

## **BREATHE EASY**

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## **Breathe Easy**

*Curable polymeric surfactant (CPS) infused substrates improve indoor air quality and protect industrial equipment by completely removing oil mist and organic vapor from air*  
*By Kirk Abbott and Hal Alper*

Airborne organic vapors and oil mist are major components of air pollution, indoor air quality issues, worker exposure and industrial equipment contamination. Gases, vapors, aerosols and mists are different forms or "phases" of airborne compounds. Definitions for these various phases follows:

- Gas -- Molecules above critical temperature that have no fixed shape or volume.
- Vapor -- A gas that is below its critical temperature (Critical temperature of a gas is the highest temperature at which it can be liquefied under pressure).
- Aerosol -- Suspension of very fine particles or droplets of a liquid in a gas (i.e., oil in air). Fog (water in air) is another example.
- Mist -- Suspended liquid droplets in the atmosphere producing a veil that reduces visibility.

Gases, vapors and aerosol mists are ubiquitous in nature and industry, which has broad implications. For example, many industrial settings require mechanical processes that use lube oils to keep equipment cool and running smoothly. Hot oil mist and vapors are generated, which once airborne, are very difficult and expensive to capture before they cause damage to the health of workers, the environment and sensitive industrial equipment. Furthermore, many chemical and biological weapons are based on related airborne compounds.

### **Sources of Hydrocarbon Pollution**

Hydrocarbon mist and vapor have been a standard byproduct of manufacturing processes since the industrial revolution. Many facilities create airborne hydrocarbons at an enormous rate. Hydraulic fluids, petroleum lubes and volatile organic compounds, such as solvents, are used to produce the products we use everyday. They are necessary to protect moving equipment from generating heat and wearing out, as well as a means to formulate various chemical products and coatings.

Anywhere air is moved with mechanical devices that use lubricants, oil mist is produced. Compressed air is a classic example of a process that contaminates air with oil. To move air, it needs to be compressed or put under pressure. Accomplishing this requires a compression chamber that must be well-oiled to avoid excess friction of metal parts moving against each other. As a compressor runs, the lube oil becomes hot and vaporizes into the air. This oil-laden compressed air contaminates sensitive pneumatic controls and other equipment causing expensive inefficiencies, operating difficulties, maintenance problems and repairs. Protocols and contingencies for the above situations are time consuming and expensive.

### **Effects of Airborne Hydrocarbons**

The total effect of airborne hydrocarbons is intertwined between the workers that are routinely exposed and the machines required to produce the products they make. Machines need oil; workers need machines. Exposure is a necessary evil, just part of the job for the industrial sector.

It is well documented that many of these pollutants are toxic, mutagenic or carcinogenic toward people and other organisms. A wide range of pernicious compounds pose a threat through industrial release or as a chemical weapon. In many ways, chemical weapons and nerve agents are similar to hydrocarbons used in industry (i.e., pesticides, aromatic compounds and solvents).

Cell membranes that make up human tissue include fatty lipids that are susceptible to damage by hydrocarbon attack. Hydrocarbons are good solvents and dissolve fatty (lipid), non-aqueous substances. Yet, we have known historically that our stomach lining is very impervious to hydrocarbons; for example, many well-meaning mothers spoon fed mineral oil to their children for decades to remedy certain ailments. Even ingesting gasoline usually results in little damage to the stomach lining. However, petroleum hydrocarbons are much more dangerous to breathe than to swallow. The tissues that make up lung and throat linings are much more fat soluble and sensitive to "de-fatting," which is why inhaling hydrocarbon vapors and mists causes serious cellular damage. The classic warning, "If ingested, do not induce vomiting," has significant merit indeed.

The toxic health effects of hydrocarbons on humans are classified as either acute or chronic. Acute health effects, or short-term/high-level exposure, are usually apparent within minutes to hours. Chronic health effects, or long-term/low-level exposure, take years to appear and are very difficult to monitor and prevent.

Acute health problems associated with petroleum-type hydrocarbon exposure include loss of coordination, dizziness, nausea and vomiting, diarrhea, unconsciousness, hemorrhaging of lung tissue up to and including death from circulatory failure. The lethal nature of chemical warfare and nerve agents, such as mustard gas, VX gas and pesticides, are well known; with these compounds there is no room for error.

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Long-term exposure and chronic health problems lead to central nervous system (CNS) depression, anorexia, fatigue, as well as more serious complications, such as tremors, sleep disorders, vertigo, headaches, liver and kidney damage, anemia, leukopenia, cancer, bone marrow damage and other blood and cell related illnesses. The lighter hydrocarbon components are powerful CNS depressants; these include gasoline and aromatic hydrocarbons, such as benzene, toluene, ethylbenzene and xylene (BTEX). Cyclopropane and other hydrocarbons have been used as anesthetics and pain killers because of their effect on the CNS.

