

Division des produits d'hygiène industrielle et de sécurité environnementale

Cartouches de respirateur contre les produits chimiques

ASSTSAS 2010, Québec



3M : synonyme de santé et sécurité



Expertise technique
et réglementation



Protection
respiratoire



Protection
des yeux



Vêtements de
protection



Protection
de l'ouïe



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3M

Centre de service technique de la Compagnie 🇨🇦 Canada

1 800 267-4414

Internet : www.3m.ca/safety/fr

Service à la clientèle de 3M : 1 800 410-6880

Renseignements sur les autres produits : 1 800 364-3577

Tous les renseignements techniques, ainsi que toutes les déclarations et recommandations contenus aux présentes sont fondés sur des données que nous jugeons dignes de confiance, mais dont l'exactitude ou l'exhaustivité n'est pas garantie. 3M ne saurait être tenue responsable des pertes ou dommages directs, indirects, spéciaux, fortuits ou conséquents découlant de la vente, de l'utilisation ou de la mauvaise utilisation des produits de la Division des produits d'hygiène industrielle et de sécurité environnementale de 3M, ou de l'incapacité de l'utilisateur à s'en servir.



Ordre du jour



- Aperçu des dangers respiratoires
- Particules et filtres
- Gaz, vapeurs et cartouches
- Types de respirateurs
- Fonctionnement des cartouches
- Différents types de cartouches
- Quand doit-on remplacer les cartouches?
- Restrictions



Aperçu des dangers respiratoires

Gaz et vapeurs



Déficiences en oxygène
DIVS

Particules dangereuses

- Poussières
- Brouillards
- Fumées
- Fibres
- Aérosols organiques



Particules dangereuses



■ Poussières

- *Se présentent au départ sous la forme de matières solides qui sont réduites en des particules de plus petite taille par le perçage, l'écrasement ou le meulage.*
- *Plus la taille des particules de poussière est petite, plus leur durée de suspension dans l'air est élevée, ce qui en facilite l'inhalation.*

■ Brouillards

- *Il s'agit de minuscules gouttelettes qui sont habituellement produites pendant la pulvérisation.*
- *De nombreux brouillards sont constitués de plusieurs ingrédients dangereux.*

■ Fumées

- *Se forment lorsque des métaux sont chauffés jusqu'à ce qu'ils soient vaporisés pour être ensuite rapidement refroidis.*
- *Cela donne naissance à de très fines particules solides qui flottent dans l'air.*

■ Fibres

- *Il s'agit de particules dont la longueur est au moins trois fois supérieure à la largeur (p. ex., amiante).*

■ Aérosols organiques

- *Il s'agit de particules en suspension dans l'air qui sont vivantes ou qui proviennent d'organismes vivants. Elles comprennent les micro-organismes et les fragments de micro-organismes, les toxines et les déchets particuliers provenant d'organismes vivants de tous genres.*
- *Exemples : Tuberculose, varicelle-zona, SRAS et grippe (lorsqu'ils sont aérogènes)*

Peuvent être
captées
avec un
filtre



Aperçu théorique des filtres



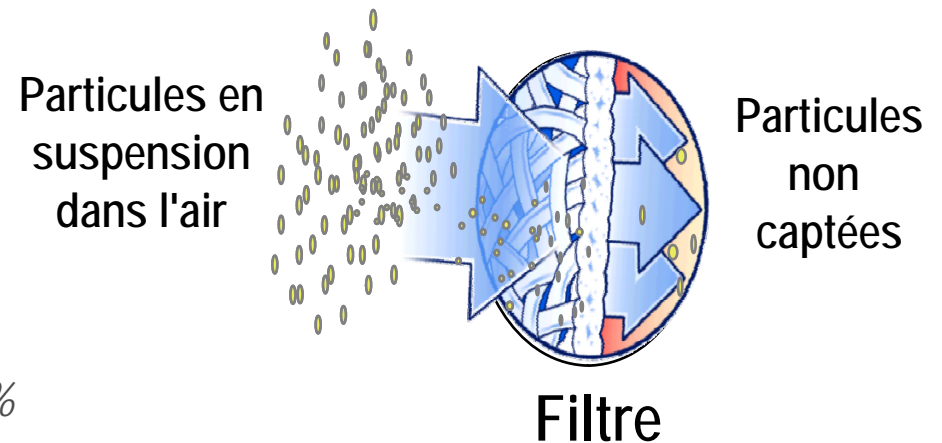
- Les filtres constituent des structures ouvertes d'une profondeur limitée composées de petites fibres orientées aléatoirement. Ils recueillent les particules dans toute leur profondeur.

- Mécanismes

- *Sédimentation par gravité* : $> 100 \mu\text{m}$
- *Impaction inertielle et interception* : $> 0,6 \mu\text{m}$
- *Diffusion* : $< 0,1 \mu\text{m}$
- *Attraction électrostatique*

- Classification

- *N/R/P*
- *Efficacités de filtrage* : 95, 99 et 100 %



Masque chirurgical



- Dispositif de prévention des infections conçu pour éviter que l'infection dont est victime l'utilisateur ne soit transmise depuis l'air expiré par celui-ci aux personnes potentiellement vulnérables.
- Peut permettre de réduire la contamination du milieu en bloquant les grosses gouttelettes expirées par l'utilisateur.
- L'emploi de masques chirurgicaux pour réduire l'exposition aux particules inhalables en suspension dans l'air est déconseillé.

Respirateur chirurgical

- Certains respirateurs homologués peuvent présenter les mêmes caractéristiques qu'un masque chirurgical.
- Respirateur homologué par le **NIOSH** et autorisé par la FDA pour l'emploi à titre de masque chirurgical.
- Les respirateurs homologués par le NIOSH :
 - *bloquent les grosses gouttelettes expirées par l'utilisateur;*
 - *sont conçus pour réduire l'exposition de l'utilisateur aux particules inhalables en suspension dans l'air.*



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Gaz et vapeurs



■ Gaz

- *Les gaz sont des substances qui ne sont ni liquides ni solides à la température et à la pression ambiantes.*
- *Certains gaz s'éloignent rapidement de leur source, souvent sans être détectés.*

■ Vapeurs

- *Les vapeurs sont des substances qui s'évaporent de liquides ou de solides.*
- *Elles peuvent s'éloigner rapidement de leur source, souvent sans être détectées.*

■ Gaz et vapeurs – Exemples

- *Gaz anesthésiques*
- *Formaldéhyde*
- *Glutaraldéhyde*
- *Alcool éthylique*

Peuvent être
captés
avec une
cartouche



Types de respirateurs



- Respirateurs d'épuration d'air
 - *Respirateurs à pression négative*
 - À ajustement serré seulement
 - Respirateurs à masque filtrant ou en élastomère
 - *Respirateurs d'épuration d'air propulsé*
 - À ajustement lâche ou serré
- Sont utilisés avec des cartouches/filtres pour éliminer les contaminants en suspension dans l'air.



Remarque : Si l'on travaille en présence de produits chimiques qui irritent les yeux, il faut choisir un respirateur qui protège également les yeux et le visage.



Types de respirateurs



- Respirateurs à adduction d'air
 - À *pression positive seulement*
 - *Sont reliés*
 - à un compresseur
 - à une pompe
 - ou à un APRA à l'aide d'un tuyau d'air comprimé.
 - À *ajustement lâche ou serré*

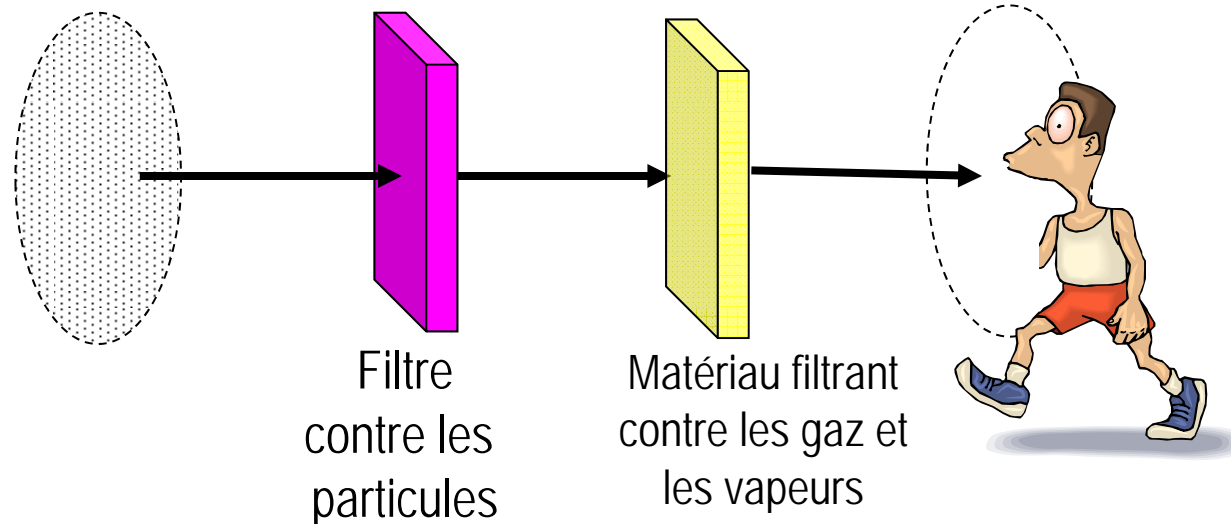


Remarque : Si l'on travaille en présence de produits chimiques qui irritent les yeux, il faut choisir un respirateur qui protège également les yeux et le visage.



