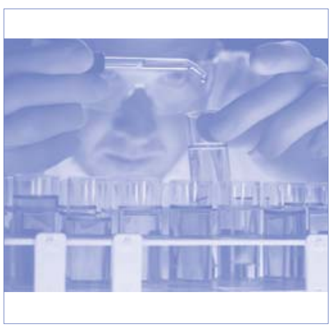
Carbon Black User's Guide

Safety, Health, & Environmental Information

IMPORTANT NOTE

This booklet is not a Material Safety Data Sheet (MSDS), nor is it intended to serve as an MSDS substitute. Please maintain and review the most current MSDS, available through your carbon black supplier, prior to working with this product.

Purpose



This guide summarizes essential health, safety, and environmental information for operational design, maintenance, training, emergency response and handling practices that may be associated with the use of carbon black. The information contained herein is provided to supplement the knowledge of trained and qualified users of carbon black.

This publication represents the current knowledge of the International Carbon Black Association (ICBA) members as of the date of publication. Users should remain informed on new developments and information about carbon black properties, handling technology and regulatory requirements that occur following the publication date. Any questions should be addressed to your carbon black supplier.

Contents

General Information

WHAT IS CARBON BLACK?

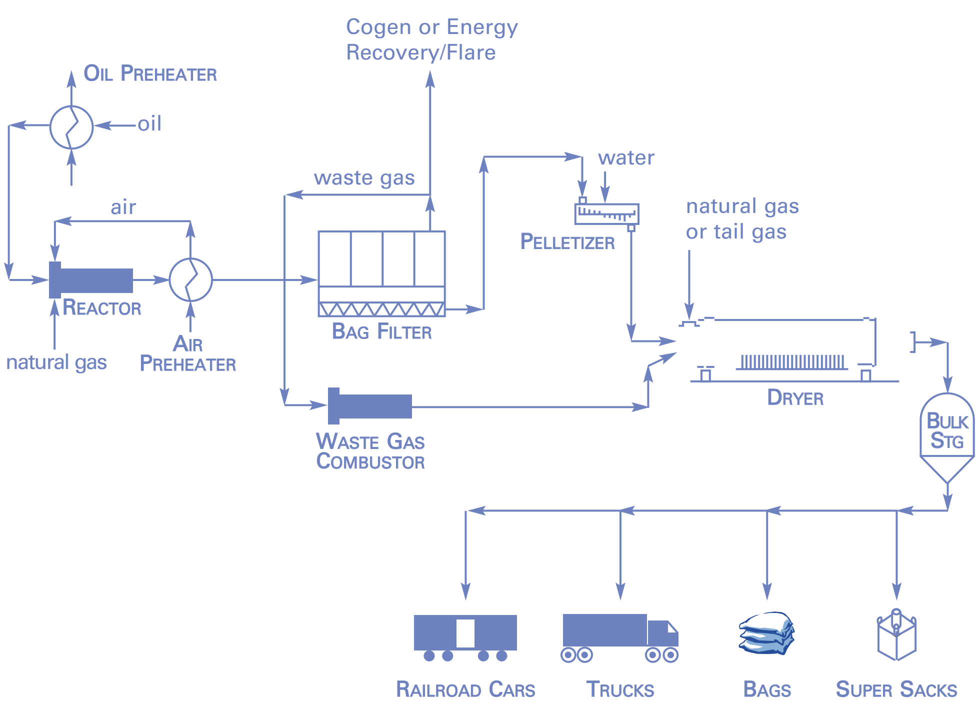
Carbon black [C.A.S. NO. 1333-86-4] is virtually pure elemental carbon in the form of colloidal particles that are produced by incomplete combustion or thermal decomposition of gaseous or liquid hydrocarbons under controlled conditions. Its physical appearance is that of a black, finely divided pellet or powder. Its use in tires, rubber and plastic products, printing inks and coatings is related to properties of specific surface area, particle size and structure, conductivity and color. Carbon black is also in the top 50 industrial chemicals manufactured worldwide, based on annual tonnage. Current worldwide production is about 18 billion pounds per year [8.1 million metric tons]. Approximately 90% of carbon black is used in rubber applications, 9% as a pigment, and the remaining 1% as an essential ingredient in hundreds of diverse applications.

Modern carbon black products are direct descendants of early "lamp blacks" first produced by the Chinese over 3,500 years ago. These early lamp blacks were not very pure and differed greatly in their chemical composition from current carbon blacks. Since the mid-1970s, most carbon black has been produced by the oil furnace process, which is most often referred to as furnace black.

HOW IS IT PRODUCED?

Two carbon black manufacturing processes (furnace black and thermal black) produce nearly all of the world's carbon blacks, with the furnace black process being the most common. The furnace black process uses heavy aromatic oils as feedstock. The production furnace uses a closed reactor to atomize the feedstock oil under carefully controlled conditions (primarily temperature and pressure). The primary feedstock is introduced into a hot gas stream (achieved by burning a secondary feedstock, e.g., natural gas or oil) where it vaporizes and then pyrolyzes in the vapor phase to form microscopic carbon particles. In most furnace reactors, the reaction rate is controlled by steam or water sprays. The carbon black produced is conveyed through the reactor, cooled, and collected in bag filters in a continuous process. Residual gas, or tail gas, from a furnace reactor includes a variety of gases such as carbon monoxide and hydrogen. Most furnace black plants use a portion of this residual gas to produce heat, steam, or electric power. *(See Figure 1. Typical Furnace Black Process Diagram.)*

Figure 1. Typical Furnace Black Process Diagram



The thermal black process uses natural gas, consisting primarily of methane or heavy aromatic oils, as feedstock material. The process uses a pair of furnaces that alternate approximately every five minutes between preheating and carbon black production. The natural gas is injected into the hot refractory-lined furnace, and, in the absence of air, the heat from the refractory material decomposes the natural gas into carbon black and hydrogen. The aerosol material stream is quenched with water sprays and filtered in a bag house. The exiting carbon black may be further processed to remove impurities, pelletized, screened, and then packaged for shipment. The hydrogen off-gas is burned in air to preheat the second furnace.

CARBON BLACK, SOOT, AND BLACK CARBON

Carbon black is not soot or black carbon, which are the two most common, generic terms applied to various unwanted carbonaceous by-products resulting from the incomplete combustion of carbon-containing materials, such as oil, fuel oils or gasoline, coal, paper, rubber, plastics and waste material. Soot and black carbon also contain large quantities of dichloromethane- and toluene-extractable materials, and can exhibit an ash content of 50% or more.

