

Soots*

Known to be human carcinogens

First Listed in the *First Annual Report on Carcinogens* (1980)

Carcinogenicity

Soots are *known to be human carcinogens* based on sufficient evidence of carcinogenicity in humans. Exposure to soots was first associated with scrotal cancer (a rare tumor) among chimney sweeps in 1775. Numerous case reports and several epidemiological studies since have confirmed an increased risk of scrotal and other skin cancers among chimney sweeps. Cohort studies in several European countries found that chimney sweeps had significantly increased risks of mortality from lung cancer, and one study found increased risks of leukemia and cancer of the esophagus and liver. Although these studies did not control for the effects of smoking or alcohol consumption, these factors were not believed to have significantly biased the risk estimates (IARC 1985, 1987). Since soots were reviewed for listing in the *First Annual Report on Carcinogens* and by the International Agency for Research on Cancer (IARC), follow-up studies of Swedish chimney sweeps reported increased risks of cancer at other tissue sites, including prostate, bladder, and total lymphatic and hematopoietic cancer (i.e., cancers of the lymphatic system and of organs and tissues involved in production of blood). Risks of esophageal and lung cancer increased with increasing exposure, and risks of lung, bladder, and esophageal cancer remained elevated after adjustment for smoking. The risk of esophageal cancer also was adjusted for alcohol consumption and remained elevated (Evanoff *et al.* 1993).

The findings in humans are supported by studies in experimental animals. Coal soot, wood soot, and various soot extracts have been tested for carcinogenicity in rats and mice; however, studies of coal soot (whole-body exposure), wood-soot extract (dermal exposure), and extract of fuel-oil soot (dermal exposure) were inadequate for evaluation of carcinogenicity. Dermal application of several soot extracts, including those derived from combustion of household coal, oil shale, and heating oil produced from shale-oil, caused skin tumors in mice. In rats, intratracheal administration of an extract of soot from the combustion of oil shale caused lung tumors. Subcutaneous implants of wood soots caused a few sarcomas at the implantation site in female rats, but similar implants in the scrotal sac did not cause any tumors in male rats (IARC 1985, 1987). Soots are known to contain a number of known and potentially carcinogenic chemicals, including arsenic, cadmium, chromium, nickel, and several polycyclic aromatic hydrocarbons (PAHs), including benz[*a*]anthracene, benzo[*a*]pyrene, dibenz[*a,b*]anthracene, and indeno[1,2,3-*cd*]pyrene. IARC (1987) concluded that there was sufficient evidence for the carcinogenicity of soot extracts but insufficient evidence for the carcinogenicity of soots in experimental animals.

Properties

Soots are black particulate matter formed as by-products of combustion or pyrolysis of organic (carbon-containing) materials, such as coal, wood, fuel oil, waste oil, paper, plastics, and household refuse. Their chemical compositions and properties are highly variable and depend on the type of starting material and the combustion conditions. Soots vary with respect to their relative amounts of carbon; their particle types, sizes, and shapes; and the types of organic and inorganic compounds adsorbed to the particles. In general, soots have a total carbon content exceeding 60% and a high content of inorganic material and/or soluble organic fraction. The soluble organic fraction of soot is extractable with organic solvents and consists of PAHs and their derivatives. Inorganic constituents may include oxides, salts, metals, sulfur and nitrogen compounds, water, and other adsorbed liquids and gases (IARC 1985, Watson and Valberg 2001).

Soots are classified into four morphologically distinct forms: (1) aciniform carbon, (2) carbonaceous xerogel particles, (3) carbon cenospheres, and (4) coke and char fragments. Aciniform carbon consists of aggregates of rounded particles fused together in random configurations, said to resemble grape clusters. Although particulate emissions from fireplaces consist largely of aciniform carbon, this form is uncommon in chimney soot. Xerogel particles form when organic materials deposited on aciniform carbon are heated, causing the particulate aggregates to be cemented together; this form is common in chimney soot. Carbon cenospheres are hard, shiny porous or hollow spheres formed when carbonaceous liquid droplets undergo carbonization with little change in shape; they are particularly associated with combustion of heavy fuel-oil sprays. Coke and char fragments consist of carbonized wood or coal and range in size from microns to millimeters; they are common in chimney soots from wood- or coal-burning fireplaces (IARC 1985).

Use

As unwanted by-products, soots have limited uses. They have been used in horticulture and in recovery of trace metals in the metallurgical industry. Weathered soot has been used as a fertilizer to provide small amounts of nitrogen and essential trace metals to plants. Soot also has been used horticulturally as a slug deterrent and as a soil conditioner, to increase heat absorption by darkening the soil (IARC 1985).

Production

Soots are not produced commercially. They are by-products of the incomplete combustion or pyrolysis of organic materials (IARC 1985).

Exposure

Humans may be exposed to soots by inhalation, ingestion, or dermal contact. The general population potentially is exposed to soots from fireplaces, furnaces, engine exhaust, and particulate emissions from any combustion source. Occupational exposure to soot may occur among chimney sweeps, heating-unit service personnel, brick masons and helpers, building demolition personnel, insulators, firefighters, metallurgical workers, horticulturists, and anyone who works where organic materials are burned. Chimney sweeps likely have the highest occupational exposure to soots. In 1982, there were an estimated 5,000 chimney sweeps in the United States. In addition to cleaning residential house chimneys, chimney sweeps clean industrial chimneys and boilers and are exposed to both gaseous and particulate combustion products. Soot concentrations to which they are exposed vary depending on the sweeping duties, type of chimney, and type of fuel. In a Danish study, soot concentrations from personal samplers ranged from 4.1 to 388 µg/L of total soot and 1.1 to 25 µg/L of respirable soot. The highest concentrations were measured in chimney ducts where coal was burned and in chimneys where wood and other fuels were burned (IARC 1985).

Regulations

No specific regulations or guidelines relevant to reduction of exposure to soots were identified

*No separate CAS registry number is assigned to soots.

REFERENCES

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