ANTIMONY TRIOXIDE AND ANTIMONY TRISULFIDE

1. Chemical and Physical Data

1.1 Synonyms

Antimony trioxide

Chem. Abstr. Services Reg. No.: 1309-64-4 - Antimony oxide
1317-98-2 - Valentinite
12412-52-1 - Senarmontite
Chem. Abstr. Name: Antimony oxide
IUPAC Systemic Name: Diantimony trioxide
Synonyms: Antimonious oxide; antimony (III) oxide; antimony sesquioxide; antimony white; AP 50; flowers of antimony; CI 77052; CI Pigment White 11; senarmontite; valentinite

Antimony trisulfide

Chem. Abstr. Services Reg. No.: 1345-04-6 - Antimony sulfide
1317-86-8 - Stibnite
Chem. Abstr. Name: Antimony sulfide
IUPAC Systematic Name: Diantimony trisulfide
Synonyms: Antimonous sulfide; antimony glance; antimony needles; antimony orange; antimony sesquisulfide; antimony trisulfide colloid; antimony vermilion; black antimony; CI 77060; CI Pigment Red 107; crimson antimony sulfide; needle antimony; stibnite

1.2 Molecular formulae and molecular weights

Sb_2O_3	antimony trioxide - Mol. wt: 291.50
Sb_2S_3	antimony trisulfide - Mol. wt: 339.68

Antimony trioxide is a dimorphic crystalline solid existing in an orthorhombic configuration as the mineral valentinite and in cubic form as senarmontite (Weast, 1985). Antimony trisulfide in its mineral form, stibnite, is an orthorhombic-bipyramidal crystalline structure (Roberts *et al.*, 1974).

1.3 Chemical and physical properties of the pure substance

Antimony trioxide

(*a*) *Description*: White, odourless, crystalline powder (Asarco, Inc., 1988a)
(*b*) *Melting-point*: 656°C (Weast, 1985)
(*c*) *Boiling-point*: Sublimes (Weast, 1985)
(*d*) *Density*: Valentinite, 5.7 g/cm^3; senarmontite, 5.2 g/cm^3 (Weast, 1985)
(*e*) *Reactivity*: Reacts with strong alkalis to form antimonates (Mannsville Chemical Products Corp., 1981)
(*f*) *Solubility*: Very slightly soluble in water; soluble in potassium hydroxide, hydrochloric acid and acetic acid (Weast, 1985); insoluble in organic solvents (Freedman *et al.*, 1978)
(*g*) *Spectroscopy data*: X-ray diffraction patterns for valentinite and senarmontite have been reported (Roberts *et al.*, 1974).
(*h*) *Refractive index*: Valentinite: 2.18, 2.35, 2.35; senarmontite: 2.087 (Weast, 1985)

Antimony trisulfide

(*a*) *Description*: Purified antimony trisulfide is usually a yellow-red amorphous powder (Weast, 1985). In its natural form (stibnite), antimony trisulfide is commonly found as well-formed crystals, sometimes very large and solid and at other times slender and fragile. The crystals are often vertically striated, bent or twisted. They are pale to dark lead-grey, but may appear tarnished, iridescent, bluish or blackish (Roberts *et al.*, 1974).
(*b*) *Density*: amorphous, 4.12 g/cm^3; stibnite, 4.64 g/cm^3 (Weast, 1985)
(*c*) *Solubility*: Very slightly soluble in water; soluble in hydrochloric acid and ethanol (Weast, 1985)
(*d*) *Spectroscopy*: The X-ray diffraction pattern for stibnite has been reported (Roberts *et al.*, 1974)
(*e*) *Refractive index*: Stibnite: 3.194, 4.064, 4.303 (Weast, 1985)

1.4 Technical products and impurities

Antimony trioxide

Trade names: Amspec-KR; Anzon-TMS; Asarco antimony oxide (LT, HT, VHT); A 1582; A 1588 LP; Blue Star; Dechlorane A-O; Exitelite; Extrema; Laurel (formerly Chemtron) Fire Shield; Thermoguard B; Thermoguard S; Twinkling Star; White Star

Antimony trioxide is available in several product grades of varying particle and tint. All are of at least 99.0% purity. Lead, arsenic and iron are common contaminants of the product in quantities of ≤ 2, ≤ 0.5 and < 0.01 wt%, respectively (Mansville Chemical Products Corp., 1985; Anzon, Inc., 1988; Asarco, Inc., 1988a,b).

