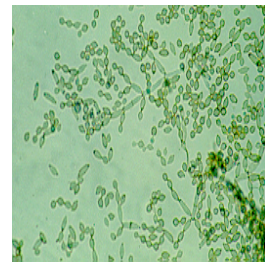
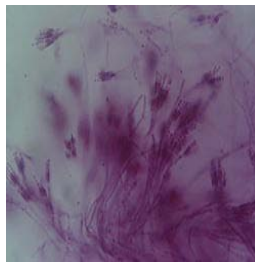
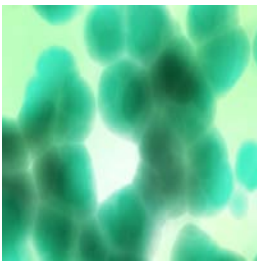
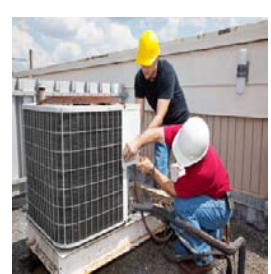
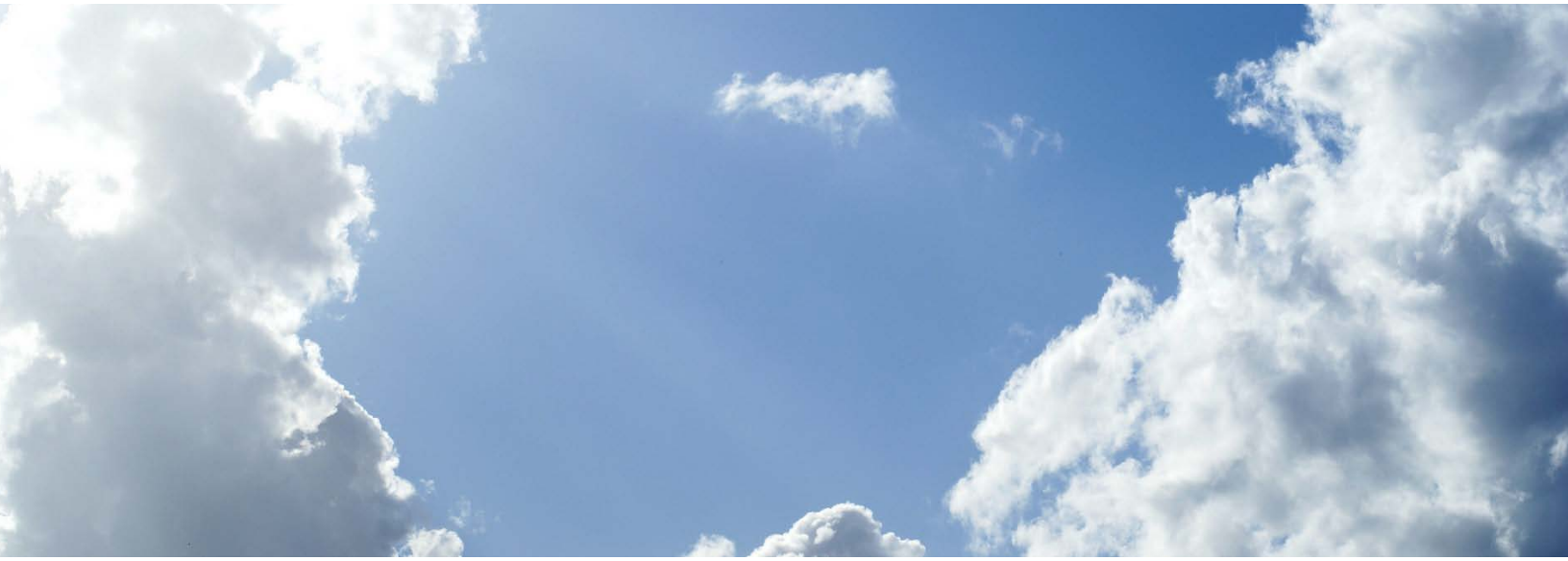


AxenaTechnologies



N-SeProtector 101
The Bacteriostatic of the Future

Axena Technologies, with Brown University, has developed a novel antimicrobial coating that can lead to improved air quality. Air filtration systems are at risk for bacteria, mold and fungal growth. These pathogenic microorganisms grow and gain strength on filters and system surfaces, ultimately becoming air-borne and adversely affecting human health and well-being. Killing pathogenic microorganisms and preventing their growth leads to cleaner air and improved human quality-of-life.

N-SeProtector 101

Axena Technologies has developed N-SeProtector 101, a nano-selenium based antimicrobial agent that can be added to products and surfaces. Selenium is a natural micronutrient whose properties are enhanced at nano-scale size. N-Se Protector101 uses nano-selenium to supplement existing products with antimicrobial protection through a fast and simple process that only requires standard equipment.

This proprietary technology kills bacteria, fungi and molds and prevents microbial colonization of surfaces. The following properties makes N-SeProtector 101 unique:

- Micronutrient – active ingredient is safe and essential for human use
- Nano-structure – inhibits bacteria adhesion and enhances antimicrobial effectiveness
- Stable – unaffected by UV light and cleaning processes
- Ease of application – simple process uses standard equipment
- Product enhancement – supplements existing products, easy integration

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Problem: Sick Building Syndrome

A healthy indoor environment is essential to human health and daily well-being. Indoor air quality (IAQ) is the upmost factor characterizing a healthy environment. Good building air quality promotes good health, positive well-being and workplace productivity. However, poor air quality can lead to many negative effects and significantly impact building occupants.

The terms "sick building syndrome" (SBS) and "building related illness" (BRI) are used to describe situations where the building air quality negatively impacts the health of its occupants. SBS and BRI are primarily caused by HVAC systems being compromised by microbial growth. Occupants can experience various respiratory or external symptoms.

Symptoms of Sick Building Syndrome

- Nausea
- Headache, dizziness
- Eye or throat irritation
- Difficulty breathing
- Dry, itchy skin
- Fatigue
- Difficulty concentrating

A 1984 World Health Organization Committee reported up to 30 percent of new and remodeled buildings worldwide to be at risk for sick building syndrome as a result of sub-standard air quality. In severe cases, affected occupants may require prolonged recovery times even after leaving the building.

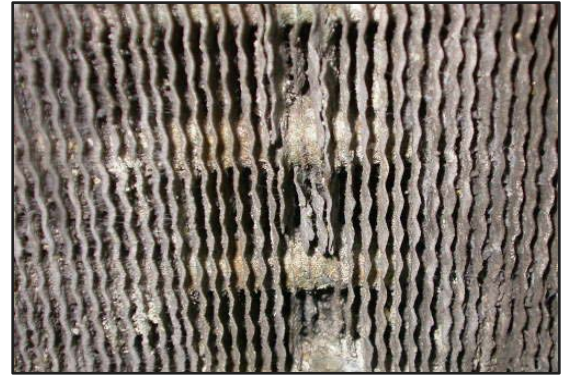
Causes of Sick Building Syndrome

- Biological contaminants – bacteria, mold and fungi
- Inadequate ventilation – ineffective distribution of air
- Chemical contaminants from indoor sources – Chemicals from adhesives, carpeting, building materials

Airborne Microbial Contamination in HVAC Systems

Exposure to the airborne microbial contaminants such bacteria and fungi is the most significant factor affecting air quality and associated negative conditions such as sick building syndrome. Microbial contaminants do not grow and reproduce in the air, but rather attach to surfaces to grow and reproduce. Numerous IAQ case studies have shown that filters, cooling coils and fiberglass duct liner, combined with dust, dirt and moisture, is a very good medium for microbial growth. Bacteria and fungi can then break off the surface and become airborne within the HVAC system. Microorganism contamination can significantly impact system performance and cause foul odors and serious health effects for building occupants.

Filters and internal duct liners (typically made of fibrous glass or glass wool) have significant risk for pathogenic microorganism growth. These system components have rough, porous surfaces that trap not just bacteria and fungi, but also dust and moisture that are the nutrients which promote microbial growth.

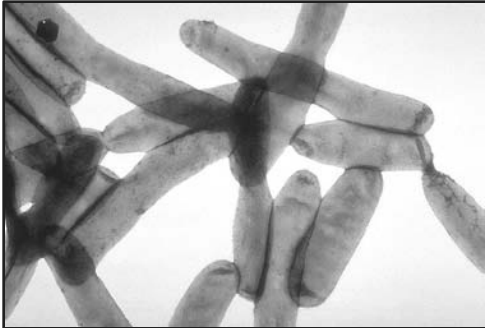


Contamination of cooling coil



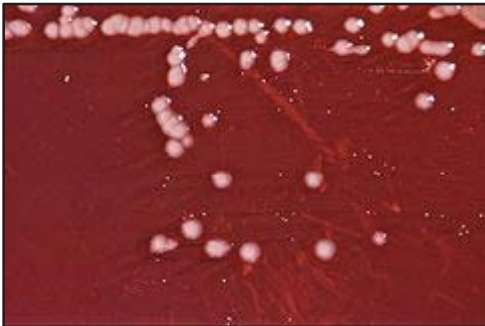
Microbial growth on internal duct liner

Common Airborne Microbial Pathogens Associated With HVAC Systems



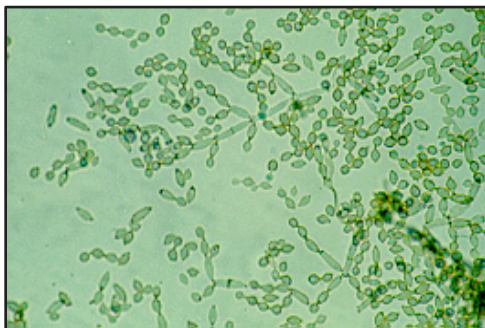
Legionella pneumophila

A thin, pleomorphic, flagellated Gram-negative bacterium of the genus *Legionella*. It is a common waterborne bacterium which may be detected in cooling tower water. It is known to cause Legionnaire's disease and pontiac fever.