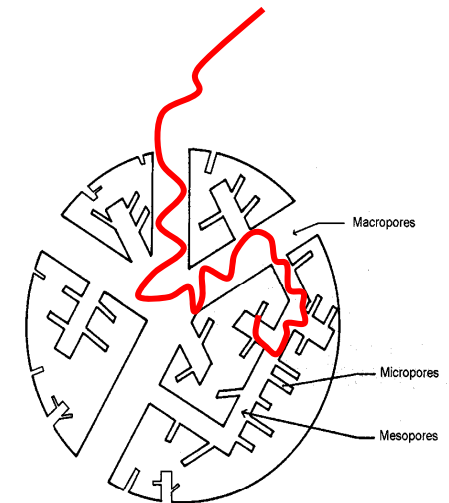
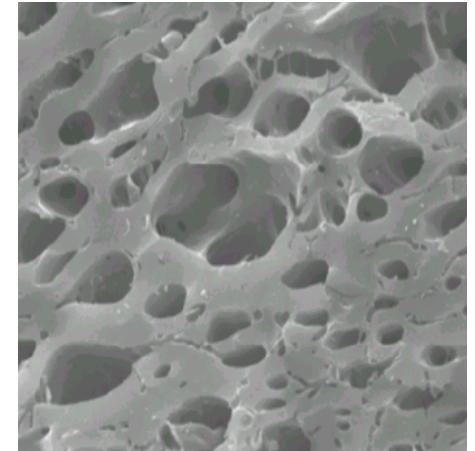
Respirateur d'épuration d'air à pression négative

- L'air ambiant passe dans un filtre ou une cartouche qui emprisonne les contaminants. L'air propre est ensuite acheminé dans le respirateur et les poumons.
- Le succès de ce type de respirateur dépend de l'étanchéité du joint formé entre le masque et le visage de l'utilisateur (des essais d'ajustement sont donc obligatoires).



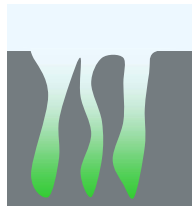
Fonctionnement des cartouches

- On active d'abord le charbon en le chauffant dans une atmosphère inerte.
- Le processus d'activation forme un vaste réseau de pores et augmente la surface interne du matériau.
- On peut également traiter le matériau carboné à l'aide de produits chimiques afin d'assurer une élimination accrue des gaz adsorbés de manière inadéquate.
- Les gaz et les vapeurs se fixent à la surface du charbon activé.
- Le charbon activé utilisé dans les respirateurs provient, le plus souvent, de la houille et des noix de coco.
- Ne sert pas à filtrer les particules!



Charbon actif

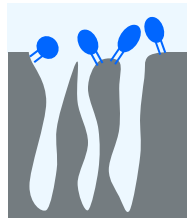
Voici ces trois mécanismes de fonctionnement



Adsorption physique

- Des molécules de vapeur sont adsorbées dans la structure poreuse du matériau carboné.
- Ces molécules sont retenues par des forces électrostatiques.
- L'humidité influe sur le résultat dans certains cas

Composés organiques

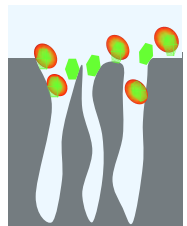


Adsorption chimique / chimisorption

- Consiste à établir une liaison chimique entre un gaz et la surface du matériau carboné.

Fluorure d'hydrogène

Ozone



Réaction chimique

- Le matériau carboné est imprégné de produits chimiques afin d'assurer une élimination accrue des gaz adsorbés de manière inadéquate.

Ammoniac, chlore,
dioxyde de soufre et
cyanure d'hydrogène



Différents types de cartouches



	Cartouches contre les vapeurs organiques	À utiliser contre certaines vapeurs organiques.
	Cartouches contre les gaz acides	À utiliser contre le chlore, le chlorure d'hydrogène, le dioxyde de soufre, le dioxyde de chlore et le sulfure d'hydrogène.
	Cartouches contre les vapeurs organiques et les gaz acides	À utiliser contre certaines vapeurs organiques et contre le chlore, le chlorure d'hydrogène, le dioxyde de soufre, le dioxyde de chlore, le sulfure d'hydrogène et le fluorure d'hydrogène.
	Cartouches contre l'ammoniac et la méthylamine	À utiliser contre l'ammoniac et la méthylamine.
	Cartouches contre le formaldéhyde	À utiliser contre le formaldéhyde et certaines vapeurs organiques.
	Cartouches contre le mercure	À utiliser contre les vapeurs de mercure ou le chlore.
	Cartouches contre les gaz multiples	À utiliser contre certaines vapeurs organiques et contre le chlore, le chlorure d'hydrogène, le dioxyde de soufre, le dioxyde de chlore, le sulfure d'hydrogène et le fluorure d'hydrogène, l'ammoniac et la méthylamine et le formaldéhyde.

Facteurs affectant la durée utile d'une cartouche



- Type de cartouche
- Concentration du contaminant
- Présence d'autres contaminants et de mélanges
 - *Les différentes molécules « luttent » entre elles pour accéder aux zones actives.*
 - *Les molécules des composés organiques peu volatils peuvent déplacer les molécules des composés organiques plus volatils.*
- Humidité
 - *L'eau remplit en partie les pores du charbon.*
 - *↓ de la capacité en présence de composés organiques*
 - *↑ de la réactivité en présence de composés inorganiques*
- Température
 - *La durée utile de la cartouche ↓ lorsque la température ↑.*
- Fréquence respiratoire et débit d'air



Quand doit-on remplacer les cartouches?

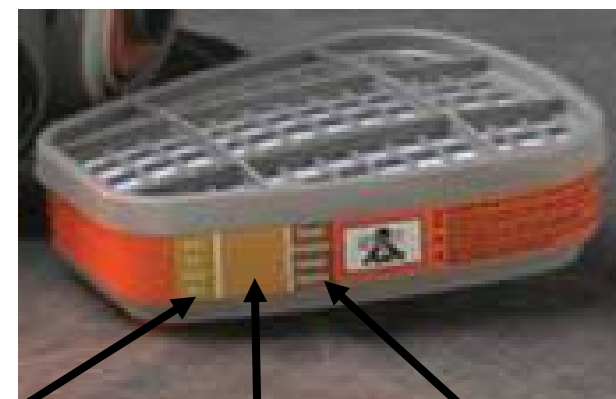


- Une personne qualifiée doit établir le calendrier de changement des cartouches.
- Le changement peut s'effectuer selon les critères suivants :
 1. *indicateur de fin de durée utile (IFDU);*
 2. *bonnes propriétés de détection (odeur, irritation, goût);*
 3. *migration chimique;*
 4. *calcul de la durée maximale d'utilisation (consulter le bulletin technique n° 186 de 3M);*
 5. *inspection matérielle (p. ex., remplacement des cartouches en cas de dommages physiques).*



Indicateurs de fin de durée utile

- Les cartouches contre les vapeurs de mercure 6009 et 60929 3M^{MC} sont dotées d'un indicateur de fin de durée utile 3M^{MC} (IFDU) passif.
- Cet indicateur à changement de couleur doit être facilement visible par celui qui porte le respirateur, sans aucune manipulation.
- Les cartouches contre les vapeurs de mercure doivent être mises au rebut :
 - *lorsque l'IFDU prend la couleur de mise au rebut indiquée sur l'étiquette;*
 - *30 jours après l'ouverture de l'emballage;*
 - *lorsque l'IFDU devient sale ou endommagé;*
 - *lorsqu'on commence à percevoir l'odeur des vapeurs ou des gaz. Les vapeurs de mercure sont inodores.*



Couleur
initiale

Indicateur
de changement
de couleur

Couleur
de mise
au rebut



Propriétés de détection



- Le calendrier de changement peut être établi en fonction des bonnes propriétés de détection associées à la substance.
 - *Odeur*
 - *Irritation*
 - *Goût*
- Bonnes propriétés de détection : Une irritation, une odeur ou un goût peuvent être détectés à des concentrations bien inférieures à la limite d'exposition en milieu de travail (OEL).
- Seuil olfactif : Il s'agit de la concentration la plus faible à laquelle un produit chimique peut être détecté par l'odorat.
- Au Québec, les respirateurs à adduction d'air doivent être utilisés pour les produits chimiques qui ne présentent pas de bonnes propriétés de détection.

