CHEMICAL SAFETY REPORT

Substance Name: **Carbon Black**
EC Number: **215-609-9**
CAS Number: **1333-86-4**
Registrant's identity: **Evonik Degussa GmbH, Essen, Germany**

CONTENTS

PART A

A.1 Summary of Risk Management Measures

An overview of the relevant risk management measures for the identified uses is presented below. These include the measures needed to control risk as

i) implemented with regard to manufacture and own use and/or

ii) *as communicated to downstream users in the annex to the extended SDS.*

First aid measures:

Inhalation: Take affected persons into fresh air. If necessary, restore normal breathing through standard first aid measures.

Skin: Wash skin with mild soap and water. If symptoms develop, seek medical attention.

Eye: Rinse eyes thoroughly with large volumes of water keeping eyelid open. If symptoms develop, seek medical attention.

Ingestion: Do not induce vomiting. If conscious, give several glasses of water. Never give anything by mouth to an unconscious person.

NOTE TO PHYSICIANS: Treat symptomatically.

Fire Fighting-Measures

1. FLAMMABLE PROPERTIES

It may not be obvious that carbon black is burning unless the material is stirred and sparks are apparent. Carbon black that has been on fire should be observed closely for at least 48 hours to ensure no smoldering material is present.

Carbon blacks containing more than 8% volatile materials may form an explosive dust-air mixture. Manufactured carbon blacks do not exceed 8% volatile materials content (unless otherwise noted by he supplier).

2. EXTINGUISHING MEDIA

Use foam, carbon dioxide (CO2), dry chemical, nitrogen (N2), or water fog. A fog spray is recommended if water is used.

DO NOT USE high pressure water stream as this may spread burning powder (burning powder will float and may spread fire).

3. PROTECTION OF FIREFIGHTERS

Wear full protective fire fighting gear (Bunker gear) including self-contained breathing apparatus (SCBA).

4. HAZARDOUS PRODUCTS OF COMBUSTION

Products of combustion include carbon monoxide (CO), carbon dioxide (CO2), and oxides of sulfur.

5. SPECIAL PRECAUTIONS FOR FIREFIGHTERS

Wet carbon black produces very slippery walking surfaces.

Accidental Release Measures

1. PERSONAL PRECAUTION

Wear appropriate personal protective equipment and respiratory protection. NOTE: Wet carbon black produces very slippery walking surfaces.

2. ENVIRONMENTAL PRECAUTION

Carbon black poses no significant environmental hazards. As a matter of good practice, minimize contamination of sewage water, soil, groundwater, drainage systems, or bodies of water.

3. METHODS FOR CLEAN-UP

Small spills should be vacuumed when possible. A vacuum equipped with HEPA (high efficiency particulate air) filtration is recommended. Dry sweeping is not recommended. If necessary, light water spray will reduce dust for dry sweeping, but over-wetting may produce very slippery walking surfaces. Large spills may be shoveled into containers.

Handling and Storage

1. HANDLING

Avoid dust exposures above the occupational exposure limit.

Use local exhaust ventilation or other appropriate engineering controls to maintain exposures below occupational exposure limit. Avoid contact with skin and eyes. If exposed, wash to avoid mechanical irritation and soiling.

Dust may cause electrical shorts if capable of penetrating electrical equipment. Ensure equipment is tightly sealed.

If hot work (welding, torch cutting, etc.) is required the immediate work area must be cleared of carbon black product and dust.

Some grades of carbon black are sufficiently electrically non-conductive and may allow a build-up of static charge during handling. Take measures to prevent the build up of electrostatic charge, such as ensuring all equipment is electrically grounded/earthed.

2. STORAGE

Store in a dry place away from ignition sources and strong oxidizers.

Before entering closed vessels and confined spaces containing carbon black test for adequate oxygen, flammable gases and potential toxic air contaminants (e.g., CO). Follow standard safe practices when entering confined spaces.

Transport Information

Carbon black is not restricted for transport by the United Nations Recommendations on the Transport of Dangerous Goods.

Exposure Control / Personal Protection

1. ENGINEERING CONTROLS

Use process enclosures and/or exhaust ventilation to keep airborne dust concentrations below the applicable occupational exposure limit.

2. PERSONAL PROTECTIVE EQUIPMENT (PPE)

2.1 Eye/face protection

Safety glasses or goggles recommended as a matter of good practice

2.2 Skin protection

Wear general protective clothing to minimize skin contact. Work clothes should not be taken home and should be washed daily.

No special glove composition is required for carbon black. Gloves may be used to protect hands from carbon black soiling. Use of a barrier cream may help to prevent skin drying. Wash hands and other exposed skin with mild soap and water.

2.3 Respiratory protection

Approved air purifying respirator (APR) for particulates should be used where airborne dust concentrations are expected to exceed occupational exposure limits. Use a positive-pressure, air supplied respirator if there is any potential for uncontrolled release, exposure levels are not known, or in circumstances where APRs may not provide adequate protection. Use of respirators must include a complete respiratory protection program in accordance with national standards and current best practices.

2.4 General hygiene considerations

Emergency eyewash and safety shower should be in close proximity as a matter of good practice. Wash hands and face thoroughly with mild soap before eating and drinking.

Stability and Reactivity

1. CHEMICAL STABILITY

Stable under normal ambient conditions.

2 CONDITIONS TO AVOID

Prevent exposure to high temperatures and open flames.

3. INCOMPATIBLE MATERIALS

Strong oxidizers such as chlorates, bromates, and nitrates.

4. HAZARDOUS DECOMPOSITION PRODUCTS

Carbon monoxide, carbon dioxide, organic products of decomposition, oxides or sulfur (sulfoxides) form if heated above decomposition temperature.

5. POSSIBILITY OF HAZARDOUS REACTION

Will not occur.

Disposal Consideration

Product can be burned in suitable incineration plants or disposed of in a suitable landfill in accordance with the regulations issued by the appropriate federal, provincial, state and local authorities.

(EU Waste Code No. 61303 per Council Directive 75/422/EEC).

Container/Packaging: Return reusable containers to manufacturer. Paper bags may be incinerated, or recycled, or disposed of in an appropriate landfill in accordance with national and local laws.

A.2 Declaration That Risk Management Measures Are Implemented

It is herewith declared that the risk management measures in the relevant exposure scenarios for the registrant's own manufacturing and use(s) are implemented.

A.3 Declaration That Risk Management Measures Are Communicated

It is herewith declared that the risk management measures are communicated to downstream users (formulators and other downstream users) by means of the safety data sheet.

PART B

B.1 Identity of the Substance and Physical and chemical Properties

B.1.1 Identification of the Substance

CAS Number:	1333-86-4
IUPAC Name:	Carbon black
Molecular Formula:	Substantially elemental carbon, C
Structural Formula:	Not applicable
Molecular Weight:	12.01 (elemental carbon)
Synonyms:	Acetylene black
	Channel black
	Furnace black
	Gas black
	Lampblack
	Thermal black

Carbon black is elemental carbon in the form of fine black powder consisting of near-spherical colloidal primary particles and particle aggregates. Depending on the manufacturing process, carbon blacks are categorised as furnace black, lampblack, acetylene black, channel black, gas black or thermal black. These types of carbon black are characterised by the size distribution of the primary particles, the degree of their aggregation and agglomeration and the various chemicals adsorbed onto the surfaces. It is important to note that the primary particle does not freely exist outside of the production chamber and the smallest free airborne particle is the aggregate which consists of a number of fused primary particles. For industrial aciniform aggregates, breakdown of aggregates with liberation of nanosized nodules is not an issue even after severe mechanical treatment (Gray and Muranko, 2006).

B.1.2 Purity/Impurities/Additives

Commercial carbon blacks are manufactured by controlled processes, and generally contain more than 97% elemental carbon with variable amounts of oxygen, hydrogen, and sulphur (less than 1% each) (ICBA, 2004).

Less than 1% of the finished product consists of solvent-extractable organic material, i.e. polycyclic aromatic hydrocarbons (PAHs) and small amounts of other polynuclear aromatic hydrocarbons (PNAs) and elemental sulphur. Examples of PAHs extracted most frequently from carbon black using a variety of extraction methods (e.g. prolonged Soxhlet extraction with benzene or toluene) include benzopyrenes, benzo[ghi]perylene, coronene, fluoranthene, anthanthrene and pyrene. These are present at levels that vary from less than 0.01 to 800 ppm, however seldom in excess of 200 ppm. Acenaphthylene, chrysene, benzo[b]fluoranthene, benz[a]anthracene, and perylene may be present in lesser amounts (DFG, 1999; IARC, 1996; McCunney et al., 2001).

There are important differences in the physical and chemical properties of carbon blacks and soot. While carbon black typically contains only traces of organic compounds (less than 1%), soot contains higher quantities of organics (up to 82%). Diesel exhaust particles typically contain amounts between 10 and 65% (Watson and Valberg, 2001).

B.1.3 Physical and chemical properties

Carbon black is substantially elemental carbon. It has no functional groups that could bring about solubility in water and organic solvents. Its vapour pressure is negligible. These physico-chemical properties are reason why important parameters like water solubility, octanol/water partition coefficient, or the dissociation constant cannot be analytically measured.

Table 1 **Summary of physical and chemical properties**

REACH ref Annex, §	Property	Value(s)	Reference
VII, 7.1	Physical state at 20 deg C and 101.3 KPa	Solid (powder, pellets)	ICBA, 2004
VII, 7.2	Melting point	3652-3697 ^{0}C (sublimation)	Weast (1983/4)
VII, 7.3	Boiling point	Study technically not feasible In accordance with section 2 of REACH Annex XI, the boiling point does not need to be determined as the substance undergoes sublimation at > 3500 ^{0}C	REACH Annex XI, section 2
VII, 7.4	Relative density	1.80 – 1.98	Kotlensky and Walker, 1960; EPA, 1980; Degussa AG,,1987
VII, 7.5	Vapour pressure	In accordance with column 2 of REACH Annex VII the vapour pressure does not need to be determined as the melting point of the substance is above 300 ^{0}C	REACH Annex VII / 7.5
VII, 7.6	Surface tension	In accordance with column 2 of REACH Annex VII the surface tension does not need to be determined as the water solubility is below 1 mg/l at 20 ^{0}C	REACH Annex VII / 7.6
VII, 7.7	Water solubility	Study technically not feasible. In accordance with section 2 of REACH Annex XI, the study does not need to be conducted as the substance is substantially elemental carbon, inert, inorganic and contains no water-soluble groups, e.g. alcohols, ethers, or acids and is therefore insoluble in water.	REACH Annex XI, section 2

VII, 7.8	Partition coefficient n-octanol/water (log Kow value)	In accordance with column 2 of REACH Annex VII, the partition coefficient n-octanol / water does not need to be determined as the substance is inorganic	REACH Annex VII / 7.8.
VII, 7.9	Flash point	In accordance withcolumn 2 of REACH Annex VII, the flash-point does not need to be determined as the substance is inorganic	REACH Annex VII / 7.9
VII, 7.10	Flammability	Ignition temperature: > 600 ^{0}C ; burns slowly (smolders) at > 400 deg C. The burning process may be so slow as to not be obvious (no visible flames or smoke) unless stirred and sparks are apparent. Direct water spray or stream may spread the fire due to the burning powder floating on the water	Degussa AG, 1990; ICBA, 1999
VII, 7.11	Explosive properties	In accordance with column 2 of REACH Annex VII (7.11, explosive properties) the study does not to be conducted if there are no chemical groups assosiated with explosive properties present in the molecules or the substance containes chemical groups associated with explosive properties which include oxygen and the calculated oxygen balance is less than -200	REACH Annex VII / 7.11
VII, 7.12	Self-ignition temperature	Thermal black and Furnace black: >140 ^{0}C. Not classifiable as a Division 4.2 self-heating substance.	BRE Global Ltd., 2008; Enviro Test Laboratories, 2006
VII, 7.13	Oxidising properties	In accordance with column 2 of REACH Annex VII, the oxidising properties of the substance do not need to be determined as the substance is an inorganic substance not containing oxygen or halogen atoms	REACH Annex VII / 7.13
VII, 7.14	Granulometry	Carbon black consists of near spherical colloidal primary particles (10-500 nm in diameter) fused into aggregates of such particles.(d_{50} 18 -32 µm geometric diameter in air), or, in the case of thermal black, primarily single spheres rather than aggregates (for details see Table 2) Further testing is scientifically not justified. In accordance with section 1 of REACH Annex XI, a granulometry study does not need to be conducted as existing data are considered equivalent to data generated by the	OECD, 2005; IARC, 1996; Degussa, 2003a; Evonik Degussa GmbH, 2009 REACH Annex XI, section 1

		corresponding test method referred to in article 13(3)	
IX, 7.15	Stability in organic solvents and identity of relevant degradation products	In accordance with column 2 of REACH Annex IX, the stability in organic solvents and identity of relevant degradation products does not need to be determined as the substance is inorganic	REACH Annex IX / 7.15
IX, 7.16	Dissociation constant	Study technically not feasible. In accordance with section 2 of REACH Annex XI, the study does not need to be conducted as the substance is substantially elemental carbon and contains no dissociable groups	REACH Annex XI, section 2
IX, 7.17	Viscosity	Study technically not feasible. In accordance with section 2 of REACH Annex XI, the study does not need to be conducted as the substance is not a liquid	REACH Annex XI, section 2

Thermal carbon black was tested isothermally to determine its self-heating properties. From the critical ignition temperatures recorded the material was found to be mildly susceptible to self ignition. The critical ignition temperature for a $27m^3$ cube of this material was calculated to be 183°C. This temperature is well above 50°C and thermal carbon black is therefore not regarded as being a self-heating substance for transportation. Thermal carbon black will not experience self-heating in practice unless exposed to temperatures well in excess of 100 °C (BRE Global Ltd., 2008).

Seven ASTM reference grades of furnace black tested in accordance with the U.N. method for Self-Heating Solids (UN Test N1, 100 mm sample cube, 140 °C) were determined to be “Not a self-heating substance of Division 4.2” (Enviro Test Laboratories, 2006). It is noted that the U.N. method is volume dependent, i.e., the auto-ignition temperature decreases with increasing volume

Carbon blacks will burn slowly (smoulder) and sustain combustion that may not be visible in the powder or pellet form. The burning process may be so slow as to not be obvious (no visible flames or smoke) unless stirred and sparks are apparent. Direct water spray or stream may spread the fire due to the burning powder floating on the water (ICBA, 1999)

Unlike diamond and graphite, which are crystalline carbons, carbon black is an amorphous carbon composed of fused primary particles called aggregates. The aggregates may consist of a few or hundreds of particles, or, as in thermal black, primarily single spheres rather than aggregates. The aggregates can bind together by van der Waals forces in more loosely associated agglomerates, or they may be compressed in pellets (up to 0.5 cm) held together by means of binders (IARC; 1996).

Average primary particle diameters of representative samples of the commercially important furnace carbon blacks range from 10 to 500 nm (Degussa, 2003a; DFG, 1999; IARC, 1996), while average aggregate geometric diameters of furnace carbon blacks determined according to DIN EN

ISO/IEC 17025 range from 18 to 32 µm (d_{50}) when dispersed in air and from 12 to 13 µm (d_{50}) when dispersed in water.

Table 2 Typical ranges of properties for five types of carbon black (IARC, 1996 (modified); Degussa, 2003a)

Property	Acetylene Black	Furnace Black	Gas black	Lampblack	Thermal Black
Average aggregate diameter according DIN EN ISO/IEC 17025	Not reported	18-32 µm (air) 12-13 µm (water)	Not reported	Not reported	300-810 nm
Average primary particle diameter	45-50 nm	17-70 nm	13-29 nm	50-100 nm	150-500 nm
Surface area (m^2/g)	60-70	20-300	90-320	20-95	6-15
Oil absorption (ml/g)	3.0-3.5	0.67-1.95	2.8-9.2	1.05-1.65	0.30-0.46
pH	5-7	5-9.5	2.5-4.5	3-7	7-8
Volatile matter (%)	0.4	0.3-2.8	5-6	0.4-9	0.10-0.50
Hydrogen (%)	0.05-0.10	0.45-0.710	Not reported	Not reported	0.3-0.5
Oxygen (%)	0.10-0.15	0.19-1.25	Not reported	Not reported	0.00-0.12
Benzene extract (%)	0.1	0.01-0.18	<0.1-0.3 (toluene)	0.00-1.4	0.02-1.7
Ash (%)	0.00	0.1-1.0	0.02	0.00-0.16	0.02-0.38
Sulfur (%)	0.02	0.05-1.5	0.3-0.5	Not reported	0.00-0.25
Density (g/L)	Not reported	120-400	120-180	Not reported	Not reported

Channel black is characterized by a small primary particle size (12-29 nm), large surface area (> 100 m^2/g), low degree of aggregation or structure, relatively high oxygen content, acidic pH, and very low ash content. The volatile content of channel black is about 5% but can be increased to as much as 18% by after-treatments with hot air (IARC, 1996).

