Evaluating Industrial Ventilation Systems:
Five Overlooked Aspects of Evaluating Industrial Ventilation Systems

Introduction

Industrial ventilation is a primary control of emissions of toxic fumes, particulates, and dusts in a workplace. Proper management and maintenance is important to ensure proper operation of the system; therefore, periodic evaluations are necessary to ensure worker safety. In assessing over 2,500 ventilation systems, five commonly overlooked aspects of industrial ventilation evaluation became apparent:

- Failure to complete a thorough health risk assessment (HRA) for the process or processes for which industrial ventilation is used;
- Lack of objective air sampling to determine ventilation system effectiveness;
- Inadequate surveying phases to include, initial, baseline, and periodic;
- Inappropriate criteria used for determining adequacy of the control; and
- Ventilation systems were evaluated yet they did not control hazards.

Completing a Thorough HRA

A health risk assessment concentrates on the hazards and risks from the hazardous substances in the workplace. Health hazards are not limited to the substances labeled as “hazardous”; in many instances hazards are produced by the process. To
begin the assessment, first identify the potential worker health hazards. Consider the following:

- Identify the substances/chemicals that are harmful by evaluating the safety data sheets (SDS);
- Contact the manufacturer if substances on the SDS are considered proprietary ingredients; and
- Determine hazardous materials or chemicals that are produced by the process to which personnel may be exposed (i.e., hexavalent chromium dust produced by sanding chrome-containing paint).

Secondly, assess the risk. To assess the risk, the severity and probability of exposure will need to be determined. What are the frequency and duration of the process? What is the potential for the exposure to be greater than the occupational exposure limit? If controls weren’t in place, what would the severity of this process be? Could the hazards cause hearing loss, acute illnesses, or chronic illnesses? These questions must be asked to determine the severity and probability of exposure.

A quantitative analysis of the workers’ exposure is required as part of the health risk assessment. Air sampling or theoretical calculation will provide this data. Evaluate the different exposure routes to determine which route is going to expose personnel to the substance and which of those exposure routes is going to affect personnel the greatest. To determine the likely exposure routes, assess how often and how long personnel work with the substance(s). Furthermore, the process plays a big role in identifying the proper exposure routes. Just because the National Institute of Occupational Safety and Health (NIOSH) Pocket Guide to Chemical Hazards states all exposure routes apply, that does not necessarily mean they apply to the process.

Thirdly, once an assessment has been accomplished on the potential substances present, determine how to prevent or control the exposure. The control stage is where different methods are evaluated to control or prevent the exposure to personnel.

- Elimination or substitution – the most effective control measure is to remove or reduce the hazard;
• Engineering controls - engineering controls require a physical change to the workplace and can include ventilation, process automation, isolation or process enclosure, and a change in design (i.e., can the process be changed to eliminate the use and/or avoid producing the hazard);

• Administrative controls – administrative controls include managerial and employee involvement to reduce exposure such as worker job rotation, job changes, education and training, preventive maintenance, housekeeping, and personal hygiene; and

• Personal protective equipment (PPE) – PPE is the last resort to controlling a hazard (e.g., respirator, gloves, Tyvek suit). PPE would be utilized if all other controls are not feasible.

All chemical hazards can be controlled by applying at least one of the control methods. Substitution, elimination, minimization, and engineering controls are the most effective hazard control method because they remove or reduce the source of the hazard rather than decrease the severity of the exposure. They are also less reliant on the user whereas other controls are subject to human error. Substitution or elimination is usually the least expensive and the most positive method to consider first. Minimization should be the second choice, and isolation the last. Isolation is most effective when the material, equipment, or process require minimal
contact or manipulations. When all of the options are infeasible, ventilation is the next viable engineering control.

Ventilation can control the exposure by exhausting or supplying air to remove hazards at the source or diluting them to a non-hazardous level. The two types of ventilation are exhaust and dilution ventilation. Local exhaust encloses the material, process, or equipment as much as possible and withdraws air from the enclosure at a sufficient flow rate to ensure the direction of air movement is always into the enclosure (e.g., fume hood). Dilution ventilation controls hazards by diluting the concentration of hazards in the air to a safe level by exhausting or supplying air into the general air (e.g., using a paint pen). Local exhaust is the preferable ventilation method but can be more costly. Dilution ventilation works best when small quantities of contaminant(s) released at uniform rates; there is an adequate distance between the worker and the source to allow dilution at a safe level; only materials of low toxicity or flammability are used; contaminants do not require collection or filtering before the air is discharged into the environment; and the contaminant will not cause corrosion or damage to equipment or affect other building inhabitants outside the general area.