Nom chimique	Seuil olfactif	OEL	Propriétés de détection
Isoflurane	Non déterminé	Non déterminée	Mauvaises
Alcool isopropylique	40 à 200 ppm	400 ppm	Bonnes
Formaldéhyde	0,027 à 1,9 ppm	0,3 ppm (C)	Mauvaises
Monoxyde de carbone	100 000 ppm	35 ppm	Mauvaises



Migration chimique



- Tout contaminant peut migrer dans une cartouche contre les vapeurs organiques si on lui laisse suffisamment de temps (consulter le bulletin technique n° 142 de 3M).
- C'est particulièrement le cas des composés plus volatils (point d'ébullition < 65 °C; p. ex., gaz anesthésiques).
 - *Point d'ébullition de l'isoflurane (à 1 atm) : 48,5 °C*
- Les composés qui sont liés par chimisorption ne sont pas susceptibles de migrer (p. ex., fluorure d'hydrogène et ozone).
- Généralement, en ce qui a trait à la mise au rebut en présence d'un risque de migration, mettre la cartouche au rebut conformément au résultat du calcul suivant :

Durée d'utilisation + durée d'entreposage = durée utile



Calcul de la durée maximale d'utilisation



- Essais en laboratoire
- Essais en milieu de travail
 - *Tiennent compte de divers produits chimiques et conditions environnementales.*
- Estimations effectuées à partir de données associées à des produits chimiques qui présentent une structure chimique similaire.
- Emploi de logiciels faisant appel à des modèles mathématiques



Logiciel de durée utile 3M – Renseignements requis



- Nom du contaminant
- Concentration du contaminant
- Limite d'exposition
- Cartouche utilisée
- Conditions du milieu de travail (HR et pression atmosphérique)
- Intensité du travail
- Facteur de correction pour les composés (au besoin)
- Choix du niveau de pénétration
- Si le contaminant a été choisi par l'utilisateur, indiquer les renseignements ci-dessous.
 - *Poids moléculaire*
 - *Indice de réfraction*
 - *Densité en phase liquide*
 - *Tension maximale de vapeur*



Logiciel de durée utile 3M – Démonstration

- Logiciel de durée utile 3M : <http://csr.v.3m.com/csr.v/>

User Contaminant

Contaminant: Standard User

Enter contaminant information below. Only Organic Vapors may be entered.

Name:	<input type="text" value="Isoflurane"/>
CAS Number:	<input type="text" value="26675-46-7"/>
Exposure Limit:	<input type="text" value="2"/> <input type="text" value="ppm"/>
Molecular Weight:	<input type="text" value="184.5"/>
Index of Refraction:	<input type="text" value="1.3002"/>
IDLH:	<input type="text"/>
Liquid Density:	<input type="text" value="1.496"/>
Saturated Vapor Pressure:	<input type="text" value="238"/> at Temp: <input type="text" value="20"/> <input type="text" value="C"/>
Exposure:	<input type="text" value="2"/> <input type="text" value="ppm"/>

← Limite d'exposition recommandée par le NIOSH
2 ppm pour les gaz anesthésiques volatils

Next Step ->




Logiciel de durée utile 3M – Démonstration

Cartridge Selection

Select a cartridge:

- [5201] Organic Vapor Respirator (Medium)
- [5203] Organic Vapor/Acid Gas Respirator (Medium)
- [5206] Multi Gas & Vapor Respirator (Medium)
- [5301] Organic Vapor Respirator (Large)
- [5303] Organic Vapor/Acid Gas Respirator (Large)
- [5306] Multi Gas & Vapor Respirator (Large)
- [6001] Organic Vapor Cartridge**
- [6003] Organic Vapor/Acid Gas Cartridge
- [6006] Multi Gas & Vapor Cartridge
- [60921] Organic Vapor/P100 Cartridge

 Add cartridge

Selected cartridge:

[6001] Organic Vapor Cartridge



Logiciel de durée utile 3M – Démonstration



Environment Information

Contaminant	Exposure	Units	Correction Factor
i Isoflurane	2	ppm	1

Relative Humidity:

Atmospheric Pressure (ATM):

Note: Acceptable range of atmospheric pressure is 0.8 to 1.2 ATM.

Temperature: The valid temperature range for this mixture is 20.0 - 20.0C or 68.0 - 68.0F.

Note: Select the temperature that is closest to your operating temperature.

Work Rate:

Light Work
 Medium Work
 Heavy Work

Ou le débit si l'on emploie un respirateur d'épuration d'air propulsé

Breakthrough Level:

1/2 Occupational Exposure Limit (TLV, PEL or WEEL)
 .1 x Exposure

Choix du niveau de pénétration

- À la limite réglementaire (TLV, PEL)
- À la moitié de la limite réglementaire
- À 10 % du niveau appliqué si ce dernier est inférieur à la limite réglementaire.



Logiciel de durée utile 3M – Démonstration



- On peut entrer des facteurs de correction pour tenir compte de ce qui suit. On peut entrer un facteur de correction distinct pour chaque contaminant choisi.
- Précision des concentrations en milieu de travail estimées – utiliser la concentration la plus élevée prévue.
- Mélanges – Dans la plupart des cas, les concentrations des vapeurs organiques sont additionnées et le mélange est traité en se fondant sur le composant présentant le temps de pénétration le plus court.
- HR > 65 % : Peut avoir une très grande incidence sur la durée utile des cartouches contre les vapeurs organiques. Ce logiciel ne tient pas compte des taux d'humidité relative supérieurs à 65 %. L'utilisateur peut toutefois entrer le facteur de correction de son choix afin que cette incertitude soit prise en compte. Les estimations de la durée utile à l'égard des gaz acides, de l'ammoniac, de la méthylamine et du formaldéhyde sont toutefois fondées sur des essais réalisés à une humidité relative de 50 %. À une faible humidité relative, la durée utile réelle à l'égard de ces substances peut être inférieure à l'estimation fournie par le logiciel. Le fait que l'humidité relative soit supérieure à 50 % peut accroître la durée utile à l'égard de ces produits chimiques.
- Bonnes propriétés de détection des contaminants : Les vapeurs organiques qui présentent de mauvaises propriétés de détection peuvent nécessiter l'emploi d'un facteur de sécurité plus élevé que les vapeurs organiques qui présentent de bonnes propriétés de détection, car ces propriétés peuvent être utilisées comme solution secondaire ou de rechange pour déterminer si la cartouche a besoin d'être remplacée.



Logiciel de durée utile 3M – Démonstration

Durée utile estimée : 191 heures

Notice!

Service life calculation based on Isoflurane at an Exposure = 2.0 ppm

Contaminants and Exposures

Isoflurane

CAS#: 26675-46-7

Exposure: 2 ppm

Correction Factor: 1

Exposure Limit: 2 ppm

Molecular Weight: 184.5

Index of Refraction: 1.3002

IDLH: 99999 ppm

Liquid Density: 1.496

Saturated Vapor Pressure: 238 at 20 C

Cartridge Selection

[6001] Organic Vapor Cartridge

Environment Information

Relative Humidity: <65%

Atmospheric Pressure (ATM): 1.0

Temperature: 20.0 C

Work Rate: Light Work

Niveau de pénétration : 0,1 x exposition

<- Previous Step

Text Version



- Effets de la migration : Mettre la cartouche au rebut conformément au résultat du calcul suivant :
 - *Durée d'utilisation + durée d'entreposage = durée utile*
 - *191 h + 24 h = environ 8 jours*

Remplacer la cartouche environ tous les 8 jours.



S'informer des exigences particulières prévues par les lois américaines (p. ex., les exigences concernant le formaldéhyde).

