The Use of Purafil® Media for the Control of Automotive Exhaust Fumes

There are six main classes of gaseous contaminants which are routinely described in automotive exhaust (a term which will be used here to refer to both automobile and diesel exhaust). As shown in Table 1, carbon monoxide (CO) is the largest component of automobile exhaust whereas the oxides of nitrogen (NO_x) constitute the main components of diesel exhaust. Even though nitrogen oxides contribute significantly to the overall contaminant load from automotive exhaust, they are not the components which would be most responsible for odor and/or health complaints from those who may have been exposed to these fumes.

In many air quality investigations where automotive exhaust is considered problematic, NO_2 and NO_x are used to evaluate aspects of an air handling system. This can be a little misleading, however, because as mentioned above, all relevant data states that oxides of nitrogen as a group is the largest component of diesel exhaust, but not of automobile exhaust. It is assumed NO_2 is used from a health hazard perspective and NO_x for relative comparisons of contaminant concentrations. If these assumptions are correct, we can then accept the limited use of NO_2 and NO_x as surrogates of automotive exhaust. However, these two compounds alone should not form the basis of an entire air quality investigation - especially one that is based primarily on odor complaints.

Table 2 shows these six classes (and one other), typical representatives of each class, their respective OSHA threshold limit values (TLV's), and their odor threshold values. Odor thresholds are included because odor is the basis for many air quality complaints. The lower the odor threshold, the lower the concentration at which this material can be detected by humans and the lower the concentration at which air quality complaints may start. Therefore, just because these contaminants may be present at levels below what would be expected to cause health concerns, it does not preclude the fact that they may be present at concentrations high enough to solicit air quality complaints and cause air quality-related problems.

TABLE 1 Emission Factors	**In Pounds Per 1000 Gallons of Fuel**	
	Automobiles	**Diesel Engines**
Aldehydes (RCHO)	4	10
Carbon monoxide (CO)	2300	60
Hydrocarbons ©	200	136
Oxides of nitrogen (NO_x)	113	222
Oxides of sulfur (SO_x)	9	40
Organic acids (as acetic)	4	31
Particulates	12	110

TABLE 2 - Threshold Values of Selected Compounds

Contaminant Class	**Representative Compound**	**Threshold Limit Value (TLV, ppm)**	**Odor Threshold (ppm)**
Aldehydes	Formaldehyde	1.0	1.0
	Acrolein	0.1	0.2-15
Carbon monoxide	Carbon monoxide	50.0	n.a.
Hydrocarbons	Toluene	200.0	2.14-15.0
	Cyclohexane	300.0	0.41
	Xylene	100	0.47-200
Oxides of nitrogen	Nitrogen dioxide	5.0	5.0
	Nitric oxide	25.0	0.3-1.0
Oxides of sulfur	Sulfur dioxide	5.0	0.47-5.0
Organic acids	Acetic acid	10.0	0.2-2.4
Others	Hydrogen sulfide	20.0	0.00047-4.6
	Ozone	0.1	0.1

This illustrates why even though NO_2 and NO_x may be used as surrogate indicators of air quality with regards to automotive exhaust, they should not be used as the sole basis of an air quality investigation or any recommendations which may result from that investigation. There have been over 700 chemical compounds isolated from automotive exhaust - many of which pose a higher potential threat to air quality and human health than these two. Many of these compounds have TLV's and/or odor thresholds lower than NO_2 and NO_X.

Whereas an air quality investigation may only be able to focus on a few of the compounds present in automotive exhaust, any remedial actions suggested as a result of that investigation must address as many of the potentially offending compounds as possible. In terms of a Purafil gas-phase air filtration system, this means the use of (at least) two dry-scrubbing media - plain activated carbon, our Purakol media, and potassium permanganate-impregnated media, our Purafil Select. Both types of dry-scrubbing media are broad-spectrum adsorbents effective against a wide range of contaminant gases.

Activated carbon does a very good job in removing most hydrocarbons, many aldehydes and organic acids, and nitrogen dioxide due (in part) to its high surface area to volume ratio. It is not as effective against the oxides of sulfur, lower molecular weight aldehydes and organic acids, nitric oxide, or hydrogen sulfide. We have recognized this for many years through testing performed at our own laboratories as well as through testing performed by independent sources. The effectiveness of various Purafil media against some of these compounds, in terms of removal capacities, is shown in Table 3.