Administrative controls are implemented, in part, to ensure engineering controls are developed, maintained, and are properly functioning. Administrative controls consist of administrative efforts such as planning, training, safe work practices, written policies and procedures, and environmental/medical surveillance.

Although PPE is the “go-to” control in many organizations, PPE is considered an additional control if engineering and administrative controls are not feasible. In some circumstances, PPE may be the only reasonable control option but for many reasons it is the least desired control. PPE does not eliminate the hazard it simply reduces the harm caused by the hazard. PPE is highly reliant on the user to be effective. If PPE is cumbersome and uncomfortable, workers might frequently avoid wearing it, even if they are aware of the increased health risks without it. PPE has limitations, advantages, and problems associated with misuse. PPE material must be suited for
the hazards and must maximize comfort, dexterity, and protection. Those wearing PPE must be knowledgeable of this. When selecting PPE, it must match the hazard, conditions of use, and be properly maintained to be effective. Misuse of any PPE may directly or indirectly contribute to the hazard or generate a new one.

**Objective Air Sampling**

When determining types of controls to use, objective air sampling should be considered. The primary reason for sampling is to determine the severity of the hazards. This involves determining the concentrations of the substances in the air that could cause acute or chronic damage to workers. Secondly, air sampling must be utilized to determine if ventilation is required and/or to ensure the ventilation system is effective in controlling hazards once in operation. For example, when a ventilation survey is accomplished and the results are outside the manufacturer’s specifications, our study found that many personnel wrongly assumed the system was not operating properly. This often results in unnecessary maintenance to “fix” the system or continuously documenting that the system did not meet the standards without resolution to the exposure. Air sampling should be utilized to confirm the effectiveness of the control, not whether the system is performing according to design criteria. If the air sampling results are below the Occupational Exposure Limit (OEL) and/or action level, the ventilation may be operating sufficiently to control the hazard. For future ventilation surveys, the survey results may be compared with the ventilation survey results obtained during the air sampling event. If air sampling results are above the OEL and the ventilation system was utilized, maintenance or other corrective actions are required. If maintenance has been accomplished and new air sampling results still show exposure greater than the action level and/or OEL, the industrial hygienist should consider additional controls such as respiratory protection. Objective air sampling is one of the most critical elements in ventilation system evaluation.
Establishing the Correct Criteria

While air sampling provides ground truth as to whether a ventilation system is effectively controlling the hazards, the *ACGIH Industrial Ventilation Manual* is the benchmark standard for design criteria when manufacturer’s specifications are not available. It may also be used as guidance when air sampling results are not yet available. When determining the criteria from guidance such as this manual, ensure that the correct criteria is used. For example, if a survey is being accomplished on a large drive-through spray paint booth the air flow rate requirements are different based on the size of the booth; therefore, this must be determined before any calculations can be completed. If the area of the booth is greater than 150 ft², the system has cross-sectional criteria of 50 acfm/ft². If the area of the booth is less than 150 ft², the system has cross-sectional criteria of 100 acfm/ft². The use of High Volume Low Pressure (HVLP) or airless electrostatic paint guns has a cross-sectional requirement of 60 acfm/ft². Once this is determined a survey can be accomplished and compared to the design criteria.

Furthermore, criteria requirements for a ventilation system may be different depending on where the survey readings are captured; in the duct or at the face of the hood. If a surveyor is capturing readings inside the duct, a pitot traverse method should be used. The velocity pressure and static pressure in inches of water (*H₂O) can be obtained. Velocity pressure must then be converted to velocity in feet per minute (fpm) and multiplied by the area of the duct to obtain the volumetric flow rate \( Q \). There are also times when a system has a minimum duct velocity requirement. For example, an underground or overhead exhaust system and a small paint booth have a minimum duct velocity requirement of 2000 fpm. If the face of the system is being surveyed, a straight face velocity survey \( V \times A = Q \) can be accomplished to obtain the volumetric flow rate.

Lastly, once air sampling results become available, periodic survey results should be compared to the ventilation survey results that were taken during the air sampling event. This is preferably a static pressure check that reflects the air flow volume (performed at the same location each time). If a static pressure reading could not be obtained for the ventilation system, face velocity readings will suffice. A periodic survey ensures the ventilation system is still operating adequately. If results are
within +/- 10% of the baseline, this is indicative of a well-functioning ventilation system. The periodic survey reduces the need for periodic air sampling because if the ventilation system is within baseline parameters it is still controlling the hazard below the occupational environmental exposure level. However, there may be regulatory drivers which require periodic air sampling (e.g., hexavalent chromium).