B.2 Manufacture and Uses

B.2.1 Manufacture

Carbon black is not known to occur as a natural product (IARC, 1996). It is manufactured by incomplete combustion of a hydrocarbon such as oil or gas with a limited supply of combustion air or by the thermal decomposition of gaseous or liquid hydrocarbons at temperatures in excess of 1100 °C. The carbon is collected as a fine black and fluffy powder.

Two major processes are presently used to manufacture carbon black, the oil furnace black process and the thermal black process; the first accounting for about 90% of production, and the latter for about 10%.

The oil furnace black process uses heavy aromatic oils as feedstock. The production furnace is a tightly enclosed reactor used to react the feedstock under carefully controlled conditions and at extremely high temperatures. The feedstock is atomized in a hot gas stream where it vaporizes and then pyrolyzed in the vapour phase to form microscopic carbon particles. In most furnace reactors, the reaction 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. Furnace black is available in several grades. They are mainly used in rubber products, inks, paints and plastics.

The thermal black process uses natural gas, mainly consisting of methane, as the starting material in a cyclic operation in which the gas is thermally decomposed (cracked). The process uses a pair of furnaces that alternate approximately every five minutes between preheating and carbon production. The methane is injected into a hot refractory-lined furnace. In the absence of air, the heat from the refractory material decomposes the methane into carbon black and hydrogen. The aerosol material stream is quenched with water sprays and filtered. The exiting carbon black may be further processed to remove impurities, pelletized, screened, and then packaged for shipment. The process yields relatively coarse particles.

Two other processes (the lamp process for production of lampblack and the cracking of acetylene to produce acetylene black) are used for small-volume specialty carbon blacks that constitute less than 1% of the total production. Lampblack is produced by burning liquid hydrocarbons, e.g. kerosene. Lampblack is often oily. It is used for contact brushes in electrical apparatus.

The gas black process was developed in the 1930s in Germany, where natural gas was not available in sufficient amounts. It is similar to the channel black process, but uses coal tar oils instead of natural gas. Yields and production rates are much higher with oil-based feedstock; this process is still used to manufacture high-quality pigment blacks with properties comparable to those of channel blacks. Degussa (now renamed Evonik) has used the gas black process on an industrial scale since 1935.

The gas furnace process is being phased out, and the channel black process is no longer used in the United States.

The fluffy carbon black coming out of the filter is pneumatically conveyed into a first storage tank. During the wet pelletisation process, the water containing the pelletising agents dissolved in it is injected via spray nozzles. The size of the pellets is around 1-2 mm. The carbon black leaving the pelletising machine contains approximately 50% by wt. water. It is dried in dryer drums by a variety of means. The most common method is indirect heating by combusting tail gas. Drying temperatures, generally between 150 and 250°C, allow further modification of the carbon black properties. The dried carbon black is transported via conveyor belts and elevators to the storage tank or packing station. Bulk densities of wet-pelletised carbon blacks are between 250 and 550 g/L.

Less than 0.1% of the production is delivered in the fluffy powder form (DFG, 1999).

B.2.2 Identified uses

Table 3: Description of identified uses

Identified Use	Sector of Use (SoU)	Product Category (PC)	Process Category (PROC)
IU1: Additive for rubber (approximately 80% of carbon black consumption)	SU11: Manufacture of rubber products	PC1: Adhesive, Sealants, PC 32: Polymer Preparations and Compounds	PROC 2: use in closed, continuous process with occasional controlled exposure PROC 3: use in closed batch process (synthesis or formulation) PROC 4: Use in batch and other process (synthesis) where opportunity for exposure arises PROC 5: Mixing or blending in batch processes (multistage and/or significant contact) PROC 8: Transfer of chemicals from/to vessels/large containers at non dedicated facilities PROC 9: Transfer of chemicals into small containers (dedicated filling line)
IU 2: Additive for plastics (approximately 10 % of carbon black consumption)	SU12: Manufacture of plastics products, including compounding and conversion	PC1: Adhesive, Sealants, PC 32: Polymer Preparations and Compounds	PROC 2: use in closed, continuous process with occasional controlled exposure PROC 3: use in closed batch process (synthesis or formulation) PROC 4: Use in batch and other process (synthesis) where opportunity for exposure arises PROC 5: Mixing or blending in batch processes (multistage and/or significant contact) PROC 8: Transfer of chemicals from/to vessels/large containers at non dedicated facilities PROC 9: Transfer of chemicals into small containers (dedicated filling line)

Identified Use	Sector of Use (SoU)	Product Category (PC)	Process Category (PROC)
IU 3: Pigment (approximately 9% of total carbon black consumption)	SU5: Manufacture of textiles, leather, fur SU6: Manufacture of pulp, paper and paper product SU9: Manufacture of fine chemicals SU10: Formulation [mixing] of preparations and/or re-packaging SU11: Manufacture of rubber products SU13: Manufacture of other non-metallic mineral products, e.g. plasters, cement	other products: PC1, PC5, PC9, PC10, PC18, PC 23, PC 26, PC 32. PC 39	PROC 2: use in closed, continuous process with occasional controlled exposure PROC 3: use in closed batch process (synthesis or formulation) PROC 4: Use in batch and other process (synthesis) where opportunity for exposure arises PROC 5: Mixing or blending in batch processes (multistage and/or significant contact) PROC 8: Transfer of chemicals from/to vessels/large containers at non dedicated facilities PROC 9: Transfer of chemicals into small containers (dedicated filling line)
IU 4: Chemical reagent (< 1 % of total carbon black consumption)	SU8: Manufacture of bulk, large scale chemicals (including petroleum products) SU9: Manufacture of fine chemicals SU10: Formulation [mixing] of preparations and/or re-packaging SU13: Manufacture of other non-metallic mineral products, e.g. plasters, cement SU14: Manufacture of basic metals SU15: Manufacture of fabricated metal products, except machinery and equipment	other products: PC 2, PC 7, PC 21; laboratory chemicals;	PROC 1: Use in closed process, no likelihood of exposure PROC 2: use in closed, continuous process with occasional controlled exposure PROC 3: use in closed batch process (synthesis or formulation) PROC 4: Use in batch and other process (synthesis) where opportunity for exposure arises PROC 5: Mixing or blending in batch processes (multistage and/or significant contact) PROC 8: Transfer of chemicals from/to vessels/large containers at non dedicated facilities PROC 9: Transfer of chemicals into small containers (dedicated filling line) PROC 12 Use of blow agents for foam production PROC 15 Use of laboratory reagents in small scale laboratories
IU 5: Refractories (< 1 % of total carbon black consumption)	SU8: Manufacture of bulk, large scale chemicals (including petroleum products) SU9: Manufacture of fine chemicals SU10: Formulation	other products: thermal insulator	PROC 2: use in closed, continuous process with occasional controlled exposur PROC 3: use in closed batch process (synthesis or formulation) PROC 4: Use in batch and other process (synthesis) where opportunity

Identified Use	Sector of Use (SoU)	Product Category (PC)	Process Category (PROC)
	[mixing] of preparations and/or re-packaging SU14: Manufacture of basic metals		for exposure arises PROC 5: Mixing or blending in batch processes (multistage and/or significant contact) PROC 8: Transfer of chemicals from/to vessels/large containers at non dedicated facilities PROC 9: Transfer of chemicals into small containers (dedicated filling line) PROC 14: Production of preparations or articles by tabletting, compression, extrusion, pelettisation PROC 15: Use of laboratory reagents in small scale laboratories PROC 22: Potentially closed operations with minerals at elevated temperature
IU 6: Portable energy (< 1 % of total carbon black consumption)	SU16: Manufacture of computer, electronic and optical products, electrical equipment	other products: catalyst support other products: PC 33: Semiconductor	PROC 1: Used in closed process, no likelihood of exposure PROC 2: use in closed, continuous process with occasional controlled exposure PROC 3: use in closed batch process (synthesis or formulation) PROC 4: Use in batch and other process (synthesis) where opportunity for exposure arises PROC 5: Mixing or blending in batch processes (multistage and/or significant contact) PROC 8: Transfer of chemicals from/to vessels/large containers at non dedicated facilities PROC 9: Transfer of chemicals into small containers (dedicated filling line) PROC 14: Production of preparations or articles by tabletting, compression, extrusion, pelettisation PROC 15: Use of laboratory reagents in small scale laboratories
IU 7: Other carbon preparations (< 1 % of total carbon black consumption)	SU9: Manufacture of fine chemicals SU10: Formulation [mixing] of preparations and/or re-packaging	Other products: e.g. automotive parts	PROC 1: Used in closed process, no likelihood of exposure PROC 2: use in closed, continuous process with occasional controlled exposur PROC 3: use in closed batch process (synthesis or formulation) PROC 4: Use in batch and other process (synthesis) where opportunity for exposure arises PROC 5: Mixing or blending in batch processes (multistage and/or significant contact)

Identified Use	Sector of Use (SoU)	Product Category (PC)	Process Category (PROC)
			PROC 8: Transfer of chemicals from/to vessels/large containers at non dedicated facilities PROC 9: Transfer of chemicals into small containers (dedicated filling line) PROC 14: Production of preparations or articles by tabletting, compression, extrusion, pelettisation

B.2.3 Uses advised against

Use as pigment in Tattoo colours for human.

B.3 Classification and labelling

Carbon black is not listed in annex 1 of Directive 67/548/EEC and is not defined as a dangerous substance or preparation according to Directive 67/548/EEC and its various amendments and adaptations.

Based on a conclusive database and in accordance with the criteria laid down in Annex VI of Directive 67/548/EEC, carbon black is *not classifiable* with regard to its physico-chemical, ecotoxicological and toxicological properties.

In particular, classification and labelling for carcinogenicity is not warranted because

- the evaluation of carbon black as a suspect carcinogen is based solely on the observation that rats develop lung tumors
- the epidemiological evidence does not show that exposure to carbon black has a carcinogenic potential in humans
- data of rat lung overload studies cannot be extrapolated to humans.

Summary of human data

The most recent evaluation of possible human cancer risks due to carbon black exposures was performed by an IARC[1] working group in February 2006 (Baan *et al*. 2006). The working group identified lung cancer as the most important endpoint to consider and exposures at carbon black production sites as the most relevant for an evaluation.

Three epidemiological studies were performed to investigate lung cancer mortality in carbon black production plants:

[1] IARC = International Agency for Research of Cancer

A UK cohort study on 1,147 workers at five plants (Sorahan *et al*. 2001) found an SMR[2] of 1.73 (61 cases, 0.95-CI[3]: 1.32, 2.22) but no trend across crudely assessed cumulative exposure, lagged up to 20 years. Elevated lung cancer SMRs were observed at two plants, the SMRs of the other three plants were unexceptionable. A German study on 1,528 workers at one plant (Wellmann *et al*. 2006, Morfeld *et al*. 2006a, Buechte et al. 2006, Morfeld *et al*. 2006b) estimated an SMR = 1.83 (50 cases, 0.95-CI: 1.34, 2.39) but could not find any positive trends with carbon black exposures. However, the German study identified smoking and prior exposures to known carcinogens as important risk factors that could explain the major part of the excess risk (Morfeld *et al.,* 2006a). A US cohort study on 5,011 workers at 18 plants (Dell *et al*., 2006) calculated an SMR = 0.85 (127 cases, 0.95-CI: 0.71, 1.00) and found no trend across time since first exposure and duration of exposure in years.

The working group at IARC concluded that the evidence in humans for the carcinogenicity of carbon black was ***inadequate*** (Baan *et al*., 2006; IARC, 2006).

In an extended follow-up of the UK study, Sorahan and Harrington (2007) applied a novel exposure metric ("lugging") while hypothesizing that carbon black may act as a late stage lung cancer carcinogen at plants with elevated SMRs. If so, the elevated SMRs of lung cancer should decrease substantially after cessation of exposure and positive associations should be found with "lugged" cumulative carbon black exposure ("lugging" the exposure by 15 years means to count only exposures received during the last 15 years). Sorahan and Harrington 2007 observed both phenomena in those (and only those) two UK plant cohorts that had elevated lung cancer SMRs. The authors asked for repetitions of their surprising findings in independent settings. Morfeld and McCunney 2007 tested the hypothesis of Sorahan and Harrington 2007 in the German study. Neither a decreasing SMR after cessation of exposure was observed nor a positive relationship with "lugged" cumulative carbon black exposure although the German cohort showed a clearly elevated lung cancer SMR. Therefore, Morfeld and McCunney 2007 were unable to lend support to the new hypothesis generated by Sorahan and Harrington (Morfeld and McCunney, 2007).

Overall, as a result of these detailed investigations, no causative link of carbon black exposure and cancer risk in humans has been demonstrated. This view is consistent with the IARC evaluation in 2006.

Summary of animal data

In numerous studies, rodents, particularly rats, have been exposed by inhalation to carbon black. Based on the results from these studies a number of conclusions may be drawn.
First, prolonged inhalation of high levels of carbon black causes delayed alveolar lung clearance and marked retention of particles. This phenomenon is described as "lung overload" (IARC 1996; Mauderly, 1996) and is common for a range of respirable insoluble dusts of low toxicity. The sequelae to these high lung burdens in rats include inflammation, which leads to a range of changes in pro- and anti-inflammatory biochemical parameters (found in bronchoalveolar lavage fluid), epithelial hyperplasia, and pulmonary fibrosis.

[2] SMR = standardized mortality ratio

[3] CI = confidence interval

Second, rats are more sensitive to the effects of carbon black overload than other species, with female rats having more pronounced reactions than male rats (ILSI, 2000). In long-term studies, only female rats were prone to a significant increase in the development of lung tumors. The lowest carbon black concentration used in a chronic inhalation study where lung tumors were induced was 2.5 mg/m^3, with rats being exposed for 16 hours/day, 5 days/week for 2 years (Nikula *et al*., 1995). However, mice exposed to 11.6 mg/m^3 carbon black for 18 hours/day, 5 days/week for 13.5 months and observed for a further 9.5 months did not exhibit an increase in lung tumors (Heinrich et al., 1995). In primates (Nikula *et al*., 1997) and in humans (Mauderly 1996), there are clear differences in particle deposition, clearance patterns, and tissue reactions, when compared to rats. These differences underline the uniqueness of the rat tumor development under conditions of lung overload and raise questions as to the validity of interspecies extrapolations of particle effects from rats to humans.

Data on coal miners provide the best available human evidence with which to explore lung overload questions. Using eight studies conducted between 1956 and 1986 from a total of 1,225 miners in the US and UK, Mauderly (1994) converted the lung burden of coal dust into units of specific lung burden and showed that long-term coal miners commonly accumulated dust burdens in the range of 7 to 14 mg per g lung. This value indicates that the dust burdens in heavily exposed human lungs are in the same range as, or greater, than in the heavily exposed experimental animals seen in chronic bioassays. In spite of these high lung burdens, coal dust exposure does not cause a significant increase in lung cancers among miners (IARC, 1996). This reasoning, although quite compelling, does not preclude the possibility that total particle surface area and particle number are also parameters pertinent to biological outcomes as it is generally accepted that the pathogenicity (including tumour induction) in rats of inhaled particles is more closely related to total particle surface area rather than mass and coal dust has a large proportion of large particle.

Third, results from genotoxicity studies suggest a direct association of mutation with inflammation and its sequelae in rat lung tumor development. Lung inflammation leads to the production of reactive oxygen species, and these mutational lesions seen in the *ex vivo hprt* assay can be prevented by experimental treatment with antioxidants (Driscoll et al. 1997). This study demonstrated that the increase in mutation frequency is caused by oxidative damage alone, typical of a secondary genotoxic mechanism.

The prevailing scientific consensus is that rat lung tumors induced by inert, **poorly soluble particles** (**PSPs**), such as carbon black, arise out of a background of chronic and persistent inflammatory changes; the corollary being that if these changes are avoided, then the tumors will not occur. In this respect, the studies of Driscoll *et al.* (1996) are of particular relevance because exposure to 1.1 mg/m^3 of respirable carbon black particles did not evoke inflammatory or mutational changes to female rats. A no observed adverse effect level (NOAEL) of 1 mg/m^3 (respirable) carbon black has been supported by more recent rodent findings by Oberdoerster, Driscoll, and colleagues (Carter et al., 2006, Elder *et al*., 2005; Driscoll *et al*., 2002; ILSI, 2000).

