

Spurious research on electrostatic filter performance

By Thomas J. Nelson, C.I.H.

Tom Nelson has performed research and written articles on respirator performance and fit-testing.

Introduction

Two recently-published articles discussed the performance of a number of electrostatic respirator filters approved by the National Institute for Occupational Safety and Health (NIOSH).^(1,2) Here, these articles will be called “the efficiency study” and “the intermittent loading study,” respectively. In each, the investigators reported changes in filter efficiency that varied with the type of loading and test aerosol used. The work presented in these studies is interesting in terms of describing the behavior of electret filters under severe laboratory conditions. However, because the test conditions used differ greatly from those found in the workplace, these studies have no practical significance. This article will describe the studies, summarize their results and explain why these findings cannot be applied to electrostatic respirator filters used in the workplace.

Background

Filters for negative pressure air-purifying respirators are tested and certified by NIOSH according to the test requirements of 42 CFR Part 84, Subpart K. NIOSH approves filters having three different levels of filter efficiency (95, 99 and 99.97%) and three levels of oil resistance (N, R and P). The N series filters can only be used in atmospheres that do not contain oils. As such, they are not required to resist degradation of filter efficiency by oil aerosols. The R and P series filters must be resistant to filter efficiency degradation by oil aerosols and can be used in atmospheres that contain oils as well as those that do not.

Many filters now manufactured use electrically-charged media to attract particles smaller than 1 µm. This improves a filter’s efficiency without increasing its breathing resistance. Filters that use this technology are commonly referred to as “electrostatic” or “electret” filters.

The efficiency study

This study was intended to describe filter penetration as a function of particle size. Three different models of N95 filtering facepiece respirators, along with one model each of the N99, R95 and P100 class filters were evaluated. The filters were tested with sodium chloride (NaCl) and dioctyl phthalate (DOP) aerosols according to the criteria in 42 CFR Part 84, except that the filters were not preconditioned in a humid environment.

(see *Electrostatic Filter Performance* on page 2)

Inside this issue

Volume 19 Number 1 2001

Recent research on electrostatic filter performance 1-2, 4-5, 13
<i>JobHealth Highlights</i> making transition to electronic format 3
The workplace performance of a loose-fitting facepiece PAPR with HEPA filters. 6-8
Respiratory protection for “first” responders 9-12
3M OH&ESD offers respiratory protection training courses. 14

Electrostatic Filter Performance

(continued from page 1)

Count median diameter is a measure of particle size. At the count median, half the particles are larger and half are smaller than the designated size. For the NaCl aerosol, the count median diameter was $0.075 \pm 0.02 \mu\text{m}$ with a geometric standard deviation (GSD) less than 1.86. For the DOP aerosol, the count median diameter was $0.185 \pm 0.02 \mu\text{m}$ with a GSD less than 1.60. The N95 filtering facepieces were tested at an air flow of 85 lpm. The other filters are used in pairs on elastomeric facepieces, so a flow rate of 42.5 lpm was used. Filter penetration by particle size was determined over a range of 0.015 to $0.4 \mu\text{m}$ using an automated filter tester with a DOP challenge aerosol.

First, three filters of each type were tested with the NaCl aerosol until maximum filter penetration was reached. Three filters of each type were also exposed to the DOP aerosol. Filter penetration was measured until 200 mg of the oil was loaded onto the filters. The results of these tests are summarized in Table 1. A final experiment involved dipping two new filters of each type in isopropanol for 15 seconds. This was done to reduce or eliminate any electrostatic charge on the fibers of each filter. The filters were allowed to dry, then using the DOP aerosol, penetration by particle size was measured for these filters and two control filters. Then, the NaCl test (described above) was conducted to determine final filter penetration. The results of the NaCl tests are summarized in Table 2.

Table 1 Penetration values for each filter tested with sodium chloride (NaCl) and dioctyl phthlate (DOP) aerosols*

Filter	Sodium Chloride		Dioctyl Phthlate	
	Initial Penetration (%)	Maximum Penetration (%)	Initial Penetration (%)	Maximum Penetration (%)
N95 - Manufacturer A	0.467	0.763	1.48	20.8
N95 - Manufacturer B	2.43	2.54	6.22	18.4
N95 - Manufacturer C	2.08	2.11	5.39	35.5
N99 - Manufacturer D	0.188	0.234	0.758	2.55
R95 - Manufacturer D	0.019	0.019	0.163	1.03
P100- Manufacturer A	0.002	0.002	0.000	0.000

*Values shown are averages for three filters

Discussion of the efficiency study

For all filters tested, the maximum penetration of the NaCl aerosol was less than the penetration allowed by the NIOSH certification test. In the DOP tests,

the penetration of the N series filters exceeded the allowable penetration for each filter. This result is expected, since N series filters are not required to be resistant to oil degradation.

(see *Electrostatic Filter Performance* on page 4)

Table 2 Maximum penetration of sodium chloride (NaCl) aerosol (most penetrating size range) before and after isopropanol dip*

Filter	Controls (As Received)	Isopropanol Dip
	Final Penetration (%)	Final Penetration (%)
N95 - Manufacturer A	0.494	34.8
N95 - Manufacturer B	2.44	39.0
N95 - Manufacturer C	3.10	42.4
N99 - Manufacturer D	0.229	51.2
R95 - Manufacturer D	0.028	46.8
P100- Manufacturer A	0.002	2.94

*Values shown are averages for three filters

You asked for it!