3M

Logiciel et mélanges

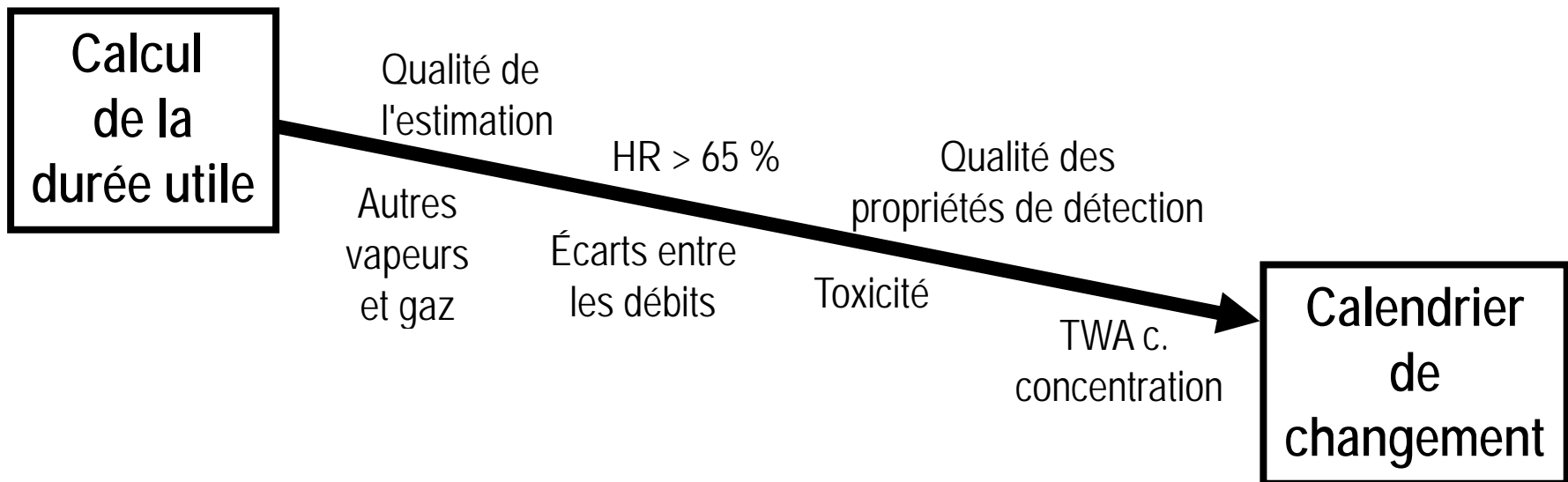


- OSHA : Si les temps de pénétration sont séparés d'au plus un ordre de grandeur, additionner les concentrations et supposer que le mélange agit comme le contaminant qui présente le temps de pénétration le plus court.
- Exemple
 - *Un mélange est composé de 100 ppm d'acétone, de 100 ppm d'acétate de butyle et de 100 ppm de toluène.*
 - *L'acétone présente le temps de pénétration le plus court.*
 - *L'estimation de la durée utile est effectuée conformément à une concentration de 300 ppm (100 + 100 + 100 ppm).*
 - *La durée utile pour 300 ppm d'acétone se chiffre donc à 416 minutes.*
- Fournit une estimation prudente.

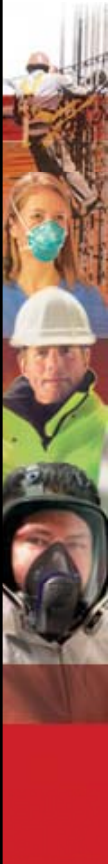


Durée utile \neq Calendrier de changement utilisé en milieu de travail

- Les calendriers de changement doivent être raisonnables, pratiques et faciles à mémoriser.



Restrictions concernant les respirateurs d'épuration d'air



- Ne pas excéder les concentrations d'utilisation maximales (FPC).
- Ne pas utiliser lorsque l'atmosphère présente un DIVS.
- La concentration d'oxygène doit être d'au moins 19,5 %.
- Ne conviennent pas à tous les gaz et à toutes les vapeurs (oxyde d'éthylène).
- N, R, P
- Propriétés de détection
- Calcul de la durée utile
- Pilosité faciale, lunettes de protection
- Essai d'ajustement pour les masques à ajustement serré
- Résistance à l'inhalation
- Peuvent ne pas protéger contre l'irritation oculaire ou cutanée ni contre l'absorption de produits chimiques.



Des questions?



Détermination de la durée utile des cartouches – Données d'essai du NIOSH



Contaminant		Concentration d'essai	Concentration de pénétration	Durée utile minimale
Ammoniac/méthylamine		1 000 ppm	50 ppm	50 minutes
Formaldéhyde		100 ppm	1 ppm	50 minutes
Fluorure d'hydrogène		70 ppm	3 ppm	30 minutes
Vapeurs organiques (CCl ₄)		1 000 ppm	5 ppm	50 minutes
Gaz acides	Dioxyde de soufre (SO ₂)	500 ppm	5 ppm	30 minutes
	Chlore	500 ppm	5 ppm	35 minutes
	Chlorure d'hydrogène	500 ppm	5 ppm	50 minutes

Dans bien des cas, la durée utile minimale des cartouches combinées (p. ex., cartouches contre les VO et les GA) diminue.



Centre de service technique de la Compagnie

Canada

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Technical Data Bulletin

OH&ESD

#142, May 1999

Reuse of Organic Vapor Chemical Cartridges

Introduction

One of the most significant changes in the Occupational Safety and Health Administration's (OSHA's) new 1910.134 respiratory protection standard is the requirement to establish change schedules for chemical cartridges used for gases and vapors. Change schedules are often based on service life measurements or estimates. To best use the service life information, it is necessary to understand how chemical cartridges work. It is especially important when organic vapor cartridges are used against volatile chemicals during more than one work shift. These chemicals may desorb from the carbon when not in use. Inappropriate reuse of the organic vapor cartridges can result in breakthrough occurring earlier than predicted by the service life estimate. For example, when the organic vapor cartridge has been used for chemicals that migrate through the cartridge during the storage or nonuse period, it should not be reused. The decision to reuse the cartridge may have an impact on worker protection and the respiratory protection program

Background

Chemical cartridges are used on respirators to help remove and lower worker exposures to harmful gases and vapors in the workplace. There are several types of chemical cartridges: organic vapor, ammonia, formaldehyde, mercury vapor and acid gases, such as hydrogen chloride, chlorine and sulfur dioxide.

It is important to understand how the different cartridge types work. All chemical cartridges consist of a container filled with a *sorbent*. A chemical cartridge *sorbent* is a granular porous material that interacts with the gas or vapor molecule to remove it from the air. Typically this sorbent is *activated carbon* or activated charcoal. *Activated carbon* is an amorphous form of carbon characterized by high adsorptivity for many gases and vapors.

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The carbon is obtained by destructive distillation of wood, nutshells, animal bones or other carbonaceous material. Activated carbon for respirators usually comes from coconut shells or coal. It is ‘activated’ by heating to 800-900°C with heat or steam, which results in a porous internal structure (honeycomb-like). The internal surface area of activated carbon averages 10,000 square feet per gram. This large surface area makes activated carbon ideal for removal of organic vapors by *adsorption*. *Adsorption* is the adherence of gas or vapor molecules to the surface of the activated carbon. The attractive force between the activated carbon and the chemical molecule is a relatively small, weak physical force. The strength of the attraction depends in part on the chemical. Since only weak physical forces are involved, the process can be reversed. This is called *desorption*. Desorption is the process of an adsorbed material “letting go” from the activated carbon. Desorption can occur naturally during periods of nonuse or by the presence of another more strongly adsorbed substance displacing a less strongly adsorbed chemical (*i.e.*, a more volatile chemical). Generally, the more volatile the chemical the less strongly adsorbed, or the more likely it will undergo desorption. Desorption during storage or nonuse times can result in chemical *migration*. *Migration* is the movement of a previously adsorbed chemical through the chemical cartridge, even without air movement. Variables that appear to impact migration include:

- Volatility – the more volatile the chemicals, the greater the concern for migration;
- Water vapor coadsorption – coadsorption [from use in atmospheres with high relative humidity (>50%)] can increase the migration effect;
- Amount of material adsorbed onto the cartridge in the first use;
- Storage time; and
- Vapor type.¹

The potentials for desorption and migration makes reuse of organic vapor cartridges a concern.

Not only are the more volatile chemicals more likely to desorb but the capacity of the carbon is generally lower for these chemicals. This includes many inorganic gases and organic vapors. Inorganic gas desorption is prevented by the use of special cartridges. For organic vapors Europe uses a boiling point of less than 65°C as a guideline for identifying the more volatile chemicals.² These chemicals are often classified as low boiling chemicals. Typical organic vapor cartridges would be expected to have lower capacity for these materials and desorption could be a major concern.

To make the cartridges more selective for certain chemicals, sorbents can be impregnated with chemical reagents. Impregnated activated carbon removes specific gas and vapor molecules by *chemisorption*. *Chemisorption* is the formation of bonds between molecules of the impregnant and the chemical contaminant. These bonds are much stronger than the attractive forces of physical adsorption. The binding is usually irreversible. Reuse of chemical cartridges that work on the principle of chemisorption typically should not be a problem. Table 1 shows the types of chemical cartridges and the mechanism used for removal of the gas or vapor.