Antimony trisulfide

Trade name: Lymphoscan

No data on technical-grade antimony trisulfide or its impurities were available to the Working Group.

2. Production, Use, Occurrence and Analysis

2.1 Production and use

(*a*) *Production*

Antimony trioxide is typically produced by roasting stibnite ores, which are reported to contain 55% antimony. The production of antimony trioxide occurs as a vapour–phase reaction at temperatures in excess of 1550°C. The stoichiometric addition of oxygen to the feed ore produces the desired product. Tetra- and pentoxides produce precipitate from the vapour as white and yellow powders, respectively. Antimony trioxide has also been isolated for many years as a by-product of lead smelting and production. Approximately 10–15% of US production occurs *via* this route. Antimony trioxide can be purified through serial vapour phase recrystallization (Freedman *et al.*, 1978; Mannsville Chemical Products Corp., 1981, 1985; Asarco, Inc., 1988a).

The following countries produce antimony trioxide: Belgium, Bolivia, China, France, Guatemala, Mexico, South Africa, the UK, the USA and Yugoslavia. Total US production has tripled since 1960 (Mannsville Chemical Products Corp., 1981, 1985; Palencia & Mishra, 1986) and was approximately 19 000 tonnes in 1987 (Llewellyn & Isaac, 1988).

Antimony trisulfide pigment is prepared by the addition of sodium thiosulfate solution to a solution of antimony potassium tartrate (tartar emetic) and tartaric acid or to a solution of another suitable antimony salt (LeSota, 1978).

(*b*) *Use*

The largest end use for antimony trioxide is as a fire retardant in plastics, rubbers, textiles, paper and paints (Mannsville Chemical Products Corp., 1981). This application represents approximately 60–75% of total US consumption (Mannsville Chemical Products Corp., 1981, 1985; Llewellyn & Isaac, 1988).

Antimony trioxide by itself is not a fire retardant. It is used as a synergist, typically at 2–10% by weight, with organochlorine and brominated compounds to diminish the inflammability of a wide range of plastics and textiles. Antimony trioxide also filters ultraviolet radiation which cause textile fibres to deteriorate (Drake, 1980; Lyons, 1980; Mannsville Chemical Products Corp., 1981, 1985).

When added to ceramic products, antimony trioxide imparts opacity, hardness and acid resistance, for instance, to sanitary ware and enamels. In the preparation of optical and ruby glass, antimony trioxide is used as a bubble remover. In other glasses, it is incorporated as a

colour stabilizer to protect against the weathering effects of the sun. Its use as a stabilizer and as a catalyst accounted for an estimated 15% of total US consumption in 1980 (Mannsville Chemical Products Corp., 1981; Windholz, 1983).

Antimony trioxide is used as a catalyst in the production of polyester resins and in the decomposition of hydrogen bromide. When used with tin dioxide at 480°C, antimony trioxide catalyses the partial oxidation of propylene (Samsonov, 1982).

Antimony trisulfide is used as a primer in ammunition and smoke markers, in the production of vermilion or yellow pigment and antimony salts such as antimony oxide and chloride, and in the manufacture of ruby glass (Mannsville Chemical Products Corp., 1985; Palencia & Mishra, 1986; Hawley, 1981).

