



ASHRAE

ΕΛΛΗΝΙΚΟ ΠΑΡΑΡΤΗΜΑ

## APPLYING GAS-PHASE AIR FILTRATION

### *Advances and Trends in Air Purification: Which Filtration System Works Best?*

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**PURAFIL**  
First...in clean air



# Introduction



- ASHRAE Standard 62.1-2007, “Ventilation for Acceptable Indoor Air Quality,” **specifies minimum ventilation rates and indoor air quality that will be acceptable** to the human occupants of a building.
  - Considers chemical, physical, and biological contaminants.
- **Acknowledges that acceptable IAQ may not be achieved** in all buildings meeting the requirements of the standard.
  - Areas of non-attainment for one or more criteria pollutant.
  - Local external sources of airborne contaminant.



## *Introduction (2)*

- Because most buildings have particulate filtration many feel contamination is being addressed.
  - **Gaseous contamination is almost universally ignored.**
    - Excuse #1 - high cost of installing, operating and maintaining air cleaning equipment.
    - Excuse #2 - no standard method to evaluate performance of air cleaning systems.
- There is growing concern about ignoring outdoor air quality.
  - It has been strongly air that **poor quality air must be treated** before it is introduced into a building.
  - No objections, no compromises.



## *Introduction (3)*

- **Previous versions of Standard 62:**
  - Outdoor air should be evaluated for acceptability.
  - If this air does not meet certain requirements the air should be treated to control the offending contaminants.
- **Current version of Standard 62:**
  - Requires outdoor air assessment and recommends outdoor air cleaning, but does not require it.
  - Distinction is not made between particulate or gaseous contaminants.
  - It is **gaseous contaminants** that many consider the primary offending materials in outdoor air.



# *Section 4.0 – Outdoor Air Quality*

## **General Requirements**

- **4.1.1 Regional Air Quality.** Assess regional outdoor air quality (Hellenic Ministry for the Environment).
  - Must determine air quality compliance status.
- **4.1.2 Local Air Quality.**
  - Survey site.
  - Must visit site and look around.





# *Section 6.2.1 Air Treatment*

## **Ventilation Rate Procedure**

- If outdoor air is judged to be unacceptable in accordance with Section 4.1, each ventilation system that provides outdoor air through a supply fan shall comply with the following sections.
- **6.2.1.1 Particulate Matter.**
  - Use G4 filter in PM<sub>10</sub> non-attainment regions and F8 filter in PM<sub>2.5</sub> non-attainment regions .
- **6.2.1.2 Ozone.**
  - Use 40% efficient ozone filter in some O<sub>3</sub> non-attainment regions.
- **6.2.1.3 Other Outdoor Contaminants.**



## *Ozone and ASHRAE 62.1-2007*

- ASHRAE's Standing Standards Project Committee (SSPC) 62.1 drafted and approved a section that addresses air cleaning requirements for ozone.
- The Standard now requires air cleaning when outdoor ozone concentrations are high, but it does not require air cleaning for other gaseous contaminants.
- Mandatory air cleaning for O<sub>3</sub> is appropriate due to the large number of people living in non-attainment areas, and the negative impact that O<sub>3</sub> has on indoor air quality and occupant well-being.



# *Ozone in Outdoor Air*

- Athens has a major problem of ozone air pollution due to its climate which is dominated by hot and dry summers with intense sunshine.
- As a result, the air quality limits for ozone are frequently exceeded.
- Increases in the proportion of airborne pollution particles, caused by traffic congestion and the consumption of low-grade unclean fuels, are responsible for thousands of deaths in Athens.\*



\* Professor Klea Katsouyianni  
Athens University's Medical School



# Motor Vehicle Exhaust



- There are six main classes of gaseous contaminants which are routinely described in motor vehicle exhaust.

Chemical Types*	Automobiles	Diesel Engines
Aldehydes (RCHO)	4	10
Carbon monoxide (CO)	2300	60
Hydrocarbons (HC)	200	136
Oxides of nitrogen (NO <sub>x</sub> )	113	222
Oxides of sulfur (SO <sub>x</sub> )	9	40
Organic acids (as acetic)	4	31
Particulates	12	110

\* Emission factors in pounds per 1000 gallons of fuel



# *Emissions from Diesel Engines*

- Toxic compounds, like polyaromatic hydrocarbons (PAH), are also found in the exhaust of diesel engines.