Exposure protocols in experimental studies and relevance to occupational exposure

Exposure patterns and particle characteristics in experimental animal studies do not mimic conditions in the occupational environment. The duration of carbon black exposure in the chronic studies ranged from 16 to 18 hours per day, which does not simulate the workplace. Prolonged exposure does not give the animals the normal recovery period for lung clearance. This is explainable by the fact that rat studies are only hazard studies and not risk based studies.

Workplace exposure assessments in contemporary carbon-black manufacturing operations in Europe and in North America reveal typical 8-hour TWA exposures to be well below 0.5 mg/m^3 respirable dust (Gardiner 1992a,b; Harber 2003a,b). In addition, industry workplace exposures are to large-size carbon black agglomerates that represent only part of the total dust (12 - 73%) exposure, with the remainder of workplace exposure being to non-carbon-black constituents. Thus, for both particle size and aerosol composition, workplace exposure characteristics are different from what has been used in the animal studies. Therefore, from a risk perspective (risk = hazard x exposure) the validity of studies showing rat tumour development under conditions of lung overload is questionable.

Mechanism of tumor development in rats and species differences

1. Lung overload

The development of lung tumors occurs only in rats under lung overload conditions (IARC, 1996; Mauderly, 1996). Neither other rodents, such as mice and hamsters, nor humans develop lung tumors under similar conditions of lung overload from PSPs. The development of lung tumors at lung overload exposures is triggered by the inability of rats to effectively clear the particles from their lungs and an exaggerated inflammatory process.

2. Role of primary genotoxic effects caused by PAH's

The proposed mechanism of tumor induction in rats is not primary genetic damage caused by the particle. Numerous mutagenicity assays with carbon black showed no inherent particle genotoxicity. All carbon blacks are insoluble in water, biological fluids, and organic solvents. Soot particles generally contain a high percentage of tarry material, with large amounts of adsorbed PAHs. In contrast, only trace amounts of organic compounds are adsorbed on carbon black (typically less than 1,000 ppm or 0.1%; Watson and Valberg, 2001). At these low levels, organic compounds are tightly bound to carbon black particles, and extensive solvent extraction procedures are needed to remove them. In a recent study, Borm and co-worker (2005) tested three carbon black particle exposure levels (1, 7, 50 mg/m^3) of Printex 90 and one concentration (50 mg/m^3) for Sterling V, as well as a sham exposure group specifically for PAH-DNA adduct-forming properties. F344 rats were exposed by inhalation for 13 weeks and then DNA was extracted from whole lung DNA immediately after exposure. The lungs of the rats for DNA analysis were not lavaged but the vascular system was perfused. DNA was extracted and used to determine oxidative DNA damage. To determine whether PAHs were available and subsequently transformed into DNA-binding metabolites, lungs of three animals from each exposure group were analysed for DNA adducts, immediately after exposure. No adducts were found in DNA from lung homogenates isolated immediately after 13 weeks of inhalation of up to 50 mg/m^3 of Printex 90 and Sterling V, which resulted in lung burdens of 4.9 mg and 7.6 mg, respectively. Lung DNA from rats following inhalation of carbon black showed no "spots" relating to PAH-DNA adduct formation compared to sham-exposed animals.

Donaldson and co-workers (1998) postulate in their review on particle-mediated lung injury, that there is no evidence to support carbon black particles having direct mutagenic activity; diesel exhaust, carbon black and titanium dioxide (TiO_2), caused similar levels of overload tumors (Heinrich *et al*., 1995), despite the fact that the extractable organic component was 40% for diesel exhaust, 0.04% for carbon black and 0% for TiO_2. The results of Gallagher *et al*. (1994) support the findings of Heinrich and co-workers, because no PAH-DNA adducts were detected in rats with overload carbon black tumors. Examinations of Bond and co-workers (1990) and Wolff and co-workers (1990) showed similar results. Donaldson and co-workers (1998) concluded that the particles themselves cause recruitment of inflammatory cells, which release respiratory burst-derived oxidants and that these oxygen free radicals could induce mutations in particle-exposed lung of rats. In summary, exposure to carbon balck in rodents does not cause primary genotoxicity, even in situations of lung overload.

3. Role of secondary genotoxic effects caused by Reactive Oxygen Species

The lack of association between the inherent genotoxic activity of PSPs and the development of rat lung tumors after chronic inhalation exposure implies a secondary mechanism for this response. At an international workshop organized by the German Research Council/DFG (Deutsche Forschungsgemeinschaft) on particle and fibre evaluation (Greim *et al.*, 2001), it was generally agreed that tumors in rat experiments are caused by a secondary, inflammatory/proliferative mechanism as opposed to direct genotoxicity. Lung overload leads to sustained inflammation, release of various biological mediators, and oxidative stress. In addition to carbon black, high exposure levels of titanium dioxide (250 mg/m³) (Lee *et al*., 1985) and talc (10 or 20 mg/m³) (Hobbs *et al*., 1994) cause lung tumors in rats. Thus, the lung tumor response to inhaled inert particles observed in female rats is not particle specific.

"Particle overload" is the key factor leading to the development of tumors in rats, and it appears that oxidative stress is the primary event / mechanism critical for tumor pathogenesis. The susceptibility of the rat may reside in the fact that rat lungs show a far greater induction of several key pro-inflammatory processes and less induction of anti-inflammatory processes than other species (Driscoll and Carter, 1999; Carter *et al*., 2006).

At and below carbon black concentrations of approximately 1 mg/m³ (respirable), it is highly unlikely that rats, other rodents, or humans are at risk for developing lung cancer (Oberdörster and Yu, 1997; Driscoll *et al*., 1995, 1996; ILSI [International Life Sciences Institute] Risk Science workshop, 2000). At the DFG workshop (Greim *et al.*, 2001), the consensus was that preventing lung inflammation will prevent the development of lung tumors.

Evidence for an effect threshold has been demonstrated in that sub-chronic inhalation of 1.1 mg/m³ respirable carbon black did not elicit inflammation or increases in *hprt* mutation frequency in epithelial cells (Driscoll *et al*., 1996). In rats, a lung-tumor threshold has also been demonstrated for diesel-exhaust exposure (Valberg and Crouch, 1999). More recently, sub-chronic inhalation of carbon black over a range of concentrations has confirmed the absence of inflammatory responses following repeated exposures to 1 mg/m^3 (Carter *et al.*, 2006; Elder *et al.*, 2005; Driscoll *et al.*, 2002). **Thus, 1 mg/m^3 of respirable-sized carbon black represents a clear NOAEL for even the most sensitive of inflammatory markers in the most sensitive of test organisms, the female rat.**

Conclusions - Animal Studies

At the DFG International Workshop Evaluation on Particle and Fibre Toxicity (Greim *et al.*, 2001) a consensus was reached regarding the tumorigenic properties of inert PSPs. The participants generally accepted that PSPs caused lung tumors in rats by a secondary genotoxic (inflammatory/proliferative) mechanism. The group concluded that *"studies to date have not demonstrated primary genotoxicity of carbon black with low PAH contamination using appropriate in vitro assays. DNA adducts related to associated organic compounds so far have not been found in lung tissue from rats exposed chronically to carbon black, although in the same studies adducts were found in diesel exhaust-exposed rats."*

Particle exposures that do not overwhelm host defense mechanisms (*e.g.,* DNA repair) and hence do not elicit inflammatory and/or proliferative responses, should not pose an increased risk of lung tumours in humans (Driscoll, 1996b; Driscoll *et al.,* 1996). In addition, using a meta-analysis approach, Valberg and Crouch (1999) demonstrated that the incidence of lung tumours was not elevated in rats with less than an average 0.6 mg/m^3 continuous lifetime exposure to diesel exhaust particles. Therefore, the use of linear models for dose-response extrapolation from "lung overload" conditions is not appropriate and should be replaced with non-linear models incorporating a threshold.

Driscoll *et al*. (1996) have demonstrated that sub-chronic inhalation of 1.1 mg/m³ (respirable) carbon black did not elicit any detectable adverse lung effects. The recent results from Oberdörster's and Driscoll's research groups (Carter *et al.*, 2006; Elder *et al.*, 2005; Driscoll *et al.*, 2002) support this finding, with a carbon black NOAEL of 1 mg/m³ (respirable).

Furthermore, participants at the ILSI workshop (2000) proposed that no uncertainty (safety) factor (for rat-to-human extrapolation) was required for neoplastic and fibrogenic endpoints associated with particle exposure, because the rat appears to be more sensitive in its responses to all particle-related effects than other species, including humans. The evaluation of carbon black by IARC (1996 and 2006) and Greim *et al.* (2001) as a suspect carcinogen is solely based on the observation that rats develop tumours under conditions of lung overload**.** The ILSI workshop (2000), which evaluated the relevance of the rat responses to particle overload for human risk assessment, concluded that at non-overload exposures, a lung-cancer hazard did not exist. A recent publication of Greim and Ziegler-Skylakakis (2007) on "Risk Assessment for Biopersistent Granular Particles" describes PSPs such as carbon black as substances for which genotoxic effects play no or at most a minor part. A threshold exists and provided this value is observed, no significant contribution to human cancer is expected.

Overall, to base human lung cancer risk predictions on the rat response after inhalation of PSPs, including carbon black, under conditions of lung overload, is therefore not considered a valid approach.

Several independent, scientific advisory groups have cautioned against using tumour data from rats exposed to high ("lung overload") concentrations of insoluble particles for quantitative risk assessment. In the United States, the Presidential / Congressional Commission on Risk Assessment and Risk Management (CRARM, 1997) noted that the responses of rat lungs to high concentrations of inhaled PSPs (specifically carbon black and titanium dioxide) are not likely to be predictive of human cancer risks. For diesel exhaust, the Clean Air Scientific Advisory Committee (CASAC, 1995 and 1998), a peer-review group for the U.S. Environmental Protection Agency (EPA), has commented on two drafts of the EPA´s Health Assessment Document on Diesel Exhaust. On both

occasions, CASAC emphasized that the data from lung-overloaded rats are not relevant for human risk assessment. Likewise, the Health Effects Institute (1995) also has concluded that rat data should not be used for assessing human lung-cancer risk from diesel-exhaust exposure.

B.4 Environmental Fate Properties

Carbon black is substantially elemental carbon. It has no functional groups that could bring about solubility in water and organic solvents. Its vapour pressure is negligible. It cannot be further degraded by hydrolysis, light or by photodegradation in air or in surface water. These physico-chemical properties are reason why important parameters like water solubility, octanol/water partition coefficient, dissociation constant or adsorption/desorption which are relevant for environmental fate and distribution cannot be analytically measured. Based on these properties it is expected that carbon black will not occur in air or water in relevant amounts. Also potential for distribution via water or air, respectively, can be dismissed. The deposition in soil or sediments is therefore the most relevant compartment of fate of carbon black in the environment. Carbon and its components are widely distributed in nature. The estimation is that carbon forms 0.032% of the Earth's crust. Free carbon is found in big reservoirs like hard coal, amorphous form of the element with other complex compounds of carbon-hydrogen-nitrogen. Pure crystalline carbon is found in the form of graphit and diamond. Carbon is an essential element in the components of all living organisms. The remains of live plants and animals form deposits of petroleum, asphalt and bitumen. The natural gas deposits contain compounds formed by carbon and hydrogen.

Industrial Carbon black emissions may occur from dryer vents, from the transport system vents, the cleanup system vent, and from cleaning, spills, and leaks (fugitive emissions). The German VDI (VDI, 1992) has presented an overview of the emissions that can be expected from furnace black plants. The emission concentrations based on the assumption that all of the generated tail-gas is combusted. Typical emission values from current furnace black and lamp black plants in Germany show a dust emissions between 0.2 to 0.4 kg/ton carbon black produced (10-30 mg/Nm^3), with typical benzo(a)pyrene and dibenzo(a, h)anthracene values below 0.002 mg/m^3 (max 0.1 mg/m^3). For gas black plants, a total dust emission value of 30 mg/m^3 is achievable, by means of filters. Typical benzo(a)pyrene and dibenzo(a, h)anthracene values are below 0.002 mg/m^3 (max 0.1 mg/m^3).

In the thermal process, carbon black is recovered in a bag filter between the two furnaces. The rest is recycled in the off-gas. Some adheres to surfaces of the checkerbrick where it is burned off in each firing cycle. Hence, carbon black emissions are negligible during normal manufacturing conditions.

Process water from the production process is generally emitted in the form of water vapour. Liquid water releases come from wash down streams unless the tail gases are dehumidified to increase the quality of the fuel gas.

The major source of carbon black emission to the environment from products will be as a component of tyre dust. Carbon black constitutes approximately 22% of the mass of a tyre, which equates to less than 30% of tyre dust (Hird et al., 2002). A tyre loses from 10% to 20% of its weight in use, with passenger car tyres showing a higher percentage loss than commercial vehicles. In the UK, where the average passenger car travelled approximately 20,000 km in 1998, an average abrasion of 172 kg of rubber per km of road is calculated, although rubber loss will be greater on motorways where the traffic volume is greater, and in breaking areas around junctions. Larger

particles fall onto the road surface and are washed into the drainage system during wet weather. Finer rubber particles are transported by aerial dispersion into the atmosphere (Hird et al., 2002; TRL Limited, 2002.)

Both shredded tyres (Park *et al*., 1996) and carbon black (Risby *et al*., 1988) have been shown to significantly adsorb organic pollutants associated with fuel exhaust, thus potentially improving the quality of highway run-off. Aqueous desorption of adsorbed organics of various polarities from carbon black has been shown to be negligible (except for one non-polar black whose surface contains weakly acidic active groups, which can desorb basic sorbents) (Risby *et al*., 1988). Thus leaching of relatively non-polar hydrocarbons such as PAHs from carbon black in tyre dust is not expected to occur in the environment.

B.4.1 Degradation

As an inorganic compound with the chemical structure "C", carbon black will not be biodegraded by microorganisms. The generally accepted guidelines for the examination of the biodegradability of substances (i.e., OECD- and EU-guidelines) can be used only for organic substances. A biodegradation study is scientifically unjustified.

In accordance with column 2 of REACH Annex VII, the ready biodegradability study (required in section 9.2.1.1.) does not need to be conducted as the substance is inorganic.

Photodegradation

Photodegradation is a process were light or light and reactive species such as oxygen- or hydroxylradicals lead to a degradation of a substance. Carbon black is inorganic and substantially, elemental carbon (C) it can not further be degraded and therefore it is not photodegradable in air, water or soil.

Stability in Water

Carbon black is substantially elemental carbon it is inert, inorganic and containes no water-soluble groups, e.g. alcohols, ethers, or acids and is therefore insoluble in water (Hawley, 1981; IARC, 1996; ITII, 1988). Carbon black is stable in water. It can not be measured analytically in water, the determination of the hydrolysis rate as fuction of pH is technically not feasible.

B.4.2 Environmental distribution

Based on the physical chemical properties (insolubility, no vapour pressure) it is expected that carbon black will not occur in air or water in relevant amounts. Also potential for distribution via water or air, respectively, can be dismissed. The deposition in soil or sediments is therefore the most relevant compartment of fate of carbon black in the environment. Carbon is widely distributed in nature and an essential element in the components of all living organisms.

B.4.3 Bioaccumulation

Based on the physical-chemical properties of carbon black as an inert solid, its insolubility and stability in water and in organic solvents, diffusion through the gills or through the membranes of the body of organisms and therefore bioaccumulation is not expected.

B.4.4 Secondary poisoning

Because of the inertness, low toxicity and no bioaccumulation potential and abundance of carbon in the nature, secondary poisoning is not to be expected.

5 Human Health Hazard Assessment

B.5 Toxikokinetics (absorption, metabolism, distribution and elimination)

Studies in Animals

Several groups have studied deposition and clearance of carbon black after inhalation and/or intratracheal instillation in several species. The majority of the studies have been performed with rats, as this is considered the most sensitive species with regard to the effects of carbon black in the respiratory tract.

In vivo Studies

As discussed in earlier sections, the smallest airborne particle of carbon black for the most commonly produced and encountered carbon blacks is the aggregate. This will have important

implications for particle penetration and depositon within the respiratory tract as well as for possible particle translocation. In the respiratory tract, carbon black particles (either free or in phagocytic cells) are cleared by the bronchial tree with some transepithelial passage of free particles to the interstitium. Some carbon is found in hilar lymph nodes but overall lymphatic clearance is low, and carbon black may also remain as a deposit of aggregates. It was shown that particle clearance is delayed at lung burdens equal or greater than 0.5 – 1 mg carbon black/g lung (Muhle *et al*., 1990; Strom *et al*., 1989). At this lung burden, the lung clearance of other particles may also be compromised (Bowden and Adamson, 1984; Lee *et al*., 1987; Muhle *et al*., 1990; Strom *et al*., 1989). Prolonged retention of carbon black particles in the lung was found in rats and mice exposed for 13 weeks to 7 and 50 mg/m^3, and in hamsters exposed for 13 weeks to 50 mg/m^3. These data show that hamsters have the most efficient clearance mechanism. Low-surface carbon black (50 mg/m^3) was more efficiently cleared from the lungs than was 50 mg/m^3 high-surface carbon black (Elder *et al*., 2005; Oberdörster, 2002).

