Technical Analysis
Air Purification Technologies

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Introduction

Air purification is the process of removing airborne contaminates from the air. Common indoor air contaminates include Volatile Organic Compounds, Microorganisms, Mold Spores, Particulates, and Allergens. Typically, air filtration has been the primary technology employed to remove many of these contaminants from the air as they pass through the HVAC system. While very high performance air filters can remove many of these airborne particles, Volatile Organic Compounds (VOCs), gasses, and microorganisms are far more difficult to address.

Indoor air quality (IAQ) has become one of the leading health issues in the country. Both government and private research studies have linked many illnesses to poor indoor air quality. One of the fastest growing areas of medical diagnosis and treatment has become environmental and occupational medicine. Beyond allergies and respiratory tract infections, the consequence of poor indoor air quality includes asthma, hypersensitivity pneumonitis, lung disease, and cancer.

According to the National Institute for Occupational Safety and Health (NIOSH) one-third Americans are exposed to poor indoor air quality every day at home, office and schools [1]. In 2000 William Fisk, a noted indoor air quality researcher, estimated that the direct cost associated with allergies and asthma due to poor IAQ exceeds $15 billion annually [2]. In the same study, Fisk estimated the total medical treatment and lost productivity cost attributed to poor IAQ exceeds $60 billion annually [3].

As a result of the health and financial impact associated with poor IAQ, air purification technologies and new construction techniques are being aggressively developed and deployed to improve indoor environmental conditions. While some of these devices have had questionable results, the push for improving air quality through purification technologies continues at an urgent pace.

Common IAQ Pollutants & Their Sources

Particulates:

Any small solid particle or liquid droplet suspended in the air are broadly referred to as particulates. These airborne pollutants include dust, smoke particles, allergens, pollen, mold spores, bacteria, and viruses. If the particulate is biologic in nature (mold, pollen, bacteria, virus) they are called bioaerosols. The sources for indoor particulate contamination are many. Virtually all surfaces, materials, furnishings and biologic contaminates can be the source for airborne particulates.

VOCs & mVOCs:

Volatile Organic Compounds and microbial Volatile Organic Compounds are a broad class of gasses that contribute to poor indoor air quality. These chemicals include formaldehyde, hydrocarbons, vinyl chloride, methane, and chloroform. Common sources for VOCs include: paint, air fresheners, disinfectants, cleaning supplies, pesticides, building materials, furnishings, and sewage gas.

Also, microorganisms produce VOCs. These chemicals are outgassed as part of the metabolic process. The chemicals produced by microorganism include aldehydes, alcohols, and ketones. These are also the chemicals responsible for moldy, musty, earthy odors typically found in water damaged building and "sick" buildings.

Ozone:

Ozone is a naturally occurring form of oxygen consisting of three oxygen molecules. Ozone is considered an indoor air pollutant and at low parts per million (ppm) can cause headaches, nausea, and respiratory irritation. Even brief exposure of ozone at concentrations above 15 ppm can cause severe lung damage and concentrations above 50 ppm are considered lethal.

Ozone is considered a leading cause for the trigger of asthma attacks and increases sensitivity to other indoor allergens like dust mites [4]. Both OSHA and the EPA have recently revised their permissible exposure limits for indoor ozone levels to 0.1 ppm (time weighted average). Many researchers have been very vocal that these levels are still unsafe. Accordingly, California has banned the sale of any air purification device emitting more than 0.05 ppm ozone [5].

Radon:

Radon is a colorless, odorless radioactive gas. Accordingly to the EPA, radon exposure accounts for 21,000 lung cancer deaths per year [6]. Radon is a naturally occurring, heavier than air gas that seeps into crawlspaces, basements, and through foundation slabs. Even at low levels (4 picoCuries per liter or less) radon has a negative impact on health. Structures built in defined radon zones must use either active or passive systems to mitigate the buildup of the gas.

Asbestos:

The use of asbestos in manufacturer goods began to decline in the 1970 when it was shown that exposure to the fiber is linked to lung cancer. In 1989 the U.S. EPA banned the use of asbestos in manufactured goods. Once inhaled, asbestos causes lung damage resulting in lung cancer (mesothelioma). The Centers for Disease Control and Prevention estimated that almost 1,500 die annually from complications resulting from asbestos exposure every year [7]. Common materials that contained asbestos include, pipe insulation, shingles, linoleum flooring, drywall spackling, acoustic tiles, and adhesives. However, there are thousands of consumer and building products still in use today that contain asbestos.

