4. CHEMICAL AND PHYSICAL INFORMATION

4.1 CHEMICAL IDENTITY

Asbestos is a generic term for a group of six naturally-occurring, fibrous silicate minerals that have been widely used in commercial products. Asbestos minerals fall into two groups or classes, serpentine asbestos and amphibole asbestos. It should be noted that serpentine and amphibole minerals also occur in nonfibrous or nonasbestiform forms. These nonfibrous minerals, which are *not* asbestos, are much more common and widespread than the asbestiform varieties. Serpentine asbestos, which includes the mineral chrysotile, a magnesium silicate mineral, possesses relatively long and flexible crystalline fibers that are capable of being woven. Amphibole asbestos, which includes the minerals amosite, crocidolite, tremolite, anthophyllite, and actinolite, form crystalline fibers that are substantially more brittle than serpentine asbestos and is more limited in being fabricated. This group can form a variety of polymeric structures through formation of Si-O-Si bonds. For the amphibole class of asbestos (amosite, crocidolite, tremolite, anthophyllite, and actinolite), the polymeric structure consists of a linear double chain, as shown in (see Figure 4-1 [top]). These chains crystallize into long, thin, straight fibers, which are the characteristic structure of this type of asbestos. For the serpentine class (chrysotile), the polymeric form is an extended sheet (see Figure 4-1, [bottom]). This extended sheet tends to wrap around itself forming a tubular fiber structure. These fibers are usually curved ("serpentine"), in contrast to the straight morphometry of the amphiboles. Some of the asbestos minerals are solid solution series, since they show a range of chemical formulas as a result of ion or ionic group substitutions. Tremolite and actinolite form such a series with iron replacing magnesium as one goes from tremolite to actinolite. The definition of how much iron must be present before tremolite becomes actinolite is not universally recognized and has changed over time (Wylie and Verkouteren 2000). Wylie and Verkouteren also cited the sodic-calcic amphiboles, winchite and richterite, which form a solid solution series and are not regulated under Federal Regulations (EPA 1987d; OSHA 1998a, 1998b). Asbestiform varieties of these amphiboles were found in vermiculite ore in Libby Montana (Wylie and Verkouteren 2000). Table 4-1 lists common synonyms and other pertinent identification information for asbestos (generic) and the six individual asbestos minerals.

The geological or commercial meaning of the word asbestos is broadly applied to fibrous forms of the silicaceous serpentine and amphibole minerals mentioned above. Asbestos minerals form under special physical conditions that promote the growth of fibers that are loosely bonded in a parallel array (fiber bundles) or matted masses. The individual fibrils, which are readily separated from the bundles of fibers, are finely acicular, rodlike crystals. Deposits of fibrous minerals are generally found in veins, in which

