

Fine Particle

POLLUTION

Residential

Air

Quality



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Fine Particle POLLUTION

Residential Air Quality

Airborne particles, such as smoke, dust and pollen, can cause personal discomfort, allergic reactions, and a soiling film that slowly coats walls, furnishings and draperies.

While outdoor air pollutants are often visible as they spew forth from smokestacks or auto exhausts, indoor pollution may show only in the dust-laden sunbeam or smoke rising from a cigarette. About 99 percent of the particles in indoor air are too small to be seen individually, as the unaided human eye can at best see a 30-micron particle.

As Figure 1 illustrates, most indoor air pollutants are much smaller than 30 microns and there are a lot of them. There may well be more than 400 million unseen particles in one cubic foot of indoor air.

It is the fact that these particles float about in the air that makes them so difficult to live with and control. If they would fall out on the floor or table top, we could vacuum or sweep them up and reduce the problem. What is it that keeps them suspended, seemingly forever?

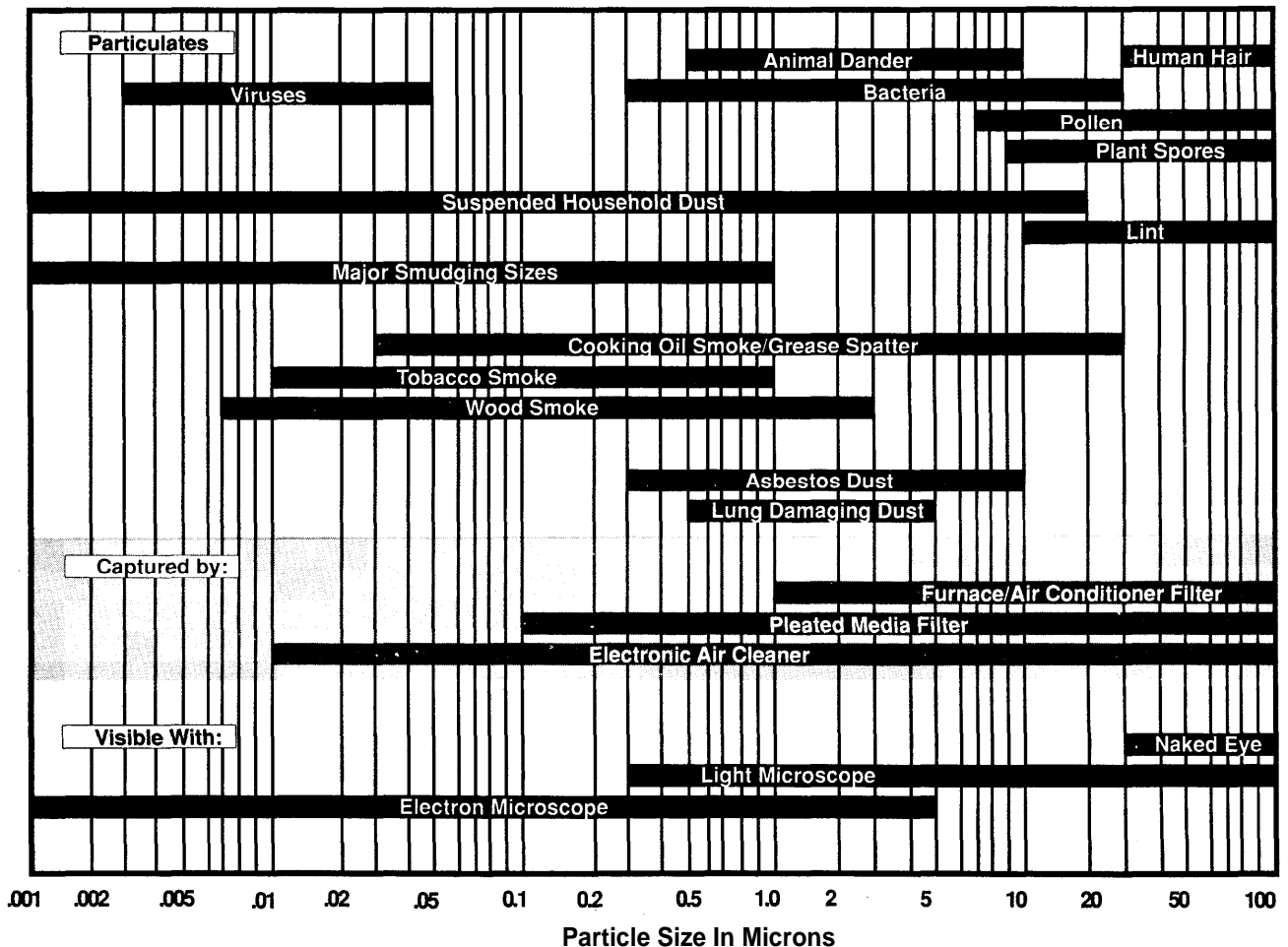


Figure 1. Size Ranges of Indoor Air Pollution Particles and Control Devices.

