FACT PACKET

The VERMICULITE-ASBESTOS CONNECTION

Waste and Toxic Substances Project
ENVIRONMENTAL ACTION FOUNDATION

1525 New Hampshire N.W.
Washington, D.C. 20036
202-745-4879

May 1983

$20.00 regular
$10.00 non-profit

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Table 1

SUMMARY OF EXTENT TO WHICH EXISTING AND POTENTIAL REGULATIONS OFFER CONTROL OF ASBESTOS-CONTAMINATED VERMICULITE

Agency	Act	Regulation or Standard	Status	Mining		Milling		Exfoliation		Use		Transportation		Disposal	
				W	GP	W	GP	W	GP	W	GP	W	GP	W	GP
1. Consumer Product Safety Commission	CPSA	Ban of non-essential consumer products	ANPRM 10/17/79	(X)[1]	(X)[1]	(X)[1]	(X)[1]	(X)[1]	(X)[1]		(X)[1]	(X)[1]	(X)[1]	(X)[1]	(X)[1]
2. Department of Transportation	HMTA	Control of transported asbestos-containing items	Final Rule[2]												
3. Mine Safety and Health Administration	FMNMSA	Exposure limits for workers	Final Rule	X											
4. Occupational Safety and Health Administration	OSHA	Exposure limits for workers	Final Rule			X		X		X					
		Labeling requirement	Final Rule	(X)[3]		(X)[3]		(X)[3]		(X)[3]	(X)[3]				
5. Federal Trade Commission	FTCA	Labeling requirement	Potential							(X)	(X)				
6. Environmental Protection Agency	CAA	NESHAPs	Final Rule[2]												

Key

GP: General population
W: Workers
X: Control
(X): Partial Control

CPSA: Consumer Product Safety Act
HMTA: Hazardous Materials Transportation Act
FMNMSA: Federal Metal and Nonmetal Mine Safety Act
OSHA: Occupational Safety and Health Act
FTCA: Federal Trade Commission Act
CAA: Clean Air Act

NOTES

1 Assumes that a ban would apply only to consumer products; all products would not be affected.

2 Regulation is not applicable to asbestos-contaminated vermiculite.

3 No manufacturers currently label asbestos-contaminated vermiculite as is required for some circumstances in the OSHA regulation.

HAZARDOUS BEDFELLOWS:

The VERMICULITE–ASBESTOS CONNECTION

Since 1971, government and industry have known that virtually all vermiculite produced in this country is contaminated with asbestos.

Why don't the 4 million people who live in homes insulated with vermiculite know this?

EXPOSURE
Environmental Action Foundation
724 Dupont Circle Building
Washington DC 20036

By Dave Pontzer with Alice Cave

It's a thoroughly modern product for the lifestyle we've grown accustomed to. Vermiculite is lightweight and non-combustible. It's free-flowing and insoluble, chemically inert, resilient and non-abrasive.

This impressive array of attributes enables vermiculite to insulate, fireproof, extend, lighten, and aerate products ranging from potting soil to concrete, plaster board to kitty litter.

In our *trusting* consumer role we've scattered free-flowing vermiculite about our attic, and we've spread vermiculite-loaded fertilizer onto our lawns. Unfortunately, in our all too frequent *uninformed* consumer role, we've handled vermiculite without knowing that it's contaminated with asbestos, a proven carcinogen.

Contamination Revealed

The vermiculite/asbestos connection went public in 1971. That's when W.R. Grace and Co., the largest domestic supplier of vermiculite, revealed the results of tests confirming asbestos contamination in the ore mined at their Libby, Montana site, producer of 80% of the nation's vermiculite ore.

In 1976, both the Occupational Safety and Health Administration (OSHA) and the Mine Safety and Health Administration got involved when workers in the vermiculite industry came under regulatory "protection" from asbestos dust. Prior to this involvement vermiculite workers were exposed to asbestos dust concentrations as high as 245 fibers per cubic centimeter (f/cm^3). The new OSHA standard of 2 f/cm^3 is even recognized as too high.

In 1979 the Consumer Product Safety Commission (CPSC) acknowledged the contamination problem when they ordered a general study of the use of asbestos in consumer products and included "potting material" (vermiculite) among the products to be tested. However, the scope of the study was later narrowed to include only products in which asbestos is *intentionally* added.

Dave Pontzer, a recent graduate of Georgetown University, just completed an internship with the WaTS Project. Alice Cave is a researcher with an environmental consulting firm.

> "In 1971, the producer of 80% of the nation's vermiculite announced that virtually all of their ore was contaminated with asbestos."

EPA Releases Documents

Through Freedom of Information requests Environmental Action Foundation has been able to examine EPA documents on asbestos contamination of vermiculite. These reports date back to 1977.

Although vermiculite has been mined in the United States since 1929, no studies on the health effects of exposure to the mineral have been located. The effects of exposure to asbestos, on the other hand, is well documented.

By 1918 there was enough evidence on asbestos hazards to cause American and Canadian insurance companies to stop selling life insurance to asbestos workers. The cancer-causing potential of asbestos was suspected as early as the 1930's, although the first standard for occupational exposure to asbestos wasn't set until 1971 by OSHA.

Regulatory Options

OSHA, under their broad mandate to provide a safe environment for workers, has two regulatory options with regards to vermiculite. The first is an exposure standard and the second a labeling requirement. Theoretically, OSHA's current exposure standards protect workers even after the vermiculite has left the processing plant. But as an EPA report notes, "Realistically, however, it is difficult to imagine the standard being enforced at many of these later sites. For example, it is doubtful that employers at greenhouses where vermiculite is used as a soil conditioner run their businesses with the asbestos standard in mind. Few employers besides those involved in the initial stages of vermiculite processing know that vermiculite is often contaminated with asbestos." This is the case with many other

> "32 of the 221 vermiculite workers tested had lung disorders normally associated with asbestos exposure."

One of the first reported incidences of asbestos-like health problems appearing among vermiculite workers was in 1978 by O.M. Scott and Sons Co., a manufacturer of agricultural chemicals. Workes at their Maryland fertilizer plant developed lung disorders normally associated with asbestos exposure. Of 221 tested, 32 had disorders ranging from fibers in the lungs to bloody pleural effusions, with symptoms ranging from coughing, fatigue and chest pain to hypertension.

The crucial point is that research on asbestos-caused cancer in laboratory animals has shown that there is no threshold level below which exposure causes no effect. Therefore, since no safe levels for atmospheric concentrations of asbestos exist, *any exposure* will produce a percentage of cancers in those exposed.

industries using vermiculite as well, including construction workers, drywall installers, brick and stone masons, plasterers, insulation workers, and anyone involved in commercial agriculture.

Why are employers and employees largely unaware of vermiculite's contamination with asbestos? OSHA's labeling regulations for asbestos, " . . . all (asbestos-containing) raw materials, mixtures, containers . . . " covers vermiculite, but the regulation is self-service. Compliance is voluntary as long as " . . . a manufacturer believes that the use (handling, storage, etc.) of a product will not create fiber levels above the OSHA standard." Even this is ultimately a moot point, since OSHA stated in April of 1980 that this exposure standard is insufficient to protect workers' health.

Vermiculite next finds its way into the home, where it is "regulated" by CPSC. The Federal Hazardous Substances Act gives CPSC the mandate to regulate hazards presented by the presence or use of toxic and other hazardous substances in the home. Like OSHA, they have the authority to ban, regulate, or require labels on products.

CPSC has already exercised this authority with respect to asbestos banning two consumer products containing asbestos fiber: artificial embers and spackling compound. Neither is associated with the vermiculite industry. At that time CPSC went so far as to say that there is no safe level of exposure to asbestos in consumer products, and that, "only banning these products can adequately protect the public from unreasonable risks of injury associated with them." As was mentioned earlier, CPSC began a study of asbestos in consumer products over three years ago, excluding products like vermiculite which contained asbestos as a contaminant. To date, nothing has been reported.