TABLE 3 - Breakthrough Capacity Test Results (typical) @ 99.5% Removal Efficiency

Contaminant	Media Tested	Capacity, weight %
Aldehydes (as formaldehyde)	Purafil Select	2.5
	Purakol	0.8
	Select CP Blend	1.8
Hydrocarbons (as toluene)	Purafil Select	1.3
	Purakol	21.5
	Select CP Blend	11.0
Nitric Oxide	Purafil Select	5.2
	Purakol	0.7
	Seelct CP Blend	3.9
Nitrogen Dioxide	Purafil Select	2.0
	Purakol	6.6
	Select CP Blend	3.7
Organic Acids (as acetic acid)	Purafil Select	10.0
	Purakol	22.6
	Select CP Blend	12.3
Sulfur Dioxide	Purafil Select	9.5
	Purakol	5.4
	Select CP Blend	6.7

The results of testing shown in Table 3, should make it apparent why, for automotive exhaust applications, Purafil always recommends the use of both Purakol and Purafil Select medias. Whenever two media are indicated, the use of two separate beds is always preferred. However, due to the flammability concerns associated with the use of plain, activated carbon, some opt for the use of the Purafil Select media alone. This offers some protection from these contaminants, but not as much as when Purakol is also employed. One way to achieve the maximum gas filtration performance and address these flammability concerns is through the use of two beds of Select CP Blend (Purakol and Purafil Select medias, 50:50 vol/vol) . This media carries a UL Classification of Class 1. Two beds of Select CP Blend are the same as a single bed of each Purakol & Purafil Select medias, but without the flammability concerns of Purakol alone.

It should be noted that a chemically-impregnated activated carbon media was also tested against these contaminants. The testing performed included Puracarb PP1505 media. This media is designed to have an enhanced capacity for sulfur-containing compounds. Although it did show a good effectiveness against these compounds, its effectiveness against other test compounds was often less than that of Purakol. When tested against various hydrocarbons, it shows only 70-80% (and most often less) of the removal capacity of plain activated carbon. It is for these reasons that a chemically-impregnated activated carbon media is not generally recommended for the control of automotive exhaust. Rather, it is a gas-phase air filtration system described as above which offers effectiveness against the broadest range of chemical contaminants in the most economical manner.

Although we have described what is felt to be the most effective and economical system for control of the (gaseous) chemical contaminants in automotive exhaust, there are a number of factors which can affect the overall performance of a system. Among these are airflow, contaminant concentrations, contaminant types, temperature, and relative humidity. In most applications, one can assume that the airflow is set and will not significantly vary from that specified for the system and would not be a factor in day-to-day system performance

Contaminant concentrations will typically be the highest during the hours of the morning and evening commutes. This illustrates the well-known fact that contaminant levels are cyclical and will vary depending on the time of day, the day of the week, and even the time of year. Similarly, the types of contaminants present at any time can be tied to the time at which monitoring is performed. Even though the contaminant levels will vary with time, these variations are relatively small and more or less predictable. They can generally be accounted for in a properly designed system using average daily (or yearly) values for the contaminants of concern. If specific data is not available, general contaminant concentration data should be readily available through the offices of the local Air Pollution Control authorities.

Changes in outdoor temperature and humidity are somewhat less predictable, and can have profound effects on the overall performance of a gas-phase air filtration system through its dry-scrubbing media. Each of these environmental parameters can work to both help and hinder the effectiveness of the media. However, of the two, changes in relative humidity can have the more deleterious effect on the media.

For the media recommended for a Purafil system, there are two main processes occurring - adsorption and chemisorption. Adsorption is a physical phenomenon analogous to soaking up water on a sponge. This is the process by which plain activated carbon removes gases from the air. Adsorption occurs more readily at lower temperatures and humidities. Low temperatures reduce the energy of the gas molecules and the amount of energy required from the system for adsorption. Low humidities reduce the amount of water which is adsorbed by the media. Adsorbed water reduces the capacity of the media for the target gases due to a reduction in the number of available adsorptive sites. The reverse is true for higher temperatures and humidity. Also, at higher temperatures, the rate of gas desorption increases. Therefore, unless a gas-phase filtration system is operated for extended periods of time at high temperatures (>95°F) and humidity (>95%), these effects are not usually significant enough to be noticed in an application such as this.

The other process which is occurring is known as chemisorption. This is actually a two-stage process. First the gases are adsorbed onto the dry-scrubbing media. Once adsorbed, they react with a chemical impregnant. This is what occurs with Purafil Select (and Puracarb) media. Potassium permanganate is the impregnant on Purafil Select media due to it being a broad-spectrum oxidizer which will react with many, but not all, chemical compounds. The reaction products formed from Purafil Select media (typically) are non-toxic salts, which remain bound to the media, and carbon dioxide and water vapor. The chemical reactions which are occurring on this media are favored, to an extent, by higher temperatures and humidities. Higher temperatures increase the rates of reactions and the extra water at a higher humidity enhances the ability of the adsorbed gases to contact the impregnant. Lower temperatures and humidity have the opposite effects. Gases which are adsorbed but not chemically reacted are subject to the same effects of temperature and humidity as for plain activated carbon. And as with carbon, desorption of these gases is also possible.