First, air molecules randomly “bumping” into the smallest particles disrupts their settling. Then, air movement—from a person walking about, the furnace or air conditioner coming on, the natural convection of warm air rising and cold air sinking—causes large and small particles to swirl about.

The number of particles may remain nearly constant, because new particles are being created as old ones attach themselves to surfaces.

As we look at each type of particulate (free particle) pollutant, keep in mind that physically they can vary in three ways—size, density and electrostatic charge. In the case of fibers, the “size” refers to their thickness (diameter), and their length will be many times greater.

It is not the intent of this publication to discuss gaseous pollutants, per se. Thus, you will not find information here on radon, formaldehyde, sulfur dioxide, or other potential indoor air pollutants. The gas, ozone, will be included, as it can be the undesirable by-product of certain particulate removal devices.

Indoor Particulate Pollutants

Types and Sources

Lint. All long fibers found in household airborne dust are considered “lint.” They may be carpet or clothing fibers that break off due to wear and tear. They could be broken segments of cat or dog hair, or even human hair.

A concern these days are asbestos fibers, which can come from older floor tile, ceiling panels, “blown” ceiling finish material, or duct or pipe insulation.

Dust. Most of the dust in indoor air is the result of dirt being tracked onto floors and carpets, and then being repeatedly ground up as we walk on it, until it is fine enough to stay suspended in the air. The amount of dust in the air at any given time depends on how heavy traffic is inside the house.

Dust also comes in with the air that normally infiltrates from the outside. Except for extremely windy days, this dust is relatively fine in size.

Smoke. Indoor smoke commonly comes from smoking tobacco or overheating the fat or cooking oil in the kitchen. However, burning candles produce large amounts of smoke, as indicated by the incomplete combustion of the yellow flame.

The gas flame of a range or other appliance will result in little smoke so long as it has a blue color.

Your fireplace or woodburning stove can put smoke into the house if the system is not operating properly. Your neighbor’s fireplace, even if operating correctly, can put smoke into your house via infiltration air.

Grease Aerosol. Skillet or deep-fat frying inevitably causes grease spatter and smoking. Some of the smoke condenses as it cools to form tiny grease droplets (aerosol). A wide range of particle sizes result from frying.

Pollen, Mold and Plant Spores. Pollen and plant spores generally get into the house with the infiltration air from the outside.

Some, such as goldenrod pollen, are very large particles and don’t move far from the plants. Ragweed and grass pollens are smaller and are more easily kept suspended by the breezes.

Some plant spores and mold spores can originate inside the home, especially in areas of high humidity, such as bathrooms and closets.

Viruses and Bacteria. Both viruses and bacteria may be present in residential air under normal conditions. Bacteria are much larger (0.3 to 30 microns) than viruses (0.003 to 0.05 microns), but both are known to “piggy-back” on larger dust particles. Thus, viruses, in particular, may not be as difficult to capture as their size would indicate.

Effects

Because the behavior and control of particulate pollutants are so greatly influenced by their size, the more important types are shown in Figure 1 with their size ranges.

The unit of size, the micron, is a very small one. It takes more than 25,000 microns to make one inch. The very finest human hair, for example, is 30 microns thick.

Most of the “dust” one sees on table tops in the home is lint. The “dancing sunbeams” of dust we see are mainly lint. Although lint is a constant nuisance, requiring frequent “dusting,” it is not important in permanent soiling of walls and furnishings or in health effects, except for rarely occurring asbestos.

The staining and smudging of walls and furnishings is caused by particles smaller than one micron, both dust and smoke, along with fine grease aerosol.

“Second-hand” tobacco smoke has been proved to be a definite health hazard, as have been the fine carbon particles resulting from incomplete combustion (yellow flames).

All fine particles can have attached odor molecules, but this is especially true of tobacco smoke. Pollens and spores can cause allergy problems, and mold spores are a source of undesirable odors.