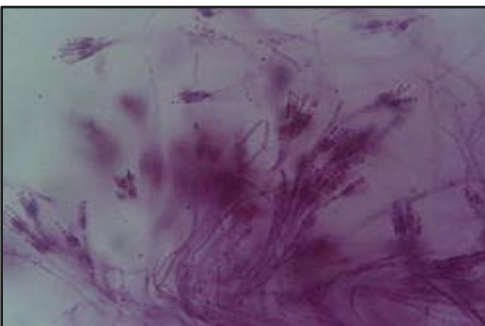
Pseudomonas aeruginosa

A is a gram-negative rod that belongs to the family *Pseudomonadaceae*. It is a common waterborne bacterium. It grows in water, from potable water to stagnant water.



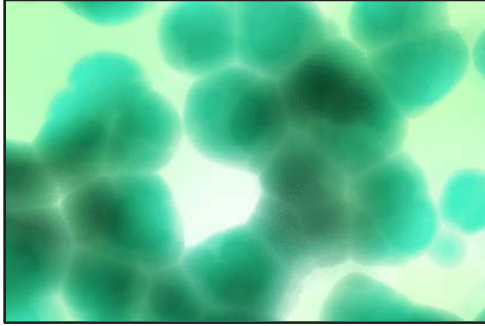
Cladosporium cladosporioides

A common fungi found outdoors. It is a common colonizer of a dirty HVAC system, particularly just downstream for cooling coils. Spores of *Cladosporium* are potentially allergenic and *Clado-sporium* has been associated with hypersensitivity pneumonitis.



Penicillium corylophilum

A genus of ascomycetous fungi of major importance in the natural environment as well as food and drug production. It produces penicillin, a molecule that is used as an antibiotic, which kills or stops the growth of certain kinds of bacteria inside the body. It is a common colonizer of a dirty HVAC system. Spores of *Penicillium* are potentially allergenic.



Endotoxins

It is a cell wall component of Gram-negative bacteria, which is common and abundant in any water. It is released into the environment when bacteria grow, divide, or die. *Endotoxin* is known to cause various adverse health effects related to the respiratory system.

Solutions to Sick Building Syndrome

Solutions to sick building syndrome usually include combinations of the following:

Pollutant source removal or modification

An effective approach to resolving an IAQ problem when sources are known and control is feasible. Examples include routine maintenance of HVAC systems, e.g., periodic cleaning or replacement of filters; replacement of water-stained ceiling tile and carpeting; institution of smoking restrictions; venting contaminant source emissions to the outdoors; storage and use of paints, adhesives, solvents, and pesticides in well ventilated areas, and use of these pollutant sources during periods of non-occupancy; and allowing time for building materials in new or remodeled areas to off-gas pollutants before occupancy. Several of these options may be exercised at one time.

Increasing ventilation rates and air distribution

It is a cost effective means of reducing indoor pollutant levels. HVAC systems should be designed, at a minimum, to meet ventilation standards in local building codes; however, many systems are not operated or maintained to ensure that these design ventilation rates are provided. In many buildings, IAQ can be improved by operating the HVAC system to at least its design standard, and to ASHRAE Standard 62-1989 if possible. When there are strong pollutant sources, local exhaust ventilation may be appropriate to exhaust contaminated air directly from the building. Local exhaust ventilation is particularly recommended to remove pollutants that accumulate in specific areas such as rest rooms, copy rooms, and printing facilities.

Air cleaning

A useful adjunct to source control and ventilation but has certain limitations. Particle control devices such as the typical furnace filter are inexpensive but do not effectively capture small particles; high performance air filters capture the smaller, respirable particles but are relatively expensive to install and operate. Mechanical filters do not remove gaseous pollutants. Some specific gaseous pollutants may be removed by adsorbent beds, but these devices can be expensive and require frequent replacement of the adsorbent material. In conclusion, air cleaners can be useful, but have limited application.

Education and communication

These are important elements in both remedial and preventive indoor air quality management programs. When building occupants, management, and maintenance personnel fully communicate and understand the causes and consequences of IAQ problems, they can work more effectively together to prevent problems from occurring, or to solve them if they do.

Source: Sick Building Syndrome/IAQ/US EPA.

While these efforts can address existing concerns, they are complicated, costly and insufficient in preventing the onset of sick building syndrome.

Selenium

Selenium – A Safe Micronutrient

Selenium (periodic symbol Se), is a chemical element with atomic number 34. Selenium is an important micronutrient for human life. In 1989 the USDA established selenium as such and recommended daily allowance for selenium of 55 µg/day for adults with a tolerable upper intake level at 400 µg/day, though many people ingest upwards of 600 µg/day with vitamin supplements sold over the counter.



Selenium occurs in several forms, Black, gray, and red selenium are shown here.

Key Selenium Benefits

- Important antioxidant
- Helps to inhibit harmful free radicals that damage cells
- Helps slow oxidation of LDL – lowers the risk of coronary artery disease
- Helps regulate blood pressure
- Reduces symptoms from elevated brain pressure: headaches, vomiting, nausea, and seizures
- Aids gland function and regulates hormones
- Essential for tissue elasticity
- Strengthens the immune system

Selenium Is Obtained From Common Food Sources

Selenium is found in many common foods, including rice, meats, and vegetables. The following are foods with particularly high amounts of selenium:

- Brazil nuts
- mushrooms (button, shiitake, reishi)
- fish (cod, flounder, halibut, herring, mackerel, salmon, smelts, red snapper, swordfish, tuna)
- seafood (lobster, oyster, scallops, shellfish, shrimp)
- eggs

Selenium – Safe for Everyday Use

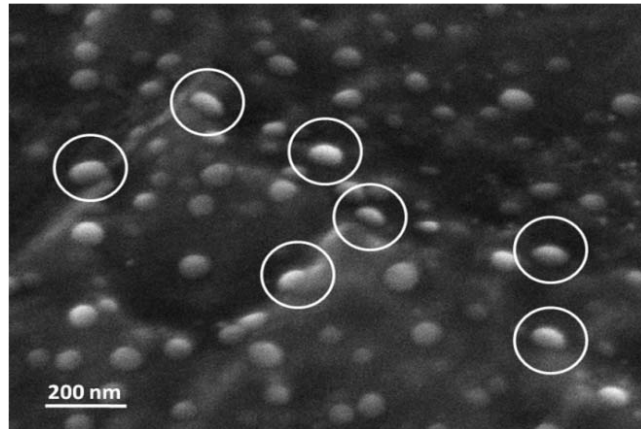
Selenium is found in many over-the-counter supplements and commonly ingested on a daily basis.

Various selenium supplements available in the market.



Introducing N-SeProtector 101 for HVAC Systems

To prevent pathogenic microorganism growth, Axena Technologies has created N-SeProtector 101, a patent-pending surface treatment that adds antimicrobial properties by naturally bonding nanoparticles of elemental selenium onto surfaces and materials. Axena's technology enhances the antimicrobial properties of elemental selenium by reducing selenium particle size into the nano-scale. Therefore, only trace amounts of N-SeProtector 101 is required to effectively kill microbes and prevent growth. N-SeProtector 101 was developed at the Nanomedicine Laboratory at Brown University in Providence, RI USA.



Scanning Electron Microscope (SEM) image of selenium nanoparticles on a surface

High efficiency filtration systems can be very expensive and may require additional maintenance procedures. Filters, even lower efficiency filters, capture airborne microorganisms. However, microbes have the ability to grow within filter material before breaking off and entering the air stream. This source of reproducing pathogens will continuously cause poor air-quality. By selecting N-SeProtector 101 coated filters, building professionals avoid the limitations of HVAC filters while overcoming the air-quality challenges common to standard Ultra Violet (UVGI) systems. N-SeProtector 101 was formulated specifically for use in buildings to improve air quality and provide complete protection against the full-range of airborne microbial contaminants.