JobHealth Highlights making transition to electronic format

In a survey conducted at the American Industrial Hygiene Conference and Exhibition (AIHCE), 70% of **industrial hygienists and occupational safety professionals** expressed a preference for receiving **technical information from 3M** in an electronic format. Therefore, to better serve you, *JobHealth Highlights* is changing exclusively to an electronic format—rather than a printed format.

To subscribe to the electronic version of *JobHealth Highlights*, simply **fill out your e-mail address below and fax it back to 3M at 651-736-6677**.

Or you can log on to www.3M.com/occsafety/subscribe and register your e-mail address. As soon as each new issue of *JHH* becomes available, we will notify you by e-mail **and you can hot link directly to the new issue on the 3M web site**.

Current and recent back issues of *JobHealth Highlights* will continue to be available on the 3M web site for easy access.

Please be assured you will only receive materials on respiratory protection, **technical bulletins, regulations updates and other important health and safety information that you select**. You will not receive advertising or promotional materials. You can subscribe or unsubscribe at any time.

We appreciate your continued interest in *JHH* and 3M OH&ESD and look forward to continuing to meet your needs for industrial respiratory protection.



I want to subscribe to *JobHealth Highlights* in an electronic format.

Name _____

Company _____

E-Mail Address _____

FAX TO: 651-736-6677

OR REGISTER ONLINE: www.3M.com/occsafety/subscribe

Electrostatic Filter Performance

(continued from page 2)

It also illustrates why N series filters are not permitted in atmospheres containing oil aerosols. For the R and P series filters, the maximum penetration observed did not exceed the allowable limit. In other words, all filters tested passed the tests they were designed to pass.

When the filters were dipped in isopropanol, penetration of submicrometer particles increased significantly. This is expected, since electret filters rely on their electrostatic charges to remove particles in the submicrometer range. Chen et al. demonstrated this effect in a study of dust/mist filtering facepieces approved under 30 CFR Part 11.⁽³⁾ Chen measured filter efficiency as a function of particle size in the range of 0.15 to 3 µm. Measurements were made on new filters and on filters treated with Static Guard™ or isopropanol to remove electrical charges. Penetration of submicrometer particles increased after treatment but began to decrease at sizes above 0.3 µm. At approximately 2 µm or larger, penetration was essentially zero. This observation helps put the current efficiency study into perspective. Electrostatic attraction is a very important particle capture mechanism *only* for submicrometer particles. Electret filters effectively remove larger particles typically found in the workplace with mechanical filtration processes. It must also be emphasized that filters in the workplace will not be dipped in isopropanol or sprayed with Static Guard.

The intermittent loading study

This study examined filter penetration by NaCl aerosol over a period of several weeks. Electret type N95 filtering facepiece respirators from three different manufacturers were evaluated. Initially, the filters were tested for NaCl penetration to a loading of 200 mg according to the 42 CFR Part 84 test criteria, except for prehumidification. The results from this test confirmed that the filters had penetration well below 5% with the NaCl test aerosol.

Next, a set of filters was tested according to the same criteria, except they were only loaded with 5 mg of NaCl. These filters were then stored in an office environment for one week. At the end of the week, the filters were tested again, as described above, with an additional 5 mg loading of NaCl. This intermittent loading sequence was repeated for up to 200 days.

Another part of the experiment tested sets of filters that sat in an office environment for a number of weeks. These filters were then introduced into the intermittent filtration loading scheme (e.g., at days 70, 91, 119, etc.). They served as controls for those filters being tested in the intermittent loading experiment.

Finally, an attempt was made to determine if high humidity adversely affects electret filter performance. Two filters from each manufacturer were dipped in distilled water for 15 seconds and allowed to dry overnight. Maximum initial NaCl penetration was measured on the dipped filters and two new filters from each manufacturer, with an initial NaCl loading of 15.5 to 28.4 mg. All the filters were stored for three weeks and initial NaCl penetration was remeasured.

(see *Electrostatic Filter Performance* on page 5)

Table 3 Penetration for three filtering facepieces intermittently loaded with sodium chloride (NaCl) aerosol

Week Tested	NaCl Loading (mg)	Penetration (%)		
		A	B	C
1 (Initial Loading)	5	1.4	1.8	0.8
5	25	3.4	3.0	1.3
11	50	5.6	4.5	1.8
16	75	7.9	6.0	2.3
21	100	10.1	7.5	-
27	125	12.4	9.0	-

Discussion of the intermittent loading study

The results of the intermittent loading portion of the study are summarized in Table 3. The authors reported that, at each loading event, NaCl penetration decreased during the test. It should be noted that initial penetration measured during each loading session was higher than that measured in the previous session.