Combustion processes—cigarette burning, gas burner flame—produce very small particles of carbon with high electrostatic charges. Very quickly, particles of opposite charge attach themselves to each other, forming “lacy” chains with dozens of particles. These “agglomerates” move much as larger particles but retain some charge, which causes them to attach to walls and furnishings more readily. Small particles in heating and cooling air traveling through metal ducts also will pick up an electrostatic charge, accounting for the smudging which develops around air outlets.

Grease aerosol from frying sticks to surfaces (walls, cabinets, appliances) upon first contact. Some of these particles are small enough to move into other rooms and coat upholstery and draperies. The grease coating, in turn, helps hold other pollutant particles which bump into the surface.

A portion of tobacco smoke initially consists of vapor, which condenses into tiny airborne droplets (aerosol). These sticky particles behave much like grease aerosols.

Carbon particles, in particular, attract large numbers of odor-bearing gas molecules. Thus, the particle carries the odorant with it as it attaches to household surfaces and gives it up very slowly. As an example, the smell of stale cigarette smoke persists in a room long after the smoker has left.

Pollens, along with mold and plant spores, cause allergy problems and odors. Most of the pollens and plant spores originate outside the home and, since they are relatively large, can be partially controlled by maintaining a tight residence.

Cleaning The Air

Other than banning smoking or conscientiously using a good vented range hood while cooking, there isn't a lot you can do to eliminate the sources of particulate air pollution in the home. But there are air cleaning systems that can reduce the concentration.

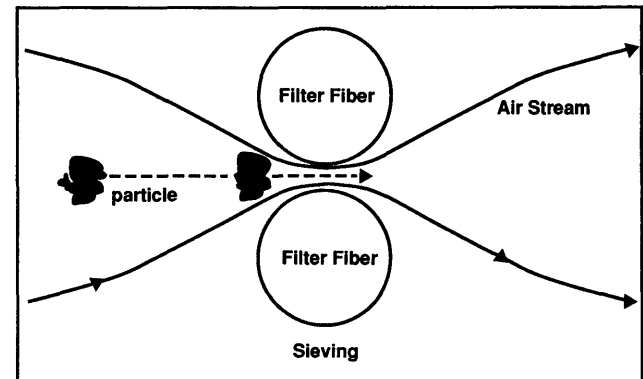
For a home equipped with a forced air furnace and central air conditioning, there are a wide variety of air cleaning devices, in terms of both cost and efficiency.

For non-forced-air systems or rental housing, there are small portable devices which are effective for individual rooms. These are in competition with heavily promoted “ionizers” and “electronic air purifiers”

of low price but dubious effectiveness. To understand the differences, it is necessary to look at the basic mechanisms of particle capture and their application.

Mechanical Filtration Mechanisms

Sieving. Although this is the common concept of air filtration, it is relatively unimportant. It is not economically feasible to make screens with openings small enough to catch anything but lint. Also, each time a particle would be caught in a screen opening, that opening would not pass air and the screen would quickly become unusable.

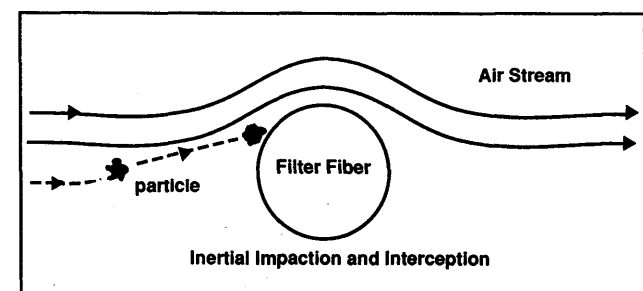


Inertial Impaction and Interception. These two mechanisms work together and are both based on the fact that a swiftly moving particle may have trouble missing an obstacle in its path.

The air stream obstacle in this case is a filter fiber, usually glass, plastic or aluminum, either loosely packed as in a common furnace filter or densely pressed in a pleated media filter.

The larger the particle and the faster the air stream, the greater the chance of a collision and, thus, the higher the efficiency of capture. For a given weight of filter fiber, the finer fibers offer more opportunities for collision and result in higher capture efficiencies.

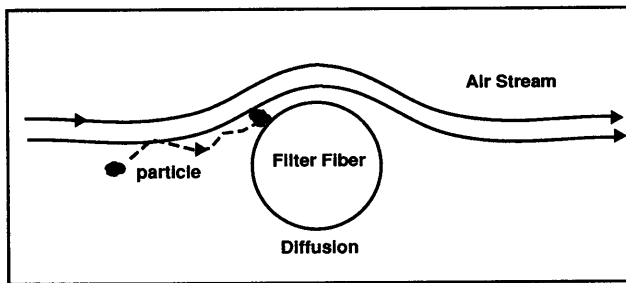
Very large particles—greater than 5 microns—may bounce off the fibers. To reduce bounce in furnace filters, an oil or adhesive is applied. Pleated media filters stop these large particles by sieving.