Standard, untreated filtration

	Removes Large Particles	Removes Biological VOC's	Eliminates Mold	Eliminates Bacteria	Eliminates Viruses
Conventional air filters	Yes	No	No	No	No
HEPA filters	Yes	No	Yes	No	No

N-SeProtector 101 Treated Filtration

	Removes Large Particles	Removes Biological VOC's	Eliminates Mold	Eliminates Bacteria	Eliminates Viruses
Conventional air filters	Yes	Yes	Yes	Yes	Yes
HEPA filters	Yes	Yes	Yes	Yes	Yes

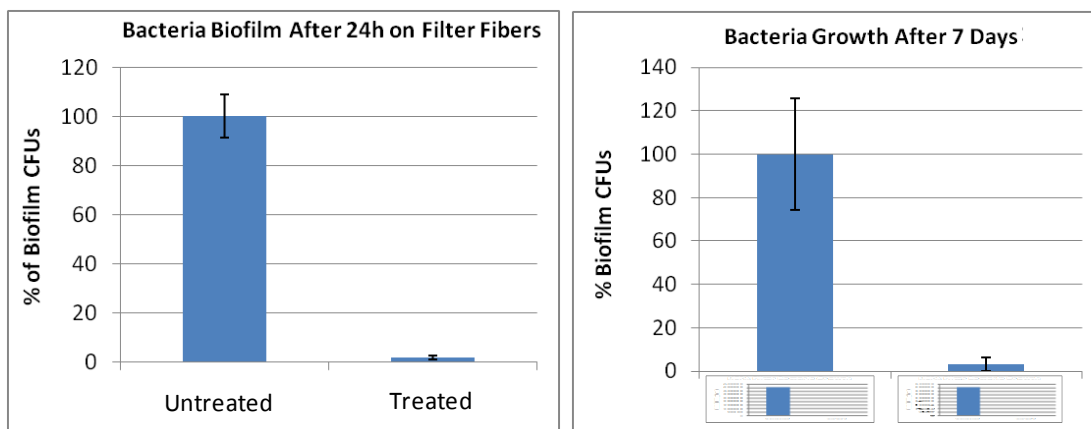
Advantages of N-SeProtector 101

N-SeProtector 101 has unique advantages over alternative technologies:

- Effectively kills bacteria, fungi and mold
- Does not generate any Volatile Organic Compounds (VOC's)
- Does not release anions or negative ions to the surrounding environment
- Destroys airborne microbial contaminants without ozone exposure
- Increases the efficiency of coated filters, including HEPA filters
- No special maintenance required
- Cost effective and easy to apply
- Safe, environmentally friendly ingredients

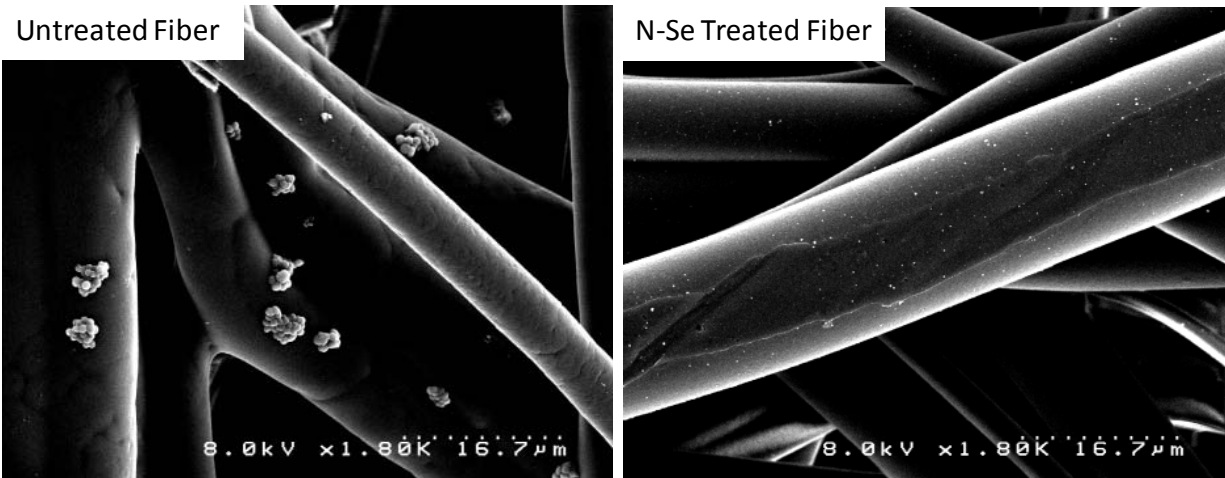
Effectiveness

When applied to filters or any other material N-SeProtector 101 prevents the growth of pathogenic microorganisms. Treated materials saw up to a 2-log reduction in pathogen biofilm growth, which is equal to 99% reduction in colony forming units (CFUs) of pathogens. The nano-selenium coating was also shown to be effective for extended periods of time.



Left: S. aureus biofilm colony counts after 24h on filter fibers relative to uncoated samples. Right: S. aureus biofilm colony counts after 7 days relative to uncoated samples

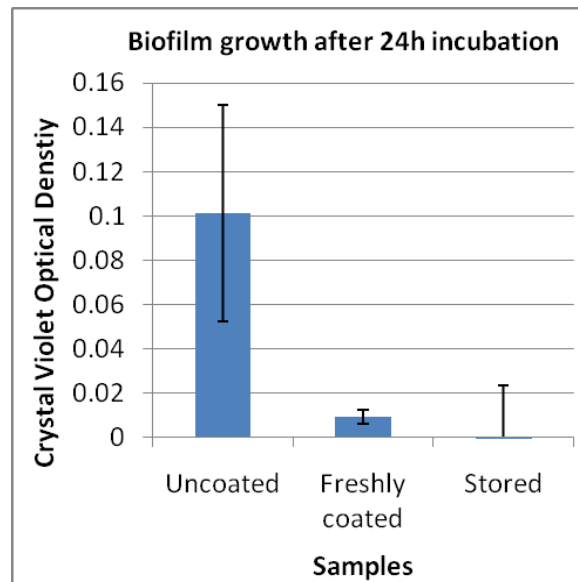
Scanning Electron Microscope (SEM) images confirm colony count experiments by visualizing aggressive colonization of untreated materials versus those treated with N-SeProtector 101.



Left: SEM image under 1800X magnification of uncoated fiber showing bacteria colonization. Right: SEM image under 1800X magnification of coated fiber showing selenium nanoparticles and no bacteria colonization.

Extended Antimicrobial Shelf Life

No impact on antibacterial efficacy was seen after 5, 10 and 15 weeks of storage on a bench top. Since selenium is stable and relatively inert, prolonged storage is not expected to have an effect on efficacy.



N-SeProtector 101 treatment antibacterial efficacy with prolonged storage

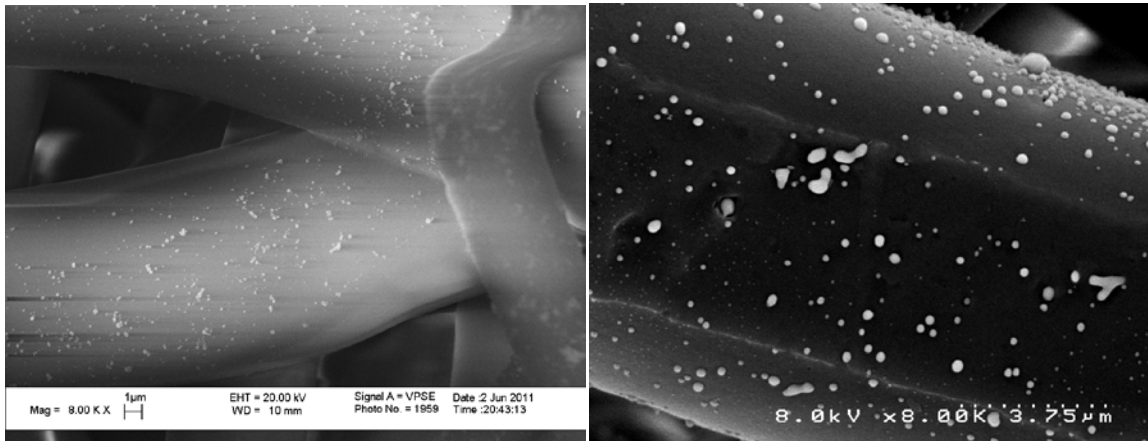
N-SeProtector 101: Composition and Application

N-SeProtector 101 has two components – a Nano-Selenium Synthesizer 101 (NSS 101) in granular powder form and a Nano-Selenium Buffering Activator 101 (NSBA 101) in liquid form. The mixture of NSS 101 and NSBA 101 will generate a high intensity colloidal nano-selenium Coating . When applied to HVAC filters, it rapidly and effectively destroys airborne microbial contaminants. Filters

coated with N-SeProtector 101 have been proven to deliver improved air-quality by destroying microbial contaminants.

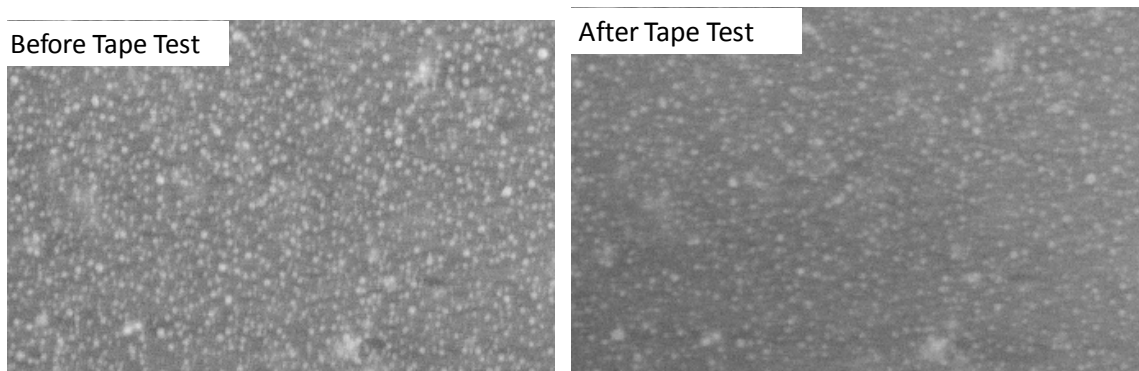
Treatment of Filters with N-SeProtector 101

Application of N-SeProtector 101 to filters is a simple and robust process. No special maintenance is necessary with treated filter material.