It was stated above that, between temperature and relative humidity, changes in relative humidity would have a more deleterious effect on the performance of a dry-scrubbing media. This is because the media tends to equilibrate with the amount of moisture in the air (see Figure 1 below). The take up of moisture on an unimpregnated media reduces its efficiency due to reduced capacity. The loss of moisture from an impregnated media reduces its efficiency due to a reduction of the water necessary for chemical reactions. This equilibration can happen very rapidly depending on the thickness of the media bed and the size of the media. Thin media beds with a small media would be affected more rapidly and severely than thicker beds employing a larger media. Thicker media beds tend to "dampen" changes in humidity and make any adverse effects less severe.

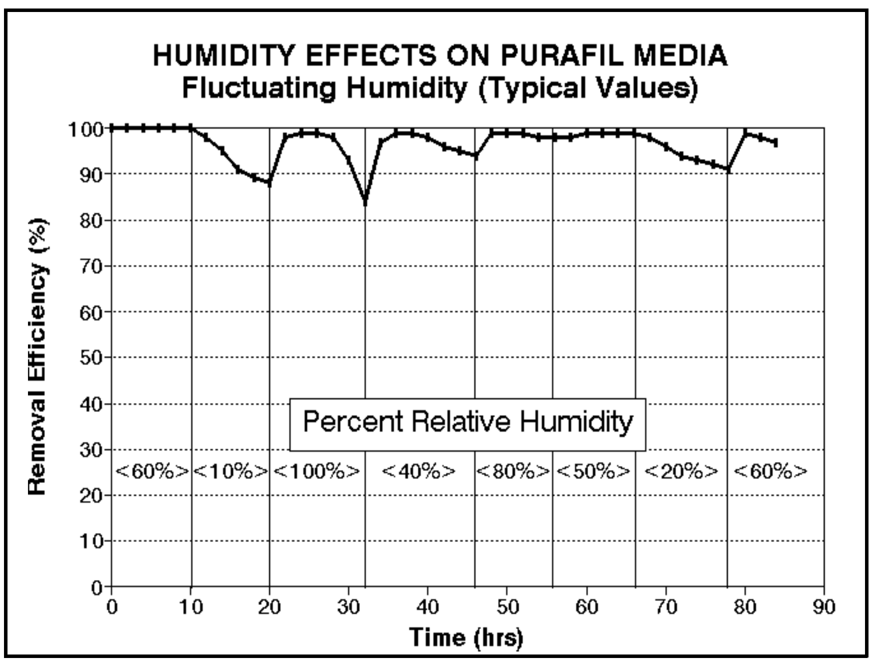

Figure 1 - Effects of Variable Relative Humidity

As can be seen in Figure 1, lowering the humidity of air passing through a chemically-impregnated media lowers the efficiency. Once the humidity is increased, the efficiency begins to recover. However, if the humidity remains at high levels, the efficiency again begins to decrease due to the adsorption sites now being occupied by water. Once the humidity is again decreased, and the moisture content of the media approaches optimum levels, the efficiency will again increase. (Conditions of the test for Figure 1 were: gas challenge concentration - 5 ppm H_2S in air; flow rate - 12.1 liters/minute; media bed depth - 1 inch; media weight - 11 grams; and residence time - 0.2 seconds in the media bed.)

This brief overview of gas-phase air filtration was intended to show that there are many different factors which can influence and affect the overall performance of a system intended for the control of automotive exhaust. It must be understood that one cannot simply install a gas-phase system and expect it perform at 100% efficiency until the media is spent. There will be many fluctuations in performance over the useful life of the media. What we should be striving for is to minimize any adverse effects these fluctuations may cause to those intended to be protected by these systems.

To summarize, the control of automotive exhaust is best accomplished employing two media - either as Purakol and Purafil Select or Select CP Blend - in two separate beds. Particulate control is also important for the protection of our media. Therefore, we recommend the use of a two-stage prefilter section consisting of a 30% roughing filter and a 95% polishing filter. The most important maintenance items for this system will be the 30% filter. Changing this filter as often as necessary protects the more expensive 95% filter and will significantly extend the services life of the our media. If this air is to be exhausted and not recirculated into the space, a final particulate filter is not required. If recirculation is a consideration, a 30% final filter is recommended.