Table 1. Chemical Cartridge Types and Removal Mechanisms

Chemical Cartridge Type	Removal Mechanism	Examples of Impregnant
Organic Vapors	Adsorption	N. A.
Ammonia/Methylamine	Chemisorption	Nickel chloride, Cobalt salts, copper salts, Acids
Acid Gases	Chemisorption	Carbonate salts, Phosphate salts, Potassium hydroxide, copper oxide
Formaldehyde	Chemisorption	Copper oxide + metal sulfates, Salts of sulfamic acids
Mercury Vapor	Chemisorption	Iodine, Sulfur
Hydrogen Fluoride	Chemisorption	Carbonate salts, Phosphate salts, Potassium hydroxide, copper oxide

This table indicates organic vapor chemical cartridges are the ones for which desorption and migration are the biggest concern. In combination chemical cartridges, such as organic vapors and acid gases, the organic vapors are predominantly removed by adsorption.

Desorption/Migration

Caution needs to be exercised in establishing a change schedule with reuse of organic vapor cartridges used for:

- Volatile chemicals that are likely to desorb during non-use;
- Two or more different chemicals adsorbed sequentially and the subsequent chemical is more strongly adsorbed.

Reuse for volatile chemicals

After use of a chemical cartridge the vapor is collected on the first layers of carbon in the cartridge. During the period of nonuse, the chemical, depending upon its volatility and other conditions, may desorb and redistribute itself from the areas of high concentration to areas of lower concentration, *i.e.*, the back layers of carbon where no vapor has been collected. Eventually the chemical will reach the back of the cartridge. When it desorbs from the back of the cartridge it goes into the air. This can result in the worker breathing the chemical vapor when they first put on the respirator (and potentially for some time afterwards) without wearing it in the contaminated area.³

Reuse in a different environment

Less volatile chemicals can cause desorption and early breakthrough of the poorly adsorbed, more volatile chemicals. For example, a maintenance worker wears a respirator for exposure to chemical A. The use period is shorter than the service life for

chemical A so no breakthrough occurs. The next day the worker goes to a different area with exposure to a different organic chemical, chemical B. Chemical B is less volatile than chemical A. Since the service life was not used up with chemical A, the organic vapor cartridges are reused. Before chemical B breaks through, it displaces the more volatile chemical A. If the change schedule does not consider this effect, chemical A may break through and the worker is exposed to chemical A. Laboratory studies have shown that a more strongly adsorbed chemical can displace a relatively weakly adsorbed chemical.⁴ This may result in a breakthrough concentration that exceeds the concentration in the air. While this work has been with mixtures, the same effect is very likely to occur from sequential exposures to two chemicals. For a maintenance worker, a compliance officer, or someone else that may use an organic vapor respirator in different environments, reuse may not be appropriate under any situation.

3M Service Life Software

The 3M Service Life Software uses a method developed by Wood for determining service life for organic vapor cartridges by modeling the adsorption capacity and rate of adsorption of organic vapors from organic liquids.⁵ The service life estimate is the time the cartridge would last until the selected breakthrough point is reached. For organic vapors it is the time cartridges would be expected to last with one continuous use. In other words, a service life estimate of 16 hours means it would last 16 hours if used continuously under the conditions of the estimate. It does not mean necessarily that it will last two 8-hour shifts when stored overnight. For nonvolatile chemicals 3M studies indicate service life is very close to the estimate even with periods of nonuse. This is not true for the more volatile chemicals.

The 3M Service Life Software uses boiling points less than 65°C to identify the highly volatile chemicals. Many of the service life estimates for the more volatile chemicals will be short due to the lower capacity of the carbon for these chemicals. Some, however, may be longer than 8 hours. When a service life estimate is made for a low boiling chemical that is longer than 8 hours, a warning is shown that advises that the chemical cartridge be disposed of after the shift. These chemicals are likely to desorb and migrate throughout the cartridge during short periods (few hours to overnight) of non-use. However, the boiling point of 65°C is not a fine line between chemicals that desorb and those that do not. The boiling point can be misleading for chemicals (e.g., alcohols) that undergo hydrogen bonding. The hydrogen bonding results in a higher boiling point than would be expected based on molecular weight. Chemicals with higher boiling points can still desorb and migrate; it may take a little longer for it to occur. Experiments with ethyl acetate (BP = 77°C) have shown significant desorption after 63 hours of storage (non-use).¹ So for this chemical, reuse after a short nonuse period may be okay, but reuse after a weekend probably should not be attempted.

Change-out Schedule Recommendations

Unfortunately, there has not been much information published for evaluating the effect of desorption or migration on cartridge service life. The two safest approaches when the service life estimate is longer than the use period are:

- Never reuse an organic vapor chemical cartridge; dispose of it after the period/shift in which it is used.
- Conduct desorption studies in a laboratory mimicking the conditions of use/reuse at your work site. Use these data when establishing the change schedule.

The ANSI Z88.2-1992 standard recommends desorption studies unless cartridges are changed daily.⁶

OSHA states in its compliance directive that where contaminant migration is possible (chemicals with boiling points below 65°C), respirator cartridges should be changed after every work shift where exposure occurs.⁷ If the employer has specific objective data (desorption studies) showing the performance of the cartridge under the conditions and schedule of use/nonuse found in the workplace, daily change would not be required.

Using 65°C as the indicator for migration does not take into account those materials that may migrate after slightly longer periods of nonuse. Another possibility is to establish guidelines for reuse based on the volatility of the chemical. Three or four levels of volatility could be established. Different periods of nonuse would be acceptable for highly volatile chemicals, moderately volatile chemicals and low volatility chemicals. No guidelines are presently available to say what boiling points, or other indicator of volatility, should be used as the cutoff between moderate and low volatility. As the volatility increases, the reuse of cartridges for organic vapors should be restricted.

- Cartridges used for organic chemicals that are very volatile should never be reused. For example chemicals with boiling points less than 65°C should never be used for more than one shift.
- Cartridges used for chemicals of moderate volatility should never be reused after periods of nonuse of a few days. For example, never reuse the cartridge if a cartridge change schedule results in storage over a weekend.
- Cartridges used for chemicals of low volatility should never be reused after some longer period of use that is still less than the service life estimate. For example, cartridges used for these types of organic chemicals should never be used longer than one or two weeks.

For mixtures the acceptable nonuse or storage period should probably be based on the most volatile component of the mixture. As more information becomes available in the future, firm recommendations about reuse can be made.

Conclusion

Before setting the change schedule, the volatility of the chemical, the cartridge use/nonuse patterns, and desorption data (if available) should all be evaluated. The prudent practice is to never reuse organic vapor cartridges when the service life estimate is greater than one work shift if desorption data are not available. For organic chemicals that migrate through the cartridge during the storage or nonuse period, the organic vapor cartridge must not be used for more than one shift.

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Respiratory Protection for Airborne Exposures to Biohazards

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Introduction

Recently there has been growing interest in the use of respirators for certain airborne biohazards. Diseases that may be caused by inhalation of airborne biological organisms include tuberculosis (TB), Hantavirus, anthrax, sudden acute respiratory syndrome (SARS) and influenza. Biohazards may become airborne; perhaps as the agent itself such as an anthrax spore, the agent riding on some other material that becomes airborne such as dusts, mists or droplet nuclei. Hantavirus infection has been caused by people inhaling soil dust that became airborne after rodents shed virus via urine, feces or other materials into the soil. In fact, it is generally thought that airborne viruses are normally attached to other particles and rarely exist as naked organisms. ⁽¹⁾

Inhalation of these bioaerosols may be reduced by wearing respirators. The Centers for Disease Control and Prevention (CDC), the World Health Organization (WHO) and many National Health Authorities have made numerous recommendations for respirator use where they believed the potential for the spread of disease through the airborne route exists. Considerations for selection and use of respirators for exposure to bioaerosols include filtration, microorganism survival on the filter, potential reaerosolization of the bioaerosol, reuse of the respirator, fit and the assigned protection factor of the respirator. These topics are addressed in this bulletin.

Routes of exposure

Inhalation is not the only route of exposure for biohazards. Infection may occur from other routes of exposure such as ingestion, skin and mucous membrane penetration (including the eyes) and animal and insect bites. Skin and mucous membrane penetration may occur by direct contact with aerosols or secondarily; e.g., a hand touching a contaminated surface and then touching a mucous membrane.

How a disease is spread indicates what types of controls are useful in preventing its spread. If the disease can be spread by contact, preventing surfaces from becoming contaminated and hand hygiene will be very important. Surgical masks may be worn by infected people in order to reduce the spread via exhaled aerosols. Surgical masks, safety glasses and face shields may be used to shield the healthcare worker's mucous membranes (eyes, nose, and mouth) from large sprays of blood and other body fluids. Use of respirators may also be appropriate.