Selenium nanoparticles on standard (left) and HEPA (right) filter fiber after treatment and deionized water rinse

Selenium nanoparticles are firmly attached to fibers when filters are treated with N-SeProtector 101. Fluid vortex and sonication has no effect on coating durability. Adhesion strength was also tested against ASTM standard tape testing with no observable impact.



Left: SEM image at 8000X magnification of selenium nanoparticles on PEI before tape test. Right: SEM image of the same position after tape test (image quality is degraded due to extended imaging of the same position).

Using Graphite Furnace Atomic Absorption Spectroscopy (GFAAS), the elution of selenium from surfaces has been shown to be negligible in saline and other liquid medias. The sustained presence of selenium supports its longevity and safety.

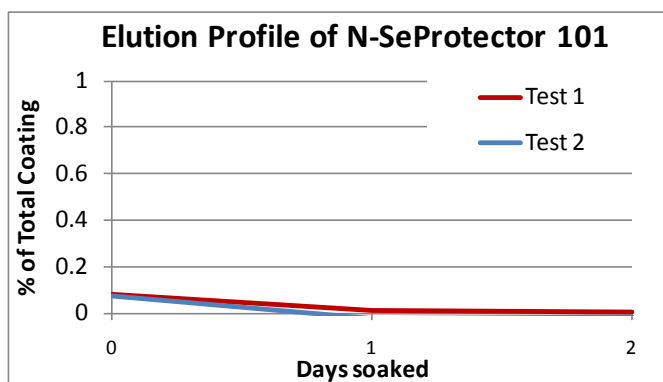
N-SeProtector 101 Supplements HVAC Systems

N-SeProtector 101 has absolutely no effect on HVAC systems. All major features are unaffected, such as:

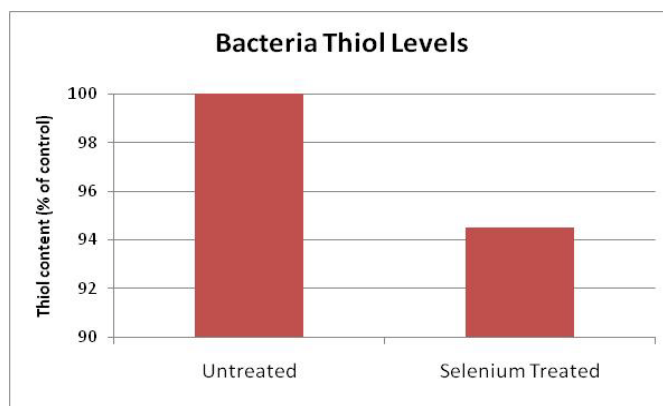
- Energy consumption
- Air flow
- Pressure
- Spacing
- Installation
- Weight
- Temperature
- Moisture
- Pollutant loading

How Selenium Works

Selenium nanoparticles naturally adhere to filter fibers introducing antibacterial properties to the material. This allows for a permanent surface coating that resists biofilm and cellular growth of bacteria and fungi. Most importantly, a nano-selenium coated surface will not leach out into the environment, making the product environmentally friendly, unlike competitive copper and silver-treated products. Airborne pathogens die as they come into contact with the antibacterial agents.



Selenium breaks the characteristic sulfur-carbon bond in thiols and proteins. This removes the microbes' protection for oxidative stress (Reactive Oxygen Species), chlorine compounds, osmotic stress, pH fluctuations, and reduced sulfur fluctuations. Thiols are provided by the microbes' intracellular cytoplasm and the protein in the cell walls and fungi cell membranes. Thus, the bacteria themselves actually bring the activating agents to begin the catalytic process resulting in their death.



Nano-selenium depletes thiols

During the natural metabolism of oxygen, oxygen ions and peroxides known as Reactive Oxygen Species (ROS) are formed. Although they play a necessary role in cell signaling, these molecules are highly reactive and need to be closely regulated to prevent damage to cell structures, DNA, nucleotides, proteins, enzymes and more. The most important intracellular redox buffer is the thiol glutathione, which has the primary role of regulating ROS, but also provides protection from chlorine compounds, acts as a reserve form of reduced sulfur, and maintains the levels of potassium ions. The regulation of

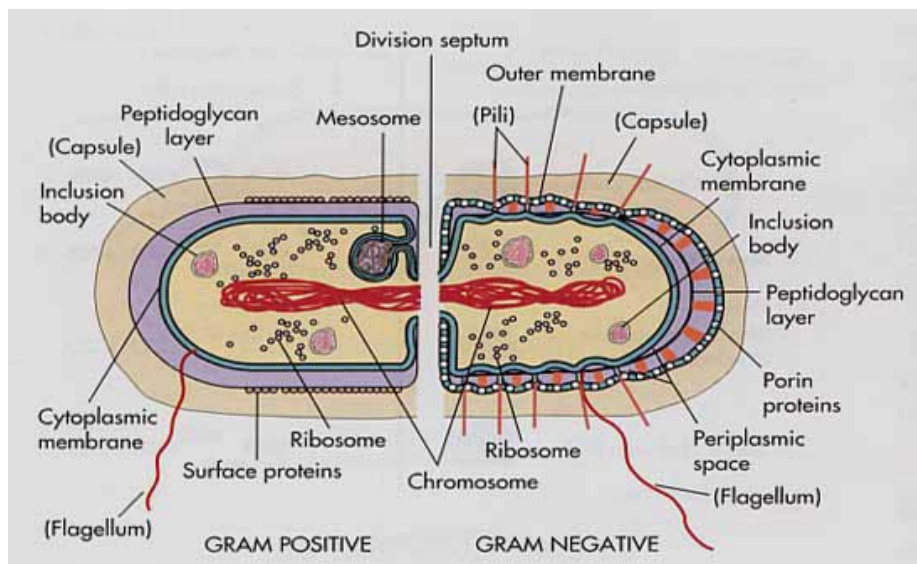
potassium ions by glutathione protects the cell from damaging pH fluctuations as well as osmotic stress, which can induce cell shock when low glutathione levels causes potassium ions and water to leak out of the cell. Glutathione is one of the most abundant thiols in bacteria and fungi.

Nano-selenium particles draw out glutathione, among other low molecular weight thiols, and destroy them by breaking the characteristic sulfur-carbon bond. Even under reducing conditions such as that in the cytosol, selenium is able to oxidize thiols and break the sulfur bonds. The cell membranes are particularly vulnerable to this effect due to its proximity to the nano-selenium particles. The depletion of glutathione and its protective functions has the following effects:

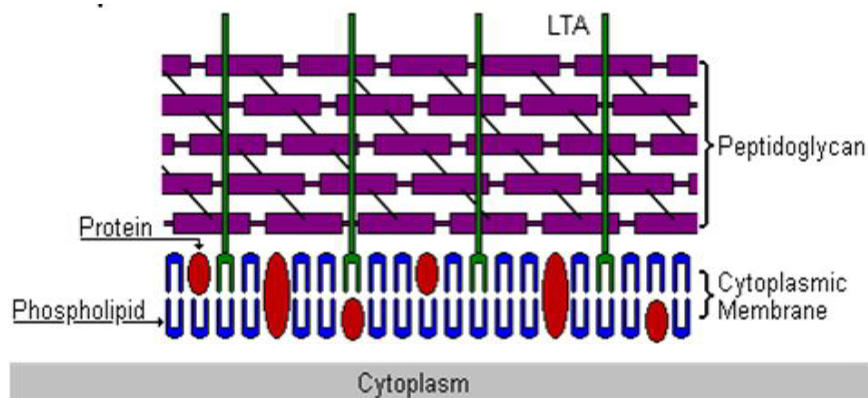
- Natural and self-produced ROS damage the cells' systems and structures.
- Osmotic stress from the internal loss of potassium ions and water, which can induce cell shock.
- Prevent microbial growth in low pH environments.
- Prevent microbial growth in low reduced sulfur environments.

Bacteria Cell Structure and Target

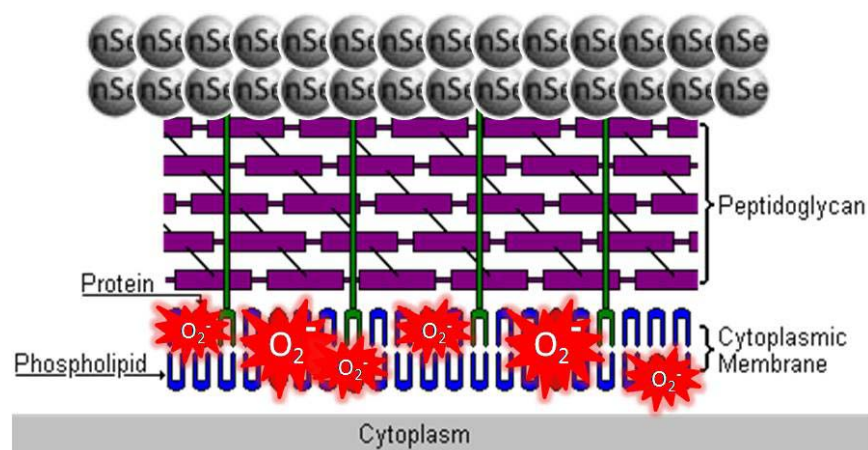
Bacteria are a large domain of single-celled, prokaryote microorganisms. Nano-selenium particles deplete thiols in the cytoplasmic membrane of bacteria, as well as on the outer membrane for gram-negative bacteria. Since Reactive Oxygen Species are naturally produced by bacteria during the metabolism of oxygen, the absence of glutathione protection of these ROS and naturally occurring external ROS will eventually destroy the cells' systems and walls.