<b>CO</b>	<b>HC</b>	<b>DPM</b>	<b>NO<sub>x</sub></b>	<b>SO<sub>2</sub></b>
ppmv	ppmv	g/m <sup>3</sup>	ppmv	ppmv
5 – 1,500	20 - 400	0.1 - 0.25	50 - 2,500	10 - 150

CO - carbon monoxide, HC – hydrocarbons, DPM - diesel particulate matter, NO<sub>x</sub> - nitrogen oxides, SO<sub>2</sub> - sulfur dioxide

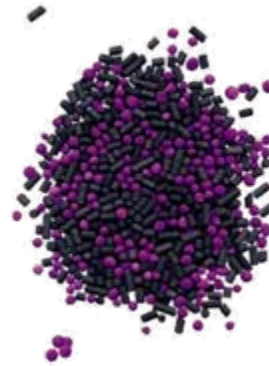


# *Air Cleaning Techniques*

- **Particulate contaminant control** is fairly easily attained with single filters or combinations of filters.



- **Chemical contaminant control** involves the use of gas-phase air filtration systems employing various dry-scrubbing media.





## *Air Cleaning Techniques (2)*

- In chemical contaminant control, there are two main processes occurring:

**Adsorption**: A reversible physical process.

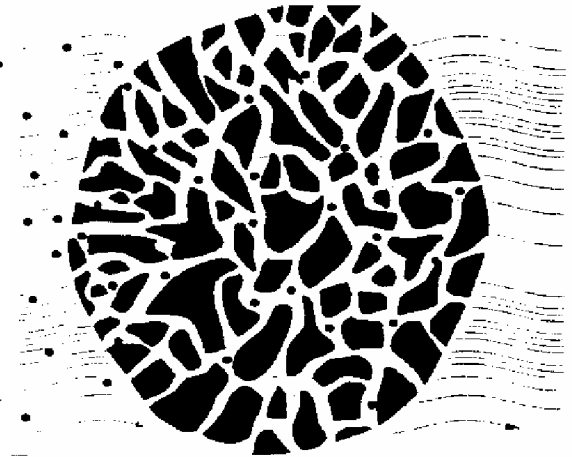
**Chemisorption**: A two-stage process involving adsorption and chemical reaction between impregnate and contaminant gas.



# *Air Cleaning Techniques (3)*

- **Adsorption**

- Most commonly involves the use of granular activated carbon (GAC) media.
- High surface area to volume ratio.
- Very good against most hydrocarbons, many aldehydes and organic acids, and nitrogen dioxide.

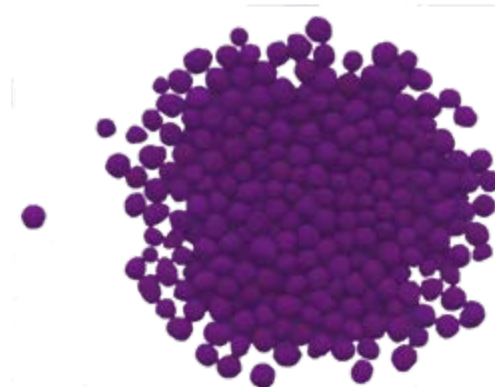
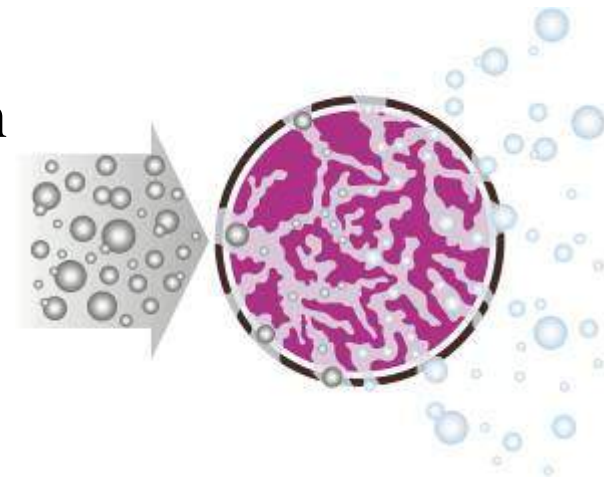




# *Air Cleaning Techniques (4)*

- **Chemisorption**

- Most commonly involves permanganate-impregnated alumina (PIA) media.
- Chemically converts contaminants to carbon dioxide, water, and non-toxic salts.
- Effective against oxides of sulfur, lower molecular weight aldehydes and organic acids, nitric oxide, and hydrogen sulfide.