Table 4-1. Chemical Identity of Asbestos

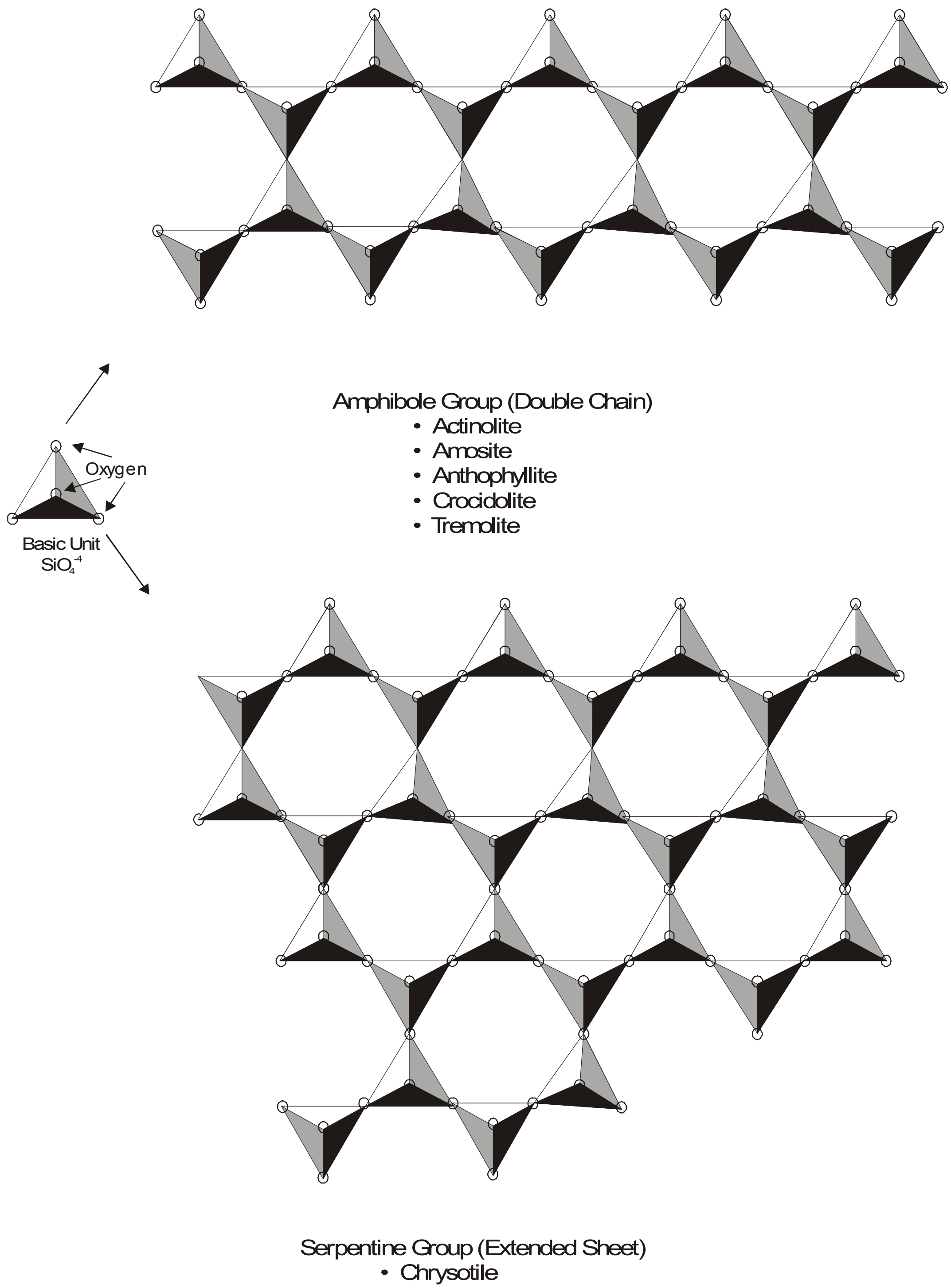
Characteristic	Asbestos	Amosite	Chrysotile	Tremolite[a]	Actinolite[a]	Anthophyllite	Crocidolite
Synonyms	No data	Mysorite, brown asbestos; fibrous cummingtonite/ grunerite	Serpentine asbestos; white asbestos	Silicic acid; calcium magnesium salt (8:4)	No data	Ferroantho-phyllite; azbolen asbestos	Blue asbestos
Trade name	No data	No data	Avibest; Cassiar AK; Calidria RG 144; Calidria RG 600	No data	No data	No data	No data
Chemical formula	No data	$[(Mg,Fe)_7Si_8 O_{22}(OH)_2]_n$	$Mg_3Si_2O_5(OH)_4$	$[Ca_2Mg_5Si_8 O_{22} (OH)_2]_n$	$[Ca_2(Mg,Fe)_5 Si_8O_{22}(OH)_2]_n$	$[(Mg,Fe)_7Si_8O_{22} (OH)_2]_n$	$[NaFe_3^{2+}Fe_2^{3+}Si_8 O_{22}(OH)_2]_n$
Chemical structure				See Figure 4-1			
Identification numbers:							
CAS registry	1332-21-4	12172-73-5	12001-29-5	14567-73-8	13768-00-8	17068-78-9	12001-28-4
NIOSH RTECS	CI6475000	BT6825000	GC2625000	XX2095000	AUO550000	CA8400000	GP8225000
EPA hazardous waste	No data	No data	No data	No data	No data	No data	No data
OHM/TADS	7217043	No data	No data	No data	No data	No data	No data
DOT/UN/NA/ IMCO shipping	IMCO 9.0 UN2212 UN2212	No data	IMCO 9.3 UN2590	No data	No data	No data	No data
HSDB	511	2957	2966	4212	No data	No data	No data
NCI	CO8991	No data	C61223A	CO8991	No data	No data	CO9007

[a]Tremolite and actinolite form a continuous mineral series in which Mg and Fe(II) can freely substitute with each other while retaining the same three-dimensional crystal structure. Tremolite has little or no iron while actinolite contains iron (Jolicoeur et al. 1992; Ross 1981; Skinner et al. 1988).

Sources: EPA 1985b; HSDB 2001a, 2001b, 2001c, 2001d; IARC 1977

CAS = Chemical Abstracts Service; DOT/UN/NA/IMCO = Department of Transportation/United Nations/North America/International Maritime Dangerous Goods Code; EPA = Environmental Protection Agency; HSDB = Hazardous Substances Data Bank; NCI = National Cancer Institute; NIOSH = National Institute for Occupational Safety and Health; OHM/TADS = Oil and Hazardous Materials/Technical Assistance Data System; RTECS = Registry of Toxic Effects of Chemical Substances

