Beyond Ozone: Cleaning Outdoor Air for IAQ

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ASHRAE Standard 62-1999, "Ventilation for Acceptable Indoor Air Quality," continues the tradition of its predecessors by specifying minimum ventilation rates and indoor air quality that will be acceptable to the human occupants of a building. It considers chemical, physical, and biological contaminants that can affect air quality but acknowledges the fact that acceptable IAQ may not be achieved in all buildings meeting the requirements of the standard.

A prime example of this is a building located in a non-attainment area for one or more of the criteria pollutants listed in the EPA's National Ambient Air Quality Standards (NAAQS). Another would be when there is a local external source of airborne pollutants (automobile exhaust, trash storage, industrial activities, etc.) that could be brought into the building through the HVAC system. Meeting the minimum ventilation standard in these instances would only result in substituting one group of pollutants for another - those with sources outside the building for those internally generated.

Previous versions of Standard 62 describe procedures by which outdoor air should be evaluated for acceptability and stated that if this air does not meet certain requirements "...the air (shall) should be treated to control the offending contaminants." The current standard now requires outdoor air assessment and recommends outdoor air cleaning, but does not require it. Although a distinction is not made between particulate or gaseous contaminants, it is most often gaseous contaminants that many consider the primary offending materials in outdoor air.

Conventional wisdom has held that because essentially every building HVAC system already has particulate filters, they should already be able to address the large majority of particulate contamination issues. However, when it comes to gaseous contaminants, this provision of the standard has been almost universally ignored. The primary excuses being given are the high cost of installing, operating and maintaining the air cleaning equipment and that there is no standard method by which the performance of these air cleaning systems can be evaluated.

Perhaps because of what many deem as unsubstantiated objections due to a general lack of knowledge about air cleaning systems for gaseous contaminants, there has been a growing concern about simply ignoring the quality of the outdoor air and using it carte blanche for ventilation purposes. If the outdoor air, at the very minimum, does not meet NAAQS it has been strongly argued that this air **must** be treated before it is introduced into a building. No objections, no compromises.

As of September 2000, the EPA lists a total of 114 non-attainment areas for one or more of the criteria pollutants. Several metropolitan areas have shown increases in criteria pollutants over the past 10 years and a closer look at the data reveals that most were exceeding the 8-hour ozone standard level. These increases in ozone levels are most likely due to increased NOx emissions and weather conditions favorable to ozone formation. Rural ozone levels also appear to be increasing.

Ozone is brought into buildings with outdoor air. When inhaled, ozone can aggravate the lungs and can lead to chest pain, coughing, shortness of breath, and throat irritation. Ozone may also worsen chronic respiratory diseases such as asthma and compromise the ability of the body to fight respiratory infections. On days when ozone air pollution is the highest, ozone air pollution has been associated with as much as 10-20% of all summertime respiratory hospital visits and admissions.

People vary widely in their susceptibility to ozone. Healthy people, as well as those with respiratory difficulty, can experience breathing problems when exposed to ozone. Exercise during exposure to ozone causes a greater amount of ozone to be inhaled, and increases the risk of harmful respiratory effects. In addition to the direct effects of ozone on health, ozone can react chemically with VOCs in the indoor air or with surface materials. These reactions may produce VOCs that may be a source of chemical irritation.

Considerate of this data and wanting to avert potential controversy over outdoor air cleaning requirements, in a compromise move, ASHRAE's Standing Standards Project Committee (SSPC) 62.1 has drafted Addendum 62z to Standard 62-1999 that addresses air cleaning requirements for ozone. The current standard requires outdoor air assessment, and recommends outdoor cleaning for contaminants of concern but it does not require cleaning for ozone. This Addendum would require gaseous air cleaning when the outdoor ozone concentration is high, but it does not require air cleaning for other gaseous contaminants. Mandatory air cleaning for ozone is appropriate because of the large number

of people living in non-attainment areas, and the negative impact that ozone has on indoor air quality and occupant well-being.[§]

According to a listing of non-attainment areas, close to half of the population of the US now live in ozone non-attainment areas. In addition, the cost/benefit ratio for ozone removal is expected to be quite low, compared with that of other outdoor contaminants. However, it is mostly these "other" outdoor contaminants that are the primary basis for the application of air cleaning systems in buildings today. It is the control of odors and gaseous contaminants from sources as diverse as automobile and diesel exhaust, HVAC exhausts, trash storage, restaurant exhausts, and various industrial processes that are causing air quality concerns and not just elevated ozone levels. Requiring air cleaning in ozone non-attainment areas is a start in addressing areas with overall poor outdoor air quality, but designing a system solely for the control of ozone is impractical, if not impossible.

