

# Use of Personal Protective Equipment for Respiratory Protection

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## Abstract

Management of hazards in biomedical research facilities requires the application of the traditional industrial hygiene responsibilities of anticipation, recognition, evaluation, and control to characterize the work environment, evaluate tasks and equipment, identify hazards, define exposure groups, and recommend controls. Generally, the diversity and unique characteristics of hazards faced by laboratory and animal facility employees and the short-term and low-level nature of the exposures factor into the selection of proper exposure control measures in the laboratory. The proper selection of control measures is based on a hierarchy of elimination and minimization by engineering controls, followed last by personal protective equipment when exposures cannot be eliminated. Once it is decided that personal protective equipment is needed, specific regulations and guidelines define safety standards for research facilities, including the elements of a sound respiratory protection program. These elements include respirator selection (including appropriate protection factors), medical evaluation, fit testing, training, inspection, maintenance and care, quality, quantity and flow of breathing air, and routine and emergency use procedures.

**Key Words:** biomedical research facility; laboratory; personal protective equipment; respiratory protection

Effective management of occupational hazards in biomedical research facilities requires the application of the traditional industrial hygiene responsibilities of anticipation, recognition, evaluation, and control. Managing risks includes characterizing the work environment, evaluating work tasks and equipment, identifying hazardous agents, and defining exposure groups. Hazards can then be further defined and the risks quantified through industrial hygiene samples and subsequent analyses of the derived data and comparisons with acceptable standards. The product of recognition and evaluation is an understanding of

exposure potentials, resulting in effective engineering controls that, at a minimum, reduce exposures to within acceptable levels and, optimally, eliminate the exposure. Personal protective equipment (PPE<sup>1</sup>) is an effective control measure when exposures in the laboratory cannot be eliminated. This article focuses on the use of PPE for respiratory system protection.

Hazard recognition is initiated with preliminary qualitative surveys and periodic inspections to identify potential hazards and to collect relevant operation information. Generally it is advisable to develop an inventory of potentially hazardous materials including chemical, biological, and physical. The diversity and unique nature of potential hazards faced specifically by the laboratory worker are widely recognized, and the nature of laboratory research and development often results in the handling of unknown or poorly characterized hazards with limited controls. One method of qualitatively overcoming this hurdle is to characterize completely the tasks performed with hazardous agents and the equipment used in those processes to understand fully the potential for exposure when these tasks are performed. Laboratories are also unique occupational environments in which exposure potential is often short term and at a low level, but to a much wider range of hazards than those typically found in facility and production work environments. This characteristic requires special consideration in making the proper selection of PPE.

The successful application of PPE hinges on proper use by individual employees. They must first understand the risks of handling chemical and biological agents and the processes that might result in exposures. Properly and effectively communicating these risks and the potential result of exposure to the respirator user will increase the probability of the respirator being used at the correct times and in the correct manner. During these communications, it is also possible to obtain additional information and to suggest potential solutions for reducing exposure potentials via open dialogue with the researchers performing the respective tasks.

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<sup>1</sup>Abbreviations used in this article: ANSI, American National Standards Institute; APF, assigned protection factor; NIOSH, National Institute for Occupational Safety and Health; OSHA, Occupational Safety and Health Administration; PAPR, powered air-purifying respirator; PPE, personal protective equipment; SCBA, self-contained breathing apparatus.

## Safety Standards

In the United States, minimum safety standards for laboratories specifically are established by the federal Occupational Safety and Health Administration's (OSHA<sup>1</sup>) Occupational Exposure to Hazardous Chemicals in Laboratories (OSHA 1990) and Hazard Communication Standards (OSHA 1994). A hazardous chemical is often defined as a chemical for which "at least one study conducted in accordance with established scientific principles exists that acute or chronic health effects may occur in exposed workers." Materials categorized as health hazards include irritants, corrosives, sensitizers, potent toxins, carcinogens, genotoxins, and chemicals that can affect target organs such as reproductive toxins, neurotoxins, hepatotoxins, and renal toxins. Other materials included in this definition are radioactive and biological agents. Additionally, it is necessary to understand physical hazards such as flammability, combustibility, explosivity, oxidation, water reactivity, and pyrophoric characteristics of both the chemicals and the processes in which they are used so that appropriate safety measures are in place for the conduct of the experiment. Consideration of safety measures in the design of an experiment may limit the potential for respiratory exposure and perhaps the need for respiratory protection.

