Why laboratories fail

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Recent inspections by the author of approximately 200 biocontainment laboratories have revealed substantial shortcomings. This paper presents a summary of these findings. Failures that may directly affect microbiological containment are explained in general terms to promote an improved understanding of the problems.

The goal of containment is to provide protection for laboratory research personnel, diagnostic staff and other specialist staff as well as to protect the population and environment outside the laboratory. Whatever organisms are used in the research should stay within the laboratory, and within the confines designed to contain them.

One would tend to think that older laboratories or low-budget laboratories would be more likely to exhibit deficiencies. However, this tendency was not observed to be the case. In many instances, the observed deficiencies were very simple oversights that could have been corrected quickly, easily and at minimal (if any) cost. Some issues relate to operational procedures rather than being concerned with facility construction problems. This paper does not describe procedural issues in detail but has included some instances of procedural failures that compromise containment due to poor facility construction or arrangement.

This firm provides advice, guidance and constructive criticism in terms of design, implementation and operation of microbiological containment facilities. The experience gained in these pursuits has led the author to some significant observations and understanding in these areas. This paper presents a summary of the most common issues uncovered at some well-established laboratories during recent inspections and visits.

Basis of the laboratory visits

The inspections and observations described in this paper were carried out for facility managers, on behalf of regulatory authorities such as Australian Quarantine and Inspection Service (AQIS) [1] and also for laboratory safety personnel and animal welfare officers. For some kinds of laboratories, extensive and regular inspections are required for license renewal. For others, occasional inspections make sense for insurance renewal and for general safety.

In inspecting in excess of 200 laboratories during the past 2 years, over 180 (90%) have failed to comply fully with AS/NZS 2982 Part 1 [2] or with AS/NZS 2243 Part 3 [3]. Many of the issues were deemed minor, but some were significant. The summaries presented have been separated into two distinct groups, one for major issues, and one for minor issues. Major means that the item could directly affect the ability of the laboratory to maintain a safe level of containment. Minor indicates that the observation concerns general safety or a personnel comfort issue, but it would be unlikely to result in a breach of containment directly and independently. Note that there is no attempt in this paper to categorise faults in terms of repair cost or the severity of the implications for the construction of the building or laboratory.

Major issues

Poorly directed building ventilation system

In a number of instances it was discovered that the building ventilation system directed air towards the open work face of a Class II Biological Safety Cabinet (BSC). The design of airflow at the operating face of a Class II BSC in a containment laboratory is the most critical aspect of the cabinet design. The airflow must not be disrupted because this can result in contamination of the operator, the laboratory equipment or both. For these reasons, it is considered a serious fault.

The worst offenders are ‘side-blow’ air supply registers. These are typically mounted in walls or on the vertical sides of exposed ducts or bulkheads in the building’s ventilation system. If the flow from these is directed towards the open face of a BSC, it will almost certainly contravene the required standards. The classic square louvre face diffuser can also cause problems if it is located directly in front of the BSC face. Perforated diffusers are less likely to cause problems, provided that they are located far enough away from the BSC. These air diffusers tend to deliver air at reduced velocity such that directional draughts are less likely to present a problem.

Cabinet testing contractors can compensate for air flow interference by increasing the inward air flow balance of the Class II BSC. This should be attempted with caution. It is important to ensure recommended air velocities are maintained within boundaries to prevent turbulence.

Location of BSCs

There are two common faults with the locations of BSCs:

- BSCs in positions where staff must pass frequently (pedestrian traffic zone). Personnel movement in close proximity to the

BSC can result in transient air flows that can disrupt the air flow at the cabinet entry.

- BSCs in positions near where doors swing open and closed. The intermittent air flow caused by the sweep of a door can also result in disturbance of the cabinet inlet air flow.

This is a similar problem to the first problem mentioned. However, it tends to be more transitional in nature, and is therefore not often picked up when performing annual BSC performance testing. Guidance on location recommendations can be found in AS/NZS 2647[4].

Hand basins

A hand basin with hands free mixer taps, a disinfectant dispenser and paper towel dispenser is required in each PC2 laboratory, located within the laboratory and near the exit. It should be in close proximity to a laboratory gown hook station and a biological waste bin. This equipment forms a critical part of the personnel decontamination procedure immediately prior to leaving the laboratory. These are often missing, are poorly located, or are of the incorrect type.

No inward air flow at PC2 lab boundaries

PC2 laboratories are required to achieve an inward air flow to prevent the recirculation of laboratory air to non-laboratory areas. Lack of or loss of this inward air flow can result in the escape of aerosols to areas such as food preparation locations and offices. This requirement has generated a lot of discussion because it is absent from some international Standards. Also, for Risk Group 2 (RG2) organisms, the hazards associated with aerosol escape should normally be minimal.

However, containment by inward air flow can achieve two important safety functions:

- Containment of odours, dusts and aerosols during normal operation of the laboratory.
- Limiting the cleanup issues associated with an accident (such as a droppage or spillage at a BSC).

Note that some laboratories use fume cupboards (FCs) to achieve the inward air flow requirement. This is acceptable but it introduces two considerations that must be suitably addressed:

- The inward air flow is required to be maintained throughout the operational range of the fume cupboard (FCs often vary their air flow according to sash position).
- The FC must remain operational at all times – this sometimes results in a nuisance noise issue for facility personnel.

Minor issues

Identification

Laboratory gases, potable water and laboratory non-potable water and other reticulated fluids should be transported in pipes that are clearly identified with labels and colour coding in accordance with Standards. This identification is often missing from laboratory services.

Emergency isolation

Laboratory gases and electrical supplies to normal power outlets are required to have emergency isolation devices. These should be located in positions that are easily accessible to persons leaving the laboratory in an emergency. These devices are often missing or poorly located. Where provided, labels are often missing or unclear.

An excellent means of testing the usefulness of these devices is to ask the laboratory staff to locate the emergency devices and explain their function. In the author's experience, it is estimated that 95% were unable to do so accurately.

Flow restrictors

Reticulated gases that are toxic or asphyxiation hazards should have flow restriction devices or automatic fail safe isolation devices fitted. These devices serve to stop or reduce the escape of potentially harmful gas into the laboratory in the event that a pipe is broken or that a connecting hose is accidentally removed or loosened. These devices are often missing from laboratories.

Sealing of benches

Benches are often not completely sealed, particularly at locations such as sink cut-outs where a liquid leak can result in long-term deterioration of bench top support material. Benches, sinks and splash backs should always be sealed to prevent penetration of liquids.

Conclusion

Most of the above faults are simple and economical to remedy. They would add little if anything to the cost of construction of a facility if considered appropriately in advance. The general quality and safety of laboratories in Australia are good; however, attention to these issues would provide an improved level of protection to personnel and the environment.

References

1. AQIS. Available at: http://www.daff.gov.au/aqis/import/general-info/qap/class-5
2. Australian/New Zealand Standard 2982 Part 1: Laboratory Design and Construction Part 1: General Requirements. Current Edition 1997.
3. Australian/New Zealand Standard AS/NZS 2243 Part 3: Safety in Laboratories Part 3: Microbiological Aspects and Containment Facilities. Current Edition 2002.
4. Australian/New Zealand Standard 2647: Biological Safety Cabinets – Installation and Use. Current Edition 2000.

Neil Walls specialises in biocontainment and biocontamination engineering. His work includes the design of containment facilities up to PC4 (the highest microbiological containment level), animal health facilities and pharmaceutical facilities. Neil's areas of work include considerations of facility layout, personal and microbiological safety, materials and cage handling facility design, and services associated with these functions. Neil represents engineering issues on AS/NZS 2243 Part 3.