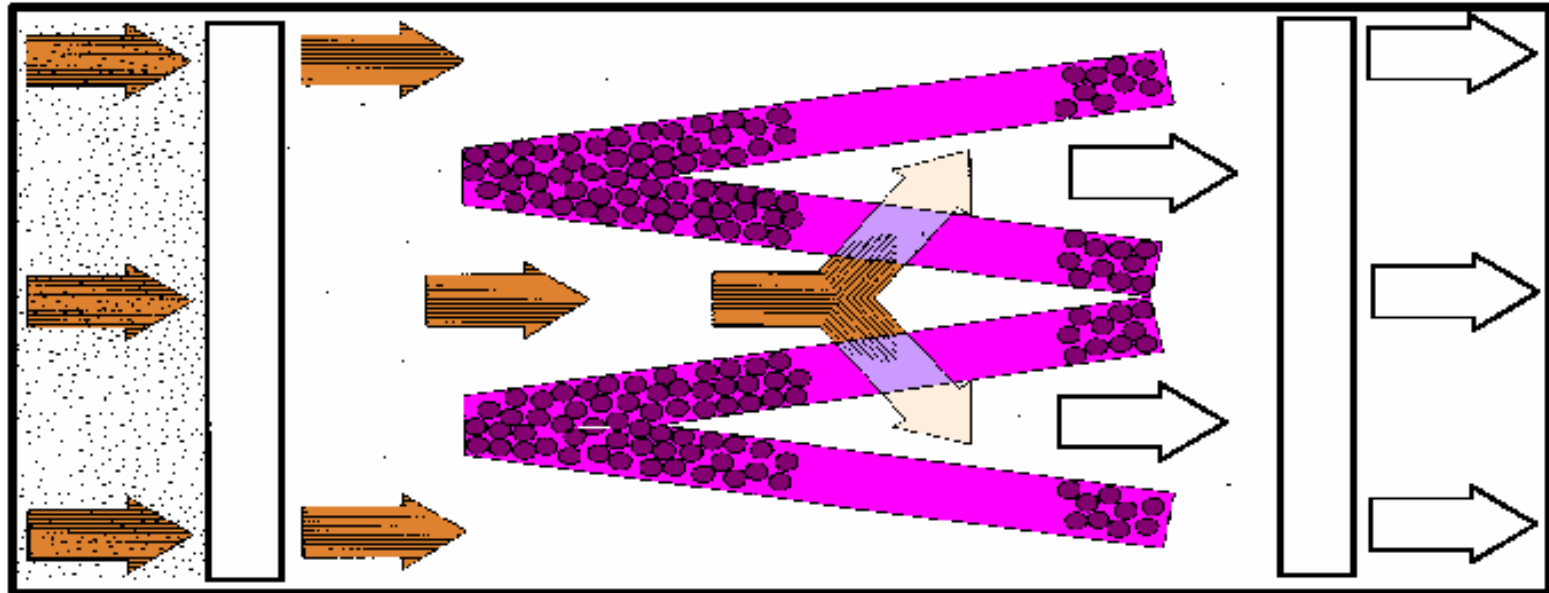


# *Chemical Filtration Systems*

- A single adsorbent or chemisorbent media will not control all contaminants.
- **Air cleaning systems need** to be equipped with **a minimum of two different media.**
  - *Granular activated carbon (GAC)*
  - *Permanganate-impregnated alumina (PIA).*
- **Media to be contained in two separate filter banks** similar to prefilters (GAC) and final filters (PIA) for particulate control applications.