CPSC also has the authority to require content labeling of products. In view of EPA reports concerning the significant levels of consumer exposure to vermiculite, this action, at the very least, should have been taken some years ago. A study prepared for EPA by an independent Virginia-based consulting firm makes this quite clear. The report states that, "Over 74 million persons use lawn and garden fertilizers each year. If the fertilizer is vermiculite-based, estimated exposure levels to asbestos of 4.4 ug/m^3* and 28 ug/m^3 could result from lawn treatment and gardening, respectively." The report goes on to estimate that 188,000 people a year are exposed to levels of asbestos as high as 13,600 ug/m^3 during the installation of vermiculite attic insulation. 4,230,000 people live in homes insulated with vermiculite.

Additionally, there are at least 3,000 owners of hobby greenhouses whose exposure to vermiculite should be comparable to that of a greenhouse employee occupationally exposed. Anyone repotting their houseplant with potting soil containing vermiculite would be exposed to a small amount of asbestos fiber, as would people who handle kitty litter, barbecue base, or who put up their own drywall, plaster, etc.

The consumer has no idea what's being handled. None of these products, from attic insulation to kitty litter is labeled, CPSC apparently not being sure how to proceed. After the strong stand taken in respect to artificial embers and spackling compound, i.e., no safe exposure level, this inaction is incomprehensible.

The EPA has done extensive research into the problems associated with asbestos contamination of vermiculite, compiling a wealth of information on the subject. As yet they've done nothing with it, issuing no regulations or warnings. It appears that since a safe lower limit for asbestos exposure cannot be found, the problem is being covered up. How else can one explain that at least three government agencies have been studying a known toxic substance, occurring in the market place, for at least five years, and not done so much as require that it be labeled. Another EPA report, also obtained through FOIA, frames the problem:

"Although the quantities of asbestos released during end-use of vermiculite are small in comparison to the mine and workplace, the aggregate risk to the consumer of product end user may be large in view of the large number of people exposed. Moreover, users may be particularly vulnerable and unprotected due to ignorance of the potential hazard."

Using vermiculite in an enclosed area, such as an attic, greatly increases the exposure level to asbestos fibers in the air. Or a garage. Or a basement. The point is clear, workers and consumers are being exposed to a known hazard without the information to handle it safely, to avoid it altogether. As the EF[illegible] report points out, "There are ad[illegible]quate substitutes for most of t[illegible] uses of vermiculite. If vermiculi[illegible] were not available, perlite, cellul[illegible] concrete and fiberglass would be t[illegible] most common substitutes."

There the matter now stands. T[illegible] tragic consequences of asbest[illegible] exposure are well established. Ve[illegible]miculite is a known carrier [illegible] asbestos fibers. These microsco[illegible] fibers are released into the atmo[illegible]phere from the time vermiculite [illegible] mined through its end use as [illegible] consumer product. Yet only t[illegible] mining and processing of vermiculi[illegible] have come under any kind of reg[illegible]lation. Upon leaving the processi[illegible] plant, vermiculite is unregulated, a[illegible] those handling it are exposed to [illegible] toxic substance with no warning [illegible] to its presence.

Our thanks to Dr. Arthur Rohl, of t[illegible] Environmental Sciences Laboratory at Mou[illegible] Sinai School of Medicine in New York, f[illegible] providing us with critical data and recent st[illegible]dies on the asbestos contamination [illegible] vermiculite.

*This *weight* method of measuring asbestos exposure (ug/m^3-milligrams per cubic meter) contrasts with the earlier *volume* method (f/cm^3-fibers per cubic centimeter) in the same way that a pound of eggs contrasts with a dozen eggs. Unfortunately, the Virginia study we refer to only used this weight method, and it's virtually impossible for us to correlate the two different systems with the information we have on hand. Further, OSHA only uses the volume method in its asbestos standard. Suffice to say, however, that as the general rule of thumb regarding asbestos, there is no safe exposure level; indicates these latter figures using the weight method are all to be considered extremely hazardous.

What and Where is Vermiculite?

[illegible] naturally occurring [illegible] the mica family. It [illegible] packed together [illegible] droplets of water [illegible] trapped between the layers [illegible] the mechanism by which vermiculite achieves its versatility. Heating vermiculite to between 1,000-2,000 degrees Fahrenheit causes the droplets to evaporate, allowing the mica to expand into small [illegible] light, low-density pieces. [illegible] vermiculite can expand up [illegible] times it's original volume. Expanded vermiculite is known as exfoliated and the heating process as exfoliation.

The [illegible] of vermiculite's uses fall [illegible] general categories: lightweight aggregates used in construction, agricultural and horticultural products, and insulation. The building industry uses vermiculite in concrete, plaster, wallboard, and similar material. Vermiculite concrete weighs much less than regular sand-based concrete and has excellent insulating properties. One inch of vermiculite concrete has the same insulating capacity as twenty inches of regular concrete. Mixed into plaster or wallboard, vermiculite adds sound deadening and fire resistant properties.

As insulation, vermiculite is poured loose between attic joists and into hollow cement block. It's also used as a packaging agent to prevent breakage during shipping.

Because of its [illegible] area and ability to absorb [illegible] gas, vermiculite is used [illegible] in agriculture and horti[illegible] most familiar as a soil conditioning agent for house plants and in greenhouses, vermiculite is also used as a plant growing medium, chemical fertilizer carrier, packing material for nursery stock, and carrier and extender for pesticides and herbicides.

Vermiculite's other [illegible] uses include use as a filler in paint, plastics and rubber, in kitty litter, and in barbecue base (to retain and reflect heat).

ATTENTION BUILDING TRADES

VERMICULITE/ASBESTOS

FACT PACKET

- EPA TEST RESULTS—CLASSIFIED DATA RETRIEVED THROUGH FREEDOM OF INFORMATION REQUESTS
- WHO IS EXPOSED? WHAT IS THE RISK?
- PROTECT YOURSELF—YOUR EMPLOYEES FROM ASBESTOS EXPOSURE

40 pp. $10.00

For immediate shipment, send check to:

Exposure, 724 Dupont Circle Bldg. Washington, DC 20036

Our Vermiculite is Asbestos-Free Declares Amverco Head

To the editor:

This firm is general counsel for American Vermiculite Corporation ("Amverco"). In that capacity, we have been asked by Mr. Leslie W. Thornbury, President of Amverco, to provide you with information concerning allegations of the presence of asbestos fibers in vermiculite sold in the United States. Amverco is a marketer of vermiculite in the United States, with its sole source of supply being the Palabora Mines in South Africa.

Please be advised that, although it may be true that some vermiculite contains asbestos fibers, the vermiculite sold by Amverco conclusively does not contain any asbestos.

For your information, we are enclosing a copy of an affidavit from Eric J. Chatfield, Ph.D., head of the Electron Optical Laboratory in the Department of Applied Physics of the Ontario Research Foundation, and a report which is attached to that affidavit entitled "Examination of Vermiculite for the Presence of Asbestos Fibres." This report was prepared in October of 1979 and proves that even after being subjected to the most intense possible scientific scrutiny, it was impossible to find any asbestos fibers in the vermiculite originating from the Palabora Mines of South Africa. In November of 1981, suit was filed against Amverco and others, *Lloyd R. Gordon, et al. v. American Vermiculite Corp., et al.*, United States District Court for the Southern District of Ohio, Eastern Division, Case No. C-2-81-1406, alleging damages resulting from the sale of vermiculite containing asbestos fibers. Dr. Chatfield's 1979 report and his affidavit were submitted by Amverco in defense of the case. Since all of the vermiculite marketed by Amverco originates from the Palabora Mines, and since evidence submitted by Amverco was conclusive concerning the absence of asbestos, Amverco obtained an Order and Judgment in this case dated March 17, 1983 from the District Court for the Southern District of Ohio, Eastern Division, in which the court ruled as a matter of law that Amverco could not be held accountable for asbestos poisoning in its sale of vermiculite. The court made a specific finding of fact that **"the vermiculite produced and sold by the defendant to plaintiff's employer contained no asbestos and did not cause or contribute in any way to plaintiff's alleged injuries"**. A copy of the court's order is enclosed...