Carbon black is chemically and physically distinct from soot and black carbon, with most types containing greater than 97% elemental carbon arranged

General Properties

Tables 1 and 2 report general information related to carbon black. Detailed physical and chemical analysis for a particular grade of carbon black may be requested from your carbon black supplier.

Table 1. Commercial names and chemical identification of carbon black

Chemical Name	Carbon Black
Synonyms	Acetylene Black, Channel Black, Furnace Black, Gas Black, Lampblack, Thermal Black
CAS Name	Carbon Black
CAS Registry Number	1333-86-4
Chemical (Molecular) Formula	C

Table 2. Properties and characteristics of carbon black (furnace process)

Formula weight	12 (as carbon)
Physical state	solid: powder or pellet
Flammable limits (vapor)	LEL: not applicable UEL: not applicable
Lower limit for explosion	50 g/m^3 (carbon black in air)
Minimum ignition temperature	
VDI 2263 (German), BAM Furnace	>932°F (>500°C)
Godbert-Greenwald Furnace	>600°F (>315°C)
Minimum ignition energy	>10J
Burn Velocity: VDI 2263, EC Directive 84/449	>45 seconds: Not classifiable as "Highly Flammable" or "Easily Ignitable"
Flammability classification (OSHA)	Combustible solid
Solubility	Water: insoluble Solvents: insoluble
Color	Black

as aciniform (grape-like cluster) particulate. On the contrary, typically less than 60% of the total particle mass of soot or black carbon is composed of carbon, depending on the source and characteristics of the particles (shape, size, and heterogeneity).

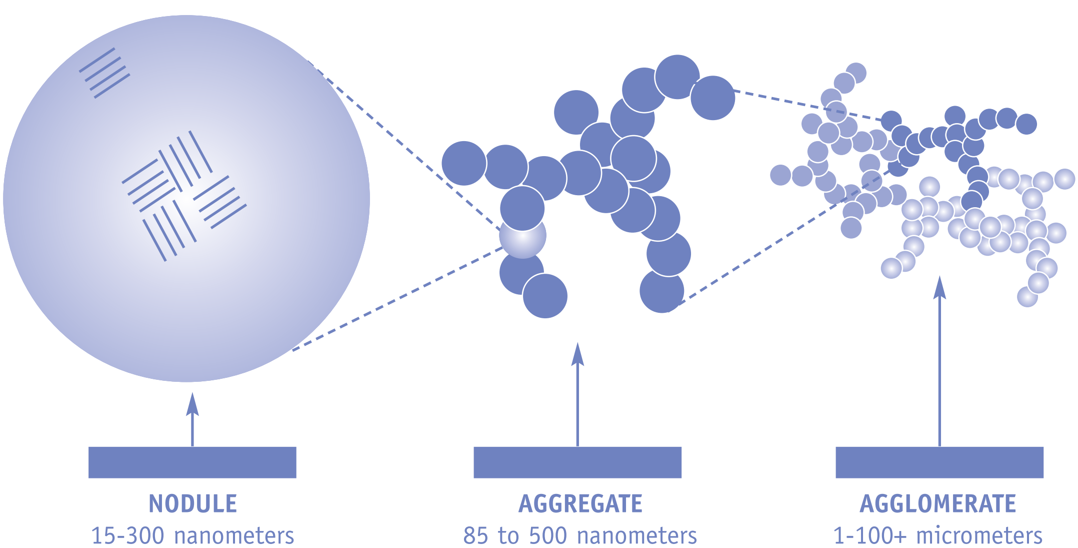
In the case of commercial carbon blacks, organic contaminants such as polycyclic aromatic hydrocarbons (PAHs) can only be extracted under very rigorous laboratory analytical procedures (soxhlet extraction using organic solvents and high temperatures). These extracts, though they may be similar to those derived from soot, are unique, however, because carbon black extracts exist only in extremely small quantities. Water and body fluids are ineffective in removing PAHs from the surface of carbon black and, therefore, they are not considered to be biologically available.

Two other commercial carbonaceous products often confused with carbon black are activated carbon and bone black. Each is produced by processes different from commercial carbon black and possesses unique physical and chemical properties.

OTHER PARTICLE SIZE CHARACTERISTICS

The term "primary particle diameter" raises many questions when describing carbon black particle size. Because manufactured carbon black is made either by partial combustion or thermal decomposition of liquid or gaseous hydrocarbons, the final product is incorrectly characterized as having exceptionally small particles, sometimes even described as ultrafines (particles < 0.1 micrometers in aerodynamic diameter). In fact, while the starting particle or nodule of carbon black is extremely small (typically less than 300 nanometers), a complex structure sequence rapidly follows within the closed reactor. The near spherical nodules coalesce into particle aggregates that become the basic indivisible entities of carbon black. Strong electrical forces maintain the bond between aggregates and promote the formation of agglomerates, which are the result of hundreds to thousands of strongly adhering aggregates. Carbon black in commerce is encountered as agglomerates. Once formed, agglomerates do not break down to the aggregate level. Figure 2 depicts the sequence of structure development, while providing typical particle size ranges at each stage. When carbon black is shipped, it is normally formed into pellets to facilitate the ease of handling and to reduce the creation of dust. Carbon black pellets generally fall between 0.1 and 1.0 millimeters in size.

Figure 2. Sequence of Structure Development



Nanoparticles are generally considered to fall below 100 nanometers (0.1 micrometers) in size. On the other hand, carbon black particles at the nodule stage may range from 15 to 300 nanometers, but are not found outside of the reactor, nor are they found as a component dust fraction in final manufactured carbon blacks.

Safety

FIRE AND EXPLOSION

Carbon blacks in the powder or pellet form burn slowly (smolder) and sustain combustion that may not be visible as flames or smoke. A direct water spray or stream may spread the fire due to the smoldering carbon black powder floating on the water. A fog spray is recommended when water is used as an extinguishing agent. Foam is also an acceptable extinguishing agent. Carbon black that has been on fire (or suspected of being on fire) should be observed for at least 48 hours to ensure that smoldering material is not present. Combustion gases generated during smoldering include carbon monoxide (CO), carbon dioxide (CO_2), and oxides of sulfur.