# *Air Cleaning for Gaseous Pollutants*



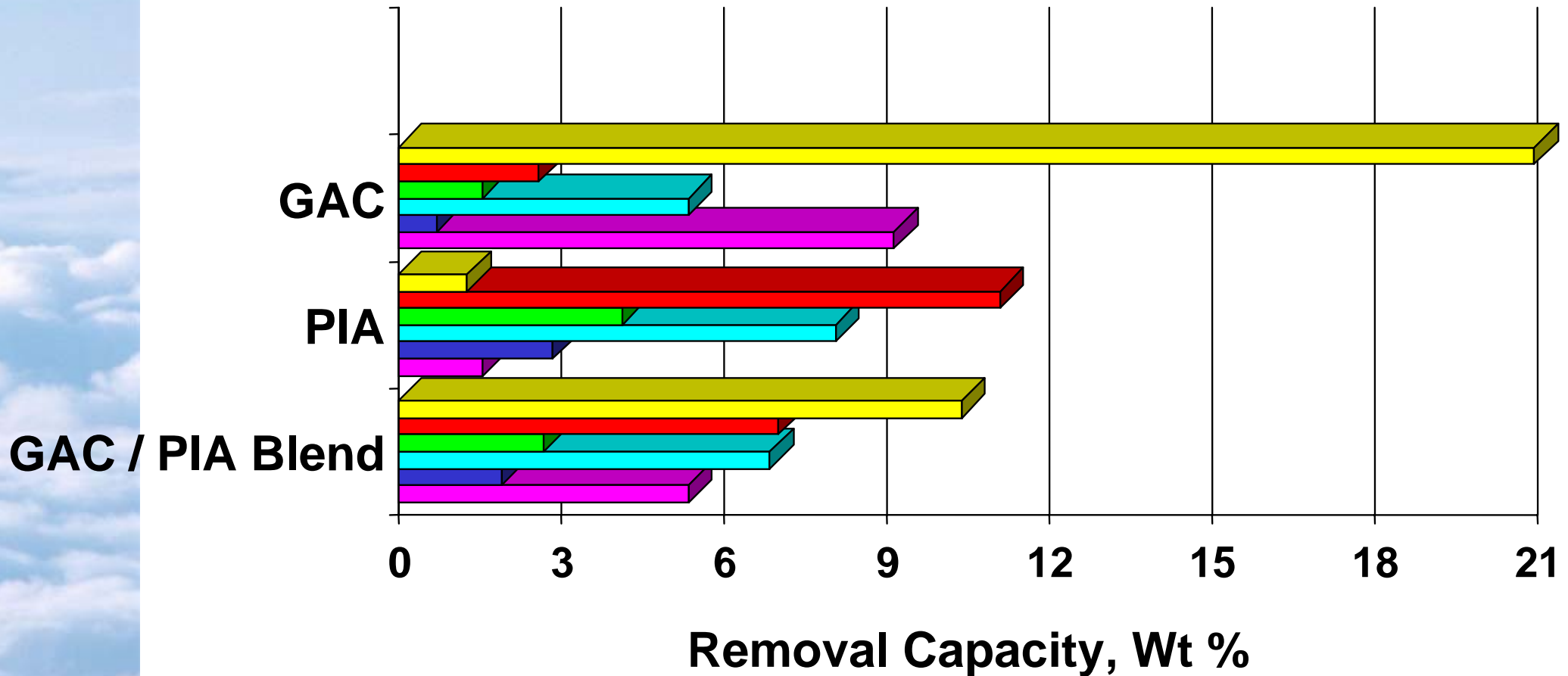
Particulate  
Prefilter

Chemical  
Filter

Particulate  
Final Filter



# Chemical Filtration Media Testing





# *Breakthrough Capacity Test Results*

<b>CONTAMINANT</b>	<b>MEDIA TESTED</b>	<b>CAPACITY, WEIGHT %</b>
Aldehydes (as formaldehyde)	<i><b>PIA</b></i>	<i><b>2.5</b></i>
	GAC	0.8
Hydrocarbons (as toluene)	PIA	1.3
	<i><b>GAC</b></i>	<i><b>21.5</b></i>
Nitrogen dioxide	PIA	2.06
	<i><b>GAC</b></i>	<i><b>6.6</b></i>
Nitric oxide	<i><b>PIA</b></i>	<i><b>5.2</b></i>
	GAC	0.7
Sulfur Dioxide	<i><b>PIA</b></i>	<i><b>9.5</b></i>
	GAC	5.4
Organic acids (as acetic acid)	PIA	10.0
	<i><b>GAC</b></i>	<i><b>22.6</b></i>



# *Development of a New Medium*

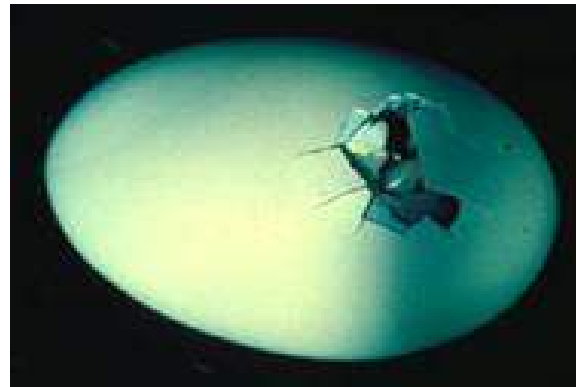
- The first PIA media was developed in the 1960s using 2% potassium permanganate ( $\text{KMnO}_4$ ).
  - The impregnation level was determined by the amount of  $\text{KMnO}_4$  that could be added to the medium and kept fully available for reaction.
  - $\text{KMnO}_4$  has a relatively low solubility in water.
- PIA with 4%  $\text{KMnO}_4$  was available in the 1970s and PIA with 8%  $\text{KMnO}_4$  has been around since the mid-1990s.