The maximum penetration permitted under NIOSH test conditions is 5% for N95 filters. Penetration exceeded this value only after 9 weeks of intermittent loading for one manufacturer's respirators and 13 weeks for another. The third manufacturer's filters did not reach a penetration level of 5% over the duration of the experiment. Filtering facepiece respirators would not be used for nine weeks or longer in any workplace with a sound respiratory protection program. This indicates that N95 filters will maintain their certified efficiency under plausible workplace use conditions.

The initial penetration values for all the control filters were similar to the penetration values found for the test filters at the beginning of the study. As the control filters were intermittently loaded, they showed a pattern of increasing penetration similar to that found for the test filters. This demonstrates that storage in the office had little effect on the filters' performance.

3M investigators performed an experiment similar to this portion of the intermittent loading study. In this case, filters were intermittently

loaded with silica dust rather than NaCl. Penetration was measured with NaCl aerosol. Filters tested in this manner showed little or no increase in test aerosol penetration over time. However, a control sample loaded with NaCl exhibited the same pattern of increasing penetration noted in the intermittent loading study. Clearly, the phenomenon of increasing penetration depends on the material with which the respirator is loaded. It should be noted that sodium chloride was chosen as the test aerosol for N series filters because it is known to mildly degrade filter efficiency against submicrometer aerosols.⁽⁴⁾

In the experiment that evaluated the effects of high humidity, the water-dipped filters from two manufacturers showed no increase in penetration in comparison with their undipped controls. One manufacturer's dipped filters showed a slight increase in penetration compared with their controls; the highest value reported for this manufacturer was 3.52%. This indicates that humidity in the workplace will not significantly degrade electret filter performance.

Further discussion and conclusions

It is important to emphasize that all the filters in both the efficiency study and the intermittent loading study performed at or above their certified efficiency levels when tested with the appropriate certification procedures. However, the test methods used in these studies were designed to challenge the filters well beyond the

requirements of 42 CFR Part 84, Subpart K, which NIOSH designed to be "worst case" tests.⁽⁴⁾ It is illogical to challenge N-series filters with DOP, since N-series filters are not designed for, nor permitted to be worn in, environments that contain oils. Similar arguments could be made regarding dipping filters in isopropanol or water, neither of which would be done in any imaginable workplace.

Other investigators have performed the type of research conducted in these studies. Brown measured changes in penetration as a function of loading with various materials and exposures including coal dust, foundry dust, lead smelting, lead battery assembly operations, refractory brick, coal tar and silica.⁽⁵⁾ He also described the phenomenon in which a filter loaded with NaCl then left for several hours will exhibit higher penetration than it did at the end of loading.⁽⁶⁾ He concluded that the phenomenon of charge loss is widespread, but, like clogging, is not usually severe in respirators because their dust loading is likely to be limited.

The efficiency study and intermittent loading study do not provide evidence that the Subpart K tests are unable to discriminate filters that will offer adequate workplace protection from those that will not. As noted earlier, particles in the workplace are much larger than NIOSH test aerosols and the aerosols used in this study.

(see *Electrostatic Filter Performance on page 13*)

The workplace performance of a loose-fitting facepiece PAPR with HEPA filters

By Jeanne O. Bidwell

Jeanne Bidwell is an Advanced Technical Service Representative with the 3M OH&ESD Laboratory.

OSHA is currently evaluating workplace protection factor (WPF) studies in order to establish assigned protection factors (APFs) for its revised Respiratory Protection Standard, 29 CFR 1910.134. This article presents and discusses the results of a recent WPF study on a 3M respirator.

In early 1998, the Occupational Safety and Health Administration (OSHA) revised its Respiratory Protection Standard, 29 CFR 1910.134.⁽¹⁾ This new rule does not yet contain assigned protection factors (APFs), which are needed in order to select appropriate respirators. Until they are established, OSHA expects employers to consider the best available information when selecting respirators.

An assigned protection factor is an estimate of the level of protection provided by a properly functioning respirator or class of respirators to properly fitted and trained users. APFs have been established by both the American National Standards Institute (ANSI) Z88.2-1992⁽²⁾ and by the National Institute for Occupational Safety and Health (NIOSH).⁽³⁾ At this time, OSHA has not made clear which APFs it is enforcing.

3M believes that the APFs established by ANSI represent the best available information because they:

- use more recent information;
- are based largely on workplace protection factor (WPF) studies or design analogy instead of fit-testing performed in the middle 1970s;
- use data from respirators approved by NIOSH instead of respirators approved by the United States Bureau of Mines (USBM); and
- provide more complete documentation about the way the APFs were established.

OSHA is currently working to set APFs for the revised standard. In doing so, they are evaluating data from both laboratory and workplace studies.

This WPF study was conducted to: 1) determine the workplace performance of a loose-fitting facepiece powered air purifying respirator (PAPR) with high efficiency particulate air (HEPA) filters and 2) compare the WPFs with the simulated workplace protection factors (SWPFs) which were measured previously in the laboratory. The current APF for this class of respirators is 25 according to both NIOSH and ANSI recommendations.

WPF and SWPF

The WPF is a measure of the protection provided in the workplace, under the conditions of that workplace, by a properly selected, fit-tested, and functioning respirator, when correctly worn and used.⁽⁴⁾

Mathematically, $WPF = C_o/C_i$ where:

- C_o represents inhalation exposure outside the respirator (ambient sample);
- C_i represents inhalation exposure inside the respirator (in-facepiece sample); and

- C_o and C_i are determined simultaneously only while the respirator is worn and used during normal work activities.

