Applications Concept:

Assess Air Exchange Reductions in Controlled Environments for Energy Savings Using Instantaneous Microbial Detection ™

Major Benefit:

- Reduces energy consumption and associated utility costs

Introduction

This application note provides some ideas on ways in which air quality can be managed by using the Azbil BioVigilant's IMD-A® system as tool for airflow reduction assessments leading to utility cost reductions. The IMD-A system can be used as a way to accurately quantify microbial variability within an environment, both passively and continuously, thus supporting the reduction of Heating, Ventilation, and Air-Conditioning (HVAC) operation in cleanrooms to reduce energy costs within a facility.

Pharmaceutical HVAC systems are designed, not only to maintain specific temperature requirements, but also to reduce the amount of airborne particulate through the cycling of room air and HEPA filtration. Because of this, HVAC energy requirements could be as much as 50 times more than a conventional cleanroom.[1] Additionally, those operations that create more dust could require even more air-handling changes, resulting in even greater energy requirements. Because microbial contamination is a major concern in these environments, oftentimes, HVAC systems operate at much higher rates to overcompensate for any perceived contamination risk. While the intent of increased air-change rates is to reduce overall particulate levels, the final HVAC setting may be overcompensated, according to the need of the environment. In short – a more focused assessment of the room air environment could support potential energy savings for a room or series of rooms.

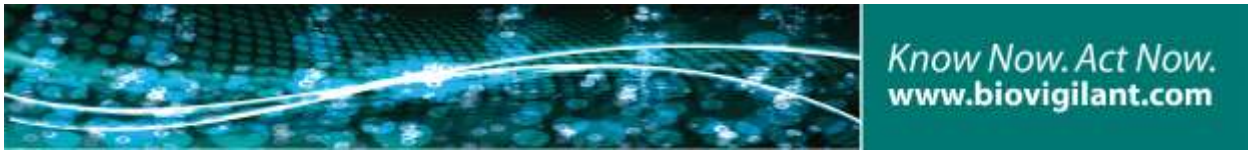
Up until this point, there has been no traditional quantitative method for discerning differences between high and low HVAC room air-change rates, from both an inert particulate and biologic standpoint. Additionally, all traditional biological testing methods have been retrospective, giving results only after a number of days, and then only for a specific and short time interval. With new air monitoring tools such as the IMD-A system, there is now a way to discern these fine details, giving users the data to reduce unnecessarily high operational costs for these HVAC systems.

The IMD-A system is ideally-suited to accurately evaluate the level of air changes really needed in any given environment through its continuous monitoring and instantaneous data reporting capabilities. These capabilities allow air quality to be assessed during the normal range of room conditions and activities at the current HVAC settings, and then again at reduced settings. Immediate comparisons can be made of the effectiveness of various HVAC settings in that location. Also, the IMD-A system has greater sensitivity for microbes than current growth-based methods, so any potential increase in microbial burden resulting from reduced HVAC settings can be detected.

Still, it would be advantageous to minimize HEPA filter velocity or airflow volume as long as it does not impact cleanroom operation in terms of maintaining sufficient level of air quality per industry standards[2]. The key issue of quantification of risk over a continuous period is the main limiting factor to reduction of energy consumption. Using traditional methods, biologic risk can only be addressed by sampling over short durations of time that are not representative of the entire manufacturing process. Additional samples could be taken, but the repeated samplings are resource intensive from both a consumable and personnel perspective. Also, each instance of material and personnel ingress and egress into the environment adds potential for contamination, and adds airflow variability to the testing environment. A continuous, passive sampling solution, such as that provided by the IMD-A system, reduces that reliance on personnel and consumables and gives strong, quantitative data that existing microbiological methods cannot provide.

[1] ASHRAE Application Handbook – HVAC Applications, 2011 edition, Chapter 18

[2] Standards for environmental monitoring in cleanrooms historically have referenced Federal Standard 209-E and USAF TO 00-25-203. Recent GMPs also include the FDA's Guidance for Sterile Drug Products Produced Aseptically, and the Annex 1 to the EU Good Manufacturing Practices for Sterile Medicinal Products. HVAC standards for pharmaceutical and biopharmaceutical cleanrooms are also compiled in the ASHRAE Applications Handbook – HVAC Applications, with a focus on cleanroom HVAC systems in Chapter 18. A comprehensive bibliography of standards is listed at the end of this document.