OSHA regulations further require the preparation of standardized operating plans. The OSHA Laboratory Standard specifically requires a written Chemical Hygiene Plan. Included in the essential elements of the plan are requirements to control exposure to air contaminants below permissible exposure limits (OSHA 1990), establish standard operating procedures for working with hazardous chemicals, and establish criteria for the selection and implementation of measures to reduce employee exposures.

To comply with the OSHA Laboratory Standard, workers must not be exposed to hazardous materials at or above the OSHA permissible exposure limits. In establishing the required safe workplace, exposure protection must be attempted first through engineering and administrative controls. In the case of laboratories, fume hoods with protection factors up to 100,000 are the most commonly used form of engineering control. As written, from OSHA's perspective (OSHA 1998), PPE can be used only after it has been found that engineering and administrative controls are not providing a sufficient level of protection:

"When such controls are not feasible to achieve full compliance, protective equipment or any other protective measures shall be used to keep the exposure of employees to air contaminants within the limits prescribed in this section. Any equipment and/or technical measures used for this purpose must be approved for each particular use by a competent industrial hygienist or other technically qualified person. Whenever respirators are used their use shall comply with the OSHA Respiratory Protection Standard."

The OSHA Respiratory Protection Standard further un-

derscores the primacy of engineering measures in this hierarchy of exposure control:

"In control of those occupational diseases caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smokes, sprays or vapors the primary objective shall be to prevent atmospheric contamination. This shall be accomplished as far as feasible by accepted engineering control measures. When effective engineering control measures are not feasible, or while they are being instituted, appropriate respirators shall be used pursuant to this section."

It is clear that respiratory protection should not be considered until effective ventilation or containment of contaminants in the laboratory cannot be guaranteed through engineering or administrative controls. In some cases, it must be specifically determined that engineering controls are not technically or economically feasible before consideration is given to the use of personal protective equipment.

## Respiratory Protection Program Elements

Generally it is good industrial hygiene practice to develop and implement a written respiratory protection program. The OSHA Respiratory Protection Standard (29 CFR 1910.134) stipulates the need for worksite-specific procedures for required respirator use and a suitably trained, authorized program administrator to oversee the workplace program. Suggested elements of a written respiratory protection program are given in Table 1.

The selection and distribution of approved respirators should be determined after carefully considering local regulations, the requirements of the American National Standards Institute (ANSI<sup>1</sup>) Practices for Respiratory Protection, Requirement 288.2 (ANSI 1992), and the National Institute for Occupational Safety and Health (NIOSH<sup>1</sup>) Respirator

**Table 1 Elements of a respirator program**

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- Procedures for selecting respirators
  - Periodic evaluation of employees required to use respirators
  - Fit testing procedures for tight-fitting respirators
  - Procedures for proper use of respirators in routine and reasonably foreseeable emergencies
  - Inspection of respirators (both emergency and nonemergency devices)
  - Provisions for the maintenance and care of respirators
  - Provisions for adequate breathing air quality, quantity, and flow for atmosphere-supplying respirators
  - Training of employees in the respiratory hazards to which they are exposed during routine and emergency situations
  - Program evaluation and auditing
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Decision Logic. In the United States, NIOSH is responsible for certifying respirators for use in workplaces (NIOSH 1987a).