Polycyclic hydrocarbons (PAHs), adsorbed on carbon black particles are retained for a longer period in the lung than the free PAHs (Sun et al., 1989; Wolff et al., 1989).

Only minimal amounts of carbon black were found in Peyer`s patches after oral exposure (LeFevre and Joel, 1986), indicating a low absorption of carbon black from the gastro-intestinal tract.

In vitro Studies

No elution of polycyclic hydrocarbons (PAHs) from furnace black or channel black was found after 180 hours of incubation with agitation at body temperature in gastric and intestinal fluid simulants, citric acid mixtures, or other body fluids and foodstuff media (Neal *et al*., 1962).

Studies in Humans

In vivo Studies

In a recent study, no evidence of a quantitatively important translocation of “ultrafine” (around 100 nm) carbonaceous particles from the lungs to the systemic circulation was found (Wiebert *et al*., 2006). Earlier reports on a rapid and substantial translocation of ultrafine particles may have been a consequence of technical shortcomings; according to the study authors, more research is however needed to establish whether a few per cent of translocated particles are sufficient to cause harmful effects (Wiebert *et al*., 2006).

Conclusion

Little carbon black is found in Peyer`s patches after oral exposure. It is unlikely that the insoluble particles are capable of skin penetration.

Uptake and retention of carbon black particles in lung macrophages have been observed following inhalation. In rats, clearance of carbon black particles from the respiratory tract is delayed at lung burdens equal or greater than 0.5 – 1.0 mg carbon black/g lung or 7 mg carbon black / m^3 (“lung overload”). Hamsters have more efficient clearance mechanism than rats or mice.

B.5.1 Acute Toxicity

Studies in Animals

Oral

There was no mortality nor were there any clinical signs of toxicity in rats by gavage with doses up to 10,000 mg/kg bw of different carbon blacks (Printex G, Printex 140, Spezialschwarz 4). The findings at necropsy were unremarkable (Degussa AG, 1977a and b; 1978a). In these studies, normally the group size is five males and five females per dose group (Limit test).

Inhalation

Nose-only inhalation exposure of Wistar rats to 4.6 mg carbon black/m³ for 4 hours produced no lung injury and no effects on blood pressure, body temperature or the activity of the animals. There were also no effects on the vasopressor and vasodilator compounds, endothelins and nitric oxide-related metabolites, respectively (Vincent et al., 2001).

Dermal

No specific study of the acute dermal toxicity has been performed. In accordance with column 2 of REACH Annex VIII, the study does not need to be conducted as the physicochemical and toxicological properties suggest no potential for a significant rate of absorption through the skin.

Other Routes of Exposure

Intratracheal

Carbon black (primary particle size 28 nm) showed a relatively low order of lung toxicity in a comparative study with fine particles from five different materials (quartz, hydrotalcite, potassium octatitanate, palladium oxide and carbon black) (Yokohira et al., 2007). The test materials were administered to groups of 14 male F344 rats by single intratracheal instillation at a dose of 4 mg/rat, suspended in 0.2 mL vehicle. Subgroups of 7 rats were sacrificed on days 1 and 28 after instillation and investigated by macroscopic and microscopic examination, including bromodeoxyuridine (BrdU) labelling indices, inducible nitric oxide (iNOS) levels, and matrix metalloproteinase-3 (MMP-3) levels. Lungs of rats sacrificed on days 1 and 28 and treated with carbon black or palladium oxide showed surface discoloration and were partially black on day 1. This change was found to be diminished on day 28. The bronchi, liver, adrenal glands, spleen, pulmonary lymph nodes, and kidneys demonstrated no remarkable macroscopic or histopathological changes. Main histopathological changes of lungs in rats treated with the test materials were neutrophil infiltration in the walls and spaces of the alveoli, pulmonary edema, pulmonary fibrosis, histiocyte infiltration in the alveoli, restructuring of alveolar walls and microgranulation. These effects were most marked in the group treated with quartz and mildest in the carbon black treated group. Cell proliferation was enhanced in all treated groups on day 1 as evidenced by BrdU labelling indices, but returned to normal values at day 28. MMP-3 and iNOS levels were not significantly altered in the carbon black treated group.

In rats, intratracheal instillation of 0.2 mL phosphate-buffered saline containing 50-125 µg carbon black particles (primary particle size, 200-250 nm) or “ultrafine” carbon black particles (primary particle size, 20 nm) produced an acute neutrophil influx into the airspaces, with accompanying

increased epithelial permeability. “Ultrafine” carbon black produced similar qualitative but greater quantitative proinflammatory effects as compared to carbon black and PM10 in the rat lung. The authors suggest that the effects may be due to a free radical activity of “ultrafine” particles (Li *et al*., 1997).

Conclusion

The acute oral toxicity of carbon black is very low; no clinical signs of toxicity were noted in rats treated by gavage with the maximum technically achievable dose (8,000-10,000 mg/kg bw). No dermal toxicity was detected. No cardiovascular or lung effects were found in rats exposed for 4 hours to 4.6 mg carbon black/m³. After intratracheal instillation, carbon black showed a relatively low order of lung toxicity in a comparative study with fine particles from five different materials (quartz, hydrotalcite, potassium octatitanate, palladium oxide and carbon black). “Ultrafine” carbon black produced similar qualitative but greater quantitative proinflammatory effects as compared to carbon black and PM10 in the rat lung.

B.5.2 Irritation

B.5.3 Skin

Studies in Animals

Carbon black (Farbruss FW 200; 100%, i.e., undiluted product) was tested for its irritant properties on the intact and scarified skin of three rabbits (Degussa AG, 1984b). The application was covered. After a 4-hours exposure to 0.5 g of the moistened test substance and during the 72 hours observation time, none of the animals exhibited any signs of skin irritation (no edema, no erythema at any of the observations).

Similarly, no signs of irritation were noted in rabbits treated with 0.5 ml of Printex G (27% in olive oil), Printex G (20% in distilled water), or Special Black 4 (20% in water) under occlusive conditions for 4 hours (both intact and scarified skin) (Degussa AG, 1977c,d; 1978b).

B.5.4 Eye

Studies in Animals

Different carbon blacks (Printex 140, Printex G and Spezialschwarz 4) were investigated in the Draize test for their eye irritancy (Degussa AG 1977e,f; 1978c). 100 mg undiluted test substance was instilled. No vehicle was used. No irritant effects were found with any of the three substances in any of the animals at any observation (scores for cornea, iris and conjunctivae: 0.0, 0.0, and 0.0).

Studies in Humans

As superficial foreign bodies, carbon black particles may be slightly irritating mechanically and may cause discoloration of lids and conjunctivae, but they are chemically inert (Grant, 1986).

B.5.5 Respiratory tract

In a non-validated mouse allergic airway sensitisation model mice were intranasally exposed to ovalbumin alone or in combination with carbon black particles. Carbon black particles were suspended in phosphate-buffered saline (PBS) at a concentration of 3.3 mg/mL, and sonicated for 2 hours. The induction of airway inflammation and the immune response were studied in the lungs and lung-draining peribronchial lymph nodes at day 8. Ovalbumin specific antibodies were measured at day 21, and the development of allergic airway inflammation was studied after ovalbumin challenge at day 28. Instillation of a total of 200 µg of "ultrafine" (primary particle below 30 nm in diameter) but not fine (primary particle over 200 nm in diameter) carbon black particles caused airway inflammation as evidenced by inflammatory parameters detected in bronchoalveolar lavage fluid and by histological analysis of the airways (de Haar et al. 2006).

Conclusion

Carbon black is not irritating to the skin and eyes of rabbits in tests performed similarly to current guidelines. As superficial foreign bodies, carbon black particles may be slightly irritating mechanically and may cause discoloration of lids and conjunctivae in humans.

B.5.6 Corrosivity

Carbon black has no corrosive properties.

B.5.7 Sensitisation

B.5.8 Skin

The potential of carbon black XPB 295 to induce and elicit delayed hypersensitivity was tested in guinea pigs using the Buehler method (Degussa, 2003b). A group of 20 test animals was induced by topical application of a 50% aqueous suspension of the test material once a week for three weeks, and challenged two weeks later with the same test concentration. Application sites showed dark coloration, but none of the treated animals had a sensitisation reaction. A "reliability check" was performed in parallel to the aforementioned study in a group of animals with alpha-cinnamic aldehyde. 60% of this group showed a sensitisation reaction, and the test system was therefore considered to be valid. In humans, no cases of allergies have been reported to the responsible occupational physicians within the carbon black producing industry (ICBA, 2005)

B.5.9 Respiratory system

In a non-validated mouse allergic airway sensitisation model mice were intranasally exposed to ovalbumin alone or in combination with carbon black particles. The induction of airway inflammation and the immune response were studied in the lungs and lung-draining peribronchial lymph nodes at day 8. Ovalbumin specific antibodies were measured at day 21, and the development of allergic airway inflammation was studied after ovalbumin challenge at day 28.

"Ultrafine" (primary particle below 30 nm in diameter) but not fine (primary particle over 200 nm in diameter) carbon black particles were shown to induce airway inflammation and displayed adjuvant activity (de Haar et al. 2006).

In humans, no cases of allergies have been reported to the responsible occupational physicians within the carbon black producing industry (ICBA, 2005).

Conclusion

Carbon black XPB 295 was not a skin sensitiser in guinea pigs (Buehler test performed according to OECD guideline 406). In humans, no cases of skin or respiratory allergies have been reported.

B.5.10 Repeated dose toxicity

Studies in Animals

Inhalation

Non-malignant respiratory effects of carbon black have been studied in various species, mostly using a single dose level causing clear pulmonary effects. The majority of these studies are therefore of no use for establishing an exposure-response relationships.

Particle retention kinetics, inflammation, and histopathology were examined in female rats, mice, and hamsters exposed for 13 weeks to high surface area carbon black (Printex 90, HSCb, primary particle size 17 nm, MMAD 1.2 - 2.4 µm) at doses of 0, 1, 7, and 50 mg/m^3. Rats were also exposed to 50 mg/m^3 low surface area carbon black (Sterling V, LSCb, MMAD 0.6 - 0.9 µm). Groups of animals were sacrificed immediately after 13 weeks of exposure, and after 3 and 11 months of recovery for bronchoalveolar lavage analysis, as well as for measurements of lung burdens and lung histopathology (Elder *et al*., 2005; Oberdörster, 2002). Prolonged retention was found in rats exposed to mid- and high-dose HSCb and to LSCb, but LSCb was cleared faster than HSCb. Retention was also prolonged in mice exposed to mid- and high-dose HSCb, and in hamsters exposed to high-dose HSCb. Lung inflammation and histopathology were more severe and prolonged in rats than in mice and hamsters, and both were similar in rats exposed to mid-dose HSCb and LSCb. The results show that hamsters have the most efficient clearance mechanisms and least severe responses of the three species tested. The results from rats also show that particle surface area is an important determinant of target tissue dose and, therefore, effects. From these results, a subchronic NOAEL of 1 mg/m^3 respirable HSCb can be assigned to female rats, mice, and hamsters.

A thorough subchronic inhalation study was performed by Driscoll *et al*. (1996) in male Fischer 344 rats using respirable carbon black. Groups of male rats were exposed to 0, 1.1, 7.1 or 52.8 mg/m^3 Monarch 880 (furnace black) for 13 weeks (6 hr/d, 5 d/week). The primary particle size was 16 nm, with a MMAD of 0.88 µm, and a specific surface area of 220 m^2/g. Groups of animals were sacrificed immediately after 13 weeks of exposure, and after 3 and 8 months of recovery for bronchoalveolar lavage analysis, as well as for measurements of lung burdens and lung histopathology. No pathological or biochemical changes were found in the lungs at 1.1 mg/m^3 (NOAEL), but there were clear dose-related increases in both biochemical and cellular markers of lung damage at the mid- and high exposure levels. By 8 months, there was substantial clearance of the carbon black retained in the lungs in the low exposure group, moderate clearance in the mid-

exposure group and very little clearance in the high exposure group. Histopathology revealed particle-containing macrophages located in the alveolar and alveolar duct regions of the lungs of rats exposed to 1.1 mg/m^3. In contrast, in rats exposed to 7.1 mg/m^3 there was evidence of inflammation characterised by accumulation of neutrophils and macrophages within the alveolar spaces. There was also evidence for focal and random areas of mild epithelial hyperplasia and mild interstitial fibrosis. Exposure to 52.8 mg/m^3 showed more pronounced epithelial hyperplasia and fibrosis. Fibrosis was greatest after the 8 month recovery period.

Severe lung damage (including lung tumours) was seen in Fischer 344 rats of both sexes exposed for 2 years to 2.5 and 6.5 mg/m^3 (16 hrs/day, 5 days/week) (see section on carcinogenicity for full details). The lung weights of all exposure groups increased in an almost linear manner throughout the exposure period. Exposure-related lesions consisted of alveolar macrophage hyperplasia, alveolar epithelial hyperplasia, chronic-active inflammation, septal fibrosis, alveolar proteinosis, bronchiolar alveolar metaplasia, focal fibrosis with alveolar epithelial hyperplasia, squamous metaplasia and squamous cysts (Nikula *et al*., 1995).

It should be noted, however, that in other studies female rats have been shown as more sensitive than the males to the pulmonary effects of carbon black.

Dermal

In an older study with limited documentation, Nau *et al*. (1958b) found no changes in organs or tissues in C3H male mice treated three times per week with various types of carbon blacks (20% carbon black suspensions in cottonseed oil, mineral oil or in 1% aqueous carboxymethylcellulose, painted onto the animals' backs) for 41 weeks.

Oral

In an early carcinogenicity study conducted by Nau *et al*. (1958a), no changes were observed in organs or tissues in mice fed with various types of carbon blacks for 12 to 18 months. Mice were fed either with 10% whole CB in the diet or with diets containing a 48 hour Soxhlet extract (mixed with diet and dried). Similarly, Pence and Buddingh (1985) found no effects in rats and mice that received carbon black in their diets (2.05 g/kg diet) for two years.

Studies in Humans

Inhalation

There are several occupational studies available in which the non-malignant respiratory effects of carbon black have been investigated.

A large multi-centre European study was performed by Gardiner *et al.* (1993) with a follow-up consisting of two separate phases (Gardiner *et al* 2001). Phase I of the study covered the period 1987-1989, phase 2 the period 1991-1992, and phase 3 the period 1994-1995. The final analysis for Phase 1 was based on 1742 employees from 15 plants (81% response rate); for phases 2 and 3 the final analyses were based on 2324 workers (19 plants), and 1994 workers (16 plants), with an overall response rate of greater than 90%. Results from phases 2 and 3 had higher worker participation rates; increased exposure measurements and greater precision due to new job titles and exposure categories; and were therefore considered more reliable than the phase 1 data.

Results of the first phase of the study by Gardiner indicated an overall good respiratory health of the study population with a low prevalence of pneumoconiotic change (0.3%) without progression in subsequent follow-up. Mean prevalences of respiratory symptoms were considered by the authors to be generally low and typical of industrial populations. No significant impairment in lung function was found. However, statistical analyses revealed a trend of increasing prevalence of respiratory symptoms and a decline in lung function scores that related to recent (not cumulative) exposure to respirable carbon black. There was no relation between these health outcomes and the inhalable dust exposures.

In phases 2 and 3, exposures dropped considerably as compared to phase 1; the arithmetic means for exposures to inhalable dust across all plants were 0.77 mg/m^3 (range 0.07-7.41), and 0.57 mg/m^3 (range 0.11 - 3.26) in phases 2 and 3 respectively. The mean prevalences of respiratory symptoms were reported to be lower in phase 3 compared with phase 2, both being lower than for phase 1. Logistic regression analysis showed a relationship between symptoms and cumulative smoking; weaker, but statistically significant relations were found for some symptoms with carbon black exposures (chronic bronchitis, sputum production in phase 2, cough and cough with sputum production in phases 2 and 3). Methodological limitations in the administration of the questionnaire however limit the conclusions that can be drawn about the reported symptoms.

Spirometry results revealed a good standard of respiratory function. However, there were statistically significant relationships between current and cumulative exposures and declines in forced expiratory volume in 1 second (FEV_1) and other parameters, pointing to obstructive effects. The findings were consistent and similar across phases 2 and 3. However, the effect was clinically insignificant.