IAQ Technologies

In an effort to reverse poor IAQ, many technologies have been developed to remove or destroy airborne contaminates. Collectively, these devices are termed “air purifiers”, however, their design and operation vary widely. While air purification devices may have a significant effect on one or more indoor air pollutants, no one technology can address all IAQ issues.

It is important to understand that certain IAQ problems cannot be addressed through air purification technologies alone. Radon, asbestos, and mold contamination require special remediation procedures performed by certified specialists. Once the source of these contaminates has been removed, air purification technologies can be employed to maintain a healthy indoor environment.

HEPA Filtration:

High Efficiency Particulate Air filters or HEPA filters are deigned to remove at least 99.97% of particles as small as 0.3 micros. Typically, HEPA filters are constructed of layers of fiber mesh mats designed to allow air to pass through while trapping ultra fine particulates. HEPA rated filters capture mold spores, pollen, dust, as well as many airborne microbial pathogens. Most high performance air filters are disposable and therefore must be routinely inspected and replaced.

UV Lights

The germicidal properties of UV light was discovered in the 1930's. Today, UV germicidal lights are used in many industries to control microorganism growth on exposed surfaces. UV lights have also been employed to control biologic buildup in HVAC systems; specifically coils and drip pans.

While UV lights can reduce biologic contaminates on surfaces, they unfortunately produce ozone (0_3). Ozone is defined by the EPA as a dangerous air pollutant. Even at relatively low parts per million (ppm) ozone can lead to respiratory irritation, pulmonary edema and chronic respiratory disease. Therefore, OSHA and the EPA have established permissible exposure limits for ozone to no more than 0.1 ppm (time weighted average).

Ion Generators:

Ion generators were a popular air purification technology broadly marketed as a consumer device during the 1990s. Ionic systems charge the air as it passes over negatively charged collector plates. Through ionic attraction, aerosols are drawn to the collector plates and are removed through periodic manual cleaning.

While the technology is effective at initially removing aerosols, collector plates require frequent cleaning, otherwise the system rapidly becomes ineffectual. However, the biggest issue surrounding this technology was the production of ozone.

When air becomes charged, ozone is produced. As discussed with UV lights, ozone is a dangerous air pollutant. Accordingly, ion generators have lost favor in the market and states are regulating or banning the sale of ozone producing devices like ion generators.

Ozone Generators:

As discussed above, ozone is a highly reactive molecule that possesses very powerful antimicrobial performance. Ozone generators convert oxygen (O_2) to ozone (O_3) by charging the air through an electrostatic generator. This method of ozone production not only creates high concentrations of ozone, it also produces nitric acid and nitric oxides that are corrosive to metal surfaces. Accordingly, ozone treatment is only reserved for speciality disinfection applications and ozone devices should not be used casually or in occupied buildings.

Titanium Dioxide Photocatalytic Systems:

Titanium Dioxide (TiO_2) systems also known as photocatalytic generators were first introduced in the late 1980's as a safe alternative to ozone generators. TiO_2 systems convert ambient free water molecules into hydroxides (HO) and peroxides (H_2O_2) through a photocatalytic reaction powered by UV light.

Hydroxides and peroxides are highly reactive molecules that quickly oxidize VOCs and microbial/biologic contaminates. While hydroxide ions do not survive for more than a few thousandths of a second, peroxides are stable and survive until they encounter an airborne particulate or settle onto a surface. Peroxides are powerful oxidizers that quickly and safely neutralize microorganisms.

While the benefits of TiO_2 systems are well defined in controlled laboratory settings, the systems quickly lose efficiency in low humidity environments. When installed HVAC systems, their antimicrobial performance becomes significantly limited beyond the system ductwork.

Nano Alloy Photocatalytic Systems:

Developed in 2007, nano-structured alloy catalysts (NSAC) represent the second generation of photocatalytic hydroxyl generation technology. When measured against TiO_2 systems, NSAC generators are substantially more reactive and therefore produce higher concentrations of hydroxides and peroxides even at low humidity levels.

In addition to broad antimicrobial performance and VOC reduction, NSAC based photocatalytic systems efficiently convert free ozone into hydroxyls and peroxides. This conversion can lead to a reduction in total free ozone concentrations within a building. The rate and degree of ozone reduction/conversion is not well defined at this time, however studies are underway.

NSAC based photocatalytic systems hold significant potential to actively control bioaerosols, VOCs, and microbial surfaces contaminates. Accordingly, the technology is being widely implemented today.