Particles ranging from submicron to 100 μm in size can remain airborne. ⁽²⁾ Particles smaller than 100 μm in size can enter the nose, mouth and throat and are considered "inhalable". Particles smaller than 10 μm can reach the large bronchioles and are considered the "thoracic" fraction and particles

smaller than approximately 5 µm can enter the deep lung and are considered the “respirable” fraction. (3) Certain diseases can be spread through the airborne route. This means that if the organism that causes the disease is aerosolized the potential exists for illness. Tuberculosis is one disease that is spread through the airborne route. Evidence has been presented that indicates the airborne route is one of the ways that severe acute respiratory syndrome (SARS) and seasonal influenza can be spread. (4-8) When airborne, viruses and bacteria can be filtered by respirators with particulate filters. Because no respirator will prevent the inhalation of all particles, such as viruses and bacteria, respirators cannot eliminate the risk of exposure, infection and illness. With so many respirator use recommendations being made on websites and other sources, it is important to understand respirators and the role they have in helping to reduce exposures to bioaerosols.

Terminology

Bioaerosols are those airborne particles that are living or originate from living organisms. (9) They include microorganisms and fragments, toxins and particulate waste from all varieties of living things.

A **respirator** is a device designed to help provide the wearer with respiratory protection against inhalation of a hazardous atmosphere. (10) For bioaerosols, particulate removing respirators are often recommended to help reduce exposure. Particulate respirators are available as:

1. a filtering half facepiece respirator where the filter is the entire respirator
2. an elastomeric (reusable) half mask with a particulate filter
3. an elastomeric (reusable) full facemask with a particulate filter
4. a powered air purifying respirator (PAPR) that includes a particulate filter

Particulate respirators are classified by their performance against local certification standards. In the US, testing is done by the National Institute for Occupational Safety and Health (NIOSH). In Europe respirators are tested against the relevant European Standard and are approved as category 3 devices under the PPE Directive 89/686/EEC.

Filtration efficiency is one of the performance parameters evaluated for certification. These tests are designed to be very stringent or “worst case.” Following are some of the minimum filtration requirements according to US and European standards. However, it is often inappropriate to compare results from the different tests as there are many test variables that affect performance such as type of aerosol, particle size, flow rate, whether the aerosol has been charge-neutralized to the Boltzmann equilibrium state, etc.

Standard	Classification	Filter Efficiency
NIOSH 42 CFR 84	95	≥ 95%
NIOSH 42 CFR 84	99	≥ 99%
NIOSH 42 CFR 84	100	≥ 99.97%
EN149:2001	FFP1 (filtering facepiece)	≥ 80%
EN149:2001	FFP2 (filtering facepiece)	≥ 94%
EN149:2001	FFP3 (filtering facepiece)	≥ 98%
EN143:2000 EN140:1999, EN136:1998	P1 (elastomeric facepiece)	≥ 80%
EN143:2000 EN140:1999, EN136:1998	P2 (elastomeric facepiece)	≥ 94%
EN143:2000 EN140:1999, EN136:1998	P3 (elastomeric facepiece)	≥ 99.95%

It should be noted that penetration of particles through the filter is only one of the possible sources of exposure to contaminants. Other potential sources such as face seal leakage, leakage as a result of improper maintenance, or not wearing the respirator when necessary may contribute more to exposure than filter penetration. Each of these factors must be addressed and controlled. For example, all particulate respirators designed to seal to the face (including filtering facepiece respirators) can be fit tested using the saccharin or Bitrex™ qualitative fit test methods. Wearers must be trained how to properly maintain their respirators and the importance of wearing them all of the time during potential exposure.

It is important to recall that respirators help reduce exposure to airborne contaminants but do not prevent the inhalation of all particles. As a result, when properly used and maintained, respirators can lower exposures to concentration considered safe for most non-biological particles. However, they do not eliminate the risk of exposure, infection or illness where biological particles where safe exposure levels have not been established. In many countries, types or classes of respirators are given an “assigned protection factor” or APF. APF is the expected ability of the respirator to reduce exposure when used according to an effective respiratory protection program. For example, an APF of 10 means that a respirator may reduce exposure by a factor of 10 (or 90%) when properly selected, maintained, fitted and worn. Therefore, even if a filter is 100% efficient, the expected amount of exposure reduction would be limited by the APF. Because no respirator will prevent the inhalation of all particles, they cannot eliminate the risk of exposure, infection and illness.

For more information on the proper selection and use of respiratory protection, please see the United States (US) OSHA standard for respiratory protection (29 CFR 1910.134), EN 529 Respiratory protective devices Recommendations for selection, use, care and maintenance — Guidance document ⁽¹¹⁾ or any applicable local standards.

A **surgical mask** is an infection control device designed to help prevent the spread of infection from the wearer’s exhaled breath to potentially susceptible persons. ⁽¹²⁾ A surgical mask may help reduce contamination of the environment by providing a barrier for large droplets expelled by the wearer. However, since surgical masks are not tested the same as respirators any “filtration efficiency” claims can not be directly compared to those for a respirator. ^(13,14) A surgical mask may also be tested to for its ability to reduce exposure of the wearer against fluid splashes. Most surgical masks are not designed to seal tightly to the face and research has shown that they do not achieve the level of contaminant reduction as provided by a NIOSH-approved respirator in laboratory studies. ⁽¹⁴⁾ Surgical masks have not been assigned protection factors by OSHA and should not be relied upon to help reduce exposure to inhalable airborne particles.

In a few cases, an approved respirator may also have the attributes of a surgical mask. These are typically referred to as “Surgical Respirators”. This means it can help block large droplets expelled by the wearer, but has also been shown to have efficacy at filtering smaller particles, and is designed to fit tightly to the face. Because of its additional use as a respirator, this type of surgical mask must also be fit tested.

Filtration

A number of questions have been raised regarding the use of respirators against biological agents. The primary question is whether or not particulate respirators can filter small particles such as fungal spores (2 to 5 μm), bacteria (0.3 to 10 μm), or viruses (0.02 to 0.3 μm).⁽¹⁵⁾ The physical size of various organisms is shown in Table 1. As noted previously, biological organisms may be carried on other particles including dust, blood, saliva, etc. Droplets generated from talking, coughing or sneezing will quickly dry in the air to form droplet nuclei. Droplet nuclei generated from coughs, sneezes and speaking have been found to range from submicron to over 20 microns.^(15,16) Influenza viruses, and other viruses, have been collected from exhaled breath.⁽¹⁷⁾ It is thought that droplet nuclei that contain *Mycobacterium tuberculosis* may range from less than 1 μm to greater than 5 microns.^(18,19) Airborne particles containing influenza viruses have been sampled from the air of hospital rooms containing influenza patients and found to be in the size range from less than 1 μm to greater than 4 μm .⁽⁴⁾ Understanding filtration mechanisms can help answer whether or not these particles can be filtered by particulate respirators.

Many particulate respirators use a non-woven fibrous filter media to capture particles. Fibers from less than 1 μm to 100 μm in size crisscross to form a web of many layers which is mostly air due to the large spaces between the fibers. It is the spaces between fibers that allow for breathability. Therefore, a particle does not become trapped because it tries to go through a hole that is too small. Rather, while flowing through the layers of filter media, a particle becomes attached to a fiber due to a number of different mechanisms. The most common of these are gravitational settling, inertial impaction, interception, diffusion, and electrostatic attraction.⁽¹⁾

To understand how a particle is captured, one must first consider the movement of air through the filter media. The path of the air around a fiber may be described in terms of imaginary streamlines. Any particle carried by the air may or may not stay within the streamlines depending largely upon the particle's size (aerodynamic diameter).

Very large particles (< 100 μm), in slow moving airstreams may settle out due to gravity. However, most respirable particles are too small for this mechanism. Respirable particles above 0.6 μm in diameter are captured efficiently by interception and inertial impaction.⁽²⁰⁾ Inertial impaction occurs when a particle cannot follow an air streamline around a fiber because of its inertia and instead impacts into the fiber. In the interception mechanism, the particle holds to the streamline, but that streamline will naturally bring the particle close enough to come in contact with the fiber. In contrast, diffusion is very efficient for particles smaller than 0.1 μm . Random movements of air molecules collide with these very small particles and cause them to wander across streamlines until they come in contact with a fiber.

Because of the complex methods by which particulate filtration occurs, the smallest particles are not the most difficult to filter. Most particulate filters have a region of lesser filtration efficiency somewhere between 0.05-0.5 μm .⁽¹⁾ Particles in this range are large enough to be less effectively pushed around by diffusion, but small enough to be less effectively captured by interception or impaction. The most penetrating particle size (MPPS) will depend on the filter media, air flow, and electrostatic charge on the particle. Filters that use electrostatic attraction may have a MPPS shifted to a slightly smaller size range.