(c) *Regulatory status and guidelines*

An occupational exposure limit of 0.5 mg/m³ as an 8-h time-weighted average (TWA) has been set for antimony and its compounds (measured as antimony) in many countries (Direktoratet for Arbeidstilsynet, 1981; Arbeidsinspectie, 1986; Institut National de Recherche et de Sécurité, 1986; Health and Safety Directorate, 1987; National Swedish Board of Occupational Safety and Health, 1987; Työsuojeluhallitus, 1987; US Occupational Safety and Health Administration, 1987; American Conference of Governmental Industrial Hygienists, 1988; Arbejdstilsynet, 1988; Deutsche Forschungsgemeinschaft, 1988). An exposure limit of 0.5 mg/m³ (8-h TWA) has also been set specifically for the handling and use of antimony trioxide (measured as antimony), in some cases with a carcinogen or skin sensitivity notation (International Labour Office, 1984; American Conference of Governmental Industrial Hygienists, 1988). Lower exposure limits (0.05 mg/m³, or no permissible exposure) have been set for the production of antimony trioxide because these compounds are classified as carcinogenic in several countries, e.g., Belgium, Finland, Italy, Sweden and the USA (International Labour Office, 1984; National Swedish Board of Occupational Safety and Health, 1987; Työsuojeluhallitus, 1987; American Conference of Governmental Industrial Hygienists, 1988).

2.2 Occurrence

(a) *Natural occurrence*

Antimony trioxide occurs in nature as the minerals valentinite and senarmontite. The orthorhombic valentinite and cubic senarmontite are secondary minerals formed by the geologic alteration of stibnite (Sb_2S_3) and other antimony minerals (Roberts *et al.*, 1974).

Antimony trisulfide occurs in nature as the mineral stibnite. It is formed as a low temperature deposit from hot solutions often associated with arsenic minerals and cinnabar. Significant deposits occur in Algeria, Borneo, Canada, China, Czechoslovakia, the Federal Republic of Germany, France, Italy, Japan, Mexico and Peru (Pough, 1960; Roberts *et al.*, 1974; Palencia & Mishra, 1986).

(*b*) *Occupational exposure*

On the basis of US National Occupational Exposure Surveys, the National Institute for Occupational Safety and Health (1974, 1983) estimated that 28 957 workers were potentially exposed to antimony trioxide in the USA in 1972–74 and 85 650 in 1981–83.

In a UK plant where antimony ore was processed, levels of antimony oxide in the air of work areas were reported to be highest during the short periods when tapping operations (pouring molten metal) at the furnace were under way; the mean value at these times was 37 mg/m³. Air levels in other areas of the plant were 0.53–5.3 mg/m³ (McCallum, 1963).

Personal TWA exposure to antimony trioxide at a glass-producing factory in the Federal Republic of Germany ranged from less than 50 μg/m³ to 840 μg/m³, with corresponding blood levels of 0.4–3.1 μg/l and a median of 1.0 μg/l (Lüdersdorf *et al.*, 1987).

A study of two major US antimony producing companies in which imported antimony sulfide ore was roasted to produce antimony trioxide showed personal TWA exposures to range from 0.21 to 3.2 mg/m³ (mean, 1.32 mg/m³) and 2.7 to 8.7 mg/m³ (mean, 5.2 mg/m³; Donaldson & Cassady, 1979).

At a smelting plant in Yugoslavia, concentrations of dust consisting of 36–90% antimony trioxide ranged from 16 to 248 mg/m³ (Karajovic *et al.*, 1960). At a plant in the USA where antimony sulfide ore was smelted, personal TWA airborne concentrations of antimony were 0.92–70.7 mg/m³; the author postulated a predominance of antimony trioxide (Renes, 1953). At another US antimony smelting plant, workers were exposed to antimony ore dust containing primarily antimony trioxide at concentrations (area samples) ranging from 0.08 to 138 mg/m³ (Cooper *et al.*, 1968). In a plant in the USA manufacturing resinoid grinding wheels, occupational exposures to antimony trisulfide were reported to range from 0.6 to 5.5 mg/m³ (Brieger *et al.*, 1954).