# *Breaking the 8% Barrier*

- Advances in permanganate chemistry led to sodium permanganate ( $\text{NaMnO}_4$ ) being used in a new dry-scrubbing air filtration medium.
  - The maximum effective  $\text{KMnO}_4$  content has been reached.
  - $\text{NaMnO}_4$  performs similar to  $\text{KMnO}_4$ .





# Air Cleaning for Automobile Exhaust\*

Measured Parameter	4% KMnO <sub>4</sub>	8% KMnO <sub>4</sub>	12% NaMnO <sub>4</sub>
Media Size (dia.)	3-4 mm	3-4 mm	3-4 mm
Sample Weight (gm)	59.47	60.26	52.50
Sample Density (gm/cc)	0.7929	0.8035	0.7000
MnO <sub>4</sub> <sup>-</sup> Content (%)	5.70	8.24	12.20
Moisture Content (%)	15.5	21.5	24.3
Crush (%)	48.0	45.2	50.2
Abrasion (%)	2.5	1.8	1.7
Time to 50 ppm Breakthrough (min)	360	680	<b>900</b>
Gas Capacity (gm/cc)	0.0892	0.1684	<b>0.2229</b>
Gas Capacity (wt %)	<b>11.25</b>	<b>20.96</b>	<b>31.85</b>

\*Testing was against NO<sub>2</sub> as per ASTM D6646-01 - Standard Test Method for Determination of the Accelerated Hydrogen Sulfide Breakthrough Capacity of Granular and Pelletized Activated Carbon



# *Advances in Air Cleaning Technology*

- Chemical filtration media have been used in many forms.
- Design limitations and budget constraints have spurred the development of many new products.
- **Advances in filter manufacturing technology** have resulted in **combination filter products** that can address **both particulate and gaseous contamination.**



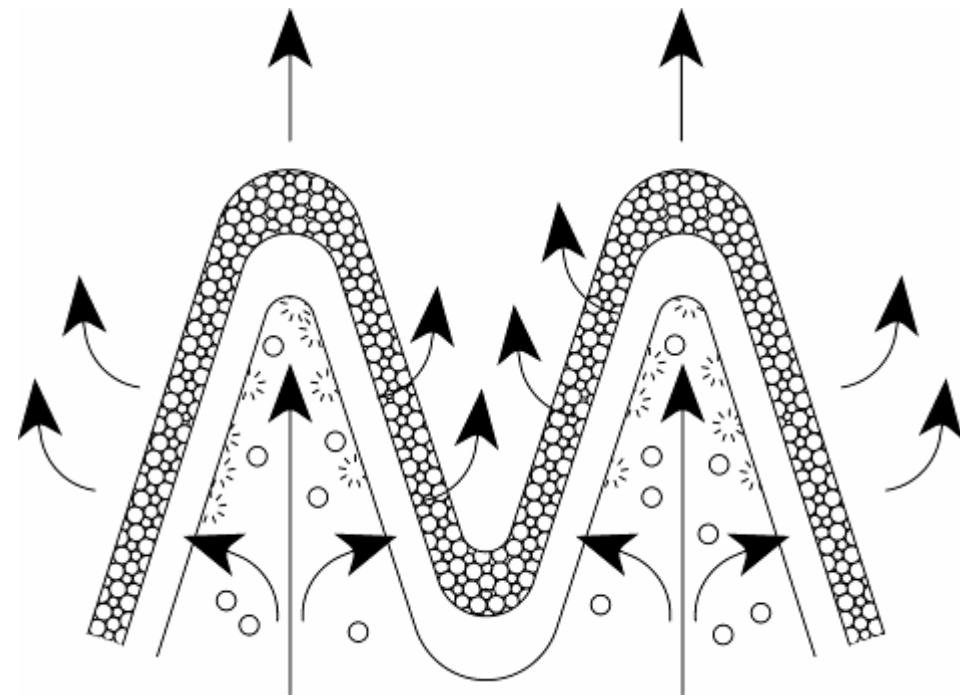
## *Advances in Air Cleaning Technology (2)*

- **Adsorbent-loaded Nonwovens** - application of both GAC and PIA media to a bi-component non-woven fiber matrix
  - Provides high initial and average removal efficiencies.
  - Lower pressure drops.
- **Provides many advantages** over existing alternatives.
  - Flexible filter design
  - Easy application into new or existing HVAC systems
  - Service life comparable to many granular media systems.