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***Compressed air is a classic example of a process that contaminates air with oil.***

Toxic effects of petroleum type hydrocarbon components are related to the volatility (a compound's ability to escape into air) and the solubility (a compound's ability to dissolve into water and water vapor). In general, the components of petroleum crude oil with the highest volatility and solubility are also the most toxic to breathe. Occupational, Safety & Health Administration (OSHA) has set limits on worker exposure to petroleum type hydrocarbons. For example, the time weighted average exposure for Benzene is 10 parts per million for a 40 hour work week.

Airborne hydrocarbons wreak havoc on industrial equipment and machinery, as well. Inefficiencies, downtime, maintenance and repairs cost money. Contaminated equipment also requires additional consumption of energy, raw materials and replacement parts.

### **Current Technologies**

Capturing hydrocarbon pollutants from air, steam and aerosol mist is critical for our health and our environment, as well as efficient operation of expensive industrial equipment. To date, removing airborne hydrocarbon compounds has been a tricky and expensive business.

Conventional treatment methods of air streams contaminated with volatile organic compound (VOCs), hydrocarbon vapors and oil mist are expensive, complicated and difficult to operate. Treatment technologies for removal of hydrocarbons from air streams are either intense physical or chemical processes, such as air scrubbing multi-layer adsorption, catalytic conversion and chemical and photolytic degradation. Each has its drawbacks, which explains why systems are typically multi-stage combinations of the above technologies. Attempts have been made using bioscrubbers or air phase bioreactors to remove hydrocarbons, but they are only able to realistically achieve a moderate removal rate due to flow rate/contact-time issues. In short, the performance of these systems varies significantly depending upon superficial air velocity, inlet concentration, mass transfer coefficients and biokinetic reaction rates.

In addition, much work has been done with granular activated carbon (GAC), which has traditional drawbacks of conventional absorbents (clogging, re-release and limited absorption capacity). Zeolite in multi-layer designs with GAC is generally effective but expensive, and as expected, the multi-layers cause flow restrictions and pressure drop. Other absorbents, organic and inorganic, have been tried in various configurations with limited success.

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***OSHA has set limits on worker exposure to petroleum type hydrocarbons in the workplace.***

### **Emerging Technologies**

Recent emerging technologies involve treated or affinity enhanced filter media. Enhancing filter affinity for organic compounds utilizing surfactants or polymers (enhancing agent) has been attempted in the past with limited success largely due to lack of one or more of the following critical properties required of the enhancing agent:

- 1.) Permanent curability;
- 2.) Affinity without desorption;
- 3.) Instantaneous binding reaction rate; and
- 4.) Low pressure drop.

Permanent curability -- Affinity-enhancing agent must have the ability to be permanently and integrally cured into the matrix of the filter media with total transfer of properties and without leaching or migrating, especially in the presence of humid air flow.

Affinity without desorption --- Enhancing agent must have high affinity (greater than 99 percent single pass efficiency) for all the types of organic compounds present in crude oil (crude oil is used as a baseline because it represents a complex cocktail of all types of organic compounds) with the ability to bind the various components (liquid and vapor) together at high flow rates without phase separation, desorption or dissolution by solvents.

Instantaneous binding reaction rate -- Binding rate to contaminants must be instantaneous or less than one second. Reaction rate must be independent of contact time and contact area over a wide range of flow rates and operating parameters.

Low pressure drop -- Affinity-enhancing agent must not restrict air flow or clog the filter as it captures hydrocarbons up to saturation, even when exposed to extreme spikes in concentration. Conventional air filters (treated or untreated) swell as they absorb hydrocarbons and quickly clog.

Moreover, to be comprehensively effective, enhanced air filters must be capable of removing aerosolized hydrocarbons, as well as particulate matter. Effective particle filtration is hindered by the presence of oily organic compounds. Solid particles, bacterial and fungal spores can be pulled through by organic compounds that are re-released off an air filter. Re-releasing oil mist facilitates particle and spore transfer complicating indoor

air quality issues, worker exposure and sick building syndrome. Therefore, effective particle filtration involves effective oil mist filtration.