The SWPF is a surrogate measure of the WPF, differing from the WPF by the fact that C_o and C_i are measured in a laboratory simulation of a workplace rather than in the actual workplace.⁽⁴⁾

Materials and methods

The 3M™ Breathe Easy™ (BE) 12 PAPR with HEPA filters was tested against cadmium particulate contaminants in a nickel-cadmium battery manufacturing plant. This workplace was chosen because:

- BE12 PAPRs were used in the workplace;
- The exposure levels were high enough to challenge the respirator; and
- The company was willing to participate in the study.

A preliminary visit to the site, which included air sampling, helped confirm these key criteria for conducting a WPF study were met.

Seven workers in the pasting area participated in the study over a three-day period. They were selected because cadmium concentrations in their work areas were expected to be the highest for that department.

A specially-designed nylon probe was used to collect the in-facepiece samples. It was built to the specifications of a probe developed at the University of Minnesota by Dr. B.Y.H. Liu.⁽⁵⁾ However, it is longer than the original Liu probe, designed to project approximately one centimeter into the respirator and adjustable to varying depths.

It was also designed to minimize particle entry losses.

(see Workplace Performance on page 7)

Workplace Performance

(continued from page 6)

The probe was placed opposite the mouth and nose area on the faceshield of the loose-fitting facepiece. It was adjusted so that it projected toward the worker's face. A sample cassette was fitted directly to the probe for collection of the in-facepiece sample.

The ambient sample cassette was placed in the worker's breathing zone (outside the respirator), typically on the collar of the worker's coveralls. A probe was fitted to the outside sample cassette, so any particle loss caused by the probe on the inside sample, would also be experienced by the outside sample.

The cassettes and sample tubing were attached to personal sampling pumps. Each worker wore two pumps as samples were taken simultaneously.

The workers were sampled for the entire shift for all three days to get as many replicates as possible. Samples were changed when breaks and lunch times permitted. Sampling times ranged from 67 to 156 minutes. As many as three samples per day per worker were collected. Pumps were calibrated in-line before and after taking each sample. The samples were collected at two liters per minute.

Field blanks were collected and handled in the same manner as the C_o and C_i samples, except no air was drawn through them. Manufacturers' blanks (unused sample cassettes) were also sent to the analytical laboratory with the field blanks and samples to check for background levels of contaminants. Particle size sampling was conducted twice using six-stage single-jet cascade impactors.

All samples and blanks were analyzed for cadmium. The ambient samples were analyzed

by flame atomic absorption spectroscopy (AAS). The in-facepiece and blank samples were analyzed via heated graphite furnace atomizer (AAS-HGA). No detectable cadmium was found on any blank sample.

Workplace protection factors were calculated by dividing ambient concentrations by the corresponding in-facepiece concentrations. The geometric mean WPF, geometric standard deviation and fifth percentile WPF were determined for all workers.

Results

Of the 45 sample sets collected, four were eliminated due to equipment failure and eight had inside sample mass values reported as non-detectable. The remaining 33 sample sets were treated statistically and used to calculate workplace protection factors. (See Table 1.)

The outside cadmium concentrations ranged from 8 to 374 $\mu\text{g}/\text{m}^3$. The permissible exposure limit (PEL) of cadmium, 5 $\mu\text{g}/\text{m}^3$, was exceeded in all cases. The inside concentrations ranged from non-detectable to 0.318 $\mu\text{g}/\text{m}^3$. All of the inside concentrations were well below the PEL. Therefore, no worker

was overexposed to cadmium during the study. These results

indicate that the respirator provided adequate protection.

The mean WPF for the respirator was 2,523 with a fifth percentile of 315. Cadmium was not detected on approximately 17% of the in-facepiece samples. No value was assigned to these samples, so they could not be used in the calculations. Thus, the statistics are conservative.

Results from the two cascade impactors indicate three particle size modes with geometric means of 1.7, 3.5, and 11 μm , with 85% of the mass in the third mode.

Discussion/Conclusion

WPFs in this study ranged from 54 to 25,240. A fifth percentile of 315 exceeded the APF of 25. No worker was overexposed to cadmium during the sampling. These WPFs are not consistent with SWPFs measured on the BE12 PAPR by Cohen et al.⁽⁶⁾ In the Cohen study, the median SWPF was greater than 250,000 and the fifth percentile ranged from 150,000 to 230,000.

(see Workplace Performance on page 8)

Table 1 WPF data from seven subjects

A	B	C	D	E	F	G
7,897	2,645	25,240	5,214	2,973	1,076	6,820
12,909	5,095	1,209	1,654	1,297	4,091	4,270
16,190	4,844	900	3,011	963	4,007	246
5,243	1,943	1,872	1,411	502	2,745	
11,966	5,144	54	303		2,906	
					4,736	

Workplace Performance

(continued from page 7)

3M believes that data from actual workplace studies and data from simulated workplace studies cannot be directly compared. Table 2 lists the differences that exist between these two types of studies. Given these differences, 3M believes that WPF studies are the most appropriate method for evaluating respirator performance and establishing APFs. This WPF study supports the current APF of 25 for loose-fitting facepiece PAPRs.