# Advances in Air Cleaning Technology (3)

- **True “combination filter”** merges particulate and chemical filtration into one product.
- Single-pass chemical removal efficiencies of 95-99+% possible.
- Rated particulate removal efficiencies of G4-F8 (30-95%) available.



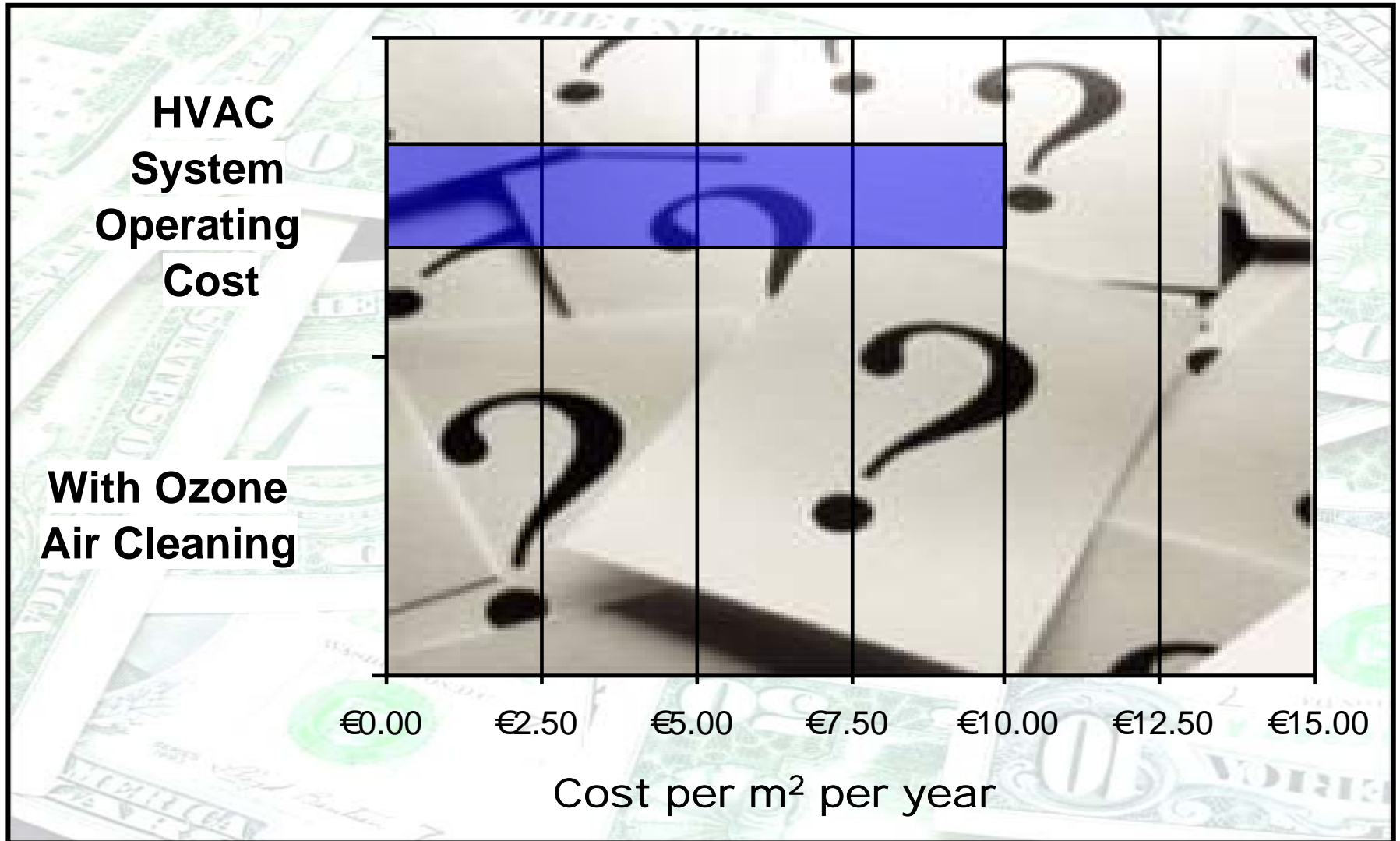


## *Next Steps*

- A new **PIA-Na media will not control all of the gaseous contaminants** of concern in vehicle exhaust.
- **GAC is needed** for hydrocarbons, ozone, and to a lesser degree SO<sub>2</sub> and NO<sub>2</sub>.
- **Caustic-impregnated carbon + alumina medium (CICA)** – is superior against SO<sub>2</sub> and other acidic contaminants.
- **“Triple blend” of PIA-Na / GAC / CICA (1:1:2) for optimum control.**