Yours very truly,

F. Edwin Hallman, Jr.
For Decker, Cooper & Hallman
A Professional Corporation

Editor's Choice

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For Decker, Cooper & Hallman
A Professional Corporation

VERMICULITE

MINERAL COMMODITY PROFILES
MCP–19, AUGUST 1978

This current report on vermiculite has been prepared by the Bureau of Mines, U.S. Department of the Interior to:

1. Provide the latest available data and information on vermiculate.

2. Invite comment, revisions, or additional information on the subject.

Please direct communications to:

C.M. Patterson
Bureau of Mines
2401 E. St. NW
Washington, D.C. 20241
Telephone number (202) 634-1202

UNITED STATES DEPARTMENT OF THE INTERIOR

A single copy of this publication is available without charge from: Publications Distribution Branch; Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, PA. 15213

VERMICULITE

By Stanley K. Haines[1]

Vermiculite, a micalike mineral with the unique property of exfoliating to a low-density, bulky material when heated, is widely used in the construction industry. Vermiculite concrete is used for roof decks and floor fill where light weight, thermal insulation, and acoustical properties are of particular importance. Vermiculite plasters and cements are employed mainly for fireproofing purposes. They are also valuable by reason of lightweight, good resilience, and good bonding properties. Loosefill vermiculite is used to insulate walls and ceilings. The use of vermiculite as a thermal insulator has gained increasing importance in light of the current desire to save energy through higher levels of home insulation. The material also has utility in agriculture, primarily due to its high absorptive capacity.

Vermiculite mines are distant from major market centers, and there are high transportation costs on shipping crude ore to exfoliation plants near the point of end use. Another problem in the industry is the limited market for the finer sized exfoliated vermiculite.

The outlook for vermiculite in the United States is good from both a supply and a demand point of view. The expected average annual growth rate is 3.6% with a total demand in the year 2000 of 600,000 tons. Total demand in 1977 was an estimated 290,000 tons.

Vermiculite ore reserves are thought to be adequate to meet future domestic needs. The United States will remain self-sufficient in vermiculite at least into the next century. The world's largest deposit is mined near Libby, Mont., by W. R. Grace & Co. Vermiculite is also mined near Enoree, S.C. W. R. Grace & Co. in the United States and the Palabora Mining Co. in the Republic of South Africa are the major producers of crude vermiculite in the world. Plans to develop vermiculite deposits near Louisa, Va., have progressed; commercial financing has been obtained, and construction has begun for a mine, mill, and plant.

[1] Physical scientist, Division of Nonmetallic Minerals.

INDUSTRY STRUCTURE

Background

World production, nearly all of which is supplied by the United States and the Republic of South Africa, was insignificant until after World War II.

Vermiculite was first named and described in 1824 by Thomas H. Webb from an occurrence he found near Worcester, Mass.

Many occurrences of vermiculite were subsequently discovered, and beginning in 1915, Denver Mining & Manufacturing Co. for several years mined and marketed vermiculite under the name of tung ash from a deposit in the Turret mining district, Chaffee County, Colo. The exfoliated vermiculite was ground and used for various decorative purposes.

The large deposit of vermiculite in the Rainy Creek district near Libby, Mont., was discovered by accident in 1916 by E. N. Alley, who was searching old prospects in the area for vanadium minerals. While inspecting a tunnel, he noticed that a candle flame caused flashes of a micalike mineral to swell and change color. The mineral proved to be vermiculite, and Mr. Alley and others incorporated the Zonolite Co. to develop the deposit. Production on a small scale began in 1921. For many years, the Rainy Creek district was the only major source of vermiculite in the world. In the interwar years, small-scale production started in the Eastern States, first in Pennsylvania, then in North Carolina, but by 1940 total annual production had reached only 22,000 tons, still mostly from Montana. The Zonolite Co. was acquired by W. R. Grace & Co. in 1963. A group of deposits near Enoree, S.C., has been worked since 1947. Small tonnages have been produced in Colorado, Georgia, North Carolina, Texas, and Wyoming, and deposits have been investigated in several other States.

Commercial production in South Africa began in 1946 from a large deposit at Palabora in

Table 1.—World vermiculite production, 1977, and capacity, 1977, 1978, and 1980

(Thousand short tons)

	Production in 1977	Capacity		
		1977	1978	1980
North America: United States	359	425	430	525
Africa: Republic of South Africa	e250	260	260	300
Rest of world[1]	e20	25	25	50
World total	e629	710	715	875

e Estimate.
[1] Excluding centrally controlled economies

Table 2.—Domestic use pattern for vermiculite

(Percent)

Use	1976	1977
Unexfoliated: Miscellaneous	8	7
Exfoliated		
Lightweight aggregates		
Concrete	27	28
Plaster	1	[1]
Premixes	15	16
Total	43	45
Thermal insulation		
Loosefill	15	15
Block	16	16
Packing	[1]	[1]
Total	31	31
Agriculture		
Horticulture and soil conditioning	14	14
Fertilizer carrier	1	1
Total	15	15
Miscellaneous	3	2
Grand total	100	100

[1] Less than ½ unit

northeastern Transvaal. Vermiculite has been found also in Kenya, Tanzania, Uganda, Southern Rhodesia, Argentina, Brazil, Canada, Chile, India, Australia, Japan, Korea, China, and the Soviet Union.

Size and Organization

In 1977, the primary domestic producers of crude vermiculite were the Construction Products Division, W. R. Grace & Co., which operates a large mine near Libby, Mont., and a group of smaller mines near Enoree, S.C., and Patterson Vermiculite Co., Enoree, S.C.

Exfoliated vermiculite was produced at about 51 plants in 29 States in 1977. South Carolina, California, Texas, New Jersey, and Florida supplied 43 percent of the total. W. R. Grace & Co., the leading producer of crude vermiculite, operated 30 exfoliating plants in 24 States.

Most exfoliating plants are small, and over half produce less than 5,000 tons each of expanded vermiculite annually. The following gives the approximate size distribution by tonnage for the industry:

Tons produced	Number of plants
Less than 5,000	28
5,000-10,000	21
10,000-20,000	1
20,000-50,000	1
Total	51

W. R. Grace & Co. is an international industrial concern with chemical, consumer product, and natural resource interests. Vermiculite is a small part of its total business. For other exfoliators, vermiculite is generally the major part of the business. Some companies also expand perlite.

The other major world producer of crude vermiculite is Palabora Mining Co., a member of the Rio Tinto Zinc Group, with a mine in East Transvaal, Republic of South Africa. An affiliate, American Vermiculite Corp. of Atlanta, Ga., distributes South African crude vermiculite in the United States and Canada. In Europe, sales are handled by Mandoval, Ltd., of London. World vermiculite production and capacity are shown in table 1.

Marketed Products

Exfoliated vermiculite is packed in 4-cubic-foot sacks for shipment or used at the exfoliating plant in preparing premixed products. It is marketed in different size fractions according to use.