The authors estimated that based on the cumulative exposure measures for inhalable carbon black in phase 3, the expected decrements after 40 years employment with a mean (8-hr TWA) exposure of 1 mg/m^3 would be 48 ml (95% CI 1-91ml) for FEV_1.

These predictions suggest that after 40 years exposure to 1 mg/m^3 (8-hr TWA) there would be no effects of carbon black exposure on forced vital capacity (FVC), slight effects on FEV_1, and negligible effects on the FEV_1/FVC ratio.

Using multiple regression analyses of the data from the US study, Harber *et al*. (2003a) found a consistent relationship between cumulative carbon black exposure and small reductions in FEV_1, but not with other spirometry parameters. The estimated slopes were minus 2 ml FEV_1 per mg-year/m^3 of cumulative "total" dust exposure and minus 0.7 ml FEV_1 per mg-year/m^3 of cumulative exposure for the inhalable fraction. In addition, heavy cumulative exposures were associated with a small increase in chronic bronchitis in non-smokers. The modelling of the data indicated that for non-smoking males, exposure to inhalable carbon black for a working lifetime (40 years) at 1, 2 and 3.5 mg/m^3 (8hr TWA) would lead to mean decreases in FEV_1 of 48, 91 and 169 ml, respectively (beyond the decreases caused by age; for comparison, the average age-related decline in FEV_1 in adult males is about 30 ml per year). Recent exposures, typically much lower than historical exposures, were not demonstrated to be associated with these effects.

Table 6 of Harber *et al*. 2003a described elevated prevalences of symptoms (chronic bronchitis) in the highest exposure pentile which is comparable to an exposure to inhalable dust of 138 mg*years/m^3 or to an average concentration over 40 years of exposure at (138 mg*years/m^3)/(40 years) = 3.5 mg/m^3. A no observed adverse effect level (NOAEL) may be derived from the same

table because up to the third pentile of cumulative exposure, no excess risk can be detected. This approach is conservative because the authors applied no age adjustment. Applying Table 6 of Harber *et al*. 2003a the NOAEL can be estimated at (3/5) *3.5 mg/m^3 = 2 mg/m^3 (inhalable).

Results from a cross-sectional study on carbon black production workers performed by Kuepper *et al*. (1994, 1996a,b) provided no clear evidence for an effect of carbon black on lung function. Exposure measurements revealed that the mean levels of respirable and total inhalable dust were 0.58 and 1.08 mg/m^3, respectively. However, no information on respiratory symptoms was provided.

Conclusion

In rats, after repeated inhalation of a furnace carbon black for 13 weeks, no pathological or biochemical changes were found in the lungs at 1.1 mg/m^3 (NOAEL), but there were clear dose related increases in both biochemical and cellular markers of inflammation and lung damage at the next higher concentration of 7.1 mg/m^3. By 8 months post-exposure there was substantial clearance of the carbon black retained in the lungs of animals exposed to 1.1 mg/m^3, moderate clearance in the mid-exposure group (7.1 mg/m^3) and very little at 52.8 mg/m^3. Lung damage (including lung tumours) was seen in rats of both sexes exposed for 2 years to 2.5 mg/m^3 (16 hrs/day, 5 days/week).

In exposed carbon black production workers, repeated inhalation exposure to carbon black can cause non-clinical decrements in pulmonary function, increases in respiratory symptoms, and, possibly chest film changes. Based on data from a large European multi-centre study covering 19 plants in 7 countries (UK, 2 plants; France, 3 plants; Germany, 5 plants; Holland, 2 plants; Italy, 3 plants; Spain, 3 plants; and Sweden, 1 plant), predictions suggest that after 40 years exposure to 1.0 mg/m^3 (inhalable fraction, 8-hr TWA) there would be minimal effects on lung function parameters. It has been estimated that exposure to a working lifetime of 40 years to inhalable carbon black at 1, 2 and 3.5 mg/m^3 (8-hour TWA) would lead to mean decreases in FEV_1 of 48, 91 and 169 ml, respectively. This may be compared to the average age-related FEV_1 in adult males of about 1,200 ml over this 40-year period. This equates to an additional 4% loss in FEV_1 when exposed to 1 mg/m^3 over 40 years. A study of production workers in North America covering 22 plants (Canada, 2 plants; United States, 20 plants) yielded comparable respiratory function results for 1 mg/m^3 40-year working –life exposures (FEV_1, 28 ml decrease).

Applying Table 6 of Harber *et al*. 2003a about the prevalence of chronic bronchitis a NOAEL can be estimated at 2 mg/m^3 (inhalable).

B.5.11 Mutagenicity

Carbon black has been tested *in vitro* for gene mutations in bacteria (Ames test), for gene mutations in mammalian cells (mouse lymphoma test, HPRT test), and for sister chromatid exchanges in Chinese Hamster Ovary cells. *In vivo* studies with carbon black include tests for mutations in the *HPRT* gene, mutations in the p-53 gene, oxidative damage to DNA, DNA adducts and for chromosomal aberrations.

In accordance with column 2 of REACH Annex VIII, the *in vitro* cytogenicity study in mammalian cells or the *in vitro* micronucleus study (required in section 8.4.2.) does not need to be conducted as adequate data from an *in vivo* cytogenicity test are available.

In vitro Studies

In the Ames test, carbon black (Printex 90) did not induce an increase in mutation frequency in any of the tester strains both with and without metabolic activation (increases in mutation frequencies were always below a factor of 2 as compared to the controls). The positive controls were functional. Cytotoxicity was observed in TA100 and WP2uvrA (without S-9) at suspension concentrations equal or greater than 2,500 µg/ml (Degussa AG, 1998a).

The toluene extract from furnace black (Printex 70, Printex 90) did not induce an increase in mutation frequency in any of the tester strains both with and without metabolic activation (increases in mutation frequencies were always below a factor of 2 as compared to the controls). The positive controls were functional (Degussa AG, 1997; 1998b).

The mutagenic activities of carbon black solvent-extracts varied widely, and both negative and positive Ames test results are reported in the literature. A mutagenic activity was generally ascribed to mutagenic polycyclic hydrocarbon compounds that were present as impurities in the carbon black (Agurell and Loefroth, 1983; Agurell and Loefroth, 1993). Extracts of selected xerographic toners and photocopies from the 1980s were also found to be mutagenic in the *Salmonella* assay. The activity was traced to nitropyrenes present as impurities in the carbon black toner colorant (Loefroth *et al*., 1980; Xerox Corp., 1980).

A rubber grade furnace black (N-339, surface area 100m²/g; DMSO suspension) was tested negative in the Ames test, in the Mouse Lymphoma Assay (performed according to current standards) and it did not induce sister chromatid exchanges in Chinese Hamster Ovary cells. The substance did also not cause morphological transformation in C3H/10T1/2 mouse embryo cells (Kirwin *et al*., 1981).

The potential contribution of lung inflammatory cells to the mutagenic responses was evaluated by co-culturing bronchoalveolar (BAL) cells with the rat alveolar epithelial cell line, RLE-6TN for 24 hours and the RLE-6TN cells selected for 6TG resistance. *In vitro* exposure of RLE-6TN cells to BAL cells from rats treated with 100 mg/kg bw carbon black increased hypoxanthine-guanine phosphoribosyl transferase (*hprt*) mutant frequency. Both macrophage and neutrophil enriched BAL cell populations were mutagenic to RLE-6TN cells, however, the mutagenic activity appeared greatest for neutrophils. Addition of catalase to BAL cell-RLE-6TN co-cultures inhibited the increase in *hprt* mutation frequency. The inhibition of BAL cell-induced mutations by catalase implies a role for cell-derived oxidants in this response (Driscoll *et al*., 1997). This implies that the mutational events are induced by a secondary mechanism.

In vivo Studies

There are significant differences between diesel exhaust particles (DE) and carbon black in their physicochemical characteristics, such as number/size distribution, mass concentration, particle composition and, most importantly, PAH content (Kuhlbusch *et al*. 2004, Watson and Valberg 2001). Both DE and carbon black are pulmonary carcinogens in the rat. There is reasonable epidemiological evidence for a carcinogenic effect in man for diesel exhaust but not for carbon black. Two mechanisms have been suggested: a genotoxic effect of organic compounds associated with the diesel particle, and an epigenetic effect resulting from large accumulations of particles that produce chronic inflammation and epithelial proliferation in the lung. To gain insights into the possible roles of these two mechanisms, inflammatory responses and DNA adducts in lungs were compared in numerous studies (Bond *et al*. 1989, Gallagher *et al*. 1994, Mauderly *et al*. 1988 and 1989; Wolff *et al*. 1990) of rats exposed to DE (app. 33% extractable organic compounds) and carbon black (<0.04% extractable organic compounds), which are also carbonaceous particles, but with virtually no organic compounds. Both DE and carbon black exposures caused similar inflammation in the lung. However, the level of DNA adducts were increased by exposure to DE, but there was only little or no increase of adducts detected in animals exposed to carbon black. Bond and co-worker (1989) showed that at 3.5 mg/m³ respirable, only DE and not carbon black was found to increase DNA adducts. Gallagher and co-worker (1994) showed adducts possibly resulting from exposure to nitro-PAHs in DE-exposed rats but not in rats exposed to carbon black. In a more recent study, Borm and co-worker (2005) tested three carbon black particle exposure levels (1, 7, 50 mg/m^3) of Printex 90 and one concentration (50 mg/m^3) for Sterling V, as well as a sham exposure group specifically for PAH-DNA adduct forming properties. F344 rats were exposed by inhalation for 13 weeks and then DNA was extracted from whole lung DNA immediately after exposure. The lungs of the rats for DNA analysis were not lavaged but the vascular system was perfused. DNA was extracted and used to determine oxidative DNA damage. To determine whether PAHs were available and subsequently transformed into DNA-binding metabolites, lungs of three animals from each exposure group were analysed for DNA adducts, immediately after exposure. No adducts were found in DNA from lung homogenates isolated immediately after 13 weeks of inhalation of up to 50 mg/m^3 of Printex 90 and Sterling V, which resulted in lung burdens of 4.9 mg and 7.6 mg, respectively. Lung DNA from rats following inhalation of carbon black showed no spots relating to PAH-DNA adduct formation compared to sham-exposed animals.

To examine the role of oxidative stress, Gallagher *et al*. (2003) analysed the formation of a known mutagenic lesion, 8-oxo-dG, in the lung DNA of rats following subchronic inhalation of 1, 7 and 50 mg/m³ of Printex 90 (high surface carbon black, 300m²/g) and to 50 mg/m³ Sterling V (low surface carbon black, 37 m²/g). The exposure concentration of Sterling V was selected to be equivalent in terms of retained mass in the lung to the high dose Printex 90 at the end of exposure. However, in terms of retained particle surface area, the retained lung dose of Sterling V was equivalent to the mid-dose of Printex 90. This design allows comparison of results on the basis of retained particle mass as well as retained particle surface area between the two carbon black particles. Increase was observed predominantly at 50 mg/m³ Printex 90. Interestingly, no increase in 8-oxo-dG was observed for Sterling V. Since both Sterling V (50 mg/m³) and Printex 90 (7 mg/m³) did not induce significant increases in 8-oxo-dG in the lung at the end of the 13-week exposure, this finding indicates that a retained large particle mass is not always correlated with similar adverse effects but that particle surface area is a better dose parameter. These findings suggest that prolonged high dose exposure to carbon black can promote oxidative DNA damage that is consistent with the

hypothesis that inflammatory cell-derived oxidants most likely play a predominant role in the pathogenesis of rat lung tumors following long-term, high-dose exposure to carbon black in rats.

A significant increase in *hprt* mutation frequency in rat alveolar epithelial cells was detected immediately after 13 weeks of exposure to 7.1 and 52.8 mg/m^3 carbon black as well as after 3- and 8-month recovery periods for the groups exposed to 52.8 mg/m^3. Exposure to 52.8 mg/m^3 carbon black resulted in *hprt* mutation frequencies which were 4.3-, 3.2-, and 2.7-fold greater than the air control group, immediately and after 3 and 8 months after exposure, respectively. A significant increase in the frequency of *hprt* mutations was detected immediately after 13 weeks of exposure to 7.1 mg/m^3 carbon black but not after 3 or 8 months of recovery. No increase in *hprt* mutation frequency was observed for epithelial cells obtained from rats exposed to 1.1 mg/m^3 carbon black. Lung tissue injury and inflammation, increased chemokine expression, epithelial hyperplasia, and pulmonary fibrosis were observed after exposure to 7.1 and 52.8 mg/m^3, with the effects being more pronounced at the higher exposure level (Driscoll *et al*., 1996).

In another study by the same authors (Driscoll *et al*., 1997), the *hprt* mutation frequency was determined in alveolar type II epithelial cells isolated from rat lungs 15 months after intratracheal instillation of saline or saline suspensions of 10 and 100 mg/kg bw carbon black, alpha-quartz or titanium dioxide. *Hprt* mutation frequency was increased in alveolar type II cells from rats exposed to 10 and 100 mg/kg bw of alpha-quartz, 100 mg/kg bw carbon black and 100 mg/kg bw titanium dioxide. Neutrophilic inflammation was detected in all rats exposed to 10 and 100 mg/kg bw of alpha-quartz, and 100 mg/kg bw carbon black. The mutations in the *hprt* gene in alveolar epithelial cells occurred only after carbon black exposures which resulted in significant inflammation and epithelial hyperplasia. This supports the hypothesis that inflammatory cell-derived oxidants and increased cell proliferation play a role in the pathogenesis of rat lung tumours in response to carbon black.

In a study comparing inflammatory responses and *ex vivo hprt* mutation frequencies in rat, mice and hamster after subchronic inhalation of carbon black (1, 7 or 50 mg/m^3), rats demonstrated greater propensity for generating a proinflammatory response and *hprt* mutations, whereas mice and hamsters demonstrated an increased antiinflammatory response. No effects on hprt mutation frequencies were found at a dose level of 1 mg/m^3, indicating a secondary indirect genotoxic response at levels at which chronic inflammation exists (Carter *et al*., 2006).

Only very low levels of either K-ras or p53 genes were mutated, and there were no significant differences between the yields of mutants recovered from diesel exhaust, carbon black, or sham-exposed rats (Swafford *et al*., 1995). Only four carbon black-induced squamous cell carcinomas were analysed for p53 gene mutations in this study, and the 18 lung tumours analysed for K-ras gene mutation all came from a single carbon black-exposed rat. These small sample sizes limit the reliability of the reported results. It is further noted, that in rat lungs - unlike the situation in human and mice lungs - the induction of p53 and/or K-ras mutations is generally very low (Rosenkranz, 1996).

No point mutations or chromosomal aberrations were detected in various *Drosophila melanogaster* stocks fed with 1% of oil furnace carbon black (Kirwin *et al*., 1981).

Conclusion

In vitro, carbon blacks were non-mutagenic in various Ames tests, whilst organic extracts exhibited a wide variety of activity, depending on the conditions of extraction. This activity is ascribed to

genotoxic impurities (mainly polycyclic aromatic compounds) present in carbon black materials. Carbon black was tested negative in a mouse lymphoma assay, and did not induce sister chromatid exchanges in Chinese Hamster Ovary cells.

In vivo, exposure of rats to doses of particles producing significant inflammation was associated with increased mutation in the hypoxanthine-guanine phosphoribosyl transferase gene (*hprt*) in alveolar type II epithelial cells isolated from rat lungs. Addition of catalase inhibited the increase in mutation frequency implying a role for cell-derived oxidants in this reaction.

Recent studies have shown that repeated exposure to carbon black in rats does not cause the formation of PAH-DNA adducts. This is consistent with collateral studies that demonstrated that PAHs were not bioavailable from carbon black in simulated lung fluid *in vitro*.

In summary it may be concluded that the available evidence strongly suggests that carbon black is not directly mutagenic. Mutations are caused by secondary mechanisms such as oxidative stress; for these effects, triggered by inflammatory processes, there is a threshold which has been show to be above 1 mg /m^3 respirable for high-surface carbon black (e.g., Printex). The threshold for low-surface carbon blacks is above this value (Gallagher *et al*. 2003).

B.5.12 Carcinogenicity

In vivo Studies

Carbon Black has been tested in a large number of animal studies using all relevant exposure routes. Carbon black has either been tested as such or as solvent extracted carbon black, i.e. carbon black for which adsorbed organic matter has been removed by solvent extraction. In some studies, also the materials extracted from carbon black were tested.

In the case of poorly soluble particles, such as carbon black, studies using subcutaneous, intramuscular and intraperitoneal injections are of limited value for the assessment of the carcinogenic potential because of the inflammation that is produced at the injection sites by the particles. These studies will therefore not be discussed in the following sections.

Inhalation

Carcinogenic effects from long-term carbon black inhalation have been evaluated in two studies in rats and in one study in mice.