Gram Positive Cell Wall

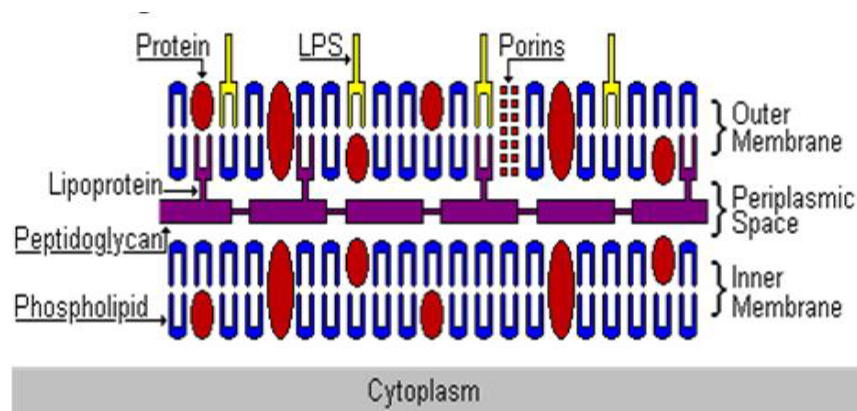


Before oxidizing thiols.

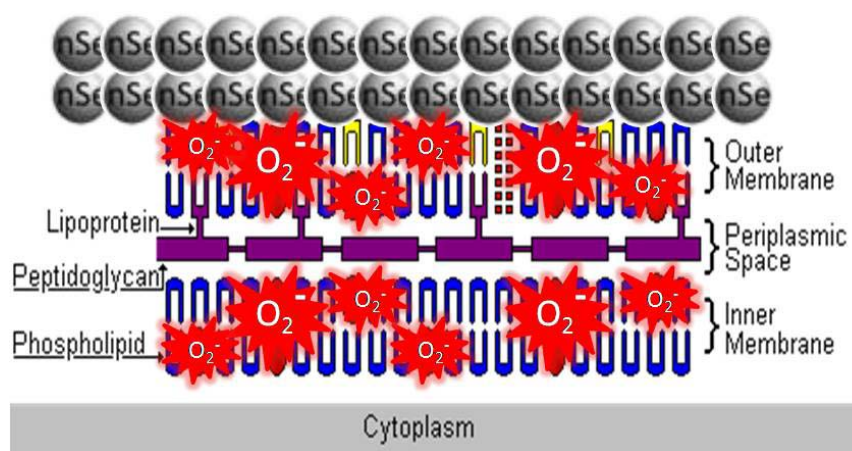


The depletion of thiols allows self-produced and naturally occurring ROS to destroy cell systems.

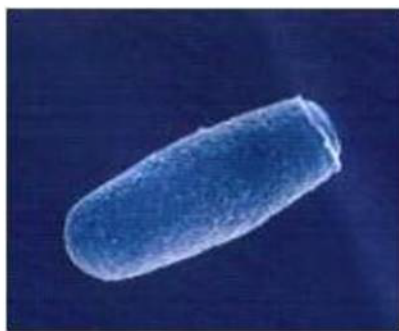
Gram Negative Cell Wall



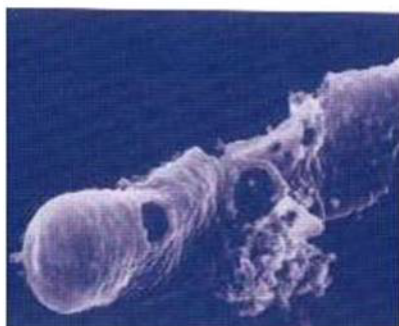
Before oxidizing thiols.



The depletion of thiols allows self-produced and naturally occurring ROS to destroy cell systems.



A scanning electron micrograph of bacteria cell before the inhibition of cell wall synthesis, inhibition of protein synthesis and disruption of cytoplasmic membrane.



A scanning electron micrograph of bacteria cell bursts from osmotic pressure due to the integrity of peptidoglycan is not maintained. This is due to the followings:

- a. Inhibition of cell wall synthesis where bacteria cell walls are destroyed.*
- b. Inhibition of metabolic pathways.*
- c. Disruption of cytoplasmic membranes.*

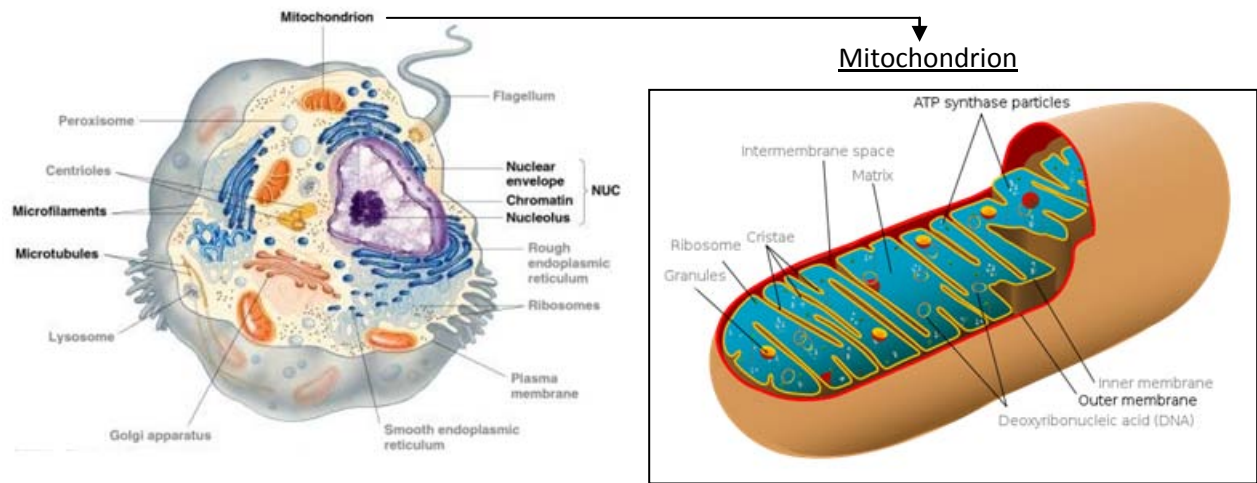
Nano-selenium breaks zinc proteins

Selenium also breaks the zinc-sulfur bonds in metallothionein and zinc finger proteins, which interferes with the transcription of genetic information from DNA to mRNA. The resulting imbalance of zinc and selenium causes genomic instability and thus disrupts cell replication. Cells that replicate quickly, such as bacteria and fungi, are more susceptible to the negative effects of genomic instability than mammalian cells that replicate slowly.

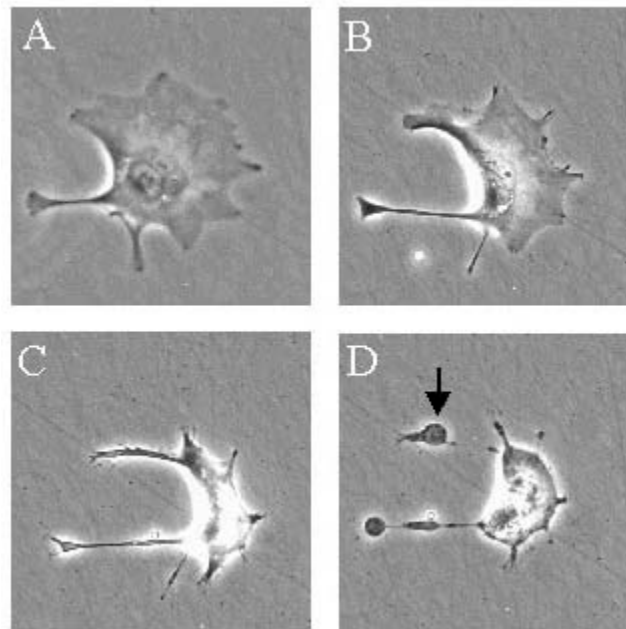
Nano-selenium also causes apoptosis in fungi

Apoptosis, or programmed cell death, is a normal component of the development and health of multicellular organisms. Cells die in response to a variety of stimuli and during apoptosis they do so in a controlled, regulated fashion. Apoptosis is a process in which cells play an active role in their own death.

In fungi, the depletion of thiols has additional adverse effects and ultimately induces apoptosis. The loss of ROS regulation ruptures the outer membrane of the mitochondria, which is basically the source of chemical energy - adenosine triphosphate (ATP) - for cells. The mitochondria is most vulnerable because it is the main generator of ROS and therefore accumulates oxidative damage faster. With the collapse of the mitochondrial membrane, not only are metabolism and respiration affected, but a release of pro-apoptotic proteins begins the process of apoptosis.