USES

Exfoliation converts crude vermiculite to a product that is very lightweight, noncombustible, free flowing, insoluble, chemically inert, resilient, and nonabrasive. It is a good thermal insulator and has high adsorbability for fluids. These qualities made exfoliated vermiculite useful in construction, agriculture, and other industries. Prior to the end of World War II, its main use was as a thermal insulator in the building industry. After the war its very low density and good insulating properties suggested its use to replace sand in lightweight concretes and plasters. Later the potential of its incombustibility began to be realized in fire barriers, and more recently its excellent adsorption characteristics were utilized in chemical processing, water and air purification, and other areas. Its use range has expanded considerably over the past 25 years. End-use consumption data appear in table 2.

Lightweight concrete made of fine-size exfoliated vermiculite and portland cement is used in large quantities in weight-saving construction where thermal insulation and acoustical qualities are of particular importance. Vermiculite concrete is used for roof decks, slabs-on-grade, prefabricated panels, and other purposes.

Premixes are used in large tonnages as coating on fireproof structural steelwork as well as to deaden sound, seal off moisture and condensation, and provide decorative textures, mainly on wallboard and concrete walls and ceilings.

Vermiculite plasters, made with gypsum or portland cement, are sprayed onto steel or concrete structural members for fireproofing purposes and to reduce weight, thus saving on foundation and other structural costs. There are also sound-deadening and acoustical properties. These plasters are also used for finish-coat plastering of walls and ceilings, but demand for this purpose has been cut by the change from lath and plaster walls to drywall construction. Vermiculite plasters adhere better in use than plasters made with alternate lightweight materials such as expanded clays, slags, shales, and perlite owing to the greater resiliency of vermiculite. Also, its flat, laminar structure provides good initial adhesion.

Coarser grades of expanded vermiculite are used as loosefill insulation in hollow masonry walls and between joists in attics of homes and other structures to reduce heat loss in winter and keep the interior cooler in summer. As loosefill or with various binders, vermiculite is used to cover molten metal, as beds for shipping hot ingots for hundreds of miles, to cover steam pipes, boilers, and hot lines for transport of chemicals such as molten sulfur, in double-shelled tanks for cryogenic applications, for packaging and shipping to prevent breakage, for insulating refractories, for mold linings, and in lubricants for extrusion and drawing.

Expanded vermiculite's high surface area and high adsorption capacity for liquids and gases has found many agricultural and chemical applications, particularly for finer grades. In agriculture, vermiculite is employed as a soil conditioning agent, plant growing medium, chemical fertilizer carrier, packing material for nursery stock, carrier and extender for pesticides and herbicides, and anticaking agent for fertilizers and for encapsulating seeds. Another agricultural use is for poultry litter. Vermiculite's ion-exchange capacity has found applications in chemistry including water purification. Its use as an adsorption medium has included sulfur recovery and pollution control in sulfur dioxide stack gas technology. Other uses for the finer grade are as an ingredient in refractory products and as a filler for paints, plastics, and rubber.

Unexpanded vermiculite is reported to have only a few uses, such as in muds for oil-well drilling and as a filler in fire-resistant wallboard.

RESERVES-RESOURCES

The major domestic reserves of vermiculite lie in one very large deposit near Libby, Mont., and in several much smaller deposits, each containing 20,000 to 400,000 tons of ore, in the Enoree and Enoree-Waldrep districts of South Carolina. Deposits of economic significance range from about 25 to 95 percent contained vermiculite. The size of the Libby deposit has been reported to be sufficient for 50 years at the present rate of mining. Important deposits have been located in central Virginia, in Louisa County. A submarginal reserves total, recoverable at 1.5 times the current cost, has been estimated (2)[2] as 2 to 3 million tons in South Carolina, North Carolina, Texas, Wyoming, Colorado and Nevada. Deposits have been found in Arkansas, Georgia, California, Washington, and Oregon. It is likely that another large deposit similar to the Libby deposit may be discovered in the United States, most probably in Colorado or Montana. Hypothetical, smaller, workable deposits of the Enoree type probably exist in the Inner Piedmont region from South Carolina to Pennsylvania. A domestic reserve of 100 million tons appears to be a conservative estimate.

The vermiculite deposit at Palabora in northeastern Transvaal Province in South Africa is one of the world's largest. Reserves in South Africa are estimated to be approximately 75 million tons. Large deposits are also known (4) to exist in the Soviet Union in the Kola Peninsula, the Urals, and the southeastern edge of the Ukrainian shield. Deposits are being mined in Argentina, Brazil, China, Korea, India, Kenya, and Tanzania. In general, at least in the market-controlled economies, exfoliation quality is inferior to that of material mined in South Africa and the United States. World reserves, other than South African, and domestic reserves and excluding the centrally controlled economies, were estimated to be 15 million tons. Exfoliated South African material is generally coarser and less dense than exfoliated U.S. material and thereby more suitable for loosefill insulation. Table 3 contains a brief assessment of world vermiculite resources.

Geology

The geologic relations of all types of vermiculite deposits suggest that pyroxenes (diopside

[2] Italicized numbers in parentheses refer to items in the list of references at the end of the report.

Table 3—World vermiculite resources

(Million short tons)

	Reserves	Other resources	Total[1] resources
North America: United States	100	25–100	125–200
Africa: Republic of South Africa	75	Large	Large
Rest of world[1]	15	Large	Large
World total[1]	190	Large	Large

[1] Exclusive of centrally controlled economies

and augite), amphiboles (hornblende and tremolite), and olivine, in ultramafic rocks, both igneous and metamorphic, were first altered by solution and volatiles from intrusive syenites, carbonatites, and pegmatites, forming biotite, phlogopite, serpentine, and chlorite. Supergene alteration by circulating ground waters later removed the alkalis, redistributed magnesium, and added H_2O as interlayer water molecules, to form vermiculite. Accessory minerals in the deposit include quartz, feldspar, apatite, corundum, chlorite, asbestos, talc, and clay. Biotite is the most common parent mineral. A similarity of the biotite and vermiculite crystal structures permits molecular interlayering in a series that extends from pure biotite though 1:1 biotite-vermiculite to pure vermiculite. Varieties in the series containing 10 to 15 percent vermiculite are called hydrobiotite.

The world's largest vermiculite deposit at Libby, Mont., is a zoned-pyroxenite pluton of Cretaceous age that cuts Precambrian sedimentary rocks. The pluton has a core of biotite in a mass of biotite pyroxenite. A shell of magnetite pyroxenite intruded the zone of weakness at the contact of the biotite pyroxenite with the country rocks. A younger mass of syenite cut both the magnetite and the biotite pyroxenite, and alkalic syenite dikes cut the biotite core. Biotite in the biotite pyroxenite, and to a small extent in the magnetite pyroxenite, was altered to hydrobiotite and vermiculite; the biotite of the dense core is virtually unaltered.

With the major exception of the deposit at Libby, almost all the world's vermiculite deposits appear to be in rocks of Precambrian age. The other large deposit in the world is at Palabora, South Africa in Precambrian rocks of a similar petrological suite as those of the Libby, Mont., deposit.

The most numerous domestic deposits, but also those with the smallest amounts of vermiculite, are in ultramafic layered metamorphic rock, characteristically in biotite schists, and are cut by pegmatites. The deposits are only a few feet thick, although they may be several hundred feet long. Ore content usually ranges from a few hundred to several thousand tons. Examples of these deposits are those being mined in the Enoree district of South Carolina and most of the deposits in Colorado, Wyoming, and Texas.

The third geologic type of domestic deposit comprises the ultramafic intrusives, such as dunites and unzoned pyroxenites and peridotites, that are cut by pegmatites and syenitic or granitic intrusive rocks. Examples are deposits in the Blue Ridge Mountains region of the United States. In these deposits, vermiculite typically occurs in lenses that are as much as 4 to 5 feet thick and 50 to 60 feet long. A few lenses are 20 feet thick and more than 100 feet long.