There has been no recorded industry experience to suggest that carbon black dust concentrations pose an explosion hazard. In fact, studies conducted by the United States Bureau of Mines (Nagy, 1965) report that carbon black dust does not present an explosion hazard *(see References)*. Under certain circumstances, however, it may be possible for smoldering carbon black to produce a sufficient concentration of combustible gases (carbon monoxide) to reach an explosive mixture in air.

Under certain test conditions described in the German VDI Guideline 2263, Test Method for Determination of Safety Characteristics of Dusts (May 1980) carbon black in combination with high ignition energy (>1kJ) and in sufficient concentration can be made explosive. The dust explosion class by this method is ST1.

The lower explosive limit for dust concentrations is 50 grams/m^3, which is more than 10,000 times the commonly cited occupational exposure limit of 3.5 mg/m^3 (total dust). The auto-ignition temperature in one liter (IMDG Code) is >284°F (>140°C).

Carbon black dust may be small enough to penetrate electrical boxes and other electrical devices, possibly creating electrical hazards resulting in equipment failure. Electrical devices that may be exposed to carbon black dust should be tightly sealed or purged with clean air, periodically inspected, and cleaned, as required.

Some grades of carbon black may be less electrically conductive, permitting a build-up of static energy during handling. Grounding of equipment and conveying systems may be required under certain conditions. (Contact your carbon black supplier if there is a question concerning the properties of your specific grade of carbon black.)

STORAGE AND HANDLING

Carbon black should be stored in a clean, dry, uncontaminated area away from exposure to high temperatures, open flame sources and strong oxidizers (e.g., chlorates, bromates, and nitrates). Since carbon black will adsorb moisture and chemical vapors, it should be stored in closed containers.

CONFINED SPACE ENTRY

Entry into bins, silos, rail tank cars, tank trucks, or other confined spaces used to ship or store carbon black should only be done following proper confined space entry procedures. Some carbon black grades may have trace concentrations of carbon monoxide adsorbed onto its particle surfaces. Confined space entry procedures should include testing for oxygen, carbon monoxide, and other toxic gases, as appropriate.

HOUSEKEEPING

Spill clean-up and general housekeeping are very important for controlling carbon black exposures. Carbon black dust spreads easily in air through virtually any air current or movement. Additionally, because carbon black is a pigment, it may stain exposed surfaces. Housekeeping procedures that avoid the production of dust or generation of fugitive emissions in the process are highly recommended. Dry vacuuming, with appropriate filtration, is the preferred method for removing surface dust and cleaning spills. Dry sweeping should be avoided. Bulk carbon black should always be covered or contained. Care should be taken to avoid generating conditions that may result in unnecessary exposure.

ACUTE FIRST AID

There is no evidence to suggest that acute exposure to carbon black may result in life threatening injury or illness. Carbon black is not a respiratory irritant, as defined by the Occupational Safety and Health Administration (OSHA), and does not produce respiratory or dermal sensitization. Ingestion is an unlikely method of accidental exposure. Like many dusts, inhalation may initiate a bronchial response among individuals with pre-existing lung conditions.

Inhalation: Short-term exposures to elevated concentrations may produce temporary discomfort to the upper respiratory tract, which may result in coughing and wheezing. Removal from carbon black exposure is normally sufficient to cause symptoms to subside without lasting effects.

Skin: Carbon black dust or powder may cause drying of the skin with repeated and prolonged contact. Skin drying may also result from frequent washing of carbon black contaminated skin. Carbon black may be washed from the skin using mild soap and water along with gentle scrubbing action. A waterless skin cleaner may also be used. Repeat washing may be necessary to remove carbon black. A protective barrier cream on exposed skin surfaces may also be an effective method for minimizing dermal exposure.

Ingestion: No adverse effects are expected from carbon black ingestion. Do not induce vomiting.

Eye: Carbon black is not a chemical irritant. Treat symptomatically for mechanical irritation. Rinse eyes thoroughly with water to remove dust. If irritation persists or symptoms develop, seek medical attention.

Health

OVERVIEW

Carbon black has been the subject of extensive scientific health studies during the past several decades. Although carbon black is classified by the International Agency for Research on Cancer (IARC) as a Group 2B carcinogen (possibly carcinogenic to humans) based on "sufficient evidence" in animals and "inadequate evidence" in humans, recent evidence indicates that the phenomenon of carcinogenicity in the rat lung is species-specific, resulting from persistent overloading of the rat lung with poorly soluble particles <1.0 micrometer in diameter. Mortality studies of carbon black manufacturing workers do not show an association between carbon black exposure and elevated lung cancer rates. *(See Human Studies and Carcinogenicity sections.)*

Studies have demonstrated, however, that regular exposure to carbon black and other poorly soluble particles may play a role in declining lung capacity as measured by forced expiratory volume in one second (FEV_1). Good occupational hygiene practices should be followed to maintain worker exposures below the occupational exposure limit. *(See Occupational Hygiene section and Appendix B.)*

HUMAN STUDIES

The health effects of carbon black exposure have been studied in the United States and Western Europe for over 60 years. These studies indicate no evidence of significant clinical health effects due to occupational exposure to carbon black.

Mortality (death rate) studies, comparing carbon black workers to the unexposed general population, indicate no unusual cancer risk from carbon black exposure. These studies followed workers employed since 1939 in the carbon black industry and found no carbon black-related increase in deaths from heart disease or lung cancer compared to the general population.

U.S. and Western European studies have also examined morbidity (illness) among carbon black workers. These studies have focused primarily on lung disorders because inhalation is the major route of exposure. Carbon black workers do not appear to develop illnesses as a result of their work with this material.

See Appendix A for more detailed information on these human studies.

ANIMAL STUDIES

Long-term inhalation studies, up to two years, have resulted in chronic inflammation, lung fibrosis, and lung tumors in some rats experimentally exposed to excessive concentrations of carbon black. Tumors have not been observed in other animal species (i.e., mice and hamsters) under similar study conditions. These same effects are observed when rats have been exposed to several other poorly soluble dust particles. Many researchers conducting rat inhalation studies believe the observed effects result from the massive accumulation of small dust particles in the rat lung after exposure to excessive concentrations. These accumulations overwhelm the natural lung clearance mechanisms of the rat and produce a phenomenon that is described as "lung overload." The effects are not thought to be the result of a specific toxic effect of the dust particle in the lung. Many inhalation toxicologists believe the tumor response observed in the above referenced rat studies is species-specific and does not correlate to human exposure.