Eukaryotic Cell



Apoptosis Process

- A. The cell begins to shrink as the rigid proteins (microfilaments and microtubules) within it break down. In the cell nucleus, chromatin (combination of DNA and proteins) in the nucleus also condenses.
- B. As the cell continues to shrink, rounding and a "horse-shoe" appearance often occurs.
- C. The nuclear envelope (membrane of the nucleus) breaks down and begins to split into separate bodies.
- D. The cell breaks apart into separate bodies.

Appendix A: Overview of HVAC System Technologies



HEPA Filter



Extended Surface Bag Filter



Pleated Panel Filter



Disposable Panel Filter



HEPA, ULPA Filter



Electrostatic Pleated Filter



Rigid Cell Extended Surface Filter



Electrostatic Filter

Air filters come in a variety of sizes and types. The primary distinction between one filter and another is the size of the filter (length, width and thickness) and the filter material or “media” that is used in the manufacture of the filter.

Though there are a wide variety of air filters, they are generally termed as disposable air filters or reusable air filters,

Reusable Air Filters

Conceptually, Reusable Air Filters are attractive – replacement costs can add up over time. Unfortunately, reusable air filters sacrifice efficiency. Reusable filters must be cleaned, often with highly toxic chemicals. Once a chemical cleaning agent is used on the filter, it is absorbed by the filter material. After filter replacement, these chemicals can be released into the circulating air posing a potential health threat.

Disposable Panel Air Filters

Disposable Panel Air Filters are the most commonly used type of air filter in furnaces, air conditioning systems or HVAC systems. Disposable panel air filters use a variety of media for filtration. A “panel” air filter is aptly named; the air filter is manufactured as a self-contained, one-piece “panel” that consists of three components:

- Air filter media material

- Internal structure that supports the air filter media material such as metal fabric, wire or even cardboard
- Box or frame in which the air filter media material and the media support material is attached to and housed within

Pleated Air Filters

Pleated Air Filters are much like Disposable Panel Air Filters in that the filter media is housed in a rigid panel. There are two main differences: the media material used to filter the air, as well as the way the material is mounted into the air filter box or frame. The filter media used in pleated filters most often resembles fabric and has the capability of removing significantly smaller particulate from the air. Further, when the filter media is integrated into the filter, it is pleated to provide more surface area for filtration. Pleated Air filters are more effective at removing particulate from the passing air.

Electrostatic Pleated Air Filters

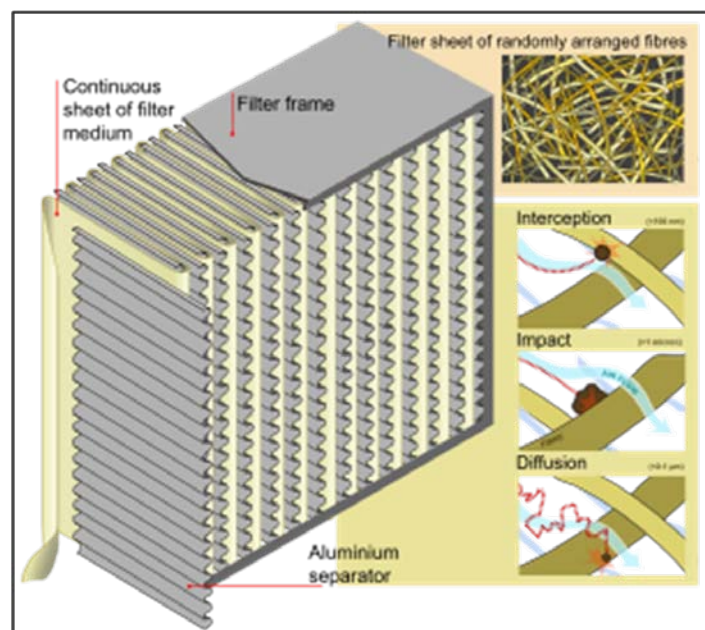
Electrostatic Pleated Air Filters are a more highly evolved version of the pleated air filter. Electrostatic Pleated Air Filters are electrically charged so that the media material acts much like a magnet to draw more particulate into the media filter material for more efficient filtration. Electrostatic material also deters microorganism growth within the material.

HEPA Filters

Conventional air filters with a MERV of 1 – 7 are usually used to trap large particles that are too big to pass through the filter, but allow smaller contaminants such as harmful airborne bacteria, molds, pollen, chemical residue and dust mites to pass. These filters are not reliable to filter airborne microbial contaminants in HVAC systems.

Mechanisms of HEPA Filters

HEPA filters are perhaps the best-known technology for reducing exposure to airborne microbial contamination in HVAC systems. HEPA stands for "High-Efficiency Particulate Air". A HEPA filter is a type of air filter that satisfies certain standards of efficiency such as those set by the United States Department of Energy (DOE). By government standards, an HEPA air filter must remove 99.97% of all contaminants and particles greater than 0.3 microns from the air that passes through. Once trapped, *contaminates* and particles are not able to



HEPA-Filter with functional description.

flow back into circulation.

HEPA filters are composed of a mat of randomly arranged fibers. The fibers are typically composed of fiberglass and possess diameters between 0.5 and 2.0 micrometer. Key factors affecting function are fiber diameter, filter thickness, and face velocity. The air space between HEPA filter fibers is much greater than 0.3 microns.

Contaminants are trapped (they stick to a fiber) through a combination of the following four basic mechanisms:

Interception - where particles following a line of flow in the air stream come within one radius of a fiber and adhere to it.

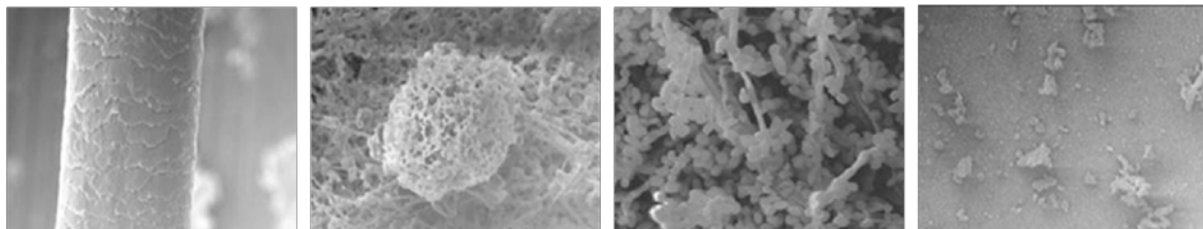
Impaction - where larger particles are unable to avoid fibers by following the curving contours of the air stream and are forced to embed in one of them directly; this effect increases with diminishing fiber separation and higher air flow velocity.

Diffusion - an enhancing mechanism is a result of the collision with gas molecules by the smallest particles, especially those below 0.1 μm in diameter, which are thereby impeded and delayed in their path through the filter; this behaviour is similar to Brownian motion and raises the probability that a particle will be stopped by either of the two mechanisms above; it becomes dominant at lower air flow velocities.

Sieving - the most common mechanism in filtration. Sieving stops large particles that are just too big to fit through the open areas of the filter. This includes all particles above 5 μm in size and larger. As you go smaller in particle size, say between 1 μm to 5 μm , occasionally some of these particles get through, but the efficiency for removal is still well into the 99.9999+% range. This is still due primarily to sieve effect and the beginning of inertial impaction effect.

Filtration Performance in HVAC Systems

The most economical and widely deployed air-cleaning technologies for HVAC systems are Low, Medium and High Efficiency Filters. This efficiency is measured by the minimum efficiency reporting value (MERV) for air filters installed in the ductwork of HVAC systems. The American Society of Heating, Refrigerating and Air-Conditioning Engineers, or ASHRAE developed this measurement method. MERV ratings (ranging from a low of 1 to a high of 16) also allow comparison of air filters made by different companies.



Airborne Microbial Contaminants trapped in filters.

How is the Performance of an Air Filter Measured?

There are different ways to measure how well air filters work, which depend on the type of design, media materials and the basic configuration. Air filters are configured either in the ductwork of HVAC systems (i.e., in-duct) or as portable air cleaners.

In-duct Particle Removal

Most mechanical air filters are good at capturing larger airborne particles, such as dust, pollen, dust mite and cockroach allergens, some molds, and animal dander. However, because these particles settle rather quickly, air filters are not very good at removing them completely from indoor areas. Although human activities such as walking and vacuuming can stir up particles, most of the larger particles will resettle before an air filter can remove them.

Flat or panel air filters with a MERV of 1 to 4 are commonly used in residential furnaces and air conditioners. For the most part, such filters are used to protect the HVAC equipment from the buildup of unwanted materials on the surfaces such as fan motors and heating or cooling coils, and not for direct indoor air quality reasons. They have low efficiency on smaller airborne particles and medium efficiency on larger particles, as long as they remain airborne and pass through the filter. Some smaller particles found within a house include viruses, bacteria, some mold spores, a significant fraction of cat and dog allergens, and a small portion of dust mite allergens.

Pleated or extended surface filters

Medium efficiency filters with a MERV of 5 to 13 are reasonably efficient at removing small to large airborne particles. Filters with a MERV between 7 and 13 are likely to be nearly as effective as true HEPA filters at controlling most airborne indoor particles. Medium efficiency air filters are generally less expensive than HEPA filters, and allow quieter HVAC fan operation and higher airflow rates than HEPA filters since they have less airflow resistance.