The main criteria for a commercial deposit are exfoliating capability , vermiculite content, and size . It must contain little or no biotite and be in good sized flakes, with few fines. The deposit should contain at least 30 percent vermiculite and preferably more than 50 percent vermiculite.

TECHNOLOGY

Vermiculite is a hydrated magnesium-aluminum-iron sheet silicate of variable composition. The crystal structure is similar to that of biotite but separated by a double layer of water molecules. In biotite, potassium ions occupy interlayer sites. The electronic charges of these ions help to hold the layers together. In vermiculite, only some of the sites are occupied, and these only by magnesium.

Expanded vermiculite is completely incombustible and retains its thermal insulating value to 2,000° F. For the higher temperatures, such as for use in fire walls, in the shipment of hot steel ingots, or in refractories, use of a finer material has the advantage of better thermal reflection of radiated heat.

Crude vermiculite denotes the mined ore that has been beneficiated and sized. The exfoliated product is also called vermiculite. The chemical composition of crude vermiculite and expanded vermiculite is identical except for the water content. The water content of crude vermiculite ranges from 4 to 14 percent. The property of exfoliation, which causes bulk to increase from 8 to 12 times and yields a product with a density of 4 to 11 pounds per cubic foot, is dependent upon conversion of part of the water of hydration to steam, which forces the laminae apart at right angles to the cleavage planes to form an accordionlike product. Exfoliation occurs over a temperature range of 800° to 2,000° F and is completed in a few seconds. If held too long above 1,100° F, all of the water of crystallization is lost and the material becomes brittle and crumbles to powder, thus losing most of its usefulness. The light-brownish-yellow, dark-yellowish-brown, greenish, or almost black color of crude vermiculite changes to a gold, golden brown, or bronze color, often with a metallic luster, during exfoliation.

Chemical composition is of little value in determining the expandability of vermiculite, and exfoliation tests provide the only satisfactory evaluation. The material can be identified in prospecting by heating with a candle flame or even a match.

Mining

Mining in Montana, South Carolina, and South Africa is by open pit methods. Removal of overburden is usually accomplished by tractor powered scrapers. The technique in Montana has been to proceed from the top down over a wide area, with several levels active simultaneously in benches 14 to 16 feet deep with connecting haulage ramps. The mining is complicated by the lack of consistency in the grade (size) of vermiculite from place to place within the mine. In South Carolina, the practice has been to strip around each ore body and expose it on all sides. In South Africa, several benches, each 15 feet deep, have taken the mine down to a phlogopite floor at 135 feet. The vermiculite ore is usually soft enough to be dug without blasting. Large dikes or barren host rock require fragmentation by drilling and blasting prior to disposal at waste sites.

Beneficiation

Techniques used at Libby are a combination of dry and wet processes using crushers, screens, jigs, and spirals. South Carolina ore is beneficiated by a wet-concentrator process including washing, crushing, table flotation, and screening. The new plant at Libby, Mont., reportedly also uses only wet-beneficiation techniques, partly to alleviate dust hazards. Centrifuges and rotary dryers generally are used to remove moisture after wet beneficiation. The beneficiated product, called crude vermiculite, is shipped prior to expansion because of the large bulk of the exfoliated product.

Exfoliation

Sized crude vermiculite is dropped continuously through a gas- or oil-fired vertical furnace at a controlled rate. The expanded product is drawn out of the furnace by a suction fan and into a classifier system to collect the vermiculite product, remove excessive fines, and allow discharge of relatively clean gases to the atmosphere. The furnace temperature is 1,600° to 2,000° F with a retention time of 4 to 8 seconds.

Exfoliated vermiculite is graded by W. R. Grace on the basis of bulk density and size as follows:

Grade	Density (pounds per cubic foot)	U.S Sieve Size
1	4 to 7	3/8-16
2	4 to 8	4-30
3	5 to 9	8-100
4	6 to 10	16-100
5	8 to 11	30-

The American Society for Testing and Materials has established specifications for vermiculite aggregate for concrete (ASTM C-332) and plaster (ASTM C-35) and for vermiculite loosefill insulation (ASTM C-516).

Research

Recent furnace designs permit a shorter residence time to reduce material losses as fines and to improve the toughness of the product. Increased utilization has been realized for formerly discarded fines in lightweight aggregates, fireproofing of high-rise buildings, and agricultural needs. Major producers are developing new beneficiating techniques for the recovery of smaller size fractions and treatment of ores with lower mineral content. In turn, industry has turned to greater dependence on computer techniques to develop the most economic mining and beneficiation plan to best fit an ore deposit.

Improved insulating and fireproofing vermiculite-containing materials and methods of application were developed for use in steam-injection oil well casings, ingot-cooling beds, building construction, and firebreaks for sealing off underground mine fires (*1*).

Further use was made of exfoliated vermiculite's high-adsorption characteristic to remove oil from a water surface, to purify waste water, and to purify air in mines. Canadian research revealed (*6*) that exfoliated vermiculite was particularly effective in purifying air in underground mines by preferentially filtering out dust particles and radon daughters.

Improved techniques were developed for incorporating chemical fertilizers onto the surface of expanded vermiculite or into the interstices of a vermiculite-based composite material.

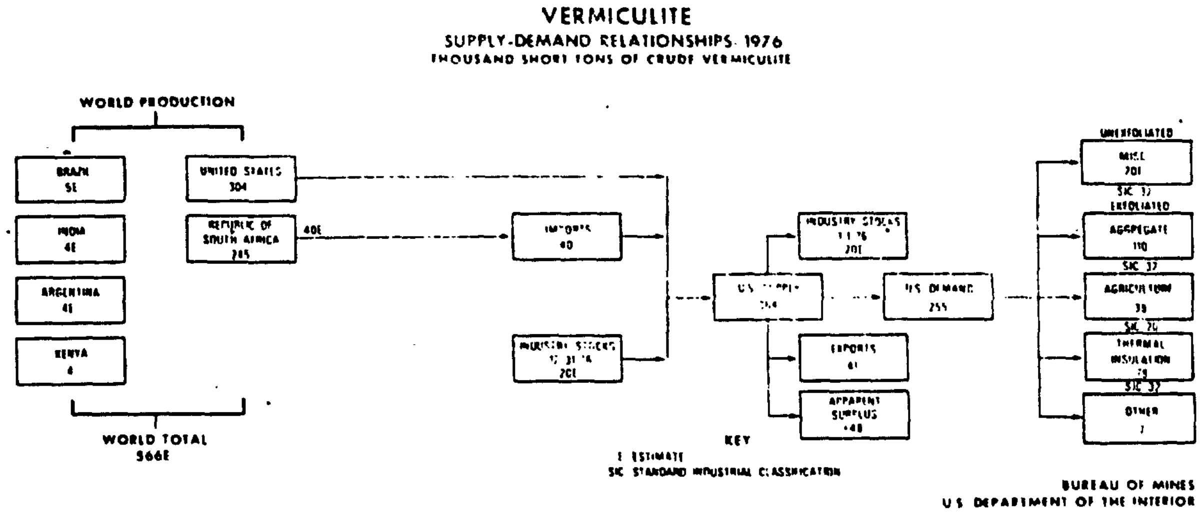

Figure 1.—Supply-demand relationships for vermiculite, 1976.

SUPPLY-DEMAND RELATIONSHIPS

Components of Supply

World production of vermiculite has risen from 371,000 tons in 1967 to an estimated 620,000 tons in 1977. During this same period domestic production increased from 255,000 tons in 1967 to the record high of 365,000 tons in 1973 and then dropped to 350,000 tons in 1977. In 1977 the United States and South Africa produced 97 percent of total world production.

In 1977 imports provided about 10 percent of the total U.S. supply. Over the last 10 years, imports have ranged from a low of 6,000 tons in 1969 to a high of 42,000 tons in 1974. South Africa has been the source of the imports.