References

1. "Respiratory Protection," *Code of Federal Regulations*, Title 29, Part. 1910.134. 1999.
2. American National Standards Institute: *American National Standard for Respiratory Protection* (ANSI Z88.2). New York: American National Standards Institute, Inc., 1992, p.6.
3. National Institute for Occupational Safety & Health: *Respirator Decision Logic*, 1987.
4. American Industrial Hygiene Association Respiratory Protection Committee: Respirator Performance Terminology. [Letter to the Editor]. *Am. Ind. Hyg. Assoc. J.* 46(5): B-22-B-24 (1985).
5. Liu, B.Y.H., K. Sega, K.L. Rubow, S.W. Lenhart, and W.R. Myers: In-Mask Sampling for Powered Air Purifying Respirators. *Am. Ind. Hyg. Assoc. J.* 45(4):278-283 (1984).
6. Lawrence Livermore National Laboratory (LLNL): Simulated Workplace Protection Factor Study of Powered Air Purifying and Supplied Air Respirators by Cohen, H.J., L.H. Hecker, D.K. Mattheis, J.S. Johnson, A.H. Biermann, and K.L. Foote, Livermore, CA: LLNL Respirator Test Facility, 1998, unpublished.

Table 2 Differences between the workplace study and a simulated workplace study

Workplace Study	Simulated Workplace Study
Actual work site	Test chamber
Workers doing their jobs	Test subjects doing exercises per protocol
Routine wearers of test respirator	May or may not have worn respirators
Actual contaminant(s)	Laboratory aerosol
Varying contaminant(s) concentration(s)	Consistent contaminant concentration
Additional personal protective equipment worn (eyeglasses, gloves, coveralls, hearing protection)	Additional personal protective equipment may or may not be worn

Tech line

To reach 3M's Technical Service staff with questions regarding our products, you can call 1-800-243-4630. If you wish to contact your local sales representative, you can leave a message by calling 1-800-896-4223.

Visit the 3M OH&ESD Web site

Information on 3M OH&ESD products, as well as on current issues in respiratory protection, can be obtained by visiting our web site.

Our address is: <http://www.3M.com/occsafety>

Respiratory protection for “first” responders

By Nicole Vars McCullough, Ph.D., C.I.H.

Nikki Vars McCullough does product research and development in the 3M OH&ESD Laboratory.

One of the fastest growing segments among respirator users today is that of “first” responders. Although there are several definitions for this term, in general, these are the people who would respond to an incident involving chemical or biological warfare agents or an intentional or accidental industrial chemical release. Initially, the definition of first responders was restricted to those who entered the scene first and wore only Level A personal protective equipment. However, this term is now being used to refer to anyone involved in the response to an incident. Today, almost every branch of our public health and safety system—including fire, law enforcement, emergency medicine, public health and emergency management departments—is training and planning to respond to incidents of these types.

In preparing to respond to an incident, one needs to understand the types of activities that may require respiratory protection. An incident scene will need to be secured and the agent (weapon) identified and quantified, when possible. Decontamination stations will need to be established. Crowd and traffic control will be essential. Victims will need medical attention. To perform these activities, it is likely that most of the personnel involved will need or

want some sort of respiratory protection. The type and level of respiratory protection will depend upon the exposures.

“Hot,” “warm” and “cold” zones are often mentioned when discussing chemical and biological incidents. The hot zone is the area immediately surrounding the agent release. The warm zone is where decontamination and limited patient treatment will most likely occur.⁽¹⁾ The cold zone is an area of very low hazard concern and is usually uncontrolled. These zones are defined for emergency management purposes but don’t necessarily dictate the type of respiratory protection that will be used. The necessary respiratory protection depends on the contaminant and its concentration. Selection of respiratory protection for potential chemical warfare agents is identical to selection for industrial situations and will be discussed later in this article.

Agents

The main agents of interest include chemicals, biological organisms and biological toxins. Military-specific chemicals that have been designed as weapons include nerve agents, blister agents and tear agents. The most common nerve agents are sarin (GB) [the chemical used in the 1995 Tokyo subway attack], soman (GD), tabun (GA) and VX. These organic vapors act quickly upon the body and can cause shortness of breath, salivation, runny nose, convulsions and death. The most common blister agents include sulfur mustard (H), distilled sulfur mustard (HD) and lewisite (L). These agents may be liquid or vapor and can cause liquid-filled, burn-like blisters on the skin and can irritate and affect the respiratory system and other internal organs. The most common tear agents, also called riot control agents, include o-chlorobenzylidene malonitrile (CS), a-chloroacetophenone (CN)

and capsaicin (OC) or pepper spray. These substances are typically particulates that can cause burning and tearing of the eyes as well as airway discomfort and skin irritation. Generally, the tear agents only temporarily disable victims and their effects are usually reversible after exposure to clean air.