The selection of an appropriate respirator is based on the types of contaminants, the results of qualitative and quantitative industrial hygiene assessments, the exposure limit for a particular hazard, and the hazardous properties of the agent to be controlled. Additional consideration must be given to the occupational situation, the period of time the respirator will be worn, comfort and proper fit, and additional stress to the respirator user. This requirement underscores certain national regulatory requirements (OSHA) to understand first the potential exposure levels so that only those respirators providing an appropriate protection factor are selected. For air-purifying respirators, OSHA also requires an established effective changeout schedule for filters, canisters, and cartridges to prevent exposure. It is not sufficient to change cartridges or the respirator only after the contaminant is smelled or tasted, or when breathing resistance is noticed.

Finally, it is important to consider the respirator's assigned protection factor (APF<sup>1</sup>)—the ratio of the ambient concentration of a given contaminant to that inside a respirator facepiece (Cohen et al. 2001). This ratio is the level of respiratory protection that a properly functioning and fitted respirator is expected to provide to a trained user. Other reference sources for APFs include the OSHA Health Standards (29CFR1910) (OSHA 1998), the American Conference of Governmental Industrial Hygienists Respiratory Protection Monograph series (AIHA 1985), the NIOSH Respirator Decision Logic (NIOSH 1987b), and the respirator manufacturers themselves. The three available types of respirators for use in laboratories include the air-purifying respirator, the supplied-air respirator, and the self-contained breathing apparatus (SCBA<sup>1</sup>).

## Air-purifying Respirators

Air-purifying respirators may be classified into two basic categories: particulate filtering respirators and vapor/gas-removing respirators. Particulate respirators primarily rely on screening out particles from the air based on the pore sizes within the filtering media. Provided they are selected appropriately, these respirators adequately protect against dusts, and mists. Their weakness, in addition to leakage around the respirator face seal, stems from the fact that particles smaller than the pore sizes within the filtering media pass through the filter to the user. Again, it is critical that the properties of the contaminant and the potential concentrations are thoroughly understood before respirator selection. Some particulate filters are also treated to charge the filter negatively, relative to the particles. This electrostatic charge adds to the filter efficiency. It is possible to take advantage of other physical properties of particles and airflows in particulate filter design. The user should understand the particular type of respirator and filter before purchase. This information, including filter efficiency, is typically readily available from respirator manufacturers.

Vapor/gas-removing respirators rely on general and gas/vapor-specific cartridges to provide protection from acid gases, organic vapors, and specific contaminants like ammonia gas and mercury vapor. Gas/vapor cartridges normally use the properties of adsorption and absorption either to retain the contaminant or to bind the contaminant chemically to the filtering media. Most of these respirators use activated carbon, which provides a large surface area for both adsorption and absorption. Cartridges that are gas specific in many cases have specific materials added to the activated carbon or in place of the activated carbon. Because these respirators operate under negative pressure and allow leakage, they must be used under the same limitations as particulate filtering respirators. Air-purifying respirators may be equipped with either chemical cartridges or canisters. Generally the difference is the amount of sorbent material and the capacity for purifying air, with canisters having greater capacity for both. Sorbents are designed to remove specific chemicals, and using the incorrect cartridge or sorbent would afford little or no respiratory protection (Norwood 1991). Cartridges are color coded for use with specific contaminants. ANSI provides information on color codes for cartridges and canisters (ANSI 1973).

The quarter and half mask respirators that are available do not afford eye protection. Full facepiece respirators, which do afford eye protection, should be used when eye irritants are present and/or when a somewhat greater protection factor is required. Many styles of half mask respirators are designed for single use and are disposable. Others are designed for multiple use before disposal. Some are designed so that only the cartridges, canisters, or filters are disposed of, and the respirator body can be cleaned and reused many times. Air-purifying respirators of this type cannot be used in contaminant atmospheres that have been determined to be immediately hazardous to life or health or where oxygen levels are less than 19.5%. If the contaminant is considered a potent compound (occupational exposure limit <50  $\mu\text{g}/\text{m}^3$ ) or if radionuclides or asbestos are present, the respirator filter should be of the high-efficiency type.