Air Cleaning

Air cleaning is one of three methods of reducing contaminants in indoor air. In order of effectiveness, the three methods are:

- Removal of the source or control of its emissions,
- Ventilation with clean dilution air,
- Air cleaning - for either particles or gases, or both.

Source control for outdoor air contaminants is most often not feasible or practical, therefore, ventilation control should be the next option. However, this may not prove viable in all cases either, as the use of large amounts of outdoor dilution air is neither cost-effective nor energy-efficient. Further, in those areas with poor outdoor air quality, it is clear that neither source nor ventilation control cannot prevent the introduction of contaminants into a building. Therefore, air cleaning must be employed.

Assuming a building's HVAC system is already equipped with adequate particulate filtration, gaseous air cleaning can be used as an adjunct to source control and ventilation. Gas-phase air filtration systems employing various dry-scrubbing adsorbent media as an integral part of an HVAC system can effectively reduce gaseous contaminants to well below levels considered objectionable by most occupants. Properly applied, gaseous air cleaning also has the potential for energy savings.

It is well-known that a single adsorbent or chemisorbent media may not adequately control multiple contaminants. The types and numbers of gaseous contaminants one would encounter in outdoor air make it likely that air cleaning systems need to be equipped with a minimum of two different media - granular activated carbon (GAC) and potassium permanganate- impregnated alumina (PIA). The preferred system would contain these media in two discreet filter beds in an arrangement analogous to roughing (GAC) and polishing (PIA) filters for particulate control applications.

It is not always feasible to incorporate a gas-phase air filtration system with two or more filter beds. Retrofit applications in particular present challenges to the HVAC engineer who is often limited by lack of physical space for the system, sufficient static pressure in the air handling system, or budgetary constraints. In these cases, blended GAC/PIA media (typically 50/50 by volume) in a single-stage system can be used. This does not affect the removal of gaseous contaminants in terms of removal efficiencies, however, this system would only have half the service life of a two-pass configuration.

New Air Cleaning Technology for Gaseous Contaminants

Dry-scrubbing chemical filtration media have been applied in many forms for the control of indoor air pollutants with the most common form continuing to be the bulk granular products. Physical limitations placed on these systems and constant budgetary constraints have spurred the development of many new chemical filtration products. Several manufacturers are applying dry-scrubbing media to various filter substrates, but most processes cause the adsorbent materials to become "blinded" or essentially spent through the use of and reaction with various binders and adhesives, and the manufacturing techniques employed. Recent advances in filter manufacturing technology, however, have eliminated these deficiencies.

[§] Note that while reducing the ozone concentration indoors may have a beneficial health effect, this requirement is primarily intended to reduce discomfort by reducing irritation due to ozone and its oxidation byproducts. Also, note that buildings with air change rates of 1.5 air changes per hour or less will be exempt from the ozone air cleaning requirement; as will those buildings located in ozone non-attainment areas wherein the maximum reported hourly average concentration of ozone in the outdoor air is 0.160 ppm or less.

The most promising new chemical filter technology that has been developed applies both GAC and PIA media to a bi-component non-woven fiber matrix that provides high initial and average removal efficiencies and lower pressure drops than traditional gaseous air cleaning systems. This product is a robust, pleatable roll good with many advantages over existing alternatives. It provides for flexible filter design allowing easy application into new or existing HVAC systems with a service life comparable to many granular media systems.

Perhaps the most important feature of this product is that it can also be produced with an integral particulate filter that practically eliminates retrofit costs. The result is a unique and effective combination filter material that can be pleated into essentially any standard filter size for the removal of both gaseous **and** particulate contaminants. There is now a single product that can effectively address all of the air cleaning concerns for outdoor air.

Air Cleaning Systems for Ozone and Outdoor Air

Air cleaning systems can be applied a couple of ways in the HVAC system for best effectiveness. The first would be to treat only the outdoor air - typically 10-20% of the total HVAC air volume. The second application would be to treat the mixed air stream (outdoor + recirculation air). Initial costs would be higher, but overall operating and maintenance costs could be lower due to energy conservation measures allowable under Standard 62.

The cost of the required gaseous air cleaning from Addendum 62z varies as a function of system type. The estimated base operating and maintenance cost is about \$1.25 per ft^2 per year for the entire HVAC system. The incremental annual operating and maintenance cost for an air cleaning system for ozone is estimated to range from \$0.03 to \$0.07 per ft^2 per year. However, this estimate is probably low because it assumes a carbon-only air cleaning system operating at a minimum ozone removal efficiency of 40%. It does not account for a couple of important design and performance considerations.

The first is the requirement for high efficiency prefilters to keep submicron dust particles from "coating" the adsorbent material and rendering it ineffective for ozone control. The second is the need to change the media on a regular basis due to physical deterioration from ozone. Failure to do so can result in bypass through the air cleaning system and significantly reduced removal efficiencies.