Higher efficiency filters with a MERV of 14 to 16, sometimes misidentified as HEPA filters, are similar in appearance to true HEPA filters, which have MERV values of 17 to 20. True HEPA filters are normally not installed in residential HVAC systems; installation of a HEPA filter in an existing HVAC system would probably require professional modification of the system. A typical residential air handling unit and the associated ductwork would not be able to accommodate such filters because of their physical dimensions and increase in airflow resistance.



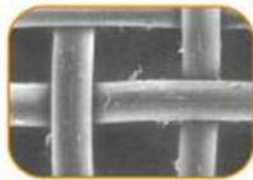
*New filter
(Before Use)*



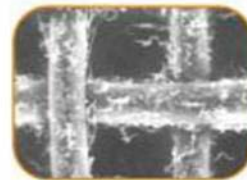
*Dirty filter
(After Use)*

Electrostatic Filter

There is no standard measurement for the effectiveness of electrostatic filter. While they may remove small particles, they may be ineffective in removing large particles. Electrostatic filter can produce ozone — a lung irritant. The amount of ozone produced varies among models. Electrostatic air filters may also produce ultrafine particles resulting from reaction of ozone with indoor chemicals such as those coming from household cleaning products, air fresheners, certain paints, wood flooring, or carpets. Ultrafine particles may be linked with adverse health effects in some sensitive populations.



Clean Electrostatic Filter



Dirty Electrostatic Filter

HEPA Filter

The ability to filter airborne microbial contaminants smaller than 0.3 microns from the air that passes through HVAC systems is a very important specification. Small airborne microbial contaminants can easily reach the deepest recesses of the lungs and, according to the U.S. EPA, may cause a wide range of extremely negative health effects, such as aggravated asthma, acute respiratory symptoms including aggravated coughing and painful or difficult breathing, eye, nose, and throat irritation, respiratory infections and chronic bronchitis, decreased lung function, shortness of breath and lung cancer.



Contaminants trapped in HEPA filter.

The mixture of dust particles and airborne microbial contaminants larger than 0.3 microns which are trapped in HEPA filter; when exposed to sufficient moisture content especially from the condensation of cooling coils and water in the drain pans can be primary amplification sites for fungi and bacteria growth. HEPA filters only remove airborne microbial contaminants by trapping them and do not kill them. Thus, exposure to contaminants in cleaning of HEPA filters can cause adverse health effects.

Minimum Efficiency Reporting Value (MERV)

MERV stands for Minimum Efficiency Reporting Value. ASHRAE assigns a MERV number intended to help people compare air filters that are for use in heating and air conditioning systems. The MERV air filter is a rating of the efficiency of the air filter, regardless of whether it is used as an air conditioner filter or furnace filter or a HVAC system that combines both heating and air conditioning into one HVAC system. The MERV rating ranks air filter efficiency by assigning a number ranging from 1 to 16, with one being the lowest air filter efficiency and 16 the highest air filter efficiency when used in an HVAC system.

Particles in the indoor air that pass through the HVAC Systems air filter are measured in microns, which is 1/1000 of a millimeter. *A human hair is about 100 microns wide.* A MERV12 rating represents the best balance between airborne particulate removal of dust, pollen, airborne pathogens, etc. and overall HVAC system efficiency. Air filters above MERV12 generally require larger, more expensive HVAC systems not normally intended for traditional home or smaller office heating and air conditioning systems. This is due to the “drag” imposed on the HVAC system. MERV12 requires 80% or better air filter efficiency on 1 - 3 micron particles and a greater than 90% air filter efficiency on 3 -10 micron airborne particles when tested in accordance with ASHRAE Test Standard 52.2 used in testing air filters and air filter efficiency.

Appendix B: Causes of Sick Building Syndrome

Sick building Syndrome is a result of poor indoor air quality (IAQ). The following have been cited as a cause or contributing factor to sick building syndrome:

Biological contaminants:

Bacteria, molds, pollen, and viruses are types of biological contaminants and the most problematic source for SBS. These contaminants may breed in stagnant water that has accumulated in ducts, humidifiers and drain pans, or where water has collected on ceiling tiles, carpeting, or insulation. Sometimes insects or bird droppings can be a source of biological contaminants. Physical symptoms related to biological contamination include cough, chest tightness, fever, chills, muscle aches, and allergic responses such as mucous membrane irritation and upper respiratory congestion.

Inadequate ventilation:

Inadequate ventilation occurs if heating, ventilating, and air conditioning (HVAC) systems do not effectively distribute air to people in the building. In an effort to achieve acceptable air-quality while minimizing energy consumption, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) recently revised its ventilation standard to provide a minimum of 15 cfm of outdoor air per person (20 cfm/person in office spaces). Up to 60 cfm/person may be required in some spaces (such as smoking lounges) depending on the activities that normally occur in that space (see ASHRAE Standard 62-1989).

Chemical contaminants from indoor sources:

Most indoor air pollution comes from sources inside the building. For example, adhesives, carpeting, upholstery, manufactured wood products, copy machines, pesticides, and cleaning agents may emit volatile organic compounds (VOCs), including formaldehyde. Environmental tobacco smoke contributes high levels of VOCs, other toxic compounds, and respirable particulate matter. Research shows that some VOCs can cause chronic and acute health effects at high concentrations, and some are known carcinogens. Low to moderate levels of multiple VOCs may also produce acute reactions. Combustion products such as carbon monoxide, nitrogen dioxide, as well as respirable particles, can come from unvented kerosene and gas space heaters, woodstoves, fireplaces and gas stoves.

Chemical contaminants from outdoor sources:

The outdoor air that enters a building can be a source of indoor air pollution. For example, pollutants from motor vehicle exhausts; plumbing vents, and building exhausts (e.g., bathrooms and kitchens) can enter the building through poorly located air intake vents, windows, and other openings. In addition, combustion products can enter a building from a nearby garage.

A Word About Radon and Asbestos...

SBS and BRI are associated with acute or immediate health problems; radon and asbestos cause long-term diseases which occur years after exposure, and are therefore not considered to be among the causes of sick buildings. This is not to say that the latter are not serious health risks; both should be included in any comprehensive evaluation of a building's IAQ.

Appendix C: Building Investigation Procedures

The goal of a building investigation is to identify and solve indoor air quality complaints in a way that prevents them from recurring and which avoids the creation of other problems. To achieve this goal, it is necessary for the investigator(s) to discover whether a complaint is actually related to indoor air quality, identify the cause of the complaint, and determine the most appropriate corrective actions.

An indoor air quality investigation procedure is best characterized as a cycle of information gathering, hypothesis formation, and hypothesis testing. It generally begins with a walkthrough inspection of the problem area to provide information about the four basic factors that influence indoor air quality:

- the occupants
- the HVAC system
- possible pollutant pathways
- possible contaminant sources.

Preparation for a walkthrough should include documenting easily obtainable information about the history of the building and of the complaints; identifying known HVAC zones and complaint areas; notifying occupants of the upcoming investigation; and, identifying key individuals needed for information and access. The walkthrough itself entails visual inspection of critical building areas and consultation with occupants and staffs.

The initial walkthrough should allow the investigator to develop some possible explanations for the complaint. At this point, the investigator may have sufficient information to formulate a hypothesis, test the hypothesis, and see if the problem is solved. If it is, steps should be taken to ensure that it does not recur. However, if insufficient information is obtained from the walk through to construct a hypothesis, or if initial tests fail to reveal the problem, the investigator should move on to collect additional information to allow formulation of additional hypotheses. The process of formulating hypotheses, testing them, and evaluating them continues until the problem is solved.

Although air sampling for contaminants might seem to be the logical response to occupant complaints, it seldom provides information about possible causes. While certain basic measurements, e.g., temperature, relative humidity, CO₂, and air movement, can provide a useful "snapshot" of current building conditions, sampling for specific pollutant concentrations is often not required to solve the problem and can even be misleading. Contaminant concentration levels rarely exceed existing standards and guidelines even when occupants continue to report health complaints. Air sampling should not be undertaken until considerable information on the factors listed above has been collected, and any sampling strategy should be based on a comprehensive understanding of how the building operates and the nature of the complaints.

Appendix D: Air Filter Efficiency Selection

Arrestance	Efficiency	MERV	Filter Type
60 - 80%	Less Than 20%	MERV 1 - 4	Disposable Panel Filters Permanent Metal Filters Fiberglass Media Latex Coated Natural Fiber Media Foam Media Automatic Roll Filter Media
80 - 90%	Less Than 20%	MERV 5	Disposable Panel Filters Synthetic Media Automatic Roll Filter Media
90 - 95%	20 - 30%	MERV 6 - 7	Cube Filters Self-Supported Pocket Filters Ring Panel Filters Pleated Panel Filters
95%	30 - 40%	MERV 7 - 8	Self-Supported Pocket Filters Ring Panel Filters Pleated Panel Filters
95 - 98%	40 - 50%	MERV 8 - 9	Extended Surface Pocket Filters
95 - 98%	50 - 60%	MERV 9 - 10	Pleated Panel Filters Extended Surface Rigid Cell Filters Extended Surface Pocket Filters
99%	60 - 70%	MERV 10 - 11	Extended Surface Pocket Filters Extended Surface Rigid Cell Filters
99%	70 - 80%	MERV 12 - 13	Extended Surface Pocket Filters Pleated Panel Filters
99%	80 - 90%	MERV 13 - 14	Extended Surface Pocket Filters Extended Surface Rigid Cell Filters
99%	90 - 95%	MERV 14 - 15	Extended Surface Pocket Filters Extended Surface Rigid Cell Filters
NA	95% DOP	MERV 16	Extended Surface Rigid Cell Filters
NA	99.97% 99.99% 99.999% 99.9995%	NA	HEPA/ULPA Filters

1. Arrestance and Dust Spot Efficiency ratings are based on the ASHRAE 52.1 – 1992 test method.
2. Minimum Efficiency Reporting Value (MERV) ratings are based on the ASHRAE 52.2 test method.