CARCINOGENICITY

The International Agency for Research on Cancer (IARC) evaluation (Monograph 65, 1996 publication) concluded, "There is sufficient evidence in experimental animals for the carcinogenicity of carbon black." This categorization was based upon IARC's guidelines, which require such a classification if one species exhibits carcinogenicity in two or more studies. Based on this evaluation, along with its finding of inadequate evidence of carcinogenicity in humans, IARC designated carbon black as a Group 2B carcinogen, that is "possibly carcinogenic to humans."

Some other research and regulatory organizations that have classified carbon black as to its carcinogenicity include:

- The American Conference of Governmental Industrial Hygienists (ACGIH) classifies carbon black as A4, Not Classifiable as a Human Carcinogen;
- The German MAK Commission classifies carbon black as a suspect carcinogen category 3B;
- The National Toxicology Program (NTP) has not listed carbon black as a carcinogen;
- The Occupational Safety and Health Administration (OSHA) has not listed carbon black as a carcinogen;
- The National Institute for Occupational Safety and Health (NIOSH) criteria document (1978) on carbon black recommends only carbon blacks with polycyclic aromatic hydrocarbon contamination levels greater than 0.1% (1,000 parts per million) be considered suspect carcinogens; and
- The Office of Environmental Health Hazard Assessment (OEHHA) of the California Environmental Protection Agency added "carbon black (airborne, unbound particles of respirable size)" (CAS No. 1333-86-4) to the Proposition 65 substances list on February 21, 2003. This listing, triggered by the "authoritative body" mechanism in the California Code of Regulations, was based solely on IARC's 1996 reclassification of carbon black as a Group 2B carcinogen.

Concern has been expressed about the polycyclic aromatic hydrocarbon (PAH or sometimes referred to as polynuclear aromatics (PNA)) content of manufactured carbon blacks. In non-adsorbed forms, some PAHs have been found to be carcinogens in animal studies. In-vitro studies indicate that the PAHs contained in carbon black are not bioavailable. Modern production and quality control procedures are generally able to maintain extractable PAH levels

to less than 0.1% (<1000 ppm) in carbon black with PAHs regulated as carcinogens representing a smaller fraction of the extractables. Extractable PAH content depends on numerous factors including, but not limited to, the manufacturing process and the ability of the analytical procedure to identify and measure extractable PAHs. Specific questions concerning PAH content should be addressed to your carbon black supplier.

MUTAGENICITY

Carbon black (untreated) is an insoluble inorganic compound. Therefore, mutagenicity testing cannot be conducted with bacterial and in-vitro systems without the use of organic solvents, which interfere with the testing.

REPRODUCTIVE EFFECTS

No effects have been found in reproductive organs following long-term animal studies.

CHRONIC INGESTION

No significant abnormalities were seen in rats or mice following feeding studies of up to two years.

EYE CONTACT

No adverse effects have been described. Carbon black in the eye causes reactions no different than other dust particles in the eye.

SKIN CONTACT

After application of a carbon black suspension to the skin of mice, rabbits, and rats, no skin tumors were reported. Dust may cause drying of the skin with repeated or prolonged contact.

SENSITIZATION

No animal data are available to indicate that humans would become "sensitized" as a result of exposure to carbon black. No cases of sensitization have been reported in humans.

CARBON BLACK IN MATERIALS IN CONTACT WITH FOODSTUFFS

Carbon black produced by certain processes has been approved under specific circumstances and for specific uses involving contact with foodstuffs. Contact your carbon black supplier for additional information.

ANIMAL IRRITANT TESTS

Primary Eye Irritation (rabbit): Produced slight conjunctiva redness, which cleared within seven days. Draise scores ranged from 10-17/110 (100/110 = maximally irritating).

Primary Skin Irritation (rabbit): Very slight erythema (redness). Index Score - 0.6/8 (4/8 = severe edema).

Oral LD_{50} (rat): >8,000 mg/kg (LD_{50} is an orally administered dose that kills 50% of the test animals. Values greater than 5,000 mg/kg are generally considered to be non-toxic).

Occupational Hygiene

OVERVIEW

Industrial or occupational hygiene management of the work environment includes ongoing efforts to anticipate and identify potential exposure conditions, measurement of exposures, and implementation of appropriate controls to reduce exposures to the lowest feasible levels. Although this section will focus on carbon black, industrial hygiene management principles are applicable to all potential exposure conditions present in a work environment.
Industrial hygiene experience within the manufacturing environment suggests the activities with the greatest potential for occupational exposure to carbon black are those related to manual handling (e.g., bag slitting, bulk weighing, sample preparation, and dry batch preparation). Maintenance operations should also be carefully observed and evaluated for

potential exposures. Each employer must conduct a hazard assessment based on knowledge of their own work environment activities and conditions.

EXPOSURE ASSESSMENT

Measurement of occupational exposure to carbon black is critical to the establishment of an effective industrial hygiene program. Exposure assessment identifies and quantifies potential occupational health risks, identifies operations requiring controls, determines compliance with occupational exposure limits, and provides information useful in characterizing historical exposures.

CARBON BLACK DUST MONITORING

Air sampling methods may vary from country to country. In the U.S. and Canada, current occupational exposure limits (OELs) for carbon black are based on total dust measurements (closed face 37mm filter cassette). The National Institute for Occupational Safety and Health (NIOSH) Method 5000, or equivalent, is recommended for the assessment of total carbon black dust in work environments. In Germany, particulates not otherwise classified (PNOC), such as carbon black, are to be measured as respirable or inhalable dust, requiring the use of specialized personal air sampling cyclones, following established conventions. (Contact your carbon black supplier for additional information.)

ENGINEERING EXPOSURE CONTROLS

Engineering controls designed to eliminate or reduce occupational exposure to carbon black dust to the lowest feasible level are preferred to the use of respirators or other types of personal protective equipment. The most cost-effective times to implement engineering controls are at the design stage of a new operation and, alternatively, during modifications to existing operations. The collection of exposure data identifies operations that may contribute to worker exposures, helps prioritize and define control design, and establishes baseline data for evaluating the effectiveness of controls.

Engineering exposure controls that have been used with success in the handling of carbon black dust include: (1) ventilation hoods for controlling exposures

to laboratory personnel engaged in handling samples; (2) local exhaust ventilation for dusty operations, such as bagging and bag splitting; and, (3) containment of powders and dusts within sealed mixing, processing, and conveying systems. Containment systems (e.g., an enclosed conveyor) are especially effective when operated under a slight negative pressure to minimize fugitive dust emissions. Principles of good industrial ventilation design can be found in the most recent edition of the ACGIH publication, *Industrial Ventilation, A Manual of Recommended Practice*.