### **CPS Infused Air Filters for Removing Oil Mist and Organic Vapor**

One technology has the ability to meet all the requirements of curability, affinity, bind rate and low pressure drop. CPS infused substrates are natural (e.g., wool and cotton) and synthetic materials (e.g., polypropylene) infused with the reaction product of various drying oils and acrylic polymers consistent with Composition of Matter Patent(s) #5,437,793 and 5,746,925. CPS infused air filter media can be used to permanently attract and remove airborne hydrocarbons without desorption. The extreme affinity of CPS for hydrocarbons allows for the instantaneous removal of organic vapors and oil from air, steam and aerosol mist.

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***This unique property allows CPS infused filters to capture the full range of hydrocarbons without impeding air flow or re-releasing contaminants at high flow rates.***

CPS infused substrates instantly bond and coagulate organic components of various phases (liquids and vapors), consolidating them into a very dense viscoelastic semi-solid. The CPS-organic coagulate is extremely oleophilic (oil-loving), hydrophobic (water-hating) and bio-static (resistant to biological reproduction). Because the coagulate turns viscoelastic or denser, the contaminants take up less space versus their normal liquid or vapor form. As air shears across or through CPS infused air filters, the coagulate becomes more compact and allows up to 99+ percent instantaneous removal of airborne hydrocarbons without clogging or desorption. Essentially, the opposite of swelling occurs within the coagulate and filter media. This unique property allows CPS infused filters to capture the full range of hydrocarbons without impeding air flow or re-releasing contaminants at high flow rates. CPS infused filters are well documented for the complete removal of hydrocarbon contaminants from water without pressure drop or desorption (reference "Protection from Organic Fouling," *Environmental Protection*, June 2001, see archives at [www.eponline.com](http://www.eponline.com)).

CPS infused air filters have affinity for all airborne aqueous insoluble, semi-soluble and mechanically aerosolized organic compounds. Typical organic pollutants captured with single-pass efficiencies of over 99+ percent include the following hydrocarbons:

- Fats, oils and grease;
- Aromatics (benzene, toluene, ethylbenzene and xylene - BTEX);
- Polyaromatics (PAH);
- Aliphatic fuels & solvents;
- Cycloalkanes;
- Chlorinated organics and solvents;

- Organic polymers; and
- Pesticides, Persistent Organic Pollutants (POPs), surrogates of ACE inhibitors, such as insecticides, LSD and nerve agents.

### **Applications**

CPS infused substrates can be used to remove oil mists in a variety of settings, including heating ventilation air conditioning (HVAC) systems and compressed air systems. Chemical bioaerosols, organic vapor mists and fungal spores are examples of naturally occurring chemical and biological aerosols. Chemical and biological warfare aerosols have many physical similarities (buoyancy, stability, etc.) to their natural occurring counterparts. Issues covered in this article also apply to anthropomorphic and anthropophilic particulates. These forms of hydrocarbon pollution have relevance to industrial, hospital, commercial building and kitchen, automobile, marine vessels, anti-terrorism and other applications where human exposure is at stake.

### **Compressed Air Case Study:**

Dust from an aluminum fabrication process is removed from plant air with 0.1 micron sleeve filters. The filters capture the aluminum dust, and they are periodically cleaned with a back-pulse of compressed air. The oil-contaminated compressed air was clogging the sleeve filters after three months of service, requiring filter replacement.

A 5 micron CPS infused cartridge filter was employed on the compressed air line (7,000 cubic meters per hour) before the sleeve filters to polish the residual lube oil. After four months of service, the sleeve filters are oil-free and running smoothly. The (10-inch) CPS infused filter captures up to 220 grams of lube oil without restricting the flow of air (inlet & outlet pressure remains steady at 5.5 bars).

The CPS infused filters are projected to extend the service life of the sleeve filters by a factor of five or more while significantly reducing energy costs, maintenance and downtime.

### **Conclusion**

CPS infused substrates protect human health, the environment and sensitive manufacturing equipment from hydrocarbon exposure in a wide range of applications. Product development and field trials with various CPS-infused air filter membranes (i.e., high efficiency particulate arresting (HEPA) filters) are currently being conducted to demonstrate the critical performance properties required of affinity-enhanced filters: (permanent curability, affinity without desorption, instantaneous bind rate and low pressure drop). Air systems utilizing CPS infused filters are extremely effective, energy efficient and easy to operate and maintain.

CPS infused filters and media are easily disposed of by incineration. They have an extremely low water and ash content resulting in a clean burning waste with a BTU value comparable to alternative fuels. The hazardous nature of the saturated filters are dictated by the absorbed/adsorbed contaminants. In many cases, the filters can be land filled with

other petroleum saturated materials (e.g., oily rags, sorbents and oil filters). CPS technology is finding use in an assortment of industries for the complete removal of organic pollutants from air and water.

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