Appendix E: ASHRAE Standard and EN Standard

It has become very difficult and confusing to try to work through the maze of different filter testing standards. The purpose of this document is to offer some assistance in comparing the ASHRAE Standards and those utilized in Europe.

The table on the next page is an attempt to combine the major testing standards into one easy to use overview. Please note that there is no way to combine all of the nuances into one table so please consult the individual test standards for more details.

Below is a quick overview comparison of the ASHRAE 52.2-2007 and EN 779:2002 methods.

ASHRAE 52.2-2007

- Domestic in use
- Uses a solid aerosol test challenge

EN 779:2002

- International use is goal
- Uses a liquid aerosol test challenge

ASHRAE 52.2

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) develops standards the design and maintenance of indoor environments. ASHRAE publishes standards for:

- Method of measurement and Test
- Standard design
- Standard practice

ASHRAE 52.2 was created to determine air filter efficiency as a function of particle size. The test method determines the ability of an air filter to remove dust by specific particle sizes ranging from 0.3 to 10 microns. This advancement led to the development of a Minimum Efficiency Reporting Value (MERV) for each filter tested.

EN779:2002

The European Committee for Standardization, Technical Committee 195, Work Group 1 (CEN/TC195-WG1) established a new standard for general ventilation filters standard under document name EN779:2002.

The EN779:1993 classification system (comprising groups F and G filters) is determined from the average filtration efficiency with respect to liquid DEHS particles of 0.4 µm diameter. Classification of F filters is based on performance with respect to 0.4 µm particles is based on the “dust-spot” opacity test. Filters found to have an average efficiency value of less than 40% will be allocated to group G and the efficiency reported as “<40%”. The classification on G filters is based on their average arrestance with the loading dust.

Type	Eurovent Class	CEN EN779 Class	ASHRAE 52.1	ASHRAE 52.2
COARSE DUST FILTER	EU1	G1	<65% Arrestance	MERV 1
	EU2	G2	65<70% Arrestance 70<75% Arrestance 75<80% Arrestance	MERV 2 MERV 3 MERV 4
	EU3	G3	80<85% Arrestance 85<90% Arrestance	MERV 5 MERV 6
	EU4	G4	>90% Arrestance	MERV 7 MERV 8
FINE DUST FILTER	EU5	F5	40<45% ASHRAE 50<55% ASHRAE	MERV 9 MERV 10
	EU6	F6	60<65% ASHRAE 70<75% ASHRAE	MERV 11 MERV 12
	EU7	F7	80<90% ASHRAE	MERV 13
	EU8	F8	90<95% ASHRAE	MERV 14
	EU9	F9	>95% ASHRAE	MERV 15
HIGH EFFICIENCY PARTICULATE AIR FILTER (HEPA)	EU10	H10	85% DOP	MERV 16
	EU11	H11	95% DOP	
	EU12	H12	99.5% DOP	***
	EU13	H13	99.95% DOP	***

	EU14	H14	99.995% DOP	***
ULTRA LOW PENETRATION AIR FILTER (ULPA)	EU15	U15	99.9995% DOP	***
	EU16	U16	99.99995% DOP	***
	EU17	U17	99.999995% DOP	***

Appendix F: General Filter Selection

Typical Applications	Type of Air Handling Equipment	Typical Air Filter Products	
		Prefilters	Final Filters
Residential Apartments, Condominiums Single Family Homes	Room Air Conditioners Residential Furnace & Air Conditioning Units	Not Applicable	Disposable Panel Filters Pleated Panel Filters (1") Polyurethane Foam Latex Coated Natural Fiber (Hog's Hair)
Light Commercial, Industrial Hotels, Motels (Sleeping Rooms) Light Industrial Nursing Homes Schools (Classrooms) Small Office Buildings	Light Commercial Heating & Air Conditioning Units Packaged Terminal Air Conditioners Unit Ventilators Fan Coil Units	Not Applicable	Disposable Panel Filters Pleated Panel Filters Ring Panel Filters Slip-Ons Filter Media & Frames
Commercial, Industrial, Institutional Airports Auditoriums Banks Bars, Cocktail Lounges Bowling Alleys Casinos Commercial Buildings Correctional Facilities Electric Utilities Food Processing Government Buildings Health Care Facilities Inpatient Care, Administrative, Sterile Processing, Food Processing, Storage, Soiled Holding Areas Hotels (Public Spaces) Industrial Plants - Offices, Plant Air	Rooftop Air Handling Units Central Station Air Handlers Built Up Frame Banks Side Access Housings	Disposable Panel Filters Pleated Panel Filters Filter Media & Frames Ring Panels, Links Poly Cube Filters Self-Supported Pocket Filters Extended Surface Pocket Filters (40%) Automatic Roll Filters	Extended Surface Pocket Filters (50 - 90%) Extended Surface Rigid Cell Filters (60 - 95%)

Institutional Facilities Museums Residential (High Rise) Restaurants, Cafeterias Retail Stores, Super Markets Schools, Universities Sports Arenas, Gymnasiums Theaters Train Stations, Bus Depots Warehouses, Storage Areas			
Sensitive Processes Health Care Protective Environment Rooms, Airborne Infection Isolation Rooms, Surgical Suites Labs Microelectronics, Semiconductor Pharmaceutical Production Photo Film Research Facilities Universities	Rooftop Air Handling Units Central Station Air Handlers Built Up Frame Banks Side Access Housings	Disposable Panel Filters Pleated Panel Filters Filter Media & Frames Ring Panels, Links Poly Cube Filters Self-Supported Pocket Filters Extended Surface Pocket Filters (40%) Automatic Roll Filters	Extended Surface Pocket Filters (50 - 90%) Extended Surface Rigid Cell Filters (60 - 95%) HEPA, ULPA Filters Disposable Ducted Ceiling Modules Replaceable Filter Ceiling Modules Fan / Filter Units

N-SeProtector 101



Product Description

N-SeProtector 101 is a nano-selenium Coating product from Axena Technologies developed by the Nanomedicine Laboratory at Brown University in Rhode Island, USA. Brown University is founded in 1764, is a member of the *Ivy League*. The Nanomedicine Laboratory at Brown University is the world leader in nano-selenium research and development.

N-SeProtector 101 is two components: **Nano-Selenium Synthesizer 101 (NSS 101)** in granular powdery form and **Nano-Selenium Buffering Activator 101 (NSBA 101)** in liquid form. The mixture of NSS 101 and NSBA 101 will generate a high intensity colloidal nano-selenium Coating. When applied to HVAC filters, it can rapidly and effectively destroy airborne microbial contaminants. Filters coated with N-SeProtector 101 have been proven to deliver a higher removal rate of against airborne microbial contaminants.

Advantages of N-SeProtector 101

High efficiency filtration systems can be very expensive and may require additional maintenance procedures. Filters, even lower efficiency filters, capture airborne microorganisms. N-SeProtector 101 enhances existing filters by preventing microbial growth on and within the filter material. Airborne contaminants and microbial growth negatively impact filtered air-quality.

N-SeProtector 101 Treated Filtration

	Removes Large Particles	Removes Biological VOC's	Eliminates Mold	Eliminates Bacteria	Eliminates Viruses
Conventional air filters	Yes	Yes	Yes	Yes	Yes
HEPA filters	Yes	Yes	Yes	Yes	Yes

N-SeProtector 101 has unique advantages over alternative technologies:

- Effectively kills bacteria, fungi and mold
- Does not generate any Volatile Organic Compound (VOC)
- Does not release anions or negative ions to the surrounding environment
- Destroys airborne microbial contaminants without ozone exposure
- Increases the efficiency of coated filters, including HEPA filters
- No special maintenance required
- Cost effective and easy to apply
- Safe, environmentally friendly ingredients

Method of Creation

N-SeProtector 101 consists of **Nano-Selenium Synthesizer 101 (NSS 101)** and **Nano-Selenium Buffering Activator 101 (NSBA 101)**.

For filter application, pour the whole bottle of NSS 101 in white granular powdery into the jerrycan of NSBA 101 in red color solution. Mix it homogenously using stirrer for about 3 minutes. An orange-red color solution indicates that the solution is homogenously mixed. The final solution can be applied through spraying, rolling or dip coating.



Dip coated effect on HVAC filter.



Spray coated effect on HVAC filter.

Packing

	Package A	Package B	Package C
NSS 101	13.3 g	66.7 g	266 g
NSBA 101	1000 g	5000 g	20000 g

Storage

N-SeProtector 101 should be stored in dry area between 85° to 100°F (29° to 38°C) away from sunlight exposure.

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