A dedicated vacuum cleaning system is a cost-effective method for cleaning spilled carbon black in areas where it is routinely used. Motors and air cleaners for the vacuum system should be placed outdoors, and exhausted away from occupied areas. Numerous vacuum connect ports that seal when not in use should be provided throughout areas where carbon black is transferred, handled or used. Sufficiently long vacuum hoses should be strategically located throughout the areas of potential use. To prevent the spread of carbon black dust, spills should be vacuumed immediately.

Effective engineering controls and good housekeeping practices will ensure that occupational exposures and fugitive dust are minimized. *(See Housekeeping section.)*

RESPIRATORY PROTECTION

When respiratory protection is required to minimize exposures to carbon black, programs should follow the requirements of the appropriate governing body for the country, province or state, such as OSHA 29CFR1910.134 (Respiratory Protection) in the

U.S.; guidelines such as the American National Standards Institute Standard for Respiratory Protection (ANSI Z88.2-1992); CR592 Guidelines for Selection and Use of Respiratory Protective Devices (a report of the European Standardization Committee (CEN)); German/European Standard DIN/EN 143 Respiratory Protective Devices for Dusty Materials (CEN); BS 4275-Recommendations for the Selection, Use and Maintenance of Respiratory Protective Equipment or HSE Guidance Note HS(G) 53-Respiratory Protective Equipment, in the UK; or equivalent guidance. *(See References section.)*

The selection of a correct respirator is based on the exposure concentration of carbon black against which protection is required, as well as the possible presence of other contaminants that may be released in the workplace. Representative exposure assessment measurements of all contaminants that may be encountered must be conducted to ensure appropriate respirator selection.

OCCUPATIONAL EXPOSURE LIMITS

Carbon black occupational exposure limits vary by country. *(See Appendix B.)* These limits are subject to change and may describe specific air monitoring procedures (e.g., closed-face 37mm filter cassette, inhalable or respirable collection devices). Check with the regulatory agency governing your region or your carbon black supplier for current requirements.

MEDICAL SURVEILLANCE

Employees who have job duties that involve exposure to carbon black dust may have questions about the health implications of exposure. These questions generally focus on understanding whether a more specialized medical examination is appropriate. It should be emphasized that based on the results of numerous worker studies a dose:response relationship between carbon black exposure and increased lung cancer rates does not exist.

In considering employee medical surveillance, the physician should understand that job duties vary considerably. The major medical issue the physician should address is whether individuals evaluated for certain jobs have a history of lung disorders, such as emphysema or asthma, or skin diseases. These conditions may be exacerbated by exposure to high dust levels of any type, including carbon black. It is advisable for the physician to become familiar with the operations, working conditions and potential exposure concentrations for the various job positions. Periodic tours of the operations by the occupational physician are recommended.

The determination of worker participation in a medical surveillance program should be based on working conditions, such as exposure concentration of carbon black and respirator use. It is desirable for the physician to develop a complete occupational history for each employee as part of any medical surveillance program to include, at a minimum, past medical history, prior working experience in other occupational settings, and personal lifestyle habits (e.g., smoking history, hobbies, etc.).

Environmental

DISPOSAL

Carbon black, with the exception of chemically treated and water dispersible carbon black grades, is appropriately and most often disposed of in landfills. (Check with your local regulatory agency or your carbon black supplier for current requirements on the disposal of chemically treated and water dispersible carbon black grades.) Carbon black is non-toxic and will not leach or release any constituents to the groundwater from a landfill. Carbon black has a very high surface area and a strong adsorptive capacity. Organic materials that come in contact with carbon black can be adsorbed and are not easily liberated thereafter. Carbon black is not biodegradable.

Carbon black can also be used as an alternative fuel for kilns, or can be incinerated (adequate residence time and oxygen content needs to be provided to assure that complete combustion occurs), since it has approximately the same heat value (BTUs) per pound as pulverized coal and will combust completely with low emissions and virtually no residual ash. Both above mentioned alternatives are environmentally suitable disposal methods, assuming they are in accordance with national, state, provincial and local regulations.

Care should always be taken with disposal actions to control dust emissions during the pick-up, transportation and subsequent depositing of waste material at the landfill site or during other disposal activities.

AIR

Carbon black is not regulated under a substance specific ambient air quality standard, but may be regulated as a dust (particulate matter) under other general rules (for the U.S., see 40 CFR Parts 50, 52, 56, 58, 60, 61, 62 and 70). Air regulations vary by region and by the general air quality in those regions. Compliance with some regulations may require the use of fabric filters or other dust collection devices.

WATER

Water discharges containing carbon black must comply with applicable requirements for solids and oxygen demand. Carbon black is not soluble in water and has a specific gravity of 1.7 to 1.9 (water = 1). Gravity settling is effective and the most common technique employed to remove carbon black from wastewater. Under some circumstances, settling may be inhibited because of the small particle size and/or high surface areas that may resist wetting. Various metallic salts, such as ferric or aluminum sulfate, and/or synthetic polymers, are effective as flocculating agents to enhance settling. The type of flocculent and optimum dosage rate can best be determined by bench scale or laboratory tests.

LEAKS OR SPILLS

Spills should be cleaned immediately to prevent the spread of carbon black. Dry vacuuming is the recommended method for collecting spilled carbon black. If a portable cleaner is used, care must be taken to ensure that filters are maintained. A central vacuum system should be considered for routine housekeeping and the clean-up of localized process leaks. The collector serving the central vacuum should be located outdoors. If it is necessary to clean a remote or small spill by dry sweeping, care should be taken not to disperse the carbon black into the air. Carbon black is not easily wetted and water may cause spilled material to disperse, so water sprays and wetting are not recommended for cleaning. Should this method be used, however, caution should be exercised since wet carbon black makes walking surfaces very slippery.

SHIPPING CONTAINERS

Reusable shipping containers should be returned to the manufacturer. Paper bags may be incinerated, recycled or disposed of in an appropriate landfill in accordance with national and local regulations.