The lint which collects on the face of a filter is finer than the fibers in most cases and increases the capture efficiency as the filter loads. However, the airflow gradually falls off and at some point the filter must be washed or replaced with a fresh one. A furnace filter should be changed when the fibers “collapse” away from the paper frame.

Diffusion. Extremely small particles are bounced around by collisions with randomly moving air molecules and collide with more fibers than they would due to inertial impaction alone.

The slower the particles move through the filter, the more opportunities there are for this to happen. So, this mechanism is most important for extremely small particles moving very slowly through thick filters of very fine fibers.



Combined Mechanisms. All of these mechanisms operate at the same time, but their relative influence depends on particle size, air (or particle) velocity, fiber diameter, and filter depth.

The lowest capture efficiency is generally for the 0.3-micron particle. For particles larger than 0.3 micron, efficiency increases with size and air velocity. For particles smaller than 0.3 micron, efficiency improves for smaller particles and lower air velocity if the filter consists of a thick bed of fine fibers.

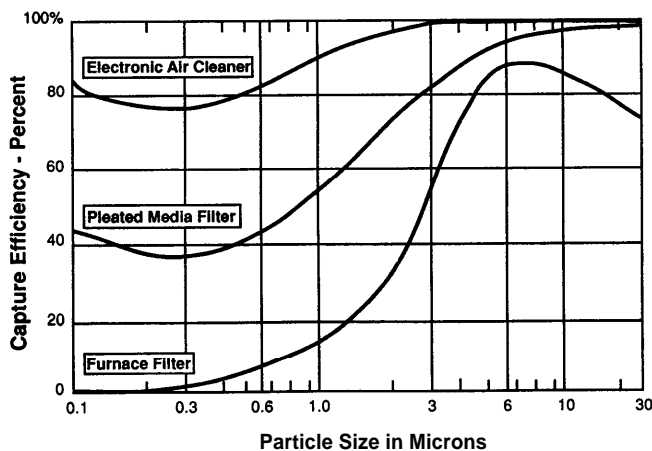


Figure 2. Size vs. Efficiency for Major Classes of Air Cleaners

Figure 2 shows typical size vs. efficiency curves for each of the major types of air cleaners (filters). It is evident that efficiency varies considerably with particle size for each class, but in general there are also large differences between classes. The curves are not precisely those for any particular filter or air cleaner, and large differences exist within classes.

Applications. Figure 1 shows the applicable size range for two types of mechanical filters—the common coarse-fibered furnace/air conditioner filter, and the finer-fibered, more densely packed pleated media filter.

By comparing each filter type to each particulate category above, the appropriateness of each filter may be determined.

Keep in mind that the pleated media filter is many times more expensive to purchase and requires more fan energy, hence is more expensive to operate. A furnace filter is commonly placed before the pleated media to extend its useful life.

As Figure 1 illustrates, the common furnace filter is very effective in removing lint, pollen and plant spores. It is somewhat less efficient on bacteria and animal dander and of little use on lung-damaging dust. As a class, furnace filters remove less than 10 percent of the smudging-sized particles and have no effect on viruses unless they are attached to larger dust particles.

Another use of Figure 1 would be to look at a particular pollutant and see how it might be controlled. For example, the chart tells us that airborne viruses are so small that an ordinary microscope cannot see them and only the electronic air cleaner can capture them unless they “piggyback” on larger particles.

Electrostatic Air Cleaners

Charged Plate and Wire Cleaners. This device uses a two-stage system of electrostatic collection. Particles entering the air cleaner pass between high-voltage ionizing wires, where they receive an intense positive electrical charge. They immediately pass between a bank of alternately charged plates, being repelled by the positively charged ones and attracted to the negatively charged, and adhere to the plates, which eventually have to be removed and washed. Figure 3 shows a charged plate and wire cleaner.

This cleaner is highly efficient for a wide range of particle sizes. Its main drawback is the electrical arcing and accompanying snap that occurs if it becomes too full of dust. Although expensive to purchase, it costs very little to operate.