Background: Design Guidelines and Fan Laws Associated with Ventilation Systems for Cleanrooms

Minimally, the ISO 14464-4 standard provides the guideline[3] for designing cleanrooms, which provides a ventilation system operation allowance in terms of the range of air velocity:

ISO Class	Air Velocity
5 (100)	>40 fpm
7 (10,000)	N/A[4]
8 (100,000)	N/A[4]

For the multitude of reasons described earlier, however, velocity and room air changes may be kept at a higher level than what is required by standards. For this reason, an accurate, quantitative way to detect biologic and inert particulate within the cleanroom environment is vital to the determination of what airflow velocities and room air-change values are needed to maintain control of the room's cleanliness.

To guide an exploration into energy savings, one can use the affinity fan laws to develop a proportionality focused on reducing fan power by reducing the overall ventilation volume. Given that airflow volume is directly proportional to fan speed, and power is proportional to the cube of the fan speed, one can then state that power required is proportional to the airflow volume with the following equation:

$$\frac{W_1}{W_2} = \left(\frac{Q_1}{Q_2}\right)^3$$

Where

W = Power

Q = Airflow Volume

Since the HEPA coverage and airflow area are fixed to the dedicated facility, the HEPA face velocity is proportional to the airflow volume; so, we can further state:

$$\frac{W_1}{W_2} = \left(\frac{F_1}{F_2}\right)^3$$

Where

F = HEPA Face Velocity

So, for example, in the case of a Class 5 (Grade A) cleanroom, by reducing the HEPA face velocity from 180 feet/min to 90 feet/min:

$$\frac{W_1}{W_2} = \left(\frac{F_1}{F_2}\right)^3 \qquad W_2 = \frac{W_1}{\left(\frac{F_1}{F_2}\right)^3}$$

$$\mathrm{W}_2 = \frac{\mathrm{W}_1}{\left(\frac{180}{90}\right)^3} = \frac{100\%}{8} = 12.5\%$$

This reduction in face velocity may result in approximately 87.5 percent power reduction theoretically, which is a significant reduction of energy.

Once a reasonable power reduction is developed, the room air changes may be modified using these values, and then evaluated using the IMD-A system.

IMD-A Systems: Ideal Monitoring Tools for Evaluating Air Quality during Room Air-Change Rate Reduction

Azbil BioVigilant's IMD-A systems detect and report the presence of airborne microbes and inert particles continuously and in real-time using an optically-based approach that requires no culturing, staining or reagents. Both the IMD-A 300 (low flow) and IMD-A 350 (high flow) instruments enable 21 CFR Part 11 compliance and are validated to USP<1223> and EP 5.1.6.

IMD-A system features include:

- Instantaneous detection of microbes and inert particles
- Simultaneous detection of particle number, size and biologic status
- Reporting of real-time results with the PharmaMaster® software interface

[3] Information from ISO 14644-4 (2001) Table B.1

[4] Typically kept above 40fpm per ISO 14644-4 Table B.1.

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- Video camera and synchronized data playback functionality
- Marker function enabling activity tracking and display in data files and reports

IMD-A systems display results in real-time using the IMD-A PharmaMaster software. The display options include a graph that plots counts for biologics, particles ≥ 0.5 µm, and particles ≥ 5 µm every second while the air is sampled, as well as updating total and average counts for each particle type so changes in contamination levels are easily noted. In addition, each IMD-A system is supplied with a small video camera that can be used to record and display activity in the room during sampling. The software features a playback function that allows a review of videos for completed samples as they were collected, replayed in synchrony with the recorded data.

When using the IMD-A system in a cleanroom environment to assess air quality before and after changes have occurred, the following general procedure may be used:

1. First, a baseline standard of room air quality within a specific zone or area is determined using the IMD-A system to visualize inert and biologic particle counts. Typically, testing would be performed under static and dynamic conditions, and in a variety of locations.