Figure 4-1. Basic Polysilicate Structures of Asbestos*



* Adapted from Hurlbut and Klein 1977

the fibers are at right angles to the walls of the vein. In the general mineralogical definition, fiber size is not specified. Health regulatory agencies use a more limited definition of asbestos fibers, and therefore, only a subset of asbestos fibers are subject to regulations and used in reporting fiber concentrations. U.S. workplace air regulations apply to chrysotile, crocidolite, amosite, and the asbestiform varieties of anthophyllite, tremolite, and actinolite (OSHA 1992). Prior to 1992, these regulations referred to chrysotile, crocidolite, amosite, anthophyllite, tremolite, and actinolite. Since nonasbestiform and asbestiform varieties of the last three minerals have the same name, new legislation was needed to specifically exclude the nonasbestiform varieties of these minerals. The word asbestos is often added after the mineral (e.g., tremolite asbestos) to signify that the asbestiform variety of the mineral is being referred to. This is not necessary for chrysotile, crocidolite, or amosite because the nonasbestiform varieties have different names (i.e., serpentine, riebeckite, and cummintonite-grunerite). OSHA defended the change in definition by noting that there was a lack of substantial evidence that exposed employees would be at significant risk because the nonasbestiform tremolite, anthophyllite, and actinolite were not regulated in the asbestos standard. OSHA (1992) noted that nonasbestiform amphibole airborne particles are regulated by a separate standard for "not otherwise specified" particulate dusts to protect against "the significant risks of respiratory effects which all particulates create at higher levels of exposure." OSHA defines an asbestos fiber for counting purposes as a particle with a length >5 μm and a length:width ratio (aspect ratio) >3:1. It should be noted that other agencies use different definitions of asbestos fibers for counting purposes. For example, EPA defines a fiber as any particle with aspect ratio >5:1 when analyzing bulk samples for fiber content.

Most amphibole and serpentine minerals in the earth's crust are of nonfibrous forms and are therefore not asbestiform. Fibrous forms may occur together with nonfibrous forms in the same deposits. Nonasbestiform amphiboles may occur in many diverse forms, including flattened prismatic and elongated crystals and cleavage fragments. These crystals exhibit prismatic cleavage with an angle of about 55E between cleavage planes. When large pieces of nonfibrous amphibole minerals are crushed, as may occur in mining and milling of ores containing the minerals, microscopic fragments may be formed that have the appearance of fibers but are generally shorter and have smaller length:width ratios (i.e., particle length >5 μm and a length:width ratio >3:1) than particles traditionally defined as fibers by health regulatory agencies (American Thoracic Society 1990; Case 1991; Ross 1981; Skinner et al. 1988). However, some cleavage fragments may fall within the dimensional definition of a fiber and be counted as an asbestos fiber in air samples or biological samples, unless evidence is provided that the particles are nonasbestiform.

4.2 PHYSICAL AND CHEMICAL PROPERTIES

Asbestos fibers are basically chemically inert, or nearly so. They do not evaporate, dissolve, burn, or undergo significant reactions with most chemicals. In acid and neutral aqueous media, magnesium is lost from the outer brucite layer of chrysotile. Amphibole fibers are more resistant to acid attack and all varieties of asbestos are resistant to attack by alkalis (Chissick 1985; WHO 1998). Table 4-2 summarizes the physical and chemical properties of the six asbestos minerals.

Table 4-2. Physical and Chemical Properties of Asbestos

Property	Amosite	Chrysotile	Tremolite	Actinolite	Anthophyllite	Crocidolite
Molecular weight[a]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Color	Brown, gray, greenish	White, gray, green, yellowish	White to pale green[b]	Green[b]	Gray, white, brown-gray, green	Lavender, blue, green
Physical state	Solid	Solid	Solid	Solid	Solid	Solid
Flexibility	Fair	Good	Brittle	Fair to brittle	Fair to brittle	Good
Melting point/ decomposition temperature	600–900 EC	800–850 EC	1,040 EC	No data	950 EC	800 EC
Specific gravity	3.43	2.55	2.9–3.2	3.0–3.2	2.85–3.1	3.37
Solubility:						
Water	Insoluble	Insoluble	Insoluble	Insoluble	Insoluble	Insoluble
Organic solvents	Insoluble	Insoluble	Insoluble	Insoluble	Insoluble	Insoluble
Acids[c]	12.00	56.00	No data	No data	2.13	3.14
Bases[c]	6.82	1.03	No data	No data	1.77	1.20
Isoelectric point	5.2–6.0	11.8	No data	No data	No data	No data
Electrical charge at neutral pH	Negative	Positive	No data	No data	Negative	Negative
Length distribution in UICC reference samples						
% >1 µm	46	36–44	No data	No data	46	36
% >5 µm	6	3–6	No data	No data	5	3
% >10 µm	1	1–3	No data	No data	1	0.7

Table 4-2. Physical and Chemical Properties of Asbestos *(continued)*

Property	Amosite	Chrysotile	Tremolite	Actinolite	Anthophyllite	Crocidolite
Flammability limits	Nonflammable	Nonflammable	Nonflammable	Nonflammable	Nonflammable	Nonflammable
Conversion factors[d]						

Sources: Chissick 1985; EPA 1980a, 1985b; HSDB 2001a, 2001b, 2001c, 2001d; IARC 1977; Jolicoeur et al. 1992; Kayser et al. 1982; NAS 1977; Ross 1981; Skinner et al. 1988; SRI 1982.

[a]All forms of asbestos are indefinite polymers.
[b]Tremolite and actinolite form a continuous mineral series in which Mg and Fe(II) can freely substitute with each other. With increasing iron content, the color of tremolite, typically creamy white, takes on a greenish cast.
[c]Percent loss in weight due to loss of counter-ions; silicate structure remains intact.
[d]See text, Section 3.2

UICC = Union Internationale Centre le Cancer