Generally quarter and half mask respirators with and without filters have APFs of 10, and full facepiece respirators have APFs of 50 to 100 (Birkner 1991). The workplace protection factor is used to determine the reduction in the air concentration of the contaminant to which the user will be exposed, thus ensuring that the employee is not overexposed. As an example, if the workplace contains 100 ppm of hexane and the APF is 10, the operator exposure is assumed to be 10 ppm. The APF can also be used to determine the maximum concentration of the contaminant that can be present when the respirator is properly used as protection.

Powered air-purifying respirators (PAPRs<sup>1</sup>) use the same basic filtering mechanisms as the negative-pressure respirators. PAPRs have the distinct advantage of using a blower fan to pull air through the selected filters. These filters are usually mounted on a belt pack with a blower and battery pack. There are many distinct styles and orientations for this filtering and motor assembly, but all work in the

same basic manner. The blower motor draws a calibrated and specified volume of air through the filters and/or canisters/cartridges; the filtered air is then distributed to either a tight-fitting mask or a loose-fitting helmet/hood assembly. The user is not required to overcome the resistance of the filtering media, which reduces the fatigue that can sometimes be a problem with using negative-pressure respirators. In addition, because PAPRs deliver a constant flow of air, there is a slight cooling effect to the user if a loose-fitting hood or helmet is used. This characteristic may also be considered a disadvantage because there is a constant flow of potentially contaminated air being drawn through the filter media. Reduction of the service life may also be a consideration.

## Supplied-air Respirators

Supplied-air respirators are available as half masks, full facepiece, loose-fitting hoods, and helmets. They maintain a positive pressure in the mask either by a continuous flow of supplied air or by pressure demand. Supplied-air respirators protect against a wider variety of air contaminants including both gases and particulates. They generally have higher level protection factors, are not time limited, and may be used in immediately dangerous to life and health (“IDLH”) atmospheres if equipped with an auxiliary tank of air to permit escape. The air supply to the respirator must meet specifications of grade D breathing air as defined by the Compressed Gas Association. The supply system must contain the necessary traps and filters to remove oil, water, and odor (daRoza 1991) and should be tested on a regular basis for oxygen, carbon monoxide, carbon dioxide, water vapor, and condensed hydrocarbons. The air can be supplied from either cylinders or air compressors. Respirators must be supplied with at least 4 CFM for tight-fitting face masks and 6 CFM for hoods and helmets, but they must not exceed 15 CFM. Consideration must be given to the type and length of hose for supply of air.

## SCBA

This apparatus is generally designed to provide protection in oxygen-deficient environments and where high-level or unknown concentrations of toxic gases, vapors, or particulates exist. Because it is portable and not tethered to a stationary air source, the SCBA is best suited to emergency or rescue situations. Due to its complexity, more specialized and lengthy training is needed for its proper use. The SCBA has very limited, if any, practical application in routine laboratory research activities.

## Ensuring Proper and Safe Use

### Training

Each respirator wearer should receive initial training and annual retraining to ensure the proper and safe use of res-

pirators. The more complex the respirator (e.g., SCBA), the more complex the training. Training should start with a discussion of the reasons respiratory protection is required and should include the nature, extent, and effects of respiratory hazards. The operational capabilities and limitations of the respirator selected should be reviewed, followed by instructions for inspecting, donning, cleaning, maintaining, and storing the respirators. Specific instructions for proper use and limitations during emergency situations should also be included in the training.

## Respirator Fit Testing

A respirator fit test and a respirator user seal check are two distinct methods for ensuring an appropriate fit of a tight-fitting facepiece style respirator with the respirator wearer. Certain facial features and facial hair, which prevent a proper seal of a facepiece, may prevent a person from wearing a respirator. The federal OSHA Respiratory Protection standard specifically prohibits a person who has any facial hair that interferes with the facepiece seal from wearing a tight-fitting respirator. A fit test should be conducted at least annually and whenever a new type of mask is provided to the employee. It is also recommended that fit tests be conducted whenever a significant weight change or change in facial features has occurred (e.g., dentures, cosmetic surgery). A user seal check should be performed by the user before entering the contaminated environment each time he/she wears the respirator.