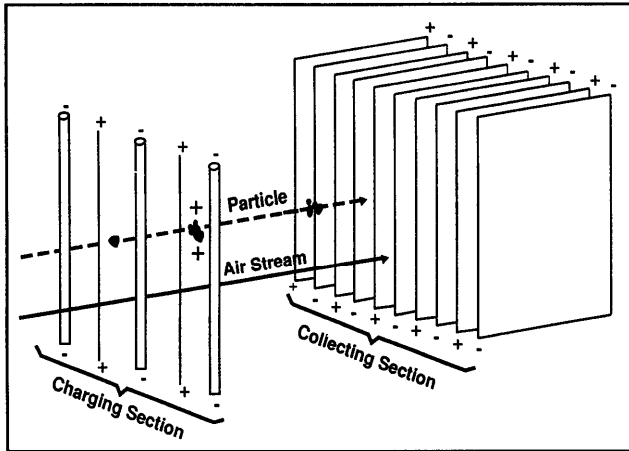


Figure 3. Two - Stage Electrostatic Air Cleaner

Charged Media Air Cleaners. These units look like mechanical filters of glass or cellulose fibers, but the high-voltage power pack attached to them induces an electrostatic field.

This is essentially a single-stage electrostatic collector, in which the charging and collecting fields are relatively weak compared to the two-stage design. The charged media filter is more efficient than the same fibers would be without a charge, but less efficient than a two-stage unit.

Self-Charging Media Filters. Constructed of coarse plastic ribbon fibers, this unit depends upon the air moving through it to induce an electrostatic charge on the fibers.

It looks like a poorly designed furnace filter and performs only slightly better. Even this slight advantage is lost if the relative humidity is at a proper level, for it depends on the air being dry.

Air Ionizers. Conflicting claims by manufacturers as to the principles of physics involved make the efficiency of such units suspect. Some literature claims that the mixture of positive and negative ions emitted results in both positively and negatively charged dust particles. The oppositely charged dust particles are attracted to each other and supposedly settle to the floor in the manner of large, heavy particles.

Other literature claims that all particles are given negative charges and are repelled by the positively charged walls. They are never collected—they simply never attach to anything.

Independent tests of such devices invariably show no reduction in dust concentration in the air and no effect on the rate of wall staining.

Some manufacturers also claim that negative ions make one feel good, but substantiating evidence is lacking.

The Ozone Problem. The charged-plate-and-wire electrostatic air cleaners employ very high electrical voltages—between 3,000 and 10,000 volts D.C. The units are perfectly safe to use and maintain, because as soon as they are opened, the electricity is automatically cut off. They also limit the current flow, putting them in the safety class of an electric fence, even if you could gain access.

However, the high electrostatic voltage means that a small—very small—amount of ozone is generated, especially if the plates become loaded with lint and cause an electric arc. Ozone places stress on the human respiratory system and at the levels found in Los Angeles smog, can be harmful to health.

No conscientious engineer would design an air cleaner to produce ozone. He or she would recognize it as a potential problem, one regulated by the U.S. Food and Drug Administration (FDA). The FDA limits ozone concentrations from such devices to five parts per 100 million parts of air. At this level, most people can sense it as a sharp, pungent, biting odor. It is the odor of air after an electrical storm.

Checking Out Claims

Problems in checking out or understanding manufacturers' claims of particle capture efficiency stem from two sources. First, all airborne particulates except specific spores or pollens consist of a wide range of sizes. The large particles contribute most of the weight; the fine particles cause the staining of surfaces.

Consumers must ask whether the stated efficiency is a "weight efficiency" or a "dust-spot (stain) efficiency." The literature should indicate which standard was followed in testing and reporting. The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) has a standard method of reporting efficiencies for central system units. The Association of Home Appliance Manufacturers' (AHAM) standard reports "Clean Air Delivery Rates (CADR)", a measure combining efficiency and air flow rate, of portable units. Independent testing organizations use the CADR method.

For example, a furnace filter might have a 28 percent weight efficiency and a 9 percent dust-spot efficiency. A pleated media filter might test 98 percent efficient by weight and 50 percent by dust-spot.

The second problem for the consumer is caused by the wording of manufacturers' claims. Typically, a filter might be said to be "up to 95 percent efficient in removing household dust." Obviously, "up to 95

percent” includes 5, 20, 55 and 94. The only interpretation which can be made with certainty is that no efficiencies are over 95 percent.

Based on Figure 1, “household dust” in suspension has particles all the way from 0.001 to 20 microns. The filter’s efficiency depends upon the size of particle it is expected to remove, so the manufacturer’s statement is doubly meaningless.

If you want an air cleaning unit that will control a number of typical indoor particulates, the data in Figure 1 should help you make a decision.

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3. _____, Consumers Report, 54:2 (Feb. 1989), pp. 88-93

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