In the study by Nikula *et al*. (1995), both male and female rats developed benign and malignant lung tumours, but with higher rates in females than in males. Increases in lung tumours were observed even at the lowest test concentration (2.5 mg/m^3).

Heinrich *et al*. (1994) and Heinrich *et al*. (1995) used only female rats in their studies; however the studies were judged to meet acceptable scientific standards. In both studies, there were clear increases in benign and malignant lung tumours in the exposed animals. Exposure concentrations for carbon black were 7.4 mg/m³ for 4 months followed by 12.2 mg/m³ for 20 months and in the other study 6.1 mg/m³ for 10 months in one group and for 20 month in the second group.

No differences in lung tumour incidence between control and exposed mice were found in the study by Heinrich *et al*. (1995), in which female mice were exposed by inhalation to 7.5 mg/m^3 for 4

months, followed by 12 mg/m^3 for 19 months for 18 hours/day, 5 days/week for 13.5 months, followed by an exposure free period of 9.5 months to carbon black (Printex 90). The animals showed reductions in body weight and a 5-fold increase in wet lung weight compared to controls.

In all of the above studies, the carbon blacks tested were of high purity with an average level of extractable organic matter of only 0.04 and 0.12%. With a view of elucidating the role of adsorbed organic matter, mainly polycyclic aromatic hydrocarbons (PAHs) in tumour development, the results of the experiments with carbon black were compared with those of experiments run in parallel with diesel exhaust. Diesel exhaust particles are similar in structure to carbon black, but the percentage of organic extractable matter is considerably higher as compared to carbon black.

In the study by Nikula *et al*. (1995), the same exposure concentrations of diesel exhaust (extractable organic matter 8.2%) were tested as for carbon black (0; 2.5 and 6.5 mg/m^3). The lung burden of particulate matter was lower for carbon black than for diesel exhaust. The type and onset of non-neoplastic lung lesions and the lung tumour response were similar in diesel exhaust and carbon black exposed animals. Hence, the amount of adsorbed organic matter did not appear to correlate with the lung tumour response.

Rats were exposed to very similar concentrations of diesel exhaust, titanium dioxide and carbon black in the study by Heinrich *et al*. (1995). The exposure regimens were intended to attain similar lung burdens of particulate for each group. After adjustment for survival rates, carbon black seemed to induce a higher incidence of lung tumours as compared to diesel exhaust and titanium dioxide. Most of the tumours were benign squamous cysts, but a high incidence of adenocarcinoma was also found in all groups.

In neither of the two studies described above there was any evidence that long-term exposure to diesel exhaust or carbon black induced novel DNA adducts in the rat lungs (see section on genotoxicity). This is supporting the view that any adsorbed mutagenic polycyclic hydrocarbons did not have a significant biological effect in the induction of lung tumours in rats.

Table 4: Lung tumour incidences in long-term inhalation studies

Carbon Black	Species / Duration	Concentration (mg/m^3)	Percent of Animals with Lung Tumours	Comments	Reference and reliability score
Elftex-12 Furnace black MMAD 1.95 µm (67%) MMAD 0.10 µm (33%) SA43 m^2/g EO 0.12%	Rat F344 (males and females) 24 months (16 hrs/d; 5d/wk)	0 (clean air control) 2.5 6.5	6.5 mg/m^3: Male 3.8%; Female 26.7%	Excludes squamous cysts	Nikula *et al*., 1995; Mauderly, 1994 (Reliability 1)
			2.5 mg/m^3: Male 1.9%; Female 7.5%	Excludes squamous cysts	
			0 (controls): Male 2.8%; Female 0%	Excludes squamous cysts	
Printex 90 Furnace black PS 14 nm MMAD 1.1 µm SA 230 m2/g EO 0.04%	Rat Wistar (females) 10-30 months (17 hrs/d; 5d/wk)	0 (clean air control) 6.0 (10 months) 6.0 (20 months)	6.0 mg/m^3 (20 months): 8%	Including "benign cystic keratinizing squamous tumours"	Heinrich *et al*., 1994 (Reliability 2 – valid with restrictions)
			6.0 mg/m^3 (10 months): 17%	Including "benign cystic keratinizing squamous tumours"	
			0 mg/m^3: not given		
Printex 90 Furnace black PS 14 nm MMAD 0.64 µm SA 227 m2/g EO 0.04%	Rat Wistar (females) 24 months (18 hrs/d; 5d/wk)	0 (clean air control) 7.5 (for 4 months) followed by 12 mg/m^3 for 20 months	12/7.5 mg/m^3: 39%	All animals killed at 30 months; including "benign cystic keratinizing squamous tumours"	Heinrich *et al*., 1995 (Reliability 2 – valid with restrictions)
			0 mg/m^3: 0.5 %	All animals killed at 30 months; including "benign cystic keratinizing squamous tumours"	
Printex 90 Furnace black PS 14 nm MMAD 0.64 µm SA 227 m2/g EO 0.04%	Mice/NMRI (females) 23 months (18 hrs/d; 5d/wk)	0 (clean air control) 7.4 (for 4 months), followed by 12.2 mg/m^3 for 9 months and an exposure free period of 9.5 months	7.4/12.2 mg/m^3: 20%	All animals killed at 23 months. Adenomas and adenosarcomas	Heinrich *et al*., 1995 (Reliability 2 – valid with restrictions)
			0 mg/m^3: 30%	All animals killed at 23 months. Adenomas and adenosarcomas	

EO = extractable organic matter; MMAD = mean mass aerodynamic diameter; SA = surface area; PS = primary particle size

Gallagher *et al*. (2003) showed that prolonged high dose exposure to carbon black can promote oxidative DNA damage that is consistent with the hypothesis that inflammatory cell-derived oxidants may play a role in the pathogenesis of rat lung tumors following long-term high-dose exposure to high surface area carbon black in rats. Based on the available data it is likely that the lung tumours in rats develop as a result of impairment of particle clearance rates at high lung burdens ("overload"), leading to sustained inflammation (oxidative stress), hyperplasia, metaplasia and tumour formation (IARC, 1996). The relevance of carbon-black induced lung tumours in rats to human health is uncertain, and it appears that the rat is the most sensitive species to the effects of lung overload (ILSI, 2000).

Intratracheal

In the first of two lifetime intratracheal studies with carbon black (Pott and Roller, 1994; Pott *et al*., 1994) a marked increase in benign and malignant lung tumours was seen in female rats treated once a week for 15 weeks with 3 mg/rat of carbon black (Printex 90).

Two types of solvent extracted carbon blacks (furnace black Printex 90, surface area 270 m^2/g and lamp black 101, surface area 22 m^2/g) were used in the second study by Heinrich *et al*. (1994). Female animals were dosed once a week with 1 mg/rat. In the Printex 90 group there was a clear increase in benign and malignant lung tumours, whilst in the lampblack group, benign lesions (cystic keratinizing squamous cell tumours) were seen in 4 of the 48 rats (Heinrich et al., 1994; Rittinghausen *et al*., 1997).

Dermal

None of the 240 mice that received for 9 months twice weekly 6-60% of seven different carbon blacks, suspended in acetone, developed any skin tumour; and pure carbon black rubbed twice weekly on the skin of 72 Swiss mice for 24 months produced also no skin tumours. Mice treated in parallel with 3,4-benzpyrene showed clearly increased tumour incidences (von Haam *et al*., 1958). Lifetime skin painting studies with 16 different carbon black products and with extracted carbon blacks showed also no evidence for the induction of skin cancer. In contrast, some of the carbon black extracts produced a high incidence of skin tumours. The value of the latter study is however limited because of the use of 1% benzene as a vehicle (Nau *et al*., 1976).

Oral

In an early study (with limited documentation) to evaluate the effect of carbon blacks on carcinogenic compounds (von Haam *et al*., 1958) three carbon blacks (Micornex, Philblack O, and Kosmsos 60; 27-29 µm primary particle size) were fed either alone (18, 12 and 9% in the diet, respectively) or in combination with p-dimethylaminoazobenzene (0.06%) to groups of 24 Harlan rats for 15 months. At the end of the study all animals were sacrificed and a complete autopsy was performed on each animal. All organs including the central nervous system were examined histologically. The animals ate without difficulty food containing the three carbon blacks. None of the animals treated with carbon black have shown any evidence of neoplasm. However, 58% of the animals treated with the azo-dye showed tumours, whilst only one single hepatoma appeared 10.25 months after the beginning of the experiment in one animal fed the azo dye adsorbed to Philblack O. According to the study authors these results demonstrated a nearly perfect inhibitory effect of adsorption on the carcinogenicity of the azo dye.

No significant gross or microscopic changes from the normal were found in any of the organs or tissues of mice (10-50/group) fed 16 different whole or extracted carbon blacks of various types (oil furnace, gas furnace, furnace, channel, channel special, thermal combustion) in water or oil based mixtures for 12-18 months (Nau *et al*., 1958). Further experiments by the same authors showed that carbon black could absorb methylcholanthrene effectively and thereby make it ineffective as a carcinogen.

Carbon black (furnace black, ASTM N-375) did not increase tumour incidences in female Sprague-Dawley rats and female CF1-mice exposed for two years through the diet to 2050 mg carbon black/kg diet (Pence and Buddingh, 1985). The study is limited by small group sizes (28-31 animals) and incomplete histopathological examinations. In parallel, Pence and Buddingh (1985) additionally injected 44 rats and 30 mice intraperitoneally with 1,2-dimethylhydrazine at the start of the study and found that carbon black did not enhance the incidence of colonic tumours induced by 1,2-dimethylhydrazine.

Human Carcinogenicity Data

In relation to lung cancer, various earlier cohort and case-control studies in the US did not show any increases in lung cancer risk in carbon black production workers, but the cases of lung cancer were identified from insurance claims, which is considered to be an unreliable means of identification (Robertson and Ingalls, 1980; Robertson *et al*., 1988; Robertson and Ingalls, 1989; Robertson, 1996; Robertson and Inman, 1996).

In a more recent and well-conducted study that followed mortality of 5,011 workers employed 1 year or more since the 1930s at 18 US carbon black facilities through December 31, 2003, no excess was observed from lung cancer (standard mortality ratio [SMR] = 0.97, 95% CI = 0.82–1.15) or from nonmalignant respiratory diseases (SMR = 0.99, 95% CI = 0.83–1.18). No trends were seen with duration of employment or time since hire for any cause of death (Dell *et al*., 2006).

A UK cohort mortality study of workers exposed to carbon black found an excess of lung cancer in some, but not all factories included in the study; there was no association between duration of carbon black exposure and lung cancer mortality, nor were possible confounders such as smoking or past occupational histories taken into account (Hodgson and Jones, 1985). An update of the UK study found a significantly elevated SMR for lung cancer (SMR 173, Observed 61) but no significant trends of lung cancer risks increasing with estimated cumulative exposure to carbon black was found (Sorahan *et al*., 2001). In a further follow-up, the mortality of the UK cohort of 1,147 male manual workers from five UK factories manufacturing carbon black was investigated for the period 1951–2004. All subjects were first employed in the period 1947–74 and were employed for 12 months or more. Limited work histories were available to calculate estimates of individual cumulative exposure to carbon black. Based on serial rates for the general population of England and Wales, significantly elevated mortality was observed for lung cancer (Observed 67, SMR 146, $P<0.01$) but not for all other causes combined (Observed 426, SMR 106). There was highly elevated lung cancer mortality at two of the plants (SMR 230, Observed 35) but no excess mortality at the other three plants combined (SMR 104, Observed 32). Analyses by period since leaving employment indicated elevated lung cancer risks were limited to those workers with some employment in the most recent 15 years. SMR analyses found an overall positive significant trend between lung cancer risks and cumulative carbon black exposure received in the most recent 15 years. The findings suggest that carbon black, or chemicals associated with the production of

carbon black, had an effect on later stages of lung cancer carcinogenesis at two of the five plants but that no such effect was found at the other three plants (Sorahan and Harrington, 2007).

The mortality from lung cancer in a cohort of 1,535 German carbon black workers employed at a carbon black manufacturing plant for at least one year between 1960 and 1998 was increased using national rates as reference (observed 50, standardized mortality ration [SMR] 218, 95% CI 161-287). Comparisons to regional rates gave SMRs of 120 (95% CI 107-133) and 183 (95% CI 136-241). No dose response relationship was found between lung cancer mortality and several indicators of occupational exposure, including years of employment and carbon black exposure. The lung cancer SMR could not fully be explained by selection, smoking or other occupational risk factors. The results, however, provide also little evidence for an effect of carbon black exposure according to the study authors (Wellmann *et al*., 2006). Further analysis of this cohort with Cox regression models showed no evidence that carbon black was a lung carcinogen (Morfeld *et al*., 2006a), and a nested case-control study found also no positive association of carbon black exposure with lung cancer mortality (Buechte *et al*., 2006). After the application of adjustment factors for previous exposures and smoking, the lung cancer SMR in this cohort was no longer significantly elevated (Morfeld *et al*., 2006b).

The relationship between workplace exposure to carbon black and lung cancer risk was examined in a population-based case-control study carried out in Montreal, Canada by Parent *et al*. (1996). Detailed job histories were elicited from 857 incident cases with histologically confirmed lung cancer as well as from 1,360 cancer controls and 633 population controls. Job histories were evaluated by a team of hygienists and chemists for evidence of exposure to a host of occupational substances, including carbon black. Logistic regression analyses adjusting for smoking and other non-occupational and occupational potential confounders suggested no significant increase in risk with relatively low exposure to carbon black. Some increase in risk for all lung cancers was apparent with relatively high exposure using cancer controls (OR = 2.17; 95%CI = 0.95 - 4.91) and population controls (OR = 1.52; 95% CI = 0.58 - 3.97). Individuals with relatively high exposure had a significantly greater risk of oat-cell carcinoma using either control series (OR = 5.05; 96% CI = 1.72- 14.87 using cancer controls and OR = 4.82; 95% CI = 1.36 - 17.02 using population controls). According to the study authors, these results provide some evidence for an association between exposure to carbon black and lung cancer. As a limitation of this study it is noted, that no exposure measurements were available and that exposure estimates were performed by retrospective expert assessment.

Increased relative risks of lung and stomach cancer observed in a cohort of rubber workers seemed to be confounded by exposure to asbestos and talc. The small number of observed deaths precluded firm conclusions with regard to laryngeal cancer (Straif *et al*., 2000).

A number of cases of skin cancer were identified in carbon black production workers in the US, whilst in a UK cohort of carbon black workers no excesses of skin cancer were found. Also, a study in the rubber and tyre manufacturing industry did not reveal an increased risk of squamous cell skin cancer in workers exposed to carbon black contaminated materials (IARC, 1996).

No excess mortality was observed from bladder cancer (SMR = 0.93, 95% CI = 0.47–1.87) in a study that followed mortality of 5011 workers employed 1 year or more since the 1930s at 18 US carbon black facilities through December 31, 2003 (Dell *et al*., 2006). An excess of bladder cancer in dockworkers with a history of previous exposure to carbon black has been identified by Puntoni *et al*. (2001a,b). However, there was no information on other possible exposures in this workforce,

and shipyard workers in the same harbour (but not exposed to carbon black did also show an excess of bladder cancer of broadly similar magnitude to that observed in the dockyard workers, suggesting the possibility of some common causal factor which could not have been carbon black.
In the UK cohort mortality study in carbon black production workers (Hodgson and Jones, 1985; Sorahan *et al*., 2001), there were six bladder cancer deaths observed versus 3.5 expected (SMR 173; 95% CI 64-377). The small excess of bladder cancer was not statistically significant.

Studies in the carbon black user industries, such as the rubber, paint and printing industries generally are difficult to interpret because of the mixed exposures to other substances. In only two studies exposure to carbon black was explicitly determined. In the first study (Blair *et al*., 1990), which was designed to evaluate the cancer risks associated with formaldehyde, a non-stastically significant increased risk of lung cancer in workers exposed to carbon black was reported, based on 20 observed cases (SMR 1.3; 95% CI 0.8-2.0). Because of the lack of information relating to carbon black and formaldehyde exposure levels and to the smoking status, the relevance of this finding remains unclear. In the second study, a nested case-control study in the tyre and rubber manufacturing industry, no relationship between exposure to carbon black and an increased risk of squamous cell skin cancer was found (Bourguet *et al*., 1987).

Recently, IARC classified Carbon Black in Group 2B ("The agent is possibly carcinogenic to humans") (IARC, 2006).

Conclusion

Animal carcinogenicity studies demonstrated that carbon black of respirable size could produce lung tumours in rats of both sexes, but not in mice or hamsters. Increases in the incidence of benign and malignant lung tumours were seen at the lowest concentration tested (2.5 mg/m^3, 16 hrs/day, 2 years). The lung tumours occurred under conditions that resulted in impaired lung clearance ("overload"). There is also evidence that inflammation and cell proliferation may have contributed to the development of rat lung tumours.