Industry stocks in table 4 and figure 1 are estimates.

Distribution of Supply

Estimated domestic demand for exfoliated vermiculite in 1977 was 280,000 tons. Exfoliated vermiculite for use as lightweight aggregate required 45 percent of the total demand and was followed by thermal insulation, 32 percent; agriculture, 15 percent; and other uses, 2 percent. The remaining 20,000 tons of the total demand was beneficiated vermiculite ore that was sold or used without exfoliation.

Over the last 10 years, exports have moved from 24,000 tons in 1967 to about 40,000 tons in 1977, with a high of 45,000 tons in 1975 and a low of 22,000 tons in 1970. The crude vermiculite was exported to Canada for exfoliation and consumption.

The surplus of 60,000 tons in 1977 represents the difference between total U.S. supply and the sum of U.S. reported demand, exports, and industry stock. The surplus may be attributed to water, unusable fines, and grit that accompany the ore.

Supply-demand relationships for 1967 through 1977 appear in table 4.

Most of the crude ore mined in the Republic of South Africa is exported through the port of Maputo in Mozambique to France, the Federal Republic of Germany, Italy, the United Kingdom, and other European countries, as well as to the United States, Canada, Australia, and Japan. Quantities of crude ore are exported from the United States to Canada. Very little exfoliated vermiculite enters world trade because of high freight costs on bulky expanded material.

Substitutes

Expanded perlite is a close substitute for vermiculite in very lightweight concrete and plaster aggregate. Vermiculite or perlite is used when the advantage of lower density more than balances considerations of lower cost and greater structural strength achieved with such lightweight, but somewhat heavier, concrete aggregates as expanded clay, shale, or slate. Alternate materials for loosefill insulation include fiberglass, slag wool, polystyrene foam, polyurethane foam, and wood fiber, milled newsprint, or wood pulp treated with fire-resistant chemicals. These materials have excel-

Table 4.—Vermiculite supply-demand relationships, 1967–77

(Thousand short tons)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977[e]
World production:											
United States	255	290	310	285	301	337	365	341	330	304	359
Rest of world	116	129	154	141	153	175	186	213	247	262	270
Total	371	419	464	426	454	512	551	554	577	566	629
Components of U.S. supply:											
Domestic production	225	290	310	285	301	337	365	341	330	304	359
Imports[1]	16	11	6	12	18	26	30	42	33	40	40
Industry stocks, Jan. 1[e]	7	7	7	7	7	7	7	7	7	20	20
Total U.S. supply	278	308	323	304	326	370	402	390	370	364	419
Distribution of U.S. supply:											
Industry stocks, Dec. 1[e]	7	7	7	7	7	7	7	7	20	20	20
Exports[2]	24	25	27	22	29	31	36	44	45	41	40
U.S. demand	180	213	250	221	209	247	293	279	245	254	300
Apparent surplus(+), deficit(−)[3]	+67	+63	+39	+54	+81	+85	+66	+60	+60	+48	+59
U.S. demand pattern:											
Crude[4]	...	...	...	...	...	...	...	5	10	20	20
Exfoliated:											
Aggregate	77	85	110	89	84	104	137	141	117	110	135
Thermal insulation	65	85	85	88	79	84	92	80	74	79	95
Agriculture	31	34	37	31	31	52	50	47	38	39	45
Other	7	9	18	13	15	7	14	6	6	7	5
Total U.S. primary demand[5]	180	213	250	221	209	247	293	279	245	255	300

[e] Estimated.
[1] Imports from the Republic of South Africa.
[2] Exports to Canada.
[3] Primarily grit and water losses during exfoliation.
[4] Beneficiated vermiculite ore, but not exfoliated.
[5] Data may not add to totals shown because of independent rounding.

lent thermal properties, but the flammability standards for some have not been fully established.

In agricultural uses, substitutes include peat, perlite, sawdust, bark, straw and other plant materials, and synthetic products. These materials are complementary in some uses. For example, vermiculite protects the moisture content of peat-soil mixtures and assists in initial wetting of the peat.

ECONOMIC FACTORS AND PROBLEMS

The average selling price of crude vermiculite was $13.17 per ton f.o.b. mine in 1956, rising to an estimated $51.00 per ton in 1977. In terms of constant 1976 dollars the increase was 75 percent from $28.00 in 1956 to $49.00 in 1977.

The average value of the exfoliated material, f.o.b. exfoliation plant, increased from $60.93 per ton in 1956 to $170.00 per ton in 1977. This represents an increase of 27 percent in terms of constant 1976 dollars ($126.56 per ton in 1956).

The quantity and cost of capital needed for expansion of facilities is of continual concern to companies in the industry. The new mill of W. R. Grace & Co. at Libby, Mont., was reported to cost $7 million, or $7,000 per ton of bulk-concentrate daily capacity. Palabora Mining Co. modernized and increased its mill and exfoliating capacity by 25 percent at a reported cost of $3.5 million. Exfoliating plants are small, and the furnace is of simple design. A new exfoliating plant at Pompano Beach, Fla., with an estimated annual capacity of 5,000 to 10,000 tons, was reported to cost $550,000 in 1972.

Railroad freight rates are high, and shipping costs for crude vermiculite sometimes exceed the mine value. The rail-freight rate for shipping vermiculite from Montana to the Atlantic and Gulf coasts is comparable with the transportation cost from South Africa. This makes it economic for some South African crude to enter the country. Most of this vermiculite is transshipped by rail or barge to inland points.

Table 5.—Time-price relationship for vermiculite

Year	Average annual prices, dollars per short tons: Actual prices	Average annual prices, dollars per short tons: Based on constant 1976 dollars
1956	$13.17	$28.00
1957	14.15	29.11
1958	14.28	28.91
1959	14.89	29.50
1960	15.62	30.42
1961	16.76	32.36
1962	16.06	30.45
1963	15.81	29.54
1964	15.99	29.41
1965	17.91	32.23
1966	18.91	32.95
1967	19.51	33.02
1968	19.60	31.75
1969	21.95	33.85
1970	22.78	33.35
1971	23.91	33.30
1972	24.01	32.11
1973	25.93	32.78
1974	29.68	34.10
1975	41.70	43.83
1976	46.15	46.16
1977	[e]51.76	[e]49.02

[e] Estimated

Owing to the bulky nature of exfoliated vermiculite and high transportation costs, exfoliating plants are located near markets.

Federal tax laws allow vermiculite producers a 14 percent depletion allowance, not to exceed 50 percent of net income. The United States does not have a tariff on crude vermiculite imports.

OPERATING FACTORS AND PROBLEMS

The vermiculite mining industry has the usual ecological problems of quarrying operations in that overburden must be disposed of carefully and consideration must be given to the final disposition of the mine site. The number of mines is small; therefore, only limited surface areas are disturbed. There is no effluent from vermiculite milling plants, because all process water is recycled from settling ponds. Dust generated at exfoliating plants is collected by enclosed collection systems. A tendency to convert from dry to wet beneficiation techniques has reduced the dust problems. The industry does not pose any severe environmental problems.

A plan to bring a group of deposits in Louisa County, Va., into production has met a number of challenges that have delayed construction of a mine, mill, and plant. The development of the site has been challenged on the grounds that such an activity would cause "sight pollution" in an area that has been declared a National Historic Landmark. Additionally, the Secretary of the Interior has accepted scenic easements for various properties located within the historic landmark. The easements cover property near the vermiculite properties but do not include any of the proposed mining sites. The easements give the Department of the Interior legal rights similar to those of the actual property owners.

The State of Virginia has issued all the necessary permits to allow Virginia Vermiculite, Inc., to begin mining. The company has obtained a commercial operations loan of $1 million to develop their 160-acre tract and plans to begin in 1978. W. R. Grace & Co. owns considerable acreage in the same area, but has announced no immediate plans to develop a mine and mill.