**Inadequate Surveying Phases**

When completing a ventilation survey, it is important to ensure the correct survey phases are used to accurately assess a ventilation system. The initial survey is the acceptance phase after the system has been installed. In the initial phase, a survey is performed to determine if the system is meeting the design criteria according to the manufacturer’s design or other authoritative source (e.g., *ACGIH Industrial Ventilation: A Manual of Recommended Practice*). If the system is not meeting design criteria, maintenance and/or evaluation of the system may be required. Occasionally, ventilation system fans are installed backwards resulting in a system failure. If a system does meet design criteria, the system can be placed into operation and a baseline survey can be accomplished.

A system is not considered baselined unless air sampling is included during the survey; simply accomplishing a ventilation survey alone does not identify if a hazard is being controlled. As stated above, the air sampling results must be below the action level and/or OEL for the system to be considered an adequate control. If during the baseline survey the ventilation system did not meet design criteria but the air sampling was below the OEL, the system can be considered to adequately control the hazard. Those results are accepted as a sufficient baseline and future periodic surveys should be compared with those results.

If future periodic surveys do not meet the baseline results, maintenance and/or new air sampling may be required to ensure the system is still controlling the hazard. To do this, complete a visual evaluation of the system and speak with workers and maintenance staff to determine if any modifications were made to the system since
the baseline survey. If there have not been any modifications to the system, contact maintenance staff to evaluate the system to determine what type of maintenance may be required to ensure proper operation of the system. Once the ventilation system is repaired, another survey will need to be completed to ensure the system is operating within baseline parameters.

**Comfort Surveys?**

Periodic ventilation surveys are required on systems that are controlling hazards to ensure that they continue to protect the worker. There are times that ventilation systems are used but they are not controlling a hazard. Many times these systems are installed for comfort purposes (i.e., used for non-hazardous dust particles). When comfort-purpose ventilation systems are used, there is no requirement to perform periodic surveys on the system. However, ensure the system is not controlling potentially flammable or explosive dust rather than a health hazard. Performing additional surveys on this system consumes valuable resources that could be directed to other risks and hazard controls. Few organizations have extra resources. When uncertain about whether a hazard is being controlled, the industrial hygienist should conduct a thorough HRA with air sampling.

**Conclusion**

Industrial ventilation is the primary control of emissions of toxic fumes, particulates, and dusts in a workplace. A completed HRA will help determine what hazards are of concern and what controls will need to be put in place to alleviate unacceptable worker exposure. When determining hazard controls, air sampling should be considered to determine the severity of the hazards and to determine if ventilation is required. This will ensure that the ventilation system is effective in controlling hazards. If a ventilation system is implemented, periodic surveys are required to ensure the system continues to effectively control the hazard. To survey the system,
the correct design criteria and survey phases will need to be established. If a system is in place but not controlling a hazard, there is no need to periodically survey that system. Proper management and maintenance is important to ensure proper operation of the system in order to ensure a healthy and safe working environment.

**ASG Team Leader Biographies**

**Alliance Solutions Group, Inc. (ASG)** is a global leader in delivering health and safety solutions through consultation, training, and analysis. Over the last decade, ASG has conducted 172 audits, 59 compliance assessments, has customized OSH training, and has assisted 115 clients worldwide. Our unprecedented experience in occupational safety and health sets us apart from training companies, vendors and large businesses. To learn more, visit us on the web at [www.asg-inc.org](http://www.asg-inc.org) or call +1.757.223.7233.

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**Mr. Robert Campbell, PE** leads ASG with 20 years of environmental, health, safety and emergency management experience. He was responsible for orchestrating an enterprise-wide implementation of an occupational health management system assessment and audit program for 90 sites worldwide. He has also managed the planning, design and implementation of a large-scale preparedness program consisting of emergency response plans, equipment, training and exercises for the U.S. military world-wide – this included 82 hospitals comprised of 20 response teams each, 150 CBRN/Hazmat response teams, 50 mobile laboratories and 52 decontamination teams. Over the last 10 years, he has grown ASG to serve over 100 clients to include a large government enterprise with 170 sites worldwide. In 2014, he published a summary of lessons learned and best practices from 1,800 global exercises and real-world response incidents in the *Handbook of Emergency Response: A Human Factors and Systems Engineering Approach*. This unprecedented scope and scale of experience has enabled ASG to gain the trust...
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