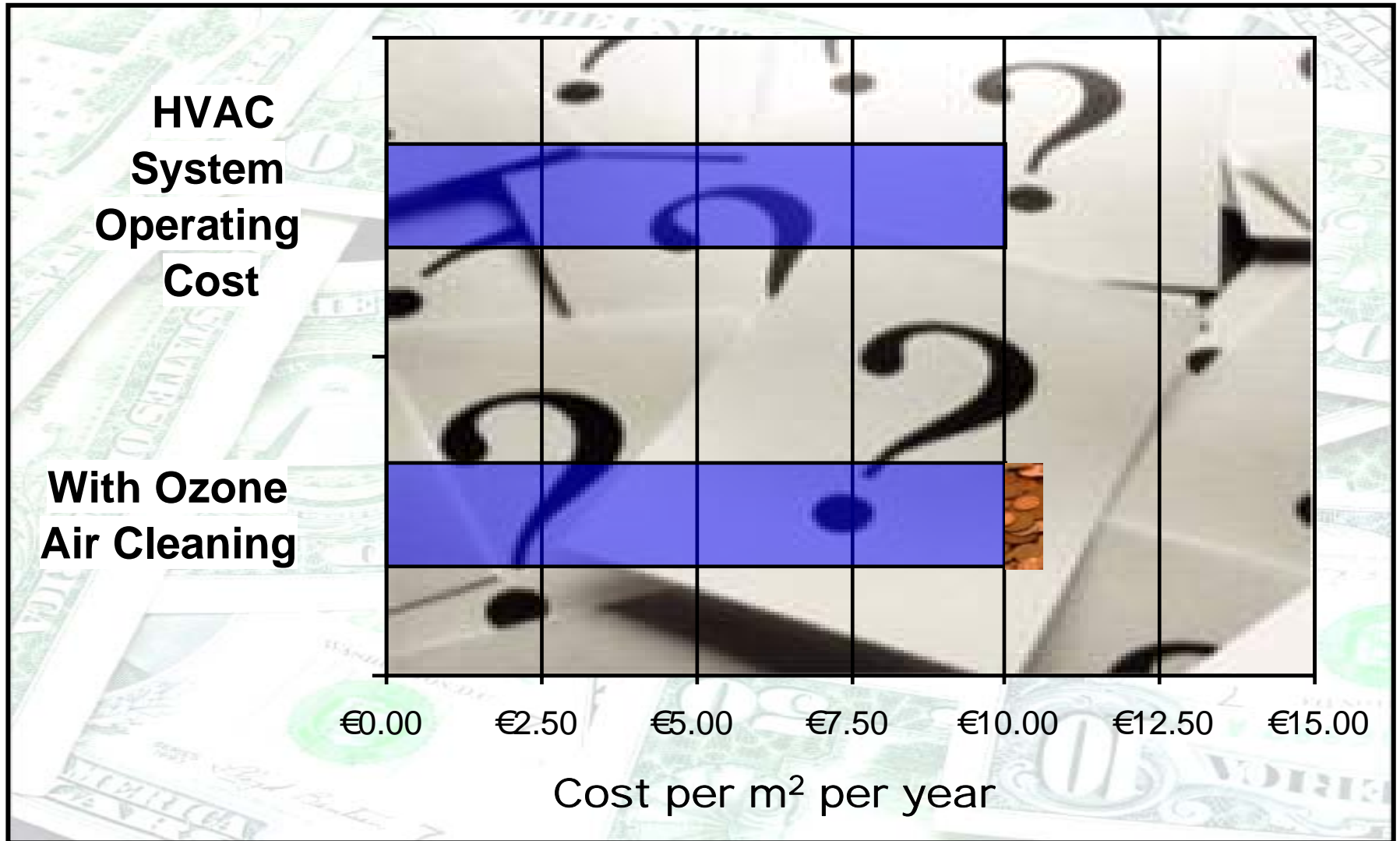


# Air Cleaning Costs





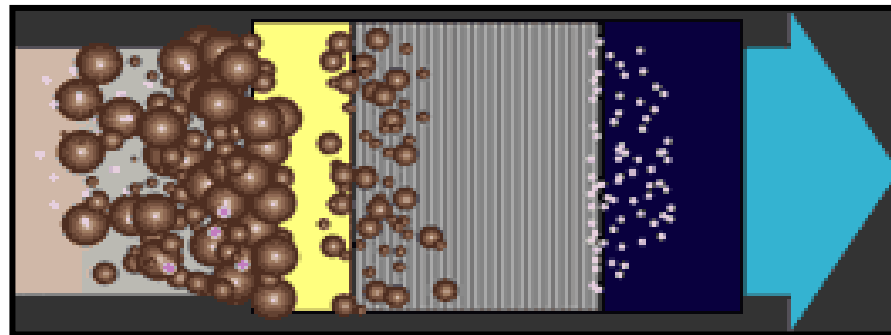
# Air Cleaning Costs





## *Cost Considerations*

- Using adsorbent-loaded non-wovens, air cleaning for Ozone can be achieved adding only €0.30 - €0.70 per m<sup>2</sup> per year
- Total air cleaning systems have an estimated annual cost of €1.80 – €3.60 per m<sup>2</sup> per year.



- Systems often have substantial installation costs due to the additional hardware required.



# *Are We There Yet?*

- Many feel that IAQ is already being addressed.
- **Gaseous pollution is almost universally ignored.**
- **Air filtration systems can effectively reduce pollutants.**
  - Best control requires a filtration system optimized for both particulate and gaseous pollutants.
  - Use in either recirculation or mixed air streams.

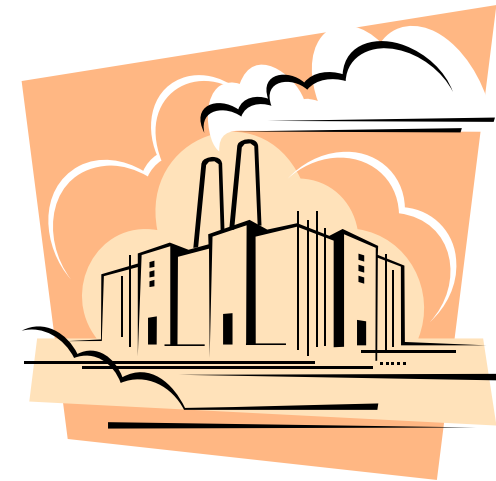
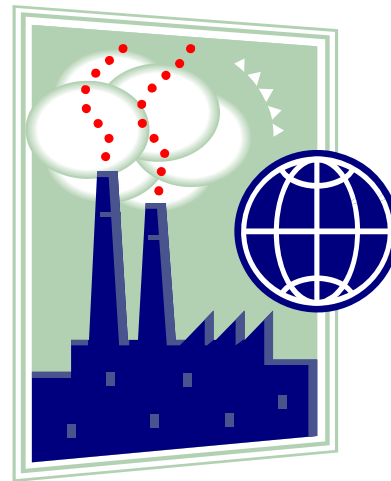




## *We're Getting Closer*

Requiring the use of air-cleaning systems for  $PM_{10}$ ,  $PM_{2.5}$ , and ozone in buildings located in areas with poor outdoor air will bring us a little closer to our goal...

*...but it is only the first step!*





## *Summary*

- By improving the IAQ in buildings, besides  $O_3$ , also other gaseous contaminations should be taken into account
- PIA-Na media show a significant higher removal capacity on for example  $NO_2$
- Adsorbent-loaded non woven filter gives an easy and low-investment solution in existing and new situations.
- Cleaning the air from gaseous contamination, can already be achieved without adding high costs per  $m^2$  per year.



## *Summary (2)*

- The control of the chemical contaminants common to indoor and outdoor air is best accomplished using two different dry-scrubbing media in a gas-phase air filtration system.

### *Granular Activated Carbon*

followed by

### *Permanganate-Impregnated Activated Alumina*

**in two separate filter banks!**

- **Two-stage particulate filter** section is recommended:
  - G4 (30%) prefilter + (F8) 95% final filter
  - Protects the dry-scrubbing media and significantly extends the service life.



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*Thank you for your attention!*

**Questions?**



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