Skin painting studies in mice using a variety of commercial carbon blacks did not induce signs of skin cancer development. Limited lifetime oral studies showed no evidence of carcinogenicity in rats and mice.

Earlier studies of the carcinogenic potential of carbon black in workers generally suffered from limitations, and are considered not to reveal clear evidence for a causal role of carbon black in the development of human cancers.

In relation to lung cancer, various cohort and case-control studies in the US did not show any increases in lung cancer risk in carbon black production workers. A recently well-conducted large cohort study in US carbon black-production workers that does not suffer from some of the limitaions in earlier studies found no increase in lung cancer, or cancer at any other site.

Cohort mortality studies of carbon black-production workers in the UK found an excess of lung cancer in some, but not all factories included in the study, and there was no association between duration of carbon black exposure and lung cancer mortality, nor were possible confounders such as smoking or past occupational histories taken into account.

A number of cases of skin cancer were identified in carbon black production workers in the US, whilst in a UK cohort of carbon black workers no excesses of skin cancer were found. Also, a study

in the rubber and tyre manufacturing industry did not reveal an increased risk of squamous cell skin cancer in workers exposed to carbon black contaminated materials.

An excess number of bladder cancer cases were recently reported in dock workers with a history of manually unloading shipments of carbon black. As there is no information on potential confounding factors such as other chemical exposures in this workforce, and shipyard workers at the same harbour but not exposed to carbon black also showed an increase in bladder cancer, a role for carbon black in bladder cancer is unlikely.

Based on the available data demonstrating a low bioavailability, the polycyclic aromatic hydrocarbons (PAHs) contained in carbon black are generally considered not to play a role in lung cancer of laboratory rats. Gallagher and co-worker (2003) showed that prolonged high-dose exposure to high surface carbon black can promote oxidative DNA damage that is consistent with the hypothesis that inflammatory cell-derived oxidants play a major role in the pathogenesis of rat lung tumors. Gene mutation events appeared greatest in neutrophils - this cell type plays a major role in inflammation processes - detected by in vitro studies (Driscoll *et al*., 1997).

The lung cancers in rats are considered by many researchers to be the result of a non-genotoxic mechanism secondary to cellular toxicity brought about by lung overloading, inflammation, and oxidative stress. The relevance of carbon black induced lung tumours in rats to human health is uncertain, and it appears that the rat is the most sensitive species to the effects of lung overload. At present the potential of such inhaled particles to induce lung tumours in humans cannot be completely ruled out on theoretical grounds, although the most reliable epidemiological evidence does not suggest such a causal link. In fact, IARC, in its most recent assessment of carbon black considered the evidence in humans for the carcinogenicity of carbon black to be *inadequate* and recommended a classification in *Group2B*, based on rat inhalation studies (Baan *et al*, 2006; IARC, 2006).

B.5.13 Toxicity for reproduction

B.5.14 Effects on fertility

Carbon black has not been tested in a study for its effect on fertility and reproduction. Based on the available toxicokinetic data and on information from repeat dose and developmental toxicity studies (the latter with diesel exhaust consisting of similarly sized carbonaceous particles with a higher content of organic extractable matter), it is very unlikely that carbon black particles will reach the reproductive organs under *in vivo* conditions.

In the respiratory tract, carbon black particles (either free or in phagocytic cells) are cleared by the bronchial tree with some transepithelial passage of free particles to the interstitium. Some carbon is found in hilar lymph nodes but overall lymphatic clearance is low, and carbon black may also remain as a deposit of aggregates. Only minimal amounts of carbon black were found in Peyer`s patches after oral exposure (LeFevre and Joel, 1986). It is unlikely that the insoluble particles are capable of skin penetration.

The available data suggest therefore that carbon black is unlikely to pose a reproductive hazard.

B.5.15 Developmental toxicity

Carbon black has not been tested in guideline studies for its effects on the developing organism. Based on the available toxicokinetic data and based on information from repeat dose and developmental toxicity studies (the latter with diesel exhaust that consists of similarly sized carbonaceous particles with a higher content of organic extractable matter), it is very unlikely that carbon black particles will reach the embryo and/or fetus under *in vivo* conditions. No adverse effects on the development are therefore expected.

Two valid studies conducted by Werchowski *et al*. (1980) showed that diesel exhaust (10% in clean air) did not affect the normal development of Sprague-Dawley rat and New Zealand white rabbit fetuses when administered by the inhalation route to the dams during the gestational days 6 through 15 (rat) or 6 through 18 (rabbit). In both studies there were no malformations or other teratogenic effects in the unborn fetuses. The occurrence of gross abnormalities in the exposed and control groups were within normal limits. The number of live and dead fetuses, number of resorptions, number of implantation sites and corpora lutea were not altered compared with controls. The test substance did not appear to affect the individual and average fetal weights and group fetal weight. Also, the diesel exhaust did not cause any maternal toxicity in either study.

Conclusion

Carbon black *per se* has not been tested in guideline studies for its effects on fertility, reproduction and the developing organism. Based on the available toxicokinetic data and based on information from repeat dose and developmental toxicity studies (the latter with diesel exhaust that consists of similarly sized carbonaceous particles with a higher content of organic extractable matter), it seems highly unlikely that carbon black particles will reach the reproductive organs, the embryo or the foetus under *in vivo* conditions. Therefore no adverse effects on reproduction and development would be anticipated.

B.5.16 Other effects

None identified.

B.5.17 Derivation of DNEL(s)

The REACH Regulation requests that “Derived No Effect Levels” (DNELs) are established for substances, reflecting the likely route(s), duration and frequency of exposure that result from the identified uses.

The main use of carbon black (about 90%) is in rubber applications (tyres and other rubber products), the remainder is used mainly in pigments for inks and surface coatings (see section B2.2). In these applications carbon black is tightly bound within a matrix with no intended release. Users of rubber, ink and paint products are therefore not exposed to carbon black *per se*. Hence, exposure of consumers is unlikely to occur and will not be considered in the derivation of DNELs.

Occupational exposure may occur during production and processing with the respiratory route being the most likely route of exposure. Work-life exposure to carbon black in carbon black

manufacturing and processing plants is therefore a relevant exposure scenario and will be the focus of the DNEL derivation.

As no acute toxicity hazard (leading to classification and labelling) has been identified, a DNEL for acute exposure is not derived.

Based on occupational surveillance and toxicological data, the leading health effect, i.e., the effect that results in the most critical DNEL, is the effect of carbon black on the respiratory system after repeated exposures. An elevated prevalence of chronic bronchitis in the highest exposure pentile was shown in long-term human studies, which is comparable to an exposure to inhalable dust of 138 mg*years/m^3 or to an average concentration over 40 years of exposure at (138 mg*years/m^3)/(40 years) = 3.5 mg/m^3.

From an extensive database of animal data it is evident that the rat is the most sensitive species for carbon black inhalation toxicity, with mice and hamsters being much less susceptible. This database also shows a no-effect-level of 1.0 mg/m^3 (respirable) in this species; the LOEL is at 7.0 mg/m^3 (histopathologic changes in the lung; markers of inflammation in broncho-alveolar lavage fluid).

Critical health effect: respiratory effects

A) Human health surveillance data

The available data suggest that the critical human health effect of carbon black is upon the airways. Various cohort and case-control studies did not show an increase in lung cancer risk in carbon black production workers. Cohort mortality studies of workers exposed to carbon black in the UK found an excess of lung cancer in some, but not all factories included in the study, but there was no association between duration of carbon black exposure and lung cancer mortality, nor were possible confounders such as smoking or past occupational histories taken into account. Overall, there is inadequate evidence in humans for the carcinogenicity of carbon black. This view is consistent with the most recent IARC evaluation of carbon black (IARC, 2006).

Large multi-centre studies in Europe by Gardiner *et al*. (1993, 2001) and in the US by Harber *et al*. (2003) demonstrate that long-term heavy occupational carbon black exposure is associated with reductions in the forced expiratory volume in 1 second (FEV_1). The data indicate that there would be minimal, non-adverse effects on lung function parameters after 40 years of exposure to 1.0 mg/m^3 (inhalable fraction, 8-hr TWA). A working lifetime of 40 years to inhalable carbon black at 1 mg/m^3 (8-hour TWA) would lead to mean a decrease in FEV_1 of 48 mL based on the European study. The comparable study in US carbon black-production workers gave a decrease in FEV_1 of 28 mL for this exposure and duration scenario. These may be compared to the average age-related FEV_1 loss in adult males of about 1,200 ml over this same 40-year period.

These studies also demonstrated that carbon black exposure is NOT associated with significant consistent reductions in the forced vital capacity.

Longitudinal follow-up from 1987-1995 of the multi-plant European cohort (van Tongeren *et al*. 2002) and long-term follow-up of persons with minor radiographic abnormalities over 25 years in

one US plant do not show progression to advanced pneumoconiosis. The paucity of high profusion radiographic findings, the absence of progression to extensive radiographic abnormality, and the absence of restrictive physiologic abnormalities show that carbon black does not lead to a fibrotic pneumoconiosis.

Harber *et al*. (2003a) describe elevated prevalences of symptoms (chronic bronchitis) in the highest exposure pentile, which is comparable to an exposure to inhalable dust of 138 mg*years/m^3 or to an average concentration over 40 years of exposure at (138 mg*years/m3)/(40 years) = 3.5 mg/ m^3. A no observed adverse effect level may be derived from the same table because up to the third pentile of cumulative exposure no excess risk can be detected. This approach is conservative because the authors applied no age adjustment. Applying Table 6 of Harber et al. (2003a) the NOEL can be estimated at (3/5) *3.5 mg/ m^3 = 2 mg/m^3 (inhalable), which corresponds to a **DNEL in humans of 2 mg/m^3 (inhalable dust fraction)**.

B) Animal studies

Based on **animal studies** with rat as the most sensitive species (see section B5.6), a DNEL can be derived based on a No-Observed-Adverse-Effect-Concentration (NOAEC) in rats after inhalation (6h/d, 5d/w) of 1.0 mg/m^3 (respirable dust fraction):

This NOAEC needs to be corrected for the differences in respiratory volume between rat and humans, and for the different daily exposure time (6 hours in animal studies vs. 8 hours in working shift):

corrected inhalatory NOAEC = inhalatory NOAEC rat x (standard respiratory volume in humans/worker respiratory volume) x (6 h / 8 h) =
1.0 mg/m^3 x (6.7 m^3 / 10 m3) x 0.75 = 0.67 x 0.75 mg/m^3 = 0.5 mg/m^3, respirable dust fraction.

As it has been shown that the rat is the most sensitive species, no default uncertainty factor (assessment factor) of 2.5 is required to account for quantitative differences in deposition, airflow patterns, clearance rates and protective mechanisms between humans and animals (ILSI, 2000). The DNEL in animals is therefore at **0.5 mg/m^3 (respirable dust fraction)**.

C) Conversion factors for particle-size metrics

US studies showed a conversion factor of about three between **inhalable** and **total** dust in the carbon black-production industry (Kerr *et al.*, 2002).

Using European data a factor of about three was also derived for the conversion of **respirable to inhalable** dust. The reasons for this difference in estimates from the US and the European carbon black-production industry are not known. Nevertheless, the derived NOEL(C)s of 0.5 mg/m^3 **respirable** (based on animal studies) and 2 mg/m^3 **inhalable** (based on human data) appear to be compatible taken the uncertainties about the conversion factor between both dust fractions into account.

B.6 Human Health Hazard Assessment of Physicochemical Properties

B.6.1 Explosivity

Carbon black is elemental carbon, in accordance with column 2 of REACH Annex VII, the study explosive properties (required in section 7.11) does not to be conducted if there are no chemical groups assosiated with explosive properties present in the molecule or the substance containes chemical groups associated with explosive properties which include oxygen and the calculated oxygen balance is less than -200.

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 (> 1 kJ) and in sufficient concentration can be made explosive. The dust explosion class by this method is ST1 (Degussa AG, 1981, 1984a, 1990, 1993; Degussa-Hüls, 1994, 1998; Going, 1998)

B.6.2 Flammability

The ignition temperature is > 600 °C. Carbon blacks will burn slowly (smolder) at > 400 °C and sustain combustion that may not be visible in the powder or pellet form. The burning process may be so slow as to not be obvious (no visible flames or smoke) unless stirred and sparks are apparent. Direct water spray or stream may spread the fire due to the burning powder floating on the water (Degussa AG, 1990; ICBA, 1999)

B.6.3 Oxidising potential

Carbon black has no oxidising potential. In accordance with column 2 of REACH Annex VII, the oxidising properties (required in section 7.13) of the substance do not need to be determined as the substance is an inorganic substance not containing oxygen or halogen atoms**.**

B.7 Environmental Hazard Assessment

B.7.1 Aquatic compartment (including sediment)

As carbon black is insoluble in water, modifications are required to the standard ecotoxicity test procedures. These have taken two forms. In one, suspensions of carbon black are maintained through stirring or aeration while the test is carried out. These tests may be influenced by the lowering of solution pH caused by some types of carbon blacks, or by the physical presence of the particles themselves. In the other modification, carbon blacks at various concentrations are equilibrated with water at or just above ambient temperatures, typically for 24 hours or less. The suspensions are then filtered, and the filtrates used in the standard tests. The lowering of solution pH due to some carbon blacks may also influence these tests. This second type of test has the potential to demonstrate the ecotoxicity of aqueous extracts of carbon black, and of any water-removable adsorbates.

Both shredded tyres (Park *et al*. (1996), and carbon black (Risby *et al*., 1988) have been shown to significantly adsorb organic pollutants associated with fuel exhaust, thus potentially improving the quality of highway run-off. Also, a lining of tyre chips has been recommended for landfills, to help prevent leaching of organic pollutants to groundwaters (Park *et al*., 1996). Aqueous desorption of adsorbed organics of various polarities from carbon black has been shown to be negligible (except for one non-polar black whose surface contains weakly acidic active groups, which can desorb basic sorbents) (Risby *et al*., 1988). Also, two field trials of the effect on water quality of tyre chip fills placed above the groundwater table showed no evidence that tyre chips increased the level of substances that have a primary drinking water standard. The two sets of samples tested for organics gave results below the method detection limit for all compounds (Basel Convention, 1999). Thus leaching of relatively non-polar hydrocarbons such as PAHs from carbon black in tyre dust is not expected to occur in the environment.

<u>Acute toxicity to fish</u>

Exact acute toxicity values could not be achieved because the chemical is insoluble in water and organic solvents. However, other data are available for five channel and gas blacks, with results for Special Black 4 and Printex U (48 hour test only) available for both suspensions and filtrates. The results for Corax N220, Printex 400, and Printex G are available from suspensions only. The more recent tests have been carried out to GLP with Zebra fish (*Brachydanio rerio*), while the older tests used *Leuciscus idus melanotus*. The older tests, for Special Black 4, Printex G, Printex U, and Printex 400 fully support the findings of the recent, GLP tests for Special Black 4 and Corax N220.

The two *Brachydanio rerio* studies with Special Black 4 are carried out to the highest standard. In the test with aqueous suspensions, 1000 mg/L and 10,000 mg/L suspensions were prevented from settling by gentle aeration for the 96-hour duration of the test. Total mortality observed in one of the 10,000 mg/L suspensions is attributed to asphyxiation, possibly influenced by the rate of particle streaming. No mortality was observed in the filtrate from the 10 000 mg/L suspension.

Apart from the *Brachydanio rerio* study with the 10,000 mg/L Special Black 4 suspension, no mortality was observed in any of the studies listed in table 5. The 14-day tests with Printex G, Printex U, Printex 400, and Special black 4 suspensions are older tests, but the results indicate that all four carbon blacks cause no mortality to *Leuciscus idus melanotus* at 5000 mg/L.

Although an LC_{50} for fish cannot be determined from the tests above, the results show that there is no mortality observed for suspensions of four different carbon blacks at 5000 mg/L. The LC_{50} would therefore be higher than 5000 mg/L. As the mortality observed with Special Black 4 at 10,000 mg/L is attributed to physical factors involving the stirring of the test vessels, it is likely that an LC_{50} of greater than 10,000 mg/L would be obtained if it were physically possible to carry out a relevant test. In addition, the filtrate tests establish that no acutely toxic material is extracted from carbon black at 10,000 mg/L, by water at room temperature.

Furthermore, 24-hour fish (*Brachydanio rerio*) studies have been reported for filtered extractions of tyre dust obtained from several European tyre companies. The tyre dust contains less than 30% carbon black. The tests, as per ISO 7346-1, using filtrate from 100g of material in one litre of water, shaken for 24 hours before filtering, gave an LC_{50} of >58,000mg/L (Basel Convention, 1999). The reported results with tyre dust support the carbon black filtrate test results for fish.