Filtration efficiencies of six different commercially available US N95 filtering facepiece respirators as tested by 3M are shown in the left side of Figure 1. (Previous research has shown that for 3M products, European FFP2 respirators have equivalent or better filtration efficiency in tests representative of health care environments.) Averaged filtration efficiencies are shown as a function of different sized sodium chloride particles at a flow rate of 85 liters per minute.

While there was variability between different samples of the same model respirator, and between different models, the MPPS included particles with a diameter between 0.04 and 0.1 μm . As seen in Figure 1, particles that are smaller or larger than the MPPS are captured with higher filtration efficiency. Filtration via diffusion (most noticeable for particles smaller than 0.1 μm) actually increases as particle size decreases. Other research has confirmed that filter efficiency increases with decreasing particle size, even for particles as small as 0.003 μm (much smaller than that of virus).⁽²¹⁾

A size distribution from a sneeze is shown on the right side of Figure 1.⁽²²⁾ It should be noted that most of the droplet nuclei are larger than the MPPS. In other words, droplet nuclei that may contain microorganisms will be filtered by these respirators with high efficiency.

There has been much confusion regarding the MPPS. Some of this may be due to the different methods used to describe the size of particulate aerosols. For bioaerosols, microbiologists may cite the size of the physical organism as shown in Table 1. Industrial hygienists often use the shape and density of the particle to calculate an aerodynamic diameter. The aerodynamic diameter is used to estimate how a particle travels through air or is deposited in the human respiratory tract. Filtration research with smaller particles is often done using a device which selects different sized particles according to the particle's ability to move through an electric field while falling. This size is called a mobility diameter.

Another possible source of confusion is the statistical terms used to describe aerosols in respirator test methods. Respirators are tested against aerosols that contain a range of different sized particles. For example, in the US, the median size of the sodium chloride aerosol used in the NIOSH 42 CFR 84 particulate filter test is 0.075 μm . However, if the same aerosol was characterized by mass instead of by count, the mass median aerodynamic diameter would be approximately 0.3 μm . Therefore, care needs to be taken when comparing filtration claims. To be safe, make sure to use a respirator that has been tested and approved per all applicable local regulations. And, as mentioned above, filtration efficiency is just one of the required components that needs to be considered when selecting and using a respirator.

An often-expressed question is whether biological aerosols are removed by respirator filters the same as non-biological aerosols. Due to concerns on the efficacy of respirator filters for *Mycobacterium tuberculosis* (TB), many studies were conducted using bioaerosols. These filter evaluations were conducted over a range of test conditions (flow, humidity), biological species representing various shapes (spheres, rod, and rod/sphere shape) and sizes, filter performance levels and varying filter media (mechanical and electret; polypropylene and fiberglass). These experiments⁽²³⁻²⁸⁾ have demonstrated that there is no significant difference in the filtration of biological aerosols and non-biological aerosols with similar physical properties. Spherical particles were usually more penetrating than rod-shaped particles with equivalent aerodynamic diameter over a range of particle sizes. Studies have confirmed that nonbiological particles of similar aerodynamic diameter can be used for assessing the performance of respirators against biological aerosols.⁽²⁹⁻³⁰⁾ Additionally,

more studies have been published evaluating the filtration efficiency of respirator filters challenged with nanometer sized particles. These studies have found that NIOSH-approved respirators show filtration efficiencies similar to what would be expected based on their approval category. ⁽³¹⁻³²⁾ Where penetrations have slightly exceeded 5%, the results were not statistically significantly different from 5%. ⁽³²⁾

Microorganism survival on filters

Another area of interest is regarding the survival of microorganisms on respirator filters. This could impact storage and handling procedures. Several studies have been conducted regarding survival on filters. Over 18 types of respirator filters and five surgical masks have been studied using several types of microorganisms followed by storage at various humidities. ⁽³³⁻³⁷⁾ The filters were typically loaded with the microorganisms at experimental concentrations that were probably higher than those expected in work settings.

The polypropylene filters used in these studies were then checked for survival of microorganisms ranging from immediately after loading to as many as 28 days later, depending on the experiment. These studies have demonstrated that there were surviving organisms immediately after loading and that they survived for varying lengths of time depending on the storage conditions of the study. Usually storage under high humidity conditions was the most favorable for long term survival. However, these storage conditions are not typical of respirator storage in respirator programs. Storage of filtering facepieces used against bioaerosols in resealable plastic bags may not be appropriate. The filters may be moist from use and storage in plastic will keep the humidity level high. These studies also indicate that while the microorganisms can remain viable on the filter, they were unable to grow.

One of these studies looked for migration of the organism to the inside of the filtering facepiece respirator and concluded that respirators may be reused over time with little risk even after a week's time of internal contamination provided the respirator is carefully handled and stored (handled by non-filter components, e.g., straps). ⁽³⁷⁾ The investigators felt any internal contamination from environmental bacteria was due to handling (removal from bag to sample).

One study looked at two high efficiency filters with varying percentages of cellulose. ⁽³⁶⁾ These filters were inoculated with *Stachybotrys atra* and stored at RH as high as 100% for 86 days. *S. atra* grew and produced toxins on these cellulose filters at the high RH conditions. Again these conditions are not typical during normal respirator use and storage.

These concerns have prompted some to state that a traditional filter without a nanoparticle coating of a biocide would turn into a breeding ground for a virus or bacterial agent. The studies mentioned above do not support this claim. While it may be relatively easy to load a filter with a biocide, determining its efficacy is more difficult. Close examination of the claim needs to be made. Claims often relate to protection of the product, such as from microbial decay rather than protection of the wearer. Many countries require that a product claim of biocidal effectiveness for protecting the wearer must be in compliance with local regulations. In the US, claims are regulated by the Environmental Protection Agency (EPA). In Europe, claims must be in compliance with the Biocide Product Directive (98/8/EC). If the claims have not been approved or are not in compliance, they may be inappropriate. Very little peer-reviewed research has been conducted on respirators which

currently claim antimicrobial properties. One investigation of respirators incorporating antimicrobial-treated filter media found that there was non-detectable or no effect on the viability of penetrating particles.⁽³⁸⁾ Another study found an insignificant difference in the fractions of surviving organisms captured on untreated filters and those filters treated with iodine and similar environmental conditions.⁽³⁹⁾

Having the filter treated with a biocide may only be beneficial in extending the shelf life of the filter. While most of the virus would be deposited on the filter as a result of breathing through the filter, bioaerosols will also be deposited on the straps, exhalation valve cover (if present), and nose clips etc. Thus caution in handling the respirator must still be taken and a biocide filter treatment may not prevent the spread of disease by contact with these respirator components

Overall, these studies suggest careful consideration for filter handling, reuse and respirator disposal, especially where the organism can be spread by contact. Precautionary measures might include the use of gloves and washing hands after handling the respirator. For organisms transmitted only by inhalation, respirator handling may not be critical. One investigator suggested training for respirator users might be necessary to recognize when exposures would require immediate disposal of respirators.

Reaerosolization of Microorganisms

Once a particle is collected onto a fiber, it will adhere to the filter fiber due to Van der Waals forces. Therefore, filters are likely to be good collectors of small particles. In contrast, reaerosolization is the process by which any aeriially deposited material on the filter can be re-suspended. It could be hypothesized to happen if there was high air flow back through the filter such as if the wearer were to cough or sneeze while wearing the respirator. In this regard, one experiment used three microorganisms and two surrogate particles [NaCl and Polystyrene latex (PSL) particles] of various size ranges from 0.6 μm to 5.10 μm .⁽⁴⁰⁾ They were loaded onto three models of filtering facepiece particulate respirators. The reentrainment velocity was 300 cm/sec. Reaerosolization was significant only for larger test particles (3 and 5 μm) into dry air. There was no reaerosolization when the RH levels were greater than 35%. These authors concluded that reaerosolization of collected TB bacteria and other particles less than a few microns in size is insignificant at conditions encountered in respirator wear. They also speculated that the conclusions were valid for other fibrous filters as well.

In a second study, investigators used 1 μm PSL particles to simulate anthrax spores.⁽⁴¹⁾ The two models of filtering facepiece particulate respirators were loaded with ~ 20 million particles. The respirators were then dropped three feet onto a hard surface. The amount released ranged from 0 to 0.5% and the average release measured 0.16% and 0.29% for the 2 models. While this loading represents a much higher degree of loading than would be expected in typical work environments, this study indicates a small, but consistent fraction of 1 μm particles captured by a respirator filter may be released into the air. These results suggest caution in handling and disposing of respirators contaminated with anthrax spores.