Many industrial chemicals also can be used as weapons. These include cyanide agents, chlorine, phosgene and ammonia. The cyanide agents, also referred to as blood agents because they interfere with the body’s ability to transport oxygen in the blood, include hydrogen cyanide (AC) and cyanogen chloride (CK). These are very volatile gases whose effects can range from dizziness, weakness, nausea or eye irritation to loss of consciousness, convulsions and death. Specific effects depend on the agent and the concentration. Chlorine and phosgene are sometimes referred to as pulmonary agents because they damage the lungs. Exposure to low levels of these agents can cause eye, nose and airway irritation. Higher exposures can cause pulmonary edema (fluid in the lungs) and death. There has also been concern about the use of ammonia as a weapon because it is accessible to the public. Ammonia can be a severe irritant to the eyes, nose, throat and lungs, and exposure to high levels can cause pulmonary edema and death.

There are two ways that biological organisms may be used as weapons against humans. The first is through infection, in which a living organism multiplies within the body. Anthrax and smallpox are two biological organisms that can cause infection and are of main concern. Anthrax is a bacterium that forms spores which can remain viable in the environment for long periods of time. Anthrax is transmitted through inhalation as well as through the skin and by

(see First Responders on page 10)

First Responders

(continued from page 9)

ingestion. While it is not directly communicable between humans, its fatality rate is approximately 90% if not properly treated. The smallpox virus has been virtually eliminated from the global human population and vaccines are no longer administered to prevent it. Smallpox is easily transmitted between humans and has a fatality rate of approximately 30%. This means the human population would be very susceptible to an outbreak if smallpox were used as a weapon.

The second method by which biological organisms can cause illness is through toxins. Many organisms create chemical by-products that are very toxic to humans. Toxins that have been used as weapons include ricin, which is a mixture of proteins derived from the beans of the castor plant; Botulinum toxin, produced by the bacterium *Clostridium botulinum*; saxitoxin, produced by an algae; and Staphylococcus Enterotoxin B (SEB) produced by the bacterium *Staphylococcus aureus*.

Respiratory protection

While there are no regulations specifically governing responses to incidents involving chemical and biological weapons, Occupational Safety and Health Administration (OSHA) regulations should be followed when applicable. When a group decides to make respiratory protection part of its emergency management and response plan, it is essential they follow the general respiratory protection standard, 29 CFR 1910.134. A full respiratory protection program must be implemented. This program must be administered by a trained individual and must include written standard operating procedures, user training, respirator maintenance procedures and proper fitting of respirators to users. The Hazardous

Waste Operations and Emergency Response standard, 29 CFR 1910.120, should also be reviewed because it covers emergency response operations for releases of—or substantial threats of releases of—hazardous substances.

Respirator selection

Selecting respirators for use in responding to incidents of chemical or biological terrorism is very similar to selecting respirators for industrial use. The same limitations and selection rules apply.

There are some situations in which a positive pressure, self-contained breathing apparatus (SCBA) or combination SCBA/airline respirator is the only appropriate type of respiratory protection. Meeting **even one** of the following conditions would require use of these respirators:

- Oxygen concentration is less than 19.5%;
- Contaminant is unknown;
- Concentration is unknown or above the immediately dangerous to life or health (IDLH) concentration;
- There is a significant health risk from exposure to the skin that would require a totally-encapsulating chemical protective suit. This type of suit can only be used with an SCBA or combination SCBA/airline respirator; and
- The contaminant cannot be removed by an air-purifying element (i.e., there is no effective cartridge, canister or filter).

SCBAs and combination SCBA/airline respirators provide the highest level of respiratory protection. Some organizations have considered purchasing only SCBAs so they simply have to use one type of respirator. There are advantages and disadvantages to

this approach. These respirators can be used in all conditions and before contaminant identification is complete. However, an SCBA has a cylinder that contains a limited amount of air, usually enough to last 30 to 60 minutes. This gives the user a limited amount of time to be in a contaminated area. It also requires the user to have plans for acquiring a sufficient number of full cylinders. In addition, SCBAs are heavy (20-30 lbs), place more burden upon the wearer and require more routine maintenance than air-purifying respirators (APRs). Users should be aware of these limitations when selecting respiratory protection and plan accordingly.

If conditions will allow air-purifying respirators to be used, it may be beneficial to do so. If **all** of the following conditions are met, an APR can be used:

- Oxygen concentration is at least 19.5%;
- Contaminant is identified;
- Concentration is quantified and below the IDLH value and below the maximum use concentration for that type of respirator and contaminant;
- There is not a significant health risk from exposure to the skin that would require a totally-encapsulating chemical protective suit;
- The contaminant can be removed by an air-purifying element (i.e., there exists an effective cartridge, canister or filter); and
- If the contaminant is a gas or vapor, a cartridge or canister change schedule has been developed.

As in industry, the type of air-purifying respirator should be selected based on the concentration of the contaminant and the assigned protection factor (APF) of the respirator. In situations

(see First responders on page 11)

First Responders

(continued from page 10)

where chemical or biological warfare agents have been released, it is generally recommended that the minimum type of respiratory protection used be a full-facepiece, air-purifying respirator. This is because many warfare agents are transmitted through the eyes and mucous membranes as well as the respiratory system. In concentrations up to 10 times the airborne exposure limit, a negative pressure, full-facepiece, air-purifying respirator that has been qualitatively or quantitatively fit-tested can be used. In concentrations up to 50 times the airborne exposure limit, a negative pressure, full-facepiece, air-purifying respirator that has been quantitatively fit-tested can be used. In concentrations up to 1,000 times the airborne exposure limit, a powered air-purifying respirator (PAPR) with hood, helmet or full facepiece should be used.