2.3 Analysis

No information was available to the Working Group on standard methods for the quantitative determination of antimony trioxide or antimony trisulfide in environmental samples. Antimony can be quantified in environmental matrices by a variety of methods, including atomic absorption spectrophotometry, inductively coupled plasma emission and X-ray fluorescence spectrometry, neutron activation analysis, anodic stripping voltammetry and various titrimetric and colorimetric methods (Freedman *et al.*, 1978; US Environmental Protection Agency, 1983; Eller, 1985; US Environmental Protection Agency, 1986; Lodge, 1989).

3. Biological Data Relevant to the Evaluation of Carcinogenic Risk to Humans

3.1 Carcinogenicity studies in animals[1]

Inhalation exposure

Rat: Groups of 49–51 female Fischer rats (CDF from Charles River), 19 weeks old, were exposed by inhalation to 0, 1.6 ± 1.5, or 4.2 ± 3.2 mg/m³ commercial grade *antimony trioxide* (measured as antimony; purity, 99.4%; arsenic, 0.02%; particle size, 0.4 μm ± 2.13 (for the high concentration) and 0.44 μm ± 2.23 (for the lower concentration)) for 6 h per day on five days per week for 13 months. Mean body weights were increased in both treated groups during the exposure period but did not differ significantly from that of controls at the end of the study. Groups of rats were sacrificed and examined histologically after three, six, nine and 12 months of exposure and two months after the end of treatment [numbers of rats sacrificed and numbers of early deaths for each period unspecified]. At 12 months after the end of treatment, 13 control, 17 low-dose and 18 high-dose rats were sacrificed and selected tissues were examined. Lung tumours localized in the bronchioloalveolar region occurred in 14/18 high-dose rats (three adenomas, nine scirrhous carcinomas ($p < 0.01$ [test unspecified]) and two squamous-cell carcinomas). One bronchioloalveolar adenoma occurred in a low-dose rat, and no lung tumour was observed in the control group at terminal sacrifice. Scirrhous carcinomas were also observed in 5/7 and 1/9 high-dose rats that died or were sacrificed between two months after the end of treatment and terminal sacrifice or between the end of treatment and two months after the end of treatment. One bronchioloalveolar adenoma occurred among six control rats that died or were sacrificed between two months after the end of treatment and terminal sacrifice. There was no significant difference in the number of other tumours occurring in treated and control groups (Watt, 1983).

Groups of 90 male and 90 female Wistar rats, eight months old, were exposed by inhalation to 0 or 45 mg/m³ (TWA) *antimony trioxide* (purity, ≥95%; arsenic, 0.004%; titanium, < 3%) for 7 h per day on five days per week for 52 weeks. Five males and females were killed at six, nine and 12 months after exposure was initiated; the remainder of the animals were killed 18–20 weeks after the end of the exposure period. There was no significant difference in survival between treated and control groups of either sex; 39 control and 31 treated females survived until terminal sacrifice [estimated survival in males was 21 and 21]. Non-neoplastic lesions (interstitial fibrosis, alveolar-cell hyperplasia and metaplasia) of the lung occurred with similar frequency in male and female rats but were slightly less severe in males. The first lung tumours were seen in two (one adenoma and one squamous-cell carcinoma) of

[1]The Working Group was aware of a study in progress of intracheal administration of antimony trioxide to hamsters (IARC, 1988).

five treated female rats sacrificed at 53 weeks; 19/70 (27%) treated females surviving at the time the first tumour was observed developed lung tumours. No lung tumour was seen in treated males or in male or female controls. The lung tumours that were found in treated females were nine squamous-cell carcinomas, five scirrhous carcinomas and 11 bronchioloalveolar adenomas or carcinomas [numbers of benign and malignant bronchioloalveolar tumours not specified]. The incidence of other tumours was not different between treated and control rats (Groth *et al.*, 1986).