The two basic types of fit tests are qualitative and quantitative. Qualitative fit tests rely on the test subject’s ability to detect a test agent by taste or smell. Two qualitative tests that have been validated in accordance with ANSI 88.10 standards (ANSI 1992) include the odor threshold test, which uses isoamyl acetate, and the taste threshold test, which uses a saccharin solution aerosol. Quantitative fit testing measures the actual leakage of contaminant into the face mask of the respirator and thereby eliminates the issues associated with a subjective response. The special testing equipment required to perform the testing is highly recommended when potential exposure to extremely toxic agents or potentially high-level contamination is expected.

User seal checks are conducted to determine whether a respirator is properly seated to the face each time the respirator is worn. Both positive- and negative-pressure checks should be conducted. These tests are simply conducted by the user. A negative-pressure check is performed by the user, who inhales while wearing the respirator and covering the inlet valve/respirator cartridges. The negative pressure created within the mask should cause the respirator to collapse to the face without air leaking in from around the facepiece seal. Any leakage into the respirator is unacceptable. The positive-pressure fit check is performed by covering the exhalation valve while slightly exhaling. The respirator should then slightly lift/bulge from the face because of the positive pressure created within the respirator

body. Any leaking that prevents the respirator from lifting/bulging is considered unacceptable. An unacceptable result from either the negative or the positive fit check should prohibit the use of that respirator until it has been properly repaired or replaced with a new respirator.

## Inspection, Cleaning, Maintenance, and Storage

Respirators should be cleaned routinely after each use and sanitized when used by more than one person, and emergency-use respirators should be cleaned and sanitized after each use (Colton 1991). During inspection, respirators should be checked for defects in the connections, facepiece, valves and canisters, and filters/cartridges. Stored emergency respirators should be inspected at least monthly.

Respirators must be maintained properly to retain their original effectiveness. No attempt should be made to replace component parts or make adjustments or repairs beyond the manufacturer's recommendations. Parts should be replaced only by individuals trained in proper respiratory maintenance and assembly. Any adjustment or repair of valves, regulators, and alarms or other major repairs should be made by the manufacturer or a manufacturer's authorized representative after the respirator has been taken out of service and replaced. It is necessary to inspect both emergency and nonemergency respirators monthly and to document the inspections accordingly.

Respirators should be stored in an easily accessible and sanitary location so that they are protected against physical and chemical agents that could damage and distort elastomeric parts. Respirators left in the open in the work environments where they are used are subject to contamination from settling airborne materials. It is necessary to store respirators in labeled plastic bags out of direct contact with potential contaminants.

## Medical Evaluation

Employees should be assigned to tasks requiring the use of a respirator only when a determination has been made that they are physically and psychologically able to use the respirator properly and thus able to perform the job safely. A medical evaluation must be performed by a physician or other licensed health care professional using a mandatory medical questionnaire or an initial medical examination that obtains the same information as the medical questionnaire. The respirator wearer's medical status should be evaluated annually.

## Program Evaluation and Auditing

Any respirator program should be reviewed periodically and audited to determine compliance with local regulations,

guidance, and industry standards. Operating procedures involving all aspects of respirator use should be modified if necessary. Additionally, monitoring data and medical surveillance should be used to evaluate the effectiveness of the respirator program. Any evidence of excessive exposure requires followup.

## Summary

Respiratory protection is a critical aspect in the effective control of occupational hazards in laboratories. Because biomedical research facilities present unique occupational environments, special considerations are needed in making the proper selection of any PPE. One aspect of hazard control not unique to animal facilities and laboratories is the principle of the primacy of engineering controls. Under that principle, use of respiratory protection should be considered only after it has been determined that engineering controls are not feasible.

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