2. Second, an assessment of the impact on air quality is made, according to the conditions of ventilation change. Potential sources of variation could be pressure dynamics of adjoining rooms, as well as equipment and personnel activity.

3. Lastly, once the ventilation volume change is determined, the IMD-A system is operated in a continuous mode and its data stored for review and assessment.

By following these three steps to compare the effects of HVAC setting changes, the IMD-A system can be used in many different applications, such as those addressed in the following examples.

Example 1 – Zone-Specific Airflow Optimization and Contamination Source

Within various cleanroom environments, many different activities may occur that are separated either physically by barrier, or by operator activity. The use of a smoke generator for investigational use helps to visualize airflow, but actively impacts room air quality by imparting particles into the environment. The use of the IMD-A system acts as a passive monitor of airflow, by evaluating not only airflow, but also how biologic and particulate flow occurs within a room or zone. In this way, potential sources of contamination may be characterized and identified during routine operations.

For example, a study outline could be developed that would examine the static room cleanliness for a long period of time (such as overnight), which could then be compared to the dynamic activities within the cleanroom (such as during an operational shift). The IMD-A system could be placed within a zone to examine the impact of specific activities within that zone, as compared to the static values collected, to determine relative impact of operator or machine activity to that specific area.

Example 2 – Airflow Modification during Non-Manufacturing Related Activities

During non-manufacturing shifts, rooms need to maintain their airborne environmental requirements, but in proportion to a more static than highly dynamic environment. As such, higher than required room air changes during these shifts may not be necessary to meet the air classifications required. The use of the IMD-A system for long periods, such as for 24 hours or more in one location, can allow for extensive modeling of the room environment, to determine if room air changes can be modified for non-manufacturing shifts.

For example, the IMD-A system may be used to evaluate the amount of time required to clean a room returning from dynamic conditions to static conditions; each of these states has a known particulate baseline that can be achieved within a certain quantity of time given existing activities. If the room air changes could be reduced, while still achieving room air cleanliness in the same amount of time, the reduction in HVAC operation will be shown to have no impact on effectively maintaining the room's environmental control.

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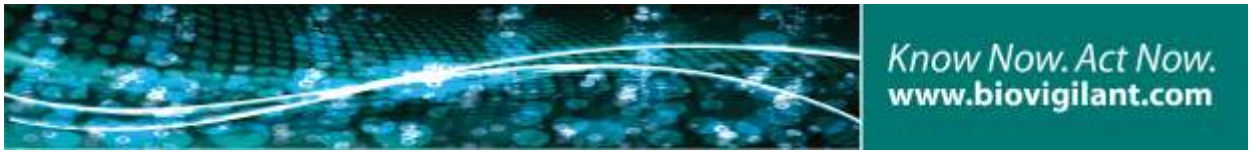

Example 3 – Overall Reduction of Room Air Changes

Because of activities during dynamic states, room-air changes may be set higher than standard requirements to assure that biologic and inert particle standards are met. The IMD-A system may be used as described in the earlier examples, as well as in multiple locations throughout a room or zone, for long or short durations, to thoroughly assess various activities, characterizing and identifying potential sources of contamination, and using that information in a risk assessment to guide Operations and Critical Systems teams in contamination reduction activities. Critical zones in rooms then can be reviewed per the risk assessment completed, with a focus on determining whether increased room air changes need to be further supported. Finally, the IMD-A system may be used for long-duration studies to assess the impact of room air-change reductions, to assure that all requirements and commitments have been met.

Support

Azbil BioVigilant can provide your organization with an IMD-A system and application support for the ventilation reduction investigation.

Here's how the service works:

- An IMD-A system is delivered to the evaluation site.
- An Azbil BioVigilant Field Application Scientist (FAS) arrives for briefing, estimating reduction potentials and assessment planning, including return-on-investment calculations.
- Accompanied by the site sponsors and engineers, the FAS conducts tests and collects air quality data for the planned conditions as well as energy data.
- An analysis of data sets is provided for assessment and operation guidance is offered in a written report.

Please contact Azbil BioVigilant's Applications team or your sales executive to learn more.

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