Conclusion

The traditional method of addressing poor indoor air quality has been accomplished through dilution. By increasing the rate of fresh air exchange, indoor air pollutants become diluted. However dilution is not an attractive solution. Fresh air used for dilution must be conditioned, dehumidified, and filtered and this requires significant energy input. Furthermore, outside air is often laden with VOCs, microbial pathogens, hydrocarbons, odors, and other pollutants that must be considered.

Microbial contamination is a very real concern regarding outdoor air. Seemingly fresh air can contain highly infectious pathogens like Histoplasmosis, Cryptococcosis, and Legionella. Many outbreaks associated with indoor exposure to these pathogens has been recorded by the CDC. Therefore, dilution air can be the source of significant IAQ issues.

To ensure healthy indoor air, we must adopt new air purification technologies and develop an integrated solution. This solution includes particulate filtration, bioaerosol control, VOC reduction, ozone reduction, and pathogen reduction. This integration of technologies must be part of an overall IAQ plan. This plan should include the participation of HVAC engineers, IAQ investigators, Industrial Hygienists, and technology integrators.

With the integration of new IAQ technologies designed to reduce particulates, VOCs, and microbial contaminates reversing poor indoor air quality is easily obtainable today. Furthermore, by harnessing the benefits of a comprehensive IAQ plan, runaway energy costs can be brought back under control. In many cases, the energy savings realized through air exchange reduction can pay for HVAC upgrades and advanced air purification technologies.

1 National Institute for Occupational Safety and Health. 1998. Building Air Quality Action Plan
2 Fisk, William J. 2000. Health and Productivity Gains from Better Indoor Environments
3 Fisk, William J. 2000. Health and Productivity Gains from Better Indoor Environments
4 U.S. Environmental Protection Agency. Health Effects of Ozone in Patients with Asthma
5 California Environmental Protection Agency. Assembly Bill 2276 (2006, Pavley)
6 U.S. Environmental Protection Agency. 2006. Assessment of Risks from Radon in Homes
7 Centers for Disease Control and Prevention. 2003. Work-Related Lung Disease Surveillance Report

Air Purification Comparison Chart

	Particulate Reduction	VOC & mVOC Reduction	Odor Reduction	Ozone Reduction	Bioaerosol Reduction	Surface Disinfection
HEPA Filtration	Yes	No	No	No	Yes	No
UV Light	No	No	No	No - Generates 0_3	Yes	Yes - Limited
Ion Generator	Yes	Yes - Limited	Yes - Limited	No - Generates 0_3	Yes	Yes - 0_3 Production
Ozone Generator	No	Yes - Significant	Yes - Significant	No - Generates 0_3	Yes - Significant	Yes - Significant
TiO_2 Photocatalytic	Yes - Limited	Yes	Yes	Unknown	Yes	Yes - Limited
NSAC Photocatalytic	Yes - Limited	Yes - Significant	Yes - Significant	Yes - Limited	Yes - Significant	Yes

HEPA Filtration — Very effective at removing airborne particulates that circulate through the HVAC system. Has no effect on VOCs, odors, or ozone. Provides limited bioaerosol reduction outside of the HVAC system and no surface disinfection effect.

UV Lights — No particulate, VOC, or odor reduction. UV lights product ozone therefore, air quality must be monitored if in use. UV lights do have some beneficial effect on bioaerosols, however, surface disinfection is only on immediate hard surfaces exposed to UV radiation. UV radiation is harmful to many surfaces including plastic electrical wire insulation.

Ion Generators — Systems are effective at reducing airborne particulates. Charged ions has a limited effect on VOC and odor reduction. Ion generators produce ozone, therefore use is restricted. Generators can reduce bioaerosols however, system must be cleaned often to be effective. Limited surface disinfection has been observed. This is from the production of ozone.

Ozone Generators — No particulate reduction. Ozone is very effective against VOCs, Odors, Bioaerosols, and surface microbes. Because Ozone can be harmful and even lethal, it should only be used in unoccupied areas by professional remediation & disinfection services.

TiO_2 Systems — Charged ions reduce the level of airborne particulates. Hydroxyl radicals are effective against VOCs and odors within the HVAC system. TiO_2 systems do reduce bioaerosols within the immediate treatment area. Laboratory research has shown significant reduction of surface contaminates within confined treatment zones.

NSAC Systems — Charged ions reduce the level of airborne particulates. Hydroxyl radicals are effective against VOCs and odors within the HVAC system. NSAC systems produce significant levels of hydroxides and peroxides. This is very effective at reducing bioaerosols, and surface contamination in a wide footprint. Limited Ozone reduction has also been observed in the laboratory.