Lack of commercial techniques of separating vermiculite and biotite has hindered the full use of some ores. An operating problem has been the production of excessive fines in grinding.

During exfoliation, unsalable quantities of minus 100-mesh vermiculite are produced if the material remains too long in the furnace hot zone.

There are only two major world suppliers of crude vermiculite and one major domestic supplier. This sometimes causes an unstable crude supply for exfoliators. The principal domestic mine is in an area of severe winters that could interrupt the normal flow of crude vermiculite to exfoliators.

About 295 workers were employed at domestic vermiculite mines and mills in 1977. Several hundred additional employees operated vermiculite exfoliating plants.

OUTLOOK

Supply

Domestic supplies of crude vermiculite should fall short of meeting requirements to the year 2000. After 3 years of decline, production has increased to near the record level of 1973. Production must grow at about 4.5 percent per year (from 1976) to reach the estimated 500,000-ton level by 1985. Most of the additional material will come from increased production by W. R. Grace & Co. and from the new capacity of Virginia Vermiculite, Ltd., in Louisa County, Va. Imports from South Africa will continue to furnish part of the total supply.

A key area of concern is the availability of larger sized material. These grades of vermiculite occur irregularly throughout the domestic deposit, making it difficult to ensure accessibility of adequate quantities. South Africa has more of the larger material, but recovering it is more expensive, which will hamper future development.

Demand

For the 10-year period 1976-85 domestic demand for vermiculite is expected to grow at an average annual rate of 7.8 percent. This gives a 1985 probable demand figure of 500,000 tons. The demand for the rest of the world is expected to draw even with U.S. demand by 1985. Cumulative demand through 1985 for the world is estimated at 6,620,000 tons.

Domestic demand is expected to taper off after 1985 to give an overall 1976-2000 growth rate of 3.6 percent. The 2000 demand will be about 600,000 tons with a 24-year cumulative total of 10 million tons.

The rest-of-the-world total for 2000 is 600,000 tons, the same as domestic demand.

Table 6.—Summary of forecasts of U.S. and rest-of-world vermiculite demand, 1976–2000

(Thousand short tons)

	1976	2000 Forecast range		Probable		Probable average annual growth rate 1976–2000 (percent)
		Low	High	1985	2000	
United States						
Total	255	400	850	500	600	3.6
Cumulative		7,800	12,100	3,400	10,000	...
Rest of world[1]						
Total	200	400	700	500	600	4.3
Cumulative		7,300	10,100	3,220	9,300	
World[1]						
Total	455	800	1,550	1,000	1,200	3.9
Cumulative		15,100	22,200	6,620	19,300	...

[1] Excluding centrally controlled economies

Table 7.—Projections and forecasts for U.S. vermiculite demand by end use, 1976 and 2000

(Thousand short tons)

End use	1976	2000			
		Statistical projection[1]	Contingency forecasts for United States		
			Forecast range		Probable
			Low	High	
Exfoliated					
Lightweight aggregate	110	267	200	300	225
Thermal insulation	79	183*	100	300	175
Agriculture	39	160	50	120	100
Other	[illegible]	0*	10	50	50
Total	235		360	770	550
Unexfoliated	20		40	80	50
Grand total	255	..	400	850	600

[1] Statistical projections are derived from regression analysis based on historical time series data and forecasts of economic indicators such as gross national product, and FRB index. Projection equations with a coefficient of determination (R squared) less than 0.70 are indicated by an asterisk (*).

Due to a lower starting base, the growth rate for the rest of the world will be 4.3 percent, or about 0.7 percentage point higher than the U.S. rate. The cumulative total for the rest of the world is 9,300,000 tons through 2000. Forecast ranges for U.S. demand by end use are listed in table 7.

Lightweight Aggregate.—Correlation with the Federal Reserve Board Index (FRBI) for construction and allied equipment established a statistical projection of 267,000 tons of vermiculite in 2000. It is expected that greater use of low-density fireproof material with sound-absorbing properties in roof decks, floor fill, and prefabricated panels will steadily increase demand for vermiculite concrete.

Concerning demand for vermiculite plasters and cement compounds, there are positive and negative factors. The use of concrete framework for low- and medium-rise buildings in place of structural steel has retarded to some degree the growth of demand for these plasters and cement compounds to fireproof steelwork, but they are often used to improve the fire resistance of reinforced and prestressed concrete columns and beams. Also, increasing emphasis on acoustical and texturing properties in building specifications should increase demand for these plaster and cement products.

The forecast range was set using a growth rate of 2.5 percent for the low end and 4.2 percent for the high end to account for changes that may occur in demand. The probable demand is 225,000 tons, 42,000 tons less than the statistical projection.

Thermal Insulation.—This end use when correlated with the FRBI for total production yields a statistical projection of 183,000 tons; however, this correlation has a low statistical reliability factor. The increased need for insulation to conserve energy may spur demand to about 175,000 tons by 2000. The wide forecast range was set to allow for possible increased use of alternate insulating materials and the possibility of greater-than-anticipated demand for homes and buildings.

The higher demand level for all types of insulating materials will increase. Vermiculite may gain in consumption should petrochemical feedstocks for the manufacture of some other insulating materials be in short supply.

The demand for vermiculite may be adversely affected by its low R value and a shortage of larger sized vermiculite for use as insulation. R is a measure of a material's resistance to heat transfer. High R values indicate, on a comparative basis, that the material is a better insulator. Vermiculite has an R value of 2.2 per inch (with some tests yielding a rating of 2.5) versus 3.7 per inch for cellulose

Table 8.—Comparison of domestic vermiculite production and demand 1954–76, and projected production in 2000

(Thousand short tons)

Year	U.S. demand	U.S. production	
1954	145	[illegible]	
1955	158	[illegible]	
1956	159	[illegible]	
1957	161	[illegible]	
1958	155	191	
1959	153	207	
1960	151	199	
1961	151	216	
1962	152	235	
1963	172	226	
1964	177	226	
1965	177	249	
1966	193	262	
1967	180	255	
1968	213	290	
1969	250	310	
1970	221	295	
1971	209	301	
1972	247	337	
1973	293	365	
1974	279	341	
1975	245	330	
1976	255	304	
1977	[e]290	[1]359	
1985	[2]500	[3]413	[2]450
2000	[2]600	[3]532	[2]550

[e] Estimated
[1] Not used in forecast
[2] Probable forecasts from table 6
[3] 20-year trend.

or 3.2 per inch for glass wool batts and 2.3 for blown-in fiberglass.

Agriculture.—Vermiculite usage in agriculture was related to gross private domestic investment to derive a statistical projection of 160,000 tons. It is expected there will be a greater demand for vermiculite for growing crops without soil (hydroponics). The probable demand was set at the high end of the forecast range for this reason but still well below the statistical projection.

Other.—No index was found to correlate reliably with other uses of vermiculite. The forecast range was set subjectively at 10,000 tons to 50,000 tons because of new uses which may develop.

Unexfoliated vermiculite.—The principal end use of this category is for fireproofing wallboard. There were not enough data to develop a long-term correlation for use in forecasting this use. Again the range was set subjectively, with a probable demand in the year 2000 of 50,000 tons due to increasing interest in better methods of fireproofing homes and commercial buildings.

Possible Supply-Demand Changes

Straight-line projection of domestic vermiculite production indicates that production will be about 413,000 tons in 1985 and 532,000 tons in 2000. With the addition of Virginia Vermiculite and other small producers to the ranks of domestic producers, production will probably increase to 450,000 tons in 1985 and 550,000 tons in 2000. The 50,000-ton shortfall between demand and supply will be met by imports.