In summary, LC_{50} values of > 5000 mg/L for aqueous suspensions of carbon black, and of > 10,000 mg/L for water accommodated filtrates should be used for fish.

Table 5 - Summary of valid acute fish test results for carbon blacks

Carbon Black	Suspension (S) or filtrate (F)	Fish species	Test duration	LC_0 mg/L	Reference
Special Black 4	S aeration	*Brachydanio rerio*	96 hours	1,000	Degussa AG, 1992a
Special Black 4	F	*Brachydanio rerio*	96 hours	10,000	Degussa AG, 1992a
Corax N220	S	*Brachydanio rerio*	96 hours	1,000	Degussa AG, 1991
Special Black 4	S aeration	*Leuciscus idus melanotus*	96 hours	1,000	Degussa AG, 1979d
Printex 400	S	*Leuciscus idus melanotus*	96 hours	1,000	Degussa AG, 1979a
Printex G	S	*Leuciscus idus melanotus*	96 hours	1,000	Degussa AG, 1979b
Printex U	F	*Leuciscus idus melanotus*	48 hours	8,000	Degussa AG, 1979c
Printex G; Printex U; Printex 400; Special Black 4	S Slow aeration	*Leuciscus idus melanotus*	14 days	5,000	Degussa AG, 1978d

Acute toxicity to aqueous invertebrates

Exact acute toxicity values could not be achieved because the chemical is insoluble in water and organic solvents. One report is available concerning the ecotoxicity of the carbon black Spezialschwarz 4 to *Daphnia magna* (Degussa AG, 1992b). This gas black is insoluble in water, and gives an acidic pH in aqueous suspension. As a preliminary range-finding study showed that the *Daphnia magna* were possibly physically hampered by particles, and as the presence of particulate matter is not recommended in the OECD TG 202 for *Daphnia* tests, the final test was carried out on a water accommodated filtrate. However, the pH of the filtrate was acidic after accommodation with the higher carbon black concentrations. At a carbon black concentration of 10,000 mg/L, the pH was lower than the lower limit of pH 6 recommended in OECD TG 202, and effects were noted on both mobility and condition. The 24 hour EC_{50} (mobility) was between 5600 mg/L and 10,000 mg/L. The condition of the *Daphnia* at 5600 mg/L was visually impaired, leading to a reported 24 hour NOEC, based on condition, of 3200 mg/L.

Although a test time of 48 hours is now recommended for acute *Daphnia* tests, this would have no effect on the pH of the solutions, which is suggested to be the main cause of toxicity. Thus the study shows that an aqueous invertebrate EC_{50} of greater than 5600 mg/L, or a NOEC of 3200 mg/L, applies for the carbon black solids used to prepare water accommodated filtrates.

In addition, 24 hour *Daphnia* tests have been reported for filtered extractions of tyre dust obtained from several European tyre companies. The tyre dust contains less than 30% carbon black. The tests, as per ISO 6341, using filtrate from 100g of material in one litre of water, shaken for 24h before filtering, gave an EC_{50} of >69 000mg/L (Basel Convention, 1999). The reported results with tyre dust support the carbon black filtrate test results for *Daphnia*.

Acute and Chronic toxicity to algae

Exact toxicity values could not be achieved because the chemical is insoluble in water and organic solvents. One algal test has been carried out, with the carbon black (furnace black) Printex 30 (Degussa-Hüls AG, 1999). No toxic effects were seen in any of the test solutions, which were filtrates of Printex 30 suspensions. The highest concentration tested was the filtrate from a 10,000 mg/L suspension, which had been accommodated for 24 hours at room temperature, on a shaking machine. Thus the study shows that an algal EC_{50} for the water accommodated filtrate of carbon black is greater than 10,000 mg/L.

In addition, 24 hour algal (*S. Capricornutum*) tests have been reported for filtered extractions of tyre dust obtained from several European tyre companies. The tyre dust contains less than 30% carbon black. The tests, as per ISO 8692, using filtrate from 100g of material in one litre of water, shaken for 24h before filtering, gave an EC_{50} of >13,000mg/L (Basel Convention, 1999). The reported results with tyre dust support the carbon black filtrate test results for algae.

Conclusion

Since carbon black is not soluble in water, it is not possible to carry out many standard ecotoxicity tests for this substance. Its low toxicity, requiring high concentrations to be tested in order that toxicity might be detected, and the low pH of some aqueous suspensions makes the testing protocol

even more difficult. Nevertheless, results with fish tests have established that a fish LC_{50} will be greater than 5000 mg/L for aqueous suspensions, and greater than 10,000 mg/L for water accommodated filtrates. The *Daphnia* results from water accommodated filtrates indicate an EC_{50} of 5600 mg/L (original suspension concentration), which is attributed to the pH of the solution. The algal test results, also from water accommodated filtrates, show no adverse effect at the highest concentration tested, at an original suspension concentration of 10,000 mg/L. The dehydrogenase activity of sewage treatment organisms has an EC_{10} of approximately 800 mg/L of suspended carbon black particles.

If the fish, *Daphnia*, and algal results were used to calculate a PNEC, an application factor of 1000 would be required. If this were applied to the fish LC_{50} of >5000 mg/L, then a PNEC of >5 mg/L would result. However, the fish and invertebrate LC_{50} and EC_{50} data are dominated by physical and pH considerations, and treatment of these results by methodology appropriate to a chemical toxicity mechanism may not be appropriate.

Chronic Toxicity Test Results

No information available.

In accordance with column 2 of REACH Annex IX, a long-term study does not need to be conducted as the chemical safety assessment according to Annex I does not indicate a need to investigate further the effect on aquatic organisms.

Sediment Compartment

In accordance with column 2 of REACH Annex X, toxicity testing on sediment organisms (requested in section 9.5.1) does not need to be conducted as the chemical safety assessment according to Annex I does not indicate a need to investigate further the effect on sediment organisms

B.7.2 Terrestrial compartment

Earthworm tests have been reported for filtered extractions of tyre dust obtained from several European tyre companies. The tyre dust contains less than 30% carbon black. The tests in which 100g of material in one litre of water is shaken for 24h and then filtered showed no toxicity (Basel Convention, 1999). This supports the expected low toxicity of carbon black to terrestrial organisms.

In accordance with column 2 of REACH Annex X, long-term toxicity testing on terrestrial organisms (requested in section 9.4.) does not need to be conducted as the chemical safety assessment according to Annex I does not indicate a need to investigate further the effect on terrestrial organisms.

B.7.3 Atmospheric compartment

Based on the physico-chemical properties it is expected that unbound carbon black will not occur in air in relevant amounts.

B.7.4 Microbiological activity in sewage treatment systems

Toxicity to Micro-organisms

Three reports are available for the effects of carbon black upon the dehydrogenase activity of sewage treatment plant organisms (activated sludge). In suspensions of up to 800 mg/L, Printex 400 (Degussa AG, 1979a) and Printex G (Degussa AG, 1979b) showed no decrease in dehydrogenase activity. In Special Black 4 suspensions, a small decrease in dehydrogenase activity was observed in both 600 mg/L and 800 mg/L suspensions, with an estimated EC_{10} of approximately 800 mg/L (Degussa AG, 1979d). Although the concentrations tested were not high enough to establish an EC_{50} for the effect of carbon black on the dehydrogenase activity of sewage treatment organisms, the existing data indicate that an EC_{50} will be greater than 800 mg/L.

It was not possible to carry out a valid test for sludge respiration, as the particulate nature of the carbon black interfered with the test (Degussa AG, 1978d).

Carbon black is not expected to interfere with the operation of sewage treatment plants. Although it was not possible to carry out a sludge respiration study, due to the particulate nature of carbon black, the dehydrogenase activity of sewage treatment organisms has been tested, with an EC_{10} of approximately 800 mg/L of suspended carbon black particles.

B.8 PBT and vPvB assessment

As an inrorganic compound with the chemical structure “C”, carbon black will not biodegraded by microorganisms. Carbon contains no water-soluble groups, e.g. alcohols, ethers, esters, or acids and is therefore insoluble in water. As substantially elemental carbon it can not further be degraded by hydrolysis or photodegradation.

Based on the physical-chemical properties of carbon black as an inert solid, its insolubility and stability in water and in organic solvents, and its particular character and forming of aggregates and agglomerates, the substance will not cross biological membranes. Bioaccumulation is not expected to occur. Furthermore, carbon is widely distributed in nature and an essential element in the components of all living organisms.

Carbon black is not classified as CMR and there is no other evidence of chronic toxicity.

Carbon black does therefore not fulfil the criteria given in Annex XIII. It is concluded that carbon black is not a PBT/vPvB substance.

B.9 Exposure Asessment

B.9.1 Exposure Scenario 1: Occupational Exposure

Carbon black is an insoluble dust; the main route of occupational exposure of relevance to human health is inhalation via the nose and mouth. Dermal absorption is unlikely to occur.

In carbon black manufacturing, exposure can occur during production, collection, and materials handling, pulverizing, pelletizing, screening, packaging, stacking, loading, and unloading, as well as during cleaning equipment and maintenance, and from leaks, and spills. Occupational exposure to carbon black in downstream user industries may occur in rubber manufacturing, ink manufacturing and printing, paint manufacturing, paper, plastics, ceramics, battery production, carbon electrode production, and in metallurgical processes like carburization.

Within any production plant, exposures to carbon black vary markedly with the highest exposures normally being seen in fitters/welders, warehouse packers and site cleaners. Exposures can also vary greatly among factories and regionally.

In the late 1980s and 1990s extensive monitoring campaigns have been conducted within the carbon black production industry in Western Europe in 1987-1989, 1991-1992, and 1994-1995 (Gardiner *et al*., 1992a,b; 1996) and the United States in 1979 – 1980 (Smith and Musch, 1982), 1994-1995 (Muranko et al, 2001), and in late 2000 (Harber *et al*., 2003a,b). These studies found that geometric mean personal exposure, measured as total and inhalable carbon black was on average less than 1.0 mg/m³ (see Table 4). Even lower exposures are likely among workers in industries using carbon black, such as rubber, printing ink and paint manufacture (IARC, 1996).

Table 6: North American and European Respirable, Inhalable and "Total" Dust Values by Sampling Campaign.

Study	Respirable fraction mg/m³	Inhalable fraction mg/m³	"Total" dust mg/m³
North American Studies (sources: Smith and Musch, 1982; unpublished internal reports 1982, 1987; Muranko *et al.*, 2001; Harber *et al.*, 2003a,b)			
1979-1980 (n=1,564 "total", 387 respirable)	0.11 GM	nm	0.46 GM
1982-1983 (n= 973 "total")	nm	nm	nc
1987 (n= 577 "total")	nm	nm	0.47 GM
1993-1995 (n=1,004 "total", 1,056 respirable)	0.15 AM 0.07 GM	nm	0.59 AM 0.20 GM
2000-2001 (n= 933 inhalable, 933 respirable)	0.24 AM 0.13 GM	1.42 AM 0.60 GM	0.48* AM 0.22* GM
European Studies (Gardiner *et al.*, 1992a,b; 1996; van Tongeren, 2000)			
1987-1989 (n= 1,316 inhalable, 1,297 respirable)	0.40 AM 0.21 GM	1.52 AM 0.57 GM	nm
1991-1992 (n=3,454 inhalable, 2,950 respirable)	0.35 AM 0.18 GM	0.81 AM 0.37 GM	nm
1994-1995 (n= 3,245 inhalable, 3,157 respirable)	0.24 AM [0.13] GM	0.57 AM [0.29] GM	nm

nm = not measured; nc = overall descriptive statistics were not calculated; * = calculated "total" based on 2.97:1 (inhalable to total) conversion factor (Kerr, 2002); [ ]= data from van Tongeren, 2000 doctoral thesis; AM = arithmetic mean; GM = geometric mean; n = sample number. "Total" designates dust collected with traditional 37-mm closed-faced filter cassette.

Kuhlbusch *et al*. (2004) compared the particle characteristics of emissions in the bagging area of three carbon black plants to diesel exhaust particles derived from tailpipe emissions (dilution tunnels) and to particles from ambient air. The particle size and chemical composition of carbon black particles found in bagging areas of the three plants were different from those characteristic of either tailpipe or ambient particles collected near busy streets. Carbon black particles released from bag filling activities had a size distribution starting at about 0.4 µm d_{ae} (d_{ae} = aerodynamic

diameter). Diesel-soot particle diameters measured mainly below 0.2 µm whereas the carbon black workplace particles had modes (maxima) around 1-2 µm d_{ae} and > 8 µm d_{ae} (the larger size mode went beyond the particle size range investigated). Diesel soot contained a significant amount of organic carbon as well as inorganic compounds. The elemental carbon, as a percentage of total carbon, averaged 55% (range, 15- 75%) for tailpipe emissions and 45% (range 28-54%) for ambient air sites. In contrast, the elemental carbon percentage in carbon black plant bagging areas averaged 85%.

Peak exposures generally refer to conditions that cannot be predicted of high intensity and short duration (<15 minutes) exposure above the 8-hour TWA occupational exposure limit. Peak exposures to carbon black are most often associated with a spill or abnormal process condition. Because of their unpredictability and the nature of the standard gravimetric personal sampling methods used to measure carbon black exposure, there is little opportunity to collect meaningful exposure data. When such events may be anticipated, production-process employees are instructed to wear respiratory protection. Carbon black manufacturers' material safety data sheets instruct downstream users to train their employees in the appropriate use of respiratory protection when work conditions may result in elevated exposures.

The Immediately Dangerous to Life or Health (IDLH) concentration for carbon black has been set at 1, 750 mg/m^3. Originally the IDLH had been based on the absence of toxicological data to suggest that an acute exposure to a high concentration of carbon black would impede escape or cause any irreversible health effects within 30 minutes. However, the revised IDLH for carbon black is 1,750 mg/m^3 based on being 500 times the NIOSH REL and OSHA PEL of 3.5 mg/m^3 (500 is an assigned protection factor for the most protective respirators for particulates). (NIOSH, 1996).

B.9.2 Exposure Scenario 2: Consumer Exposure

Carbon black is used in a wide variety of consumer products, such as tyres, various rubber products, surface coatings, inks and in toners. In these products the carbon black is bound into a matrix. IARC concluded that exposures to carbon black in the use of these products were negligible (IARC, 1996).

Finely powdered carbon black used in toners for photocopying machines is part of a matrix. Wet toners contain carbon black in a hydrocarbon solvent and are applied to the photo conductor by a roller and bath. Wet toners are almost invariably handled by a sealed system of containers that plug into the reservoir (HSE, 1990). Exposure to inhalable dust during the use of photocopiers has been measured in the range 0.05 – 0.23 mg/m³. The toner component was found to be less than 20% of the inhalable dust fraction (HSE, 1990). During normal use, the exposure to carbon black from toner is not considered significant. Reports on diseases in connection with toner suffer from methodological weaknesses, insufficient documentation of medical history and exposure; inadequate examination and insufficient evaluation of the causal relationship (Ewers and Nowak, 2006).

B.10 Risk Characterisation

A risk characterisation is carried out by comparing the estimated exposure for relevant exposure scenarios with the critical DNEL for the leading health effect. This is done separately for the population group potentially exposed (workers, consumers and humans exposed via the environment) and the exposure routes (inhalation, dermal, oral).

B.10.1 Exposure scenario 1 – Worker Exposure

For systemic, long-term effects, DNELs are generally needed for worker dermal and inhalation exposure. In a first tier these two worker DNELs usually need to be derived and used to assess the occupational exposure.

No adverse health effects could be identified after dermal exposure to carbon black and a DNEL cannot therefore be derived. As there are no health risks associated with this route of exposure, it is not necessary to perform a risk characterisation.

The DNEL for worker inhalation exposure was derived as **2.0 mg/m^3** (inhalable fraction) based on chronic bronchitis. Hence, the quantitative risk characterisation is as follows:

Risk characterisation ratio (RCR) = Current Exposure / DNEL = < 2.0 mg/m^3/2.0 mg/m^3

As the exposure is below the DNEL, the risk is adequately controlled.

B.10.2 Exposure scenario 2 – Consumers

Consumer exposure to carbon black is negligible. A risk characterisation does not need to be performed.

B.10.3 Exposure scenario 3 – Indirect exposure: humans exposed via the environment

Indirect exposure to carbon black via the environment is negligible. A risk characterisation does not need to be performed.

B.10.4 Exposure scenario 4 – Environment

No adverse environmental effects could be identified and a reliable PNEC cannot therefore be derived. As there are no environmental risks associated with carbon black, it is not necessary to perform a risk characterisatioin.

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