Selection and Use

When respiratory protection is needed for exposures to bioaerosols, the user should select a certified / approved particulate respirator according to recommendations from CDC, WHO or applicable local agencies. Remember that the NIOSH particulate filter rating does not include face seal leakage, only filter penetration. Therefore, the assigned protection factor must be considered to ensure the expected reduction in respirator exposure is adequate for your intended application. Although the European certification testing includes face seal leakage, some countries have assigned protection factors that are lower than the nominal protection factors calculated from the certification tests.

Once a respirator has been selected, a continuing, effective respiratory protection program as specified by applicable local regulations must be implemented. This includes training on the respiratory hazards, fit testing, maintenance, disposal, etc.

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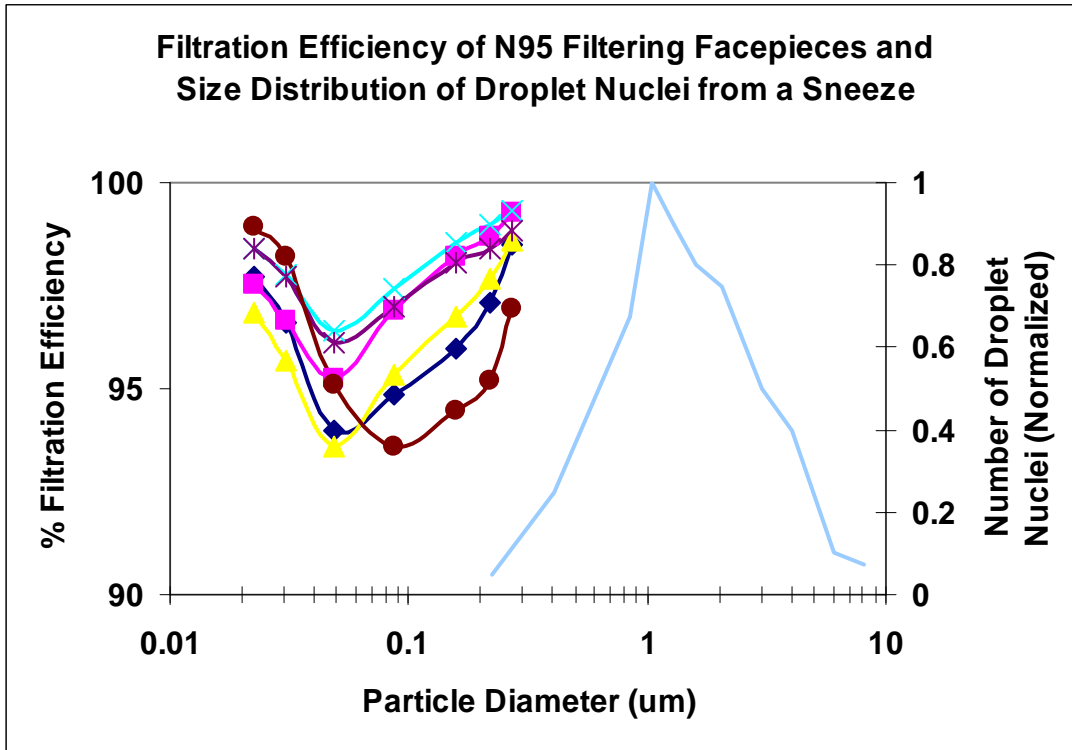
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Table 1. Size of Various Microorganisms

Microorganism (common name or disease)	Physical Size (µm)
Hepatitis virus (Hepatitis B)	0.042 – 0.047
Adenovirus (respiratory infections)	0.07 – 0.09
Filoviruses (Ebola)	0.08 diameter 0.79-0.97 length
Bunyaviridae (Hantavirus)	0.08-0.12
Orthomyxoviridae (Influenza A, B, & C)	0.08-0.12
Coronaviridae (SARS –CoV)	0.10-0.12
Variola Virus (Smallpox)	0.14-0.26 diameter 0.22-0.45 length
<i>Mycobacterium tuberculosis</i> (TB)	< 1 to > 5 µm diameter
<i>Bacillus anthracis</i> spore (Anthrax infection)	1.0-1.5 diameter

Figure 1. Averaged Filtration Efficiency for Six N95 respirators (on the left), and Size Distribution of Droplet Nuclei from a Sneeze (on the right).





Technical Data Bulletin



#186 — Establishing Cartridge Change Schedules for Anesthetic Gases (Isoflurane, Sevoflurane)

Published: January, 2009

Background

Minimizing exposure to anesthetic gases is best done by proper administration technique and local exhaust ventilation (scavenger systems). Respirators may also be used to help further reduce exposure. Respirators with organic vapor cartridges may be used during exposure to anesthetic gases such as isoflurane and sevoflurane. However, gas and vapor cartridges have a limited service life. The United States Occupational Safety and Health Administration (OSHA) standard for respiratory protection (29 CFR 1910.134) mandates that users develop cartridge change schedules based on either “end of service life indicators” or empirical data.

Estimating Cartridge Service Life

Many respirator manufactures have developed software programs to help users develop cartridge change schedules. The 3M™ Service Life Software may be found at www.3M.com/OccSafety. The software includes many common industrial chemicals. Users may also enter their own “user defined” organic vapors. The user must supply information about the organic vapor as shown in the form below.

User Contaminant

Contaminant: Standard User

Enter contaminant information below. Only Organic Vapors may be entered.

Name:

CAS Number:

Exposure Limit: ppm

Molecular Weight:

Index of Refraction:

IDLH:

Liquid Density:

Saturated Vapor Pressure: at Temp: C

Exposure: ppm

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CAS number and the Immediately Dangerous to Life or Health (IDLH) level are only for reference and are not required to estimate service life. The exposure limit is only used if the user chooses to estimate service life until the amount of vapor coming through the cartridge is equal to some fraction of the exposure limit. If the user instead chooses to estimate service life until the amount of vapor coming through the cartridge is a fraction of the ambient concentration, then the choice of exposure limit is not relevant. Since many of the anesthetic gases do not have published exposure limits, the user will need to enter an arbitrary number of choice (e.g. 100 ppm) and then select breakthrough to a fraction of the ambient concentration. In order to use the software, exposure must be measured for the user's specific application. 3M™ Organic Vapor Monitors may be used to measure certain anesthetic gases.

The remaining chemical information is given in the table below. Saturation vapor pressure depends on temperature. The Service Life Software program allows temperatures selected in 10°C increments, so saturation vapor pressure is given at both 20°C and 30°C. Organic vapor cartridge service life decreases with increasing temperature, so calculations done at 30°C will give a conservative estimate for temperatures between 20°C and 30°C.

Name	Isoflurane	Sevoflurane
CAS Number	26675-46-7	28523-86-6
Molecular Weight	184.5	200.1
Index of Refraction	1.3002	1.2752
Liquid Density	1.496	1.52
Saturated Vapor Pressure	238 mm @ 20°C 367 mm @ 30°C	157 mm @ 20°C 244 mm @ 30°C

The service life software estimates how long a cartridge will last if it is exposed continuously (e.g. 40 hours). However, many users ask about intermittent use for shorter periods of time. This is a more difficult question as organic vapors may migrate through the cartridge during periods of non-use. This is especially a concern for organic vapors with a boiling point less than 65°C, which includes many anesthetic gases. One conservative approach would be to use the estimate from the software as the time since the cartridges were first exposed. Thus, cartridges are disposed when the time (use and non-use together) has expired. (Please see technical data bulletin #142, "Reuse of Organic Vapor Chemical Cartridges" for more information).

3M has also tested the 3M™ Organic Vapor Cartridges, 6001 against intermittent exposure of isoflurane. Two 6001 cartridges were each challenged with 10 ppm isoflurane in air at 32 liters/minute and 50% RH for 30 minutes every day for 6 days. (Flow rate of 32 liters/minute through each cartridge of a dual cartridge respirator is equivalent to 64 liter/minute flow through the respirator which is a moderate to heavy breathing rate). One 6001 cartridge was challenged with 50 ppm isoflurane under the same conditions. During these 30 minute periods the effluent

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air from the cartridges was analyzed for isoflurane by gas chromatography. No isoflurane was observed in the effluent (0.1 ppm detection limit) at any time during the 6 days.

The test data show that 6001 cartridges may be used up to 6 days of intermittent isoflurane exposure if use conditions are similar to our testing. However, cartridges should be stored in a cool dry place between periods of use. Service life may be shorter if used at higher concentrations, high relative humidity or if other organic vapors are also present. Sevoflurane is less volatile than isoflurane and thus service life under the same conditions would be longer.

It should be noted that respirators help reduce, but do not eliminate exposure. Respirators must be used as part of a comprehensive respiratory protection program that includes, but is not limited to training, fit testing, medical evaluation, inspection, maintenance, etc. In the United States, employers providing respiratory protection must follow the OSHA Respiratory Protection Standard 1910.134.

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