Groups of 90 male and 90 female Wistar rats, eight months old, were exposed by inhalation to 0 or 36–40 mg/m³ (TWA) antimony ore concentrate (containing 46% antimony, principally as *antimony trisulfide*; titanium, < 4%; aluminium, 0.5%; tin, 0.2%; lead, 0.3%; iron, 0.3%; arsenic, 0.08%) for 7 h per day on five days per week for up to 52 weeks. Five males and five females were killed six, nine and 12 months after exposure had been initiated; the remainder of the animals were killed 18–20 weeks after the end of the exposure period. There was no significant difference in survival between treated and control groups of either sex; 39 control and 33 treated females survived until terminal sacrifice [estimated survival in males was 23 and 21]. Non-neoplastic lesions (interstitial fibrosis, alveolar-cell hyperplasia and metaplasia) of the lung occurred at similar frequency in male and female rats but were slightly less severe in males. The first lung tumour was seen in a treated female that died 41 weeks after the beginning of treatment; 17/68 (25%) treated females surviving at the time the first tumour was observed developed lung tumours. No lung tumour was seen in treated males or in male or female control rats, and there was no difference in the incidences of other tumours between treated and control groups of either sex. The lung tumours that occurred in treated females were nine squamous-cell carcinomas, four scirrhous carcinomas and six bronchioloalveolar adenomas or carcinomas [numbers of benign and malignant bronchioloalveolar tumours not specified] (Groth *et al.*, 1986).

3.2 Other relevant data

The toxicology of antimony compounds has been reviewed (National Institute for Occupational Safety and Health, 1978).

(*a*) *Experimental systems*

(i) *Absorption, distribution, excretion and metabolism*

After administration of 2% *antimony trioxide* to rats in the diet for eight months, very high levels were found in the thyroid, while retention was much lower (in decreasing order) in the liver, spleen, kidney, heart and lungs (Gross *et al.*, 1955a). After administration of 1% antimony trioxide to rats in the diet for 12 weeks, the highest antimony concentrations were found (in decreasing order) in the blood, spleen, lungs, kidneys, hair, liver and heart; 12 weeks after the end of treatment, levels in the blood, lungs and kidneys had decreased to about 50%, but the spleen still contained about 75% of the concentration observed at termination of exposure (Hiraoka, 1986).

In rats exposed for two to 14 months by inhalation to 100–125 mg/m³ antimony trioxide, pulmonary retention increased with increasing length of exposure; following cessation of exposure, pulmonary levels declined slowly (Gross *et al.* 1955b).

Exposure of rats by inhalation to 119 mg/m³ antimony trioxide dust (geometric mean particle size, 1.3 μm) for 80 h resulted in total urinary excretion of less than 40 μg antimony trioxide within four days (Gross *et al.*, 1955a).

A single administration to rats by stomach tube of 0.2 g antimony trioxide suspended in water resulted in total urinary excretion of 3.2% of the dose during the subsequent eight days. Faecal excretion was detected in rats for several weeks following cessation of administration of 2% antimony trioxide in the diet; after three weeks, faecal excretion was lower than urinary excretion levels (Gross *et al.*, 1955a).

Exposure of female dogs by inhalation to about 5.5 mg/m³ *antimony trisulfide* dust from a smelter (particle size, < 2 μm) for ten weeks resulted in urinary excretion of up to 16–18 mg/l antimony (Brieger *et al.*, 1954).