Cartridge, canister and filter selection

If an air-purifying respirator has been selected, the cartridge, canister or filter must be chosen. For chemical agents that are also used in industry, such as ammonia or chlorine, one should select a cartridge or canister that has approval from the National Institute for Occupational Safety and Health (NIOSH) for that substance or class of substances. Some chemical

warfare agents, however, do not have NIOSH approval schedules and do not fall into any of the chemical classes for which there are NIOSH approvals. In these cases, the respirator manufacturer should be contacted to determine if there has been any testing to determine or document whether a cartridge or canister is effective against a given chemical. For example, there is no NIOSH approval schedule for cyanogen chloride. However, there are several military specifications that include test procedures for that chemical.

Table 1 shows the threshold limit value (TLV) or airborne exposure limit (AEL), IDLH concentration and type of documentation that a cartridge or canister should have in order to be used for various chemical warfare agents. If users do not understand the type of testing performed, they should question the manufacturer carefully to ensure that they understand the limitations of a cartridge or canister.

Some chemical warfare agents could be dispersed on particles or as mists. For these reasons, a combination cartridge or canister with a particulate filter should be selected. While there are no specific regulations governing the type of filters used, typically P100 filters are used with negative pressure APRs and high efficiency (HE) filters are used with PAPRs.

Biological agents are also particles and can be removed by particulate filters with the same efficiency as non-biological particles having the same physical characteristics (size, shape, etc.). However, there are no exposure limits (such as PELs, TLVs or AELs) established for biological agents. Therefore, while a respirator may help reduce an exposure, it cannot be guaranteed to eliminate exposure or the risk of contracting illnesses, diseases or infections. When selecting respiratory protection for exposure to biological agents, users should rely on recommendations of agencies such as the Centers for Disease Control and Prevention or on the judgement of experienced professionals.

In summary, if respiratory protection is included in an emergency response plan, a full respiratory protection program must be implemented including selection, training, fit-testing, and recordkeeping. It is important to understand and follow the guidelines for respirator selection, which are the same for first responders as they are for general industry. In addition, it is essential that users fully understand the capabilities and limitations of respirator systems and of any cartridges, canisters or filters they have selected.

Reference

1. Sidell, F.R., Patick, W.C. III, and T.R. Dashiell. 1998. *Jane's Chem-Bio Handbook*. Jane's Information Group, Alexandria, VA.

First Responders

(continued from page 11)

Table 1 Exposure limits and recommended documentation for selecting air-purifying cartridges and canisters for certain chemical warfare agents

Gas or Vapor	Threshold Limit Value ^a	IDLH Concentration ^b	Efficacy Documentation
Chlorine	0.5 ppm TWA, 1 ppm STEL	30 ppm	NIOSH approval for chlorine
Ammonia	25 ppm TWA, 35 ppm STEL	500 ppm	NIOSH approval for ammonia
Methylamine	5 ppm TWA, 15 ppm STEL	100 ppm	NIOSH approval for methylamine
Phosphine	0.3 ppm TWA, 1 ppm STEL	200 ppm	NIOSH approval for phosphine
CN ^c	0.05 ppm	16 ppm	NIOSH approval for CN, or NIOSH approval for OV and P100 or HE, or tested to a military specification
CS ^c	0.05 ppm C	0.25 ppm	NIOSH approval for CS, or NIOSH approval for OV and P100 or HE, or tested to a military specification
Hydrogen Cyanide	4.7 ppm C	50 ppm	NIOSH approval for HCN (escape only) or tested to a military specification
Cyanogen Chloride	0.3 ppm C	ND	No NIOSH approval schedule available. Tested to military specification
Chloropicrin	0.1 ppm TWA	4 ppm	NIOSH approval for organic vapors or tested to military specification
Phosgene	0.1 ppm TWA	2 ppm	No NIOSH approval schedule available. Tested to military specification
	Airborne Exposure Limit ^d	IDLH Concentration ^d	
Sarin (GB)	0.0001 mg/m ³	0.2 mg/m ³	NIOSH approval for organic vapors or tested to military specification ^e
Tabun (GA)	0.0001 mg/m ³	0.2 mg/m ³	NIOSH approval for organic vapors or tested to military specification ^e
Soman (GD)	0.00003 mg/m ³	0.06 mg/m ³	NIOSH approval for organic vapors or tested to military specification ^e
VX	0.00001 mg/m ³	0.02 mg/m ³	NIOSH approval for organic vapors or tested to military specification ^e
Mustard Agents: H, HD, HT	0.003 mg/m ³	0.003 mg/m ³	The U.S. Army recommends use of an SCBA ^f