Future periods of tight supply, particularly in the larger sized material, will be met with rising prices. With prices higher, some previously subeconomic resources may become reserves and production may ensue.

A shortage of supply of the larger material may hamper the development of the insulating markets. In the midseventies this has been evident in that many exfoliators have felt that they could have sold considerably more vermiculite for insulation if the crude had been available.

Possible Technological Progress

Technological improvements in prospecting might lead to new discoveries during the forecast period. New methods for separating vermiculite and biotite might emerge. Larger markets probably will be further developed for the finer sized exfoliated material. New uses for vermiculite could emerge, such as in new composite building materials to manufacture prefabricated units and in adsorption of impurities in air and waste water.

REFERENCES

1. Botha, B. J. R. Vermiculite-Sealing Plaster in Mines. South African Min. and Eng. J., v. 80, pt. 1, No. 3967, Feb. 14, 1969, p. 363.
2. Bush, A. L. Lightweight Aggregates. Ch. in United States Mineral Resources. U.S. Geol. Survey Prof. Paper 820, 1973, pp. 333–335.
3. Industrial Minerals (London). Vermiculite: Increased Capacity Encourages Optimism—but Construction Still the Key to Demand. No. 115, April 1977, pp. 17–31.
4. Vermiculite: A Market in Transition. No. 38, November 1970, pp. 9–13.
5. Petrov, V. P. Perlite and Vermiculite (Geology, Exploration, and Production Technology). Moscow, 1962 (trans. by the U.S. Geol. Survey, 1973, 217 pp.).
6. Washington, R. A., W. Chi, and R. Regan. The Use of Vermiculite To Control Dust and Radon Daughters in Underground Uranium Mine Air. Can. Min. and Met. Bull., v. 66, No. 731, March 1973, pp. 152–55.

SOURCES OF CURRENT INFORMATION

U.S. Bureau of Mines publications:

Vermiculite. Ch. in Mineral Commodity Summaries, annual.
Vermiculite. Ch. in Mineral Facts and Problems, 1975.
Vermiculite. Ch. in Minerals Yearbook, Annual.
Vermiculite. Mineral Industry Surveys, Annual.

Other sources:

Engineering and Mining Journal
Mining Engineering
Mining Journal (London)
Industrial Minerals

Table 1. Distribution of Exfoliated Vermiculite Sold or Used in 1975-197[illegible]

Application	1975		1976		1977	
	Short tons	Percent of total	Short tons	Percent of total	Short tons	Percen[illegible] of tot[illegible]
Aggregates:						
Concrete	75,000	32	67,706	25	65,920	21
Plaster	4,000	1	3,099	1	3,599	1
Premixes[a]	38,000	17	39,448	15	30,130	9
Subtotal	117,000	50	110,253	41	99,649	31
Insulation:						
Loose fill	39,000	16	39,058	14	74,900	23
Block	35,000	15	39,310	15	50,980	16
Packing	---	--	390	--	168	--
Subtotal	74,000	31	78,758	29	126,048	39
Agriculture:						
Horticulture and soil conditioning	31,000	13	36,379	13	40,780	13
Fertilizer carrier	7,000	3	37,450[b]	14	47,580	15
Subtotal	38,000	16	73,829[b]	27	88,360	28
Miscellaneous:	6,000	3	7,334	3	6,797	2
Total	235,000	100	270,174	100	320,854	100

Source: Haines 1977.

[a] Includes vermiculites used in premixes for acoustic and fireproofing purposes, decorative textures, moisture sealants, etc.

[b] Revised.

EXPOSED POPULATIONS

Excerpts from:

INTERIM FINAL REPORT

Exposure Assessment for
Asbestos-Contaminated Vermiculite

EPA Contract No. 68-01-6271
Task No. 1

Prepared by :

Versar Inc.
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February 18, 1982

7. EXPOSED POPULATIONS

The following section presents the best available data concerning the number of persons exposed to asbestos-contaminated vermiculite. In many cases, the data apply to the total numbers of producers and users of vermiculite; no attempt is made to estimate the proportion using the asbestos-contaminated mineral. Section 7.1 lists the occupationally-exposed populations, Section 7.2 deals with consumers of vermiculite products, and Section 7.3 estimates the population exposed to asbestos via ambient air near vermiculite emission point sources.

7.1 Occupational Populations

7.1.1 Miners and Millers

There are four active vermiculite mines in the U.S.: W.R. Grace in Libby, Montana; Grace in Enoree, South Carolina; the Patterson Vermiculite Co., also in Enoree; and Virginia Vermiculite in Louisa County, Virginia. The Grace mine in Libby produced 181,000 kkg of vermiculite in 1979 (JRB 1982). Ore is mined by bench quarrying using power shovels and ammonium nitrate blasting. After mining, it is hauled by trucks to a nearby primary processing plant and then to the mill (JRB 1982). The Libby mine employs 250 persons (EIS data base 1980). The Grace mine at Enoree produced 119,000 kkg in 1979 (JRB 1982). Ore is mined from several open pits, exploited with little or no blasting. It is then hauled by trucks on public roads to a central concentrating mill (JRB 1982). Based on operations at the Libby mine, it is assumed that the Grace mine at Enoree employs 200 persons. The Patterson Vermiculite Company mined 5,000 kkg in 1979 (JRB 1982). The ore is mined from open pits and hauled by trucks to the mill two miles away (JRB 1982). Patterson has between 20 and 49 employees (EIS data base 1980). The Virginia Vermiculite mine began operations in 1979, mining 9,000 kkg (JRB 1982). Further data are unavailable. Using figures for Patterson as a guide, it is assumed that the Virginia mine employs between 20 and 49 persons.

Table 17. Location, Employment, and Products of U.S. Exfoliation Plants

Name	Location	Number of Employees	Product
Brouk Co.	St. Louis, MO		
Cleveland Builders Supply Co.	Cleveland, OH		gypsum
Diversified Insulation Inc.	Minneapolis, MN		insulation
J.P. Austin Assoc., Inc.	Beaver Falls, PA		
W.R. Grace Co., Construction Products Div.	Irondale, AL		
W.R. Grace Co., Construction Products Div.	Phoenix, AZ		
W.R. Grace Co., Construction Products Div.	North Little Rock, AR	35	exfoliated vermiculite
W.R. Grace Co., Construction Products Div.	Newark, CA		
W.R. Grace Co., Construction Products Div.	Santa Ana, CA	200	concrete products
W.R. Grace Co., Construction Products Div.	Denver, CO		crude petroleum; oil and gas exploration; exfoliated vermiculite
W.R. Grace Co., Construction Products Div.	Pompano Beach, FL	25	chemicals
W.R. Grace Co., Construction Products Div.	Jacksonville, FL	36	exfoliated vermiculite
W.R. Grace Co., Construction Products Div.	Tampa, FL	75	fertilizers

Table 17. (continued)

Name	Location	Number of Employees	Product
.R. Grace Co., Construction Products Div.	Oklahoma City, OK		equipment rental and leasing; crude petroleum, oil and gas exploration, oil field and other machines
.R. Grace Co., Construction Products Div.	Portland, OR		
.R. Grace Co., Construction Products Div.	New Castle, PA	45	plastic products
.R. Grace Co., Construction Products Div.	Kearney, SC		
.R. Grace Co., Construction Products Div.	Travelers Rest, SC		
.R. Grace Co., Construction Products Div.	Enoree, SC	133	exfoliated vermiculite
W.R. Grace Co., Construction Products Div.	Nashville, TN	20	insulation; also fertilizers (105 employees)
W.R. Grace Co., Construction Products Div.	San Antonio, TX		
W.R. Grace Co., Construction Products Div.	Dallas, TX		soap and detergents
W.R. Grace Co., Construction Products Div.	Milwaukee, WI	21	chocolate and cocoa, exfoliated vermiculite