(ii) *Toxic effects*

The oral LD_{50} for *antimony trioxide* in rats is above 20 g/kg bw; however, reduced growth and other nonspecific effects were seen with 1 g/kg bw (Smyth & Carpenter, 1948). In contrast, administration of 16 g/kg bw antimony trioxide to rats by stomach tube resulted in no apparent ill effects within a 30-day observation period (Gross *et al.*, 1955a). Reduced weight gain, a slight reduction in absolute weight of the spleen and heart and a slight increase in absolute and relative weight of the lungs were observed in rats given 1% antimony trioxide in the diet for 12 weeks (Hiraoka, 1986). Vomiting and gastrointestinal disturbances occurred in dogs after daily ingestion of approximately 0.15 g/kg bw antimony trioxide or more; vomiting was induced by similar doses in a cat, and continued daily doses caused significant weight loss (Flury, 1927).

Intratracheal instillation of 50 mg antimony trioxide–containing smelter dust to rats did not result in lung fibrosis, although thin argyrophilic fibres were seen (Potkonjak & Vishnjich, 1983). No fibrosis was described after long-term, repeated exposure of rats and rabbits by inhalation to 100–125 mg/m³ and 89 mg/m³ antimony trioxide (average particle size, 0.6 μm), respectively. However, at these dose levels, rapid mortality occurred, particularly in rabbits, due primarily to pneumonia (Gross *et al.*, 1955b).

Increased lung weight, focal fibrosis, adenomatous hyperplasia, multinucleated giant cells and pigmented macrophages were observed in female rats exposed to 1.6 and 4.2 mg/m³ antimony trioxide (commercial grade; average particle size, 0.4 μm) for one year by inhalation. Similar doses caused no exposure-related change in miniature pigs (Watt, 1983). Increased death rates due to pneumonia were observed in guinea-pigs following inhalation exposure to antimony trioxide; cloudy swelling of the liver cells occurred in almost half of the animals exposed, but there was no other indication of systemic toxicity (Dernehl *et al.*, 1945).

Rats exposed to 3.1 mg/m³ *antimony trisulfide* by inhalation for six weeks developed electrocardiographic changes, notably with flattened T-waves; on autopsy, the heart was found to be dilated, with signs of degenerative changes; focal haemorrhage and congestion in the lungs were considered to be secondary to heart failure. Similar pathological effects were seen in rabbits exposed to 5.6 mg/m³ for six weeks. Cardiotoxic changes were observed in two dogs exposed to 5.6 mg/m³ for ten weeks, but not in two dogs exposed to 5.3 mg/m³ for seven weeks (Brieger *et al.*, 1954).

Degenerative changes in the liver and in the tubular epithelium of the kidney were observed in rabbits exposed to 27.8 mg/m³ antimony trisulfide for five days (Brieger *et al.*, 1954).

(iii) *Effects on reproduction and prenatal toxicity*

Female rats were exposed by inhalation for 4 h per day for 1.5–2 months to 0 or 250 mg/m³ *antimony trioxide*. They were then mated, and exposures continued until days 3–5 before expected delivery. Pregnancy was obtained in 16/24 treated females and in 10/10 controls. Litter size and weight of offspring at birth and weaning were not altered by exposure to antimony trioxide (Belyaeva, 1967).

Pregnant female rats (six to seven per group) were exposed by inhalation to 0, 0.027, 0.082 or 0.27 mg/m³ antimony trioxide for 24 h per day for 21 days. Fetal growth and viability were assessed at the end of gestation. Maternal body weight gain was not affected by exposure, but, at the high-dose level, increased pre- and postimplantation death of embryos was observed. At the mid-dose level, preimplantation loss and fetal growth retardation were evident (Grin *et al.*, 1987).

No data on *antimony trisulfide* were available to the Working Group.

(iv) *Genetic and related effects*

Antimony trioxide produced differential killing in DNA repair-proficient compared to repair-deficient strains of *Bacillus subtilis*. In a spot test, it was not mutagenic to *Escherichia coli* B/r WP2 or to *Salmonella typhimurium* TA1535, TA1537, TA1538, TA98 or TA100 [details not given] (Kanematsu *et al.*, 1980).

No data on *antimony trisulfide* were available to the Working Group.