TRANSPORTATION

Commercial carbon black is not classified as a hazardous material by the following agencies:

- Canadian Transport of Dangerous Goods Regulations
- European Transport of Dangerous Goods Regulations
- International Air Transport Association (IATA)
- United Nations (no UN number)
- U.S. Department of Transportation

Specific questions regarding transport classification should be referred to your carbon black supplier.

ENVIRONMENTAL PROTECTION REGULATIONS

In the U.S., carbon black is subject to annual inventory reporting requirements under Sections 311 and 312 of the Emergency Planning and Community Right-to-Know Act of 1986 (SARA Title III) if carbon black is used in quantities of 10,000 pounds or greater during a calendar year. Carbon black is subject to these requirements because it is regulated under the Occupational Safety and Health Administration (OSHA) Subpart Z (29 CFR 1910.1000). Carbon black is not an Extremely Hazardous Substance under SARA Title III, Section 302, and is not subject to SARA Title III, Section 313 - Toxic Chemical Release Reporting. Carbon black is not a hazardous substance under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, 40 CFR 302) or the Clean Water Act (40 CFR 116). Additionally, carbon black is not a hazardous waste under the Resource Conservation and Recovery Act (RCRA, 40 CFR 262), and is not a hazardous air pollutant under the Clean Air Act Amendments of 1990 (CAA, 40 CFR Part 63).

The U.S. Environmental Protection Agency also administers the Toxic Substance Control Act (TSCA) list of chemicals in commerce. Carbon black is on the Chemical Hazard Information Profile (CHIP) list of TSCA.

Although carbon black is not subject to release reporting requirements under CERCLA or SARA Title III, certain PAH components are subject to reporting requirements. State and local release reporting regulations should always be consulted.

In the European Union (EU), under Council Directive 97/689/EEC and its amendments, carbon black is not considered a hazardous waste. The carbon black waste code number is 61303 and can be found in Council Directive 75/422/EEC.

European Union (EU) Council Directive 67/548/EEC and its various amendments, including 9/831/EEC, relating to the classification, packaging and labeling of dangerous substances do not define carbon black as a dangerous substance.

In Canada, carbon black is not listed on the National Pollutant Release Inventory (NPRI).

NATIONAL REGISTRIES AND OTHER APPLICABLE REGULATIONS (not all inclusive)

Carbon black, CAS number 1333-86-4, appears on the following inventories.

Australia: Australian Inventory of Chemical Substances (AICS).

Canada: Canadian Environmental Protection Act (CEPA), Domestic Substance List (DSL); Workplace Hazardous Material Identification System (WHMIS). Carbon black is listed as a D2A controlled substance.

China: Inventory of Existing Chemical Substances.

European Union (EU): European Inventory of Existing Commercial Chemical Substances (EINECS), 215-609-9.

Germany: VDI guideline 2580, Emission Control Production Plants for Carbon Black - Classification of Carbon Black in Water: Water Endangering Class (WGK) is not water endangering, ID number 1742.

Japan: Ministry of International Trade and Industry (MITI) List of Existing Chemical Substances. (Not specifically listed.)

Korea: Toxic Chemical Control Law (TCCL), Existing Chemical List (ECL).

Philippines: Philippine Inventory of Chemicals and Chemical Substances (PICCS).

United States: Toxic Substances Control Act (TSCA) Inventory, Chemical Hazard Information Profile (CHIP); Clean Air Act (1990), Carbon black is not made from nor does it contain any Class 1 or Class 2 ozone depleting substances as defined under the 1990 amendments to the Act.

Note: Readers are urged to review their national, provincial, state, local, and federal safety, health and environmental regulations, as well as their carbon black supplier's material safety data sheet (MSDS). Specific questions should be addressed to your carbon black supplier.

This guide is not a substitute for the current product MSDS. Please contact your carbon black supplier for the appropriate carbon black MSDS.

APPENDIX A
Mortality and Morbidity Studies Overview

Numerous studies have been conducted in the carbon black industry to determine if carbon black exposure causes or contributes to death (mortality) or illness (morbidity) in workers. Most studies have focused on lung disorders, since the major route of exposure to carbon black is inhalation. This section is a general overview of the major carbon black health studies. It addresses primarily those cohort studies that provide the most meaningful data concerning occupational exposure to carbon black dust.

MORTALITY STUDIES

A mortality study attempts to establish the death (mortality) rate, usually by specific disease categories within a worker population, over a set period of time in comparison to normal populations. A retrospective cohort study searches for a relationship between an event (such as death or illness) and exposure to a specific hazard or work at a certain job. A cohort consists of people who share a common characteristic such as having worked in carbon black manufacturing plants.

A routine outcome measure used in mortality studies is the Standardized Mortality Ratio (SMR), which is essentially a ratio of the mortality rate in the studied population divided by the expected mortality rate in the reference population. An SMR of two, for example, indicates that the study group had twice the rate of death from a certain disease than the reference population. In a mortality study, SMRs are calculated for all major illnesses, including specific types of cancer. Rates of disease from the reference population are derived usually from public health statistics.

Several mortality studies have been conducted in Europe and the U.S., none of which indicate an excess risk of death from cancer or other illnesses among carbon black workers exposed to carbon black.

EUROPE

Hodgson and Jones (1985) analyzed data from five British factories covering approximately 20,000 person-years of exposure for workers in a cohort spanning the period 1947-1980. The authors noted that two of the factories had incomplete population data. For all five factories, the SMR for lung cancer was 1.52. For those factories with complete population data, the SMR was 1.23. The study did not correct for the effects of smoking and neither of these elevations in SMR was statistically significant. More importantly, the investigators found no elevated risk with increasing dust concentration or with duration of employment. The authors concluded that the slight, non-significant elevation in lung cancer risk was unrelated to carbon black exposure.

The British study was updated in 2001 (Sorahan, *et al.*, 2001). A total of 1147 male workers was evaluated for the period from 1951-1996. A mildly elevated SMR of 1.13 was noted for all cancer mortality and an SMR of 1.73 was reported for lung cancer. The authors attempted to determine whether the elevation in lung cancer rates was related to carbon black. Additional analyses, however, showed no link between cumulative exposure to carbon black or length of time working in the industry and risk of lung cancer. The authors concluded: "The study has been unable to link cumulative exposure to carbon black with elevated risks of lung cancer."

Another mortality study has been conducted at a German carbon black manufacturing facility. This investigation addressed mortality risks of approximately 2,000 workers employed at least one year between 1960 and 1998. Cumulative exposure to carbon black was also assessed. The results, though not published at the time of this printing, are expected in late 2004.