ND is not determined

TWA is time-weighted average

STEL is short-term exposure limit

NIOSH is National Institute for Occupational Safety and Health

ppm is parts per million parts of air

mg/m³ is milligrams per cubic meter of air

C is ceiling

SCBA is self-contained breathing apparatus

a. TLV is threshold limit value from the American Conference of Governmental Industrial Hygienists. ACGIH Threshold Limit Values and Biological Exposure Indices, 2000.

b. IDLH is immediately dangerous to life or health. NIOSH Pocket Guide to Chemical Hazards. 1990. DHHS (NIOSH) Publication No. 90-117.

c. Only tight-fitting, air-purifying respirators and tight-fitting PAPRs can be NIOSH approved for CN and CS. Approval for CN and CS is not applicable to PAPRs with loose-fitting headgear such as hoods or helmets.

d. Department of the Army. 2/26/97. *The Army Chemical Agent Safety Program*. Army Regulation 385-61. Department of the Army, Washington, D.C. The IDLH values are used solely for the purpose of establishing the concentrations at which SCBA or supplied-air respirators are required. (Author's note: The only "supplied air respirators" acceptable for IDLH exposures are combination SCBA/airline respirators).

e. Diethyl methylphosphonate (DMMP) is commonly used as a surrogate test agent for nerve agents.

f. Author's note: The United States Army recommends the use of a supplied air respirator due to the carcinogenic properties of mustard agents. The only "supplied air respirators" equivalent to SCBAs are combination SCBA/airline respirators. Standard respirator decision logic does not require either of these devices for carcinogens. Any effective respirator, e.g., NIOSH-approved for organic vapors, may be used up to the true IDLH value or maximum use concentration for that respirator, whichever is lower.

Electrostatic Filter Performance

(continued from page 5)

Airflow (i.e., work rate) is much lower than that used by NIOSH in the certification tests. In his studies, Brown concluded, “A worst possible case, as far as loss of electric charge is concerned, would result in the electrical deposition becoming negligible. Although it is possible to achieve this condition by very aggressive laboratory tests, nothing approaching it is likely to happen in practice.”⁶

Finally, a number of workplace protection factor (WPF) studies have been performed on half-facepiece respirators with dust/mist, dust/mist/fume and N95 electret filters under actual use conditions. These studies have consistently found average WPFs well above 100. These WPF studies provide additional evidence that filter efficiency in the workplace has been and will continue to be adequate.

“Static Guard” is a trademark of Alberto Culver Company.

References

1. Martin, S. B. and E. S. Moyer: Electrostatic Respirator Filter Media: Filter Efficiency and Most Penetrating Particle Size Effects. *Appl. Occup. Env. Hyg.* 15(8): 609-617 (2000).
2. Moyer, E. S. and M. S. Bergman: Electrostatic Filter Media Efficiency Degradation Resulting from Intermittent Sodium Chloride Aerosol Exposure. *Appl. Occup. Env. Hyg.* 15(8):600-608 (2000).
3. Chen, C. C., M. Lethimäki and K. Willeke: Loading and Filtration Characteristics of Filtering Facepieces. *Am. Ind. Hyg. J.* 54(2):51-60 (1993).
4. “Respiratory Protective Devices; Final Rules and Notice,” *Federal Register* 60:110 (8 June 1995) pp. 30336-30404.
5. Brown, R.C., D. Wake, R. Gray, D.B. Blackford, and G.J. Bostock: Effect of Industrial Aerosols on the Performance of Electrically Charged Filter Material. *Ann. Occ. Hygiene*, 32(3):271 (1988).
6. Brown, R.C.: Modern Concepts of Air Filtration Applied to Dust Respirators. *Ann. Occ. Hygiene* 33(4):615-644. (1989).

3M OH&ESD offers respiratory protection training courses

Since 1995, 3M has offered two professional development courses that provide valuable information to individuals involved in respiratory protection programs. The courses are based on the technical and regulatory aspects of a sound respirator program and emphasize important practical issues including selection principles, cartridge change schedules and testing of breathing air quality. A large equipment display from a number of respirator manufacturers is used to supplement the classroom and workshop presentations. Both courses carry continuing education units (CEUs), American Board of Industrial Hygiene Certification Maintenance points and other professional development credits.

Respiratory Protection is a comprehensive 4-1/2 day course intended for anyone who manages all or part of a respiratory protection program. All respirator types and each element of a respirator program are thoroughly discussed. Workshop sessions are used extensively to reinforce the course material.

Current Topics in Respiratory Protection is a two-day course designed to provide the latest in technical and regulatory information to experienced program managers.

The 2001 schedule of course locations and dates is listed here. To find out more about these courses, please do one of the following:

- Contact your 3M Sales Representative;
- Phone 1-800-659-0151, ext. 275;
- Visit our web site at www.3M.com/occsafety;
- Dial the 3M Fax On Demand system at 1-800-646-1655.

Respiratory Protection	
Dates	Location
April 2-6	Phoenix, AZ
July 16-20	Minneapolis, MN
September 10-14	Portland, OR
October 15-19	Charleston, SC

Current Topics in Respiratory Protection	
Dates	Location
July 23-24.....	Minneapolis, MN

3M Occupational Health and Environmental Safety Division

3M Center, Building 235-2W-70
St. Paul, MN 55144-1000