(*b*) *Humans*

(i) *Absorption, distribution, excretion and metabolism*

Three workers with pulmonary changes related to exposure to antimony trioxide excreted 425, 480 and 680 μg/l antimony in urine, while another patient with antimony pneumoconiosis had urinary levels of 55 and 28 μg/l seven months and four years after retirement, respectively (McCallum, 1963). High levels [not given separately] of antimony were detected in the urine of workers exposed for several years to antimony trioxide; high excretion levels were also found after one month's cessation of exposure (Klučík & Kemka, 1960). High excretion levels were also seen in antimony production workers examined by Cooper *et al.* (1968). X-Ray spectrometry has demonstrated that inhaled antimony dust may be retained in the lung for long periods (McCallum, 1967; McCallum *et al.*, 1971). The amount of antimony retained in the lungs tended to rise with duration of employment at an antimony smelter, suggesting that accumulation may take place (McCallum *et al.*, 1971).

Among antimony trisulfide workers exposed to antimony levels generally higher than 3 mg/m³, urinary excretion of antimony was 0.8–9.6 mg/l (Brieger *et al.*, 1954).

(ii) *Toxic effects*

Accidental oral intake of antimony trioxide leached from enamel or ceramic glaze into acid beverages was reported to result in a burning sensation in the stomach, colic, nausea, vomiting and, occasionally, collapse (Monier-Williams, 1934). Complete recovery occurs after several days (Dunn, 1928).

Smelter workers exposed to antimony trioxide frequently complained of symptoms related to mucous membrane irritation, such as rhinitis (with cases of septal perforation and loss of smell), pharyngitis, laryngitis (sometimes with aphonia), gastroenteritis, bronchitis and pneumonitis. Other symptoms, less often encountered, included weight loss, nausea, vomiting, abdominal cramps and diarrhoea (Renes, 1953).

In other studies, only skin irritation (Oliver, 1933) or no indication of systemic toxicity (Potkonjak & Pavlovich, 1983) was found in smelter workers. Skin lesions ('antimony spots') in workers exposed to antimony trioxide develop mainly in areas exposed to heat and where sweating occurs (Stevenson, 1965). Occasionally, positive patch tests with antimony trioxide have been recorded (Paschoud, 1964). Antimony trisulfide has not been reported to cause dermatitis (National Institute for Occupational Safety and Health, 1978).

Radiographic changes (rounded opacities) in smelter workers exposed to antimony trioxide were first described in 1960 in Yugoslavia (Karajović *et al.*, 1960). The smelter dust contained antimony trioxide and some pentoxide, with low concentrations of silica and arsenic oxide. In a follow-up study of these smelter workers, the earliest changes were seen only after at least nine years of exposure, and no evidence was found of progression after cessation of exposure. Some evidence was found of mixed restrictive as well as obstructive changes in bronchi and small airways (Potkonjak & Pavlovich, 1983).

McCallum (1963) also noted in the UK that smelter workers with pneumoconiosis, a condition he termed 'antimony pneumoconiosis', were generally symptomless. The degree of radiographic abnormalities was correlated with the amount of antimony retained in the lungs and with duration of exposure; early changes were recorded in these workers after only a few years of employment (McCallum *et al.*, 1971). In a cross-sectional study of 274 smelter workers in 1965–66, 26 new cases of antimony pneumoconiosis were found and 18 were already under observation (McCallum, 1967). A subsequent study included 113 men, 46 of whom had radiographic abnormalities; six had severe abnormalities (McCallum *et al.*, 1971). Additional cases of pneumoconiosis with rounded opacities were seen in antimony smelter workers in the USA; the radiographic abnormalities were not associated with changes in pulmonary function (Cooper *et al.*, 1968). Possible antimony pneumoconiosis has also been recorded in two chemical workers exposed to antimony trioxide dust (Guzman *et al.*, 1986).