UNITED STATES

The carbon black workers who were studied in the U.S. (Ingalls, 1950; Ingalls and Risquez-Iribarren, 1961; Ingalls and Robertson, 1975; Robertson and Ingalls, 1980; Robertson and Inman, 1996) were employed by many different manufacturers. Several of these studies examined the same cohort and expanded the person-years of observation with each subsequent publication. The most recent report (Robertson and Inman, 1996) represents accumulated data for workers spanning the years 1935-1994. Lung cancer deaths observed (34) were compared to expected lung cancer mortality rates, giving a Standardized Mortality Ratio (SMR) of 0.84. This value indicates that carbon black workers actually had a lower rate of death from lung cancer in comparison to the general population.

MORBIDITY STUDIES

Occupational morbidity studies attempt to measure the incidence of illness among a worker population that may be attributable to exposure to a chemical or physical agent in the work environment. Morbidity studies can be performed at one particular time (cross-sectional), based on a review of old records (retrospective), or into the future over time (longitudinal). Carbon black workers have participated in two large cross-sectional morbidity studies in Europe and in the U.S.

The European and U.S. studies were reviewed by Gardiner (1995). The studies addressed potential relationships between exposure (defined quantitatively and qualitatively) and designated health endpoints, such as abnormal chest films, declines in lung function, or increased rates of certain respiratory symptoms. Comparisons among studies are complicated however, because of the different methodologies used to assess exposure and health effects. For example, different carbon black exposure fractions (that is, inhalable, respirable and "total" dust) have been measured via various types of sampling methods. Similarly, the number of readers used to review chest films, equipment standardization for assessing lung function, and the types of questionnaires to collect information on symptoms have varied considerably among different studies. For example, in contrast to other studies, one German study used whole body phlethysmography to assess lung function (Kuepper *et al.*, 1996). The use of different measures to evaluate the health endpoints can lead to inconsistencies in results.

EUROPE

Among over 3,000 carbon black workers employed at 19 European plants with a mean work history of over ten years, weak associations were noted between exposure to carbon black (based on job titles) and chronic cough and sputum production (Crosbie, 1986). No data were available on dust levels, thus dose:response relationships could not be established. Minor exposure-associated declines in forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) were also noted.

In the late 1980s, a similar multi-country European study of approximately 3,000 carbon black workers was initiated (Gardiner *et al.*, 1993). Data on exposure and health outcomes were collected on three separate occasions (designated as phases): Phase I (1987 - 1989), Phase II (1991 - 1992), and Phase III (1994 - 1995). The study is analogous to a prospective longitudinal study. Health outcome measures included pulmonary function, respiratory symptoms, and chest radiographs.

In Phase I, 3,086 workers from eighteen plants in seven European countries participated. According to investigators, the results indicated a relationship between exposure to carbon black and certain symptoms (cough, sputum production). Average exposure to carbon black was 1.52 mg/m^3 (inhalable fraction). The manner in which the symptom information was collected, however, was the subject of an independent scientific review, conducted at the request of ACGIH's TLV® Committee. The review noted methodologic problems with the manner in which symptom data were acquired and analyzed. The review concluded that this portion of the data from the European study could not be meaningfully interpreted.

Lung function measurements averaged more than 100% of that predicted for a person's age, height and sex for all categories of exposure except for cigarette smokers in the highest exposure group (98.3% of the predicted value). When all the results were analyzed in aggregate form, however, a small, but statistically significant relationship was noted between exposure to carbon black and decrements in FVC and FEV_1. The authors described their findings as “consistent with a non-irritant effect on the airways” (Gardiner *et al.*, 1993).

Among the 1,096 workers who underwent chest films, 9.9% showed readings of 1/0 (small opacities) or greater, the scoring system used by the International Labor Organization (ILO) for reading chest radiographs for pneumonoconiosis. These results, however, were actually lower than the average background chest film readings of European populations (11.3%) unexposed to any type of dust (Meyer *et al.*, 1997). Of the entire working group, three people had ratings of 2/2 or greater (increased profusion of small opacities).

Data from Phases II and III have also been published (Gardiner *et al.*, 2001 and van Tongeren *et al.*, 2001). In Phase II, 2,955 workers were evaluated. Approximately 48% of the group were cigarette smokers. The average exposure to carbon black was 0.81 mg/m^3 (inhalable fraction), which is approximately 50% less than the results reported in Phase I of the study. In Phase III, the participation rate was 95%, with 45% of the group being cigarette smokers. Average exposure to carbon black was 0.57 mg/m^3 (inhalable fraction), a further decrease from Phase II. The average age of the carbon black workers was 41, with the average length of employment in the industry being 15 years.

The authors reported that carbon black exerted a significant effect on most respiratory symptoms and on lung function (Gardiner *et al.*, 2001). The authors of the study, however, acknowledged shortcomings in the symptom data: "respiratory symptom results may have been biased and care should be taken in the interpretation of these results" (Gardiner *et al.*, 2001). Although decrements in lung function were measured, the authors also reported that the percentage of predicted lung function volumes exceeded 100% for FEV_1 and FVC, suggesting that conclusions regarding the health implications of carbon black exposure were based on the statistical significance of the results rather than the clinical relevance.

In a cross-sectional study of a German carbon black manufacturing facility, 677 examinations were performed among exposed employees (Kuepper *et al.*, 1996). No significant relationship was noted between bronchial hyper-reactivity (as assessed by body plethysmography) and exposure to carbon black. Exposure to carbon black did not increase the risk of either symptoms or lung function decrement in non-smokers or ex-smokers. A small effect on the smoking population was noted.

In a 1975 study in the former Yugoslavia, respirable dust concentrations of 7.2 mg/m^3 and 7.9 mg/m^3 were reported (Valic, 1975). In this review of 35 workers, a minor reduction in FEV_1 was noted among smokers. No relationship was noted among the non-smoking control group. Based on the recent particle size characterization studies conducted in Western European and North American carbon black plants (Kerr, 2001; Kuhlbusch, accepted for publication, Journal of Occupational & Environmental Health, 2004), the magnitude of these respirable dust concentrations reported in Yugoslavia in 1975 suggest extremely high exposure levels to “total” and inhalable dust.

