general lack of validation technique in the industry. For example even the NSF49 does not have a performance test for validating this aspect of the cabinet. Consequently validation technique often depends on the service company and is not reproducible throughout the industry. Furthermore many service companies simply take one reading in the centre of the work zone which clearly does not suffice given the fact that the user is expecting the UV lamp to be effective in decontamination all work zone surfaces. But then clearly measuring the UV intensity at all work surface positions is an impracticality.