Following several deaths, possibly related to heart disease, among workers exposed to 0.6–5.5 mg/m^3 antimony trisulfide, a study revealed electrocardiographic changes, mainly in T-waves, in 37/75 workers; after cessation of exposure, the changes persisted in 12/56 workers who were re-examined. Gastrointestinal disturbances were also reported (Brieger *et al.*, 1954). Electrocardiographic changes were also observed in smelter workers by Klučík and Ulrich (1960).

(iii) *Effects on fertility and on pregnancy outcome*

Belyaeva (1967) described the reproductive outcomes of 318 women in the USSR working with dusts containing metallic antimony, antimony trioxide and antimony pentasulfide and of 115 control women. The women exposed to antimony dusts more frequently had premature births (3.4% *versus* 1.2%, respectively) and spontaneous abortions (12.5% *versus* 4.1%, respectively). The average birth weights of the 70 children of the exposed women were

similar to those of the 20 children of the control women (3360 g and 3350 g, respectively); however, at one year of age, the children of the exposed women were significantly lighter than the control children (8960 g and 10 050 g, respectively). [The Working Group noted that the numbers of premature births and spontaneous abortions were not stated.]

(iv) *Genetic and related effects*

No data were available to the Working Group.

3.3 Case reports and epidemiological studies of carcinogenicity to humans

In a report which quoted an unpublished statement issued in 1973 that ten cases of lung cancer had occurred among antimony process workers in the UK in 1969–71, with 8.0 expected, it was stated that no data were given on smoking nor on the methods used to calculate expected rates (National Institute for Occupational Safety and Health, 1978).

4. Summary of Data Reported and Evaluation

4.1 Exposure data

Antimony trioxide is produced from stibnite ores (antimony trisulfide) or as a by-product of lead smelting and production. It is used mainly in fire-retardant formulations for plastics, rubbers, textiles, paper and paints. It is also used as an additive in glass and ceramic products and as a catalyst in the chemical industry. Occupational exposure may occur during mining, processing and smelting of antimony ores, in glass and ceramics production, and during the manufacture and use of products containing antimony trioxide.

Antimony trisulfide is used in the production of explosives, pigments, antimony salts and ruby glass. Occupational exposure may occur during these processes and also during the mining, processing and smelting of ores containing antimony trisulfide.

4.2 Experimental carcinogenicity data

Antimony trioxide was tested for carcinogenicity by inhalation exposure in male and female rats of one strain and in female rats of another strain, producing a significant increase in the incidence of lung tumours (scirrhous and squamous-cell carcinomas and bronchioloalveolar tumours) in females in both studies. No lung tumour was seen in male rats.

Antimony ore concentrate (mainly antimony trisulfide) was tested for carcinogenicity by inhalation exposure in male and female rats of one strain, producing a significant increase in the incidence of lung tumours (scirrhous and squamous-cell carcinomas and bronchioloalveolar tumours) in females. No lung tumour was seen in males.

4.3 Human carcinogenicity data

The available data were inconclusive.

4.4 Other relevant data

Antimony trioxide causes pneumoconiosis in humans. One study of women exposed to dusts containing metallic antimony, antimony trioxide and antimony pentasulfide suggested that they may have had an excess incidence of premature births and spontaneous abortions and that their children's growth may have been retarded.

Antimony trioxide induced DNA damage in bacteria. (See Appendix 1.)

4.5 Evaluation[1]

There is *inadequate evidence* for the carcinogenicity of antimony trioxide and antimony trisulfide in humans.

There is *sufficient evidence* for the carcinogenicity of antimony trioxide in experimental animals.

There is *limited evidence* for the carcinogenicity of antimony trisulfide in experimental animals.

Overall evaluations

Antimony trioxide *is possibly carcinogenic to humans (Group 2B).*

Antimony trisulfide *is not classifiable as to its carcinogenicity to humans (Group 3).*

5. References

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[1]For definitions of the italicized terms, see Preamble, pp. 27–30.

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