UNITED STATES

Morbidity studies of U.S. carbon black workers have been performed for over 20 years. A recent cross-sectional morbidity study of the North American work force assessed relationships between exposure to carbon black, symptoms and lung function (Harber *et al.*, 2003). This study was based upon extensive data collected from production facilities throughout the U.S. and Canada. It utilized highly standardized techniques to facilitate high-quality data acquisition. The most recent effort reviewed workers from 22 North American manufacturing facilities (Harber *et al.*, 2003). In the study, 1,755 workers underwent a chest film, pulmonary function test and completed a health questionnaire. Analyses showed links between cumulative exposure and small reductions in lung function (FEV_1). Recent exposures showed no effects. These results indicated that exposure to carbon black at 1.0 mg/m^3, over a 40-year career, could result in an additional 27 ml decrement in FEV_1. In contrast, normal age-related decline in lung function during that same time would be about 1200 ml.
A case-control morbidity study was conducted on U.S. employees in seven carbon black plants (Robertson and Ingalls, 1989). Workers who submitted health insurance claims with diagnoses of certain types of illnesses, in particular, respiratory and circulatory ailments, were evaluated in relation to exposure to carbon black. Based on estimates of cumulative dust exposures, no significant relationship was noted between carbon black and the designated diseases.

In addition to health indices of pulmonary function, symptoms, and fibrotic disease, the U.S. carbon black workforce was also evaluated for cancer morbidity, that is, malignancies that had been diagnosed, but which had not led to death (Ingalls, 1950; Ingalls and Risquez-Iribarren, 1961; Robertson and Ingalls, 1989). The incidence of cancer among carbon black workers was compared both to unexposed carbon black workers and to cancer rates compiled in various states. No increase in cancer morbidity was noted in these investigations.

A nested case control study was also performed on this same cohort (Robertson and Ingalls, 1989). A case was defined as a member of the study population who filed a health insurance claim with a diagnosis of either a malignancy or a disorder of the circulatory or respiratory system. Two controls were matched to each worker and cumulative exposure to carbon black was estimated by relating measured concentrations of carbon black to specific job categories. No statistically significant increase in the risk of any malignancy was noted.

SUMMARY OF HUMAN STUDIES

Mortality studies have evaluated the risk of death from illness, including cancer, non-malignant respiratory disease, and cardiovascular disease. These studies did not link any increases in either overall mortality or lung cancer deaths to carbon black exposure.

Morbidity issues associated with occupational exposure have pertained to whether carbon black causes increases in risk of respiratory symptoms, decrements in lung function, or abnormalities on a chest film. Long-term exposure to carbon black in the manufacturing industry may lead to minor decrements in FEV_1 (27 - 48ml of additional loss over a 40-year working lifetime) and small changes in radiographs. Chest film opacities observed in carbon black workers tend to resemble opacities found in populations unexposed to dust, although slight increases have been noted in some carbon black workers. The studies do not delineate whether such effects are specific to carbon black or reflect effects that may be seen with other relatively inert, poorly soluble, inorganic dusts.

Acute exposure to carbon black does not pose any significant risk to health, beyond what might be expected from exposure to any poorly soluble dust. In occupational settings, airborne carbon black consists of large-sized agglomerates that can deposit in the upper respiratory tract. As a result, cough and irritation to the eyes may occur at high levels in some settings. Such effects are expected to be transitory and not to result in any long-term effect on lung function. Consisting almost entirely of carbon, carbon black is not metabolized. Once inhaled, the carbon black is removed via the mucociliary transport system of the lungs.

APPENDIX B
Selected Occupational Exposure Limits for Carbon Black

Country	Concentration mg/m³ (date of last known exposure limit)
Australia	3.0 TWA (1993)
Brazil	3.5 TWA (1995)
Canada	3.5 TWA (1991)
China	4.0 TWA (2002) 8.0 TWA STEL (15 min)
Germany	MAK: 1.0 respirable, 4.0 inhalable, as annual average (1997) TRGS 900: 6.0 respirable, 10 inhalable; as 8-hr TWA; effective April 2004, exemptions apply, consult regulatory agency
Italy	3.5 TWA (1995)
Mexico	3.5 TWA (1991)
Republic of Korea	3.5 MAC (1995)
Russia	4.0 TWA (1993)
United Kingdom	3.5 TWA OES (1995) 7.0 TWA STEL (10 min)
United States	ACGIH-TLV 3.5 TWA (1995) NIOSH-REL 3.5 TWA (1978) OSHA-PEL 3.5 TWA (1971)

ACGIH .... American Conference of Governmental Industrial Hygienists
MAC/MAK .... maximal allowable concentration
mg/m³ .... milligrams per cubic meter
NIOSH .... National Institute for Occupational Safety and Health
OES .... occupational exposure standard
OSHA .... Occupational Safety and Health Administration
PEL .... permissible exposure limit
REL .... recommended exposure limit
STEL .... short-term exposure limit
TLV........................... threshold limit value
TRGS........................ Technische Regeln für Gefahrstoffe (Technical Rules for Hazardous Substances)
TWA .... time weighted average, eight (8) hours unless otherwise specified

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The International Carbon Black Association attempts to maintain a complete and current bibliography of occupational and environmental health related literature for carbon black. Contact your carbon black supplier for additional information.

Notes

Notes

The **Carbon Black Users Guide** is a publication of the International Carbon Black Association (ICBA). The information contained herein is accurate to the best of its knowledge. The ICBA and its member companies provide this information to supplement the knowledge of persons skilled in the intended use and safe handling of carbon black. The user of this product has sole responsibility to determine the suitability of the product for any use and the manner of use contemplated. Any potential safety and health hazards associated with this product of which the member companies are aware are described in the Material Safety Data Sheet (MSDS). The MSDS, updated on a periodic basis in accordance with applicable health and safety standards, is available from your carbon black supplier and should be carefully reviewed prior to working with the product.

an International Carbon Black Association publication

The International Carbon Black Association (ICBA) is a non-profit corporation originally founded in 1977 as the Environmental Health Association of the Carbon Black Industry (EHACBI). In 1996, the EHACBI merged with its sister organization, the European Carbon Black Centre (ECBC), to form the ICBA. The purpose of the ICBA, like its predecessor organizations, is to sponsor, conduct and participate in investigations, research, and analyses relating to the health, safety, and environmental aspects of the production and use of carbon black. The member companies of the ICBA are Cabot Corporation, Cancarb Limited, Columbian Chemicals Company, Continental Carbon Company, Degussa Corporation, Degussa Engineered Carbons, Sid Richardson Carbon Company, and The Birla Group.