Generally speaking, a properly designed, installed, and maintained gaseous air cleaning system will be able to remove significantly more than just ozone from the outdoor air. Even in non-attainment areas, the resulting indoor air quality will be improved to the point that building occupants will be able to tell when the media is spent and should be replaced, regardless of its efficiency against ozone.

Cost Considerations

As opposed to the \$0.03 - 0.07 value some have reported, typical air cleaning systems employing granular adsorbents in trays or filter modules have an estimated annual cost closer to \$0.20-0.40 per ft^2 per year. The large amount of media contained in these systems makes them attractive based on the longer times between media replacement, however, these systems often have substantial installation costs due to the additional hardware required.

The type of air cleaning system that can significantly reduce the annual operating and maintenance costs and avoid the front-end costs associated with granular media systems will be one that employs the new adsorbent-loaded combination media filters described above. These would add an estimated \$0.07 - 0.10 per ft^2 per year.

Using these cost estimates for a typical 100,000 ft^2 office building, the HVAC O&M cost would be \$125K per year. Assuming the use of 20% outdoor air and (approx.) 1 cfm or air per ft^2, air cleaning using with typical bulk granular media systems could add another \$4-8K to this figure, assuming a 1-year media life. Use of the combination filters would add \$5,600.00 to \$8,000.00 to this figure, assuming using a standard 24x24x4" pleated filter with a quarterly changeout. It also assumes that this building was designed using the Ventilation Rate Procedure (VRP) from Standard 62.

As opposed to the VRP's indirect solution for the control of indoor contaminants, the IAQ Procedure provides a direct solution by reducing and controlling the concentrations of contaminants, through air cleaning, to specified acceptable levels. Standard 62 acknowledges that air cleaning, along with recirculation, is an effective means for controlling contaminants when using the IAQ Procedure. Employing this procedure allows the amount of outside ventilation air to be reduced below standard levels if it can be demonstrated that the resulting air quality meets the required criteria.

Using the IAQ Procedure and reducing the outdoor air volume from 20K cfm to 10K cfm and using air cleaning on the mixed air stream instead of the outdoor air alone, we can recalculate the annual air cleaning O&M costs and compare them to cleaning the outdoor air alone. This is shown in the table below.

Total Air Volume, cfm	HVAC O&M Cost/Year, $	Air Volume to be Cleaned, cfm	Air Cleaning Cost, $/cfm	Filter Changes/ Year	Air Cleaning Cost/Year, $	Total HVAC O&M Cost/Year, $
100,000	125,000	20,000	0.07 - 0.10	4	5,600 - 8,000	130,600 - 133,000
90,000	112,500	90,000	0.07 - 0.10	3	6,300 - 9,000	118,800 - 121,500

Due to a lower total contaminant load to the air cleaning system based on the reduction in outdoor air contamination and dilution with indoor air, anticipated filter changes are reduced to 3 times/year. This reduces the overall HVAC O&M cost by more than 9% per year.

In some instances, yearly filter changeouts may be the same for either application depending on the contribution from indoor sources. However, one would still be able to realize an overall reduction of 2-3% in HVAC O&M costs while providing indoor air quality better than cleaning the outdoor air alone.

Beyond Ozone

In contrast to particle filters, gaseous air cleaners are used in only a small minority of buildings because of a lack of strong and enforceable requirements for cleaning the outdoor air, the associated higher operating and maintenance costs and a general lack of perceived benefits in doing so. Regardless, considerable effort is still being devoted to the development of new products for gaseous air cleaning.

A new combination filter has been developed that provides the ability to effectively and economically control both particulate and gaseous contaminants for the improvement and maintenance of IAQ. When this product is used in the application of the IAQ Procedure, one gains the dual benefits of improved IAQ and the ability to reduce their overall HVAC system operating and maintenance costs through a reduction in outdoor air volume.

As mentioned above, ASHRAE Standard 62 makes no distinction between particulate and gaseous contaminants when considering outdoor air quality and its impact on IAQ. Nor does it distinguish between these contaminant types in indoor air except in the methods used for their control. A proposed revision to the standard would require the use of air cleaning systems for ozone in non-attainment areas, and although it is an important first step in addressing the outdoor air being used for ventilation purposes, many still feel it just that - only the first step.

Just as ASHRAE acknowledges the fact that acceptable IAQ may not be achieved in all buildings meeting the minimum requirements of the standard, we must also acknowledge the fact that although adding a requirement for ozone control will bring us a little closer to our goal, but we may still have a considerable way to go in order to assure that meeting the requirements of ASHRAE Standard 62 will indeed assure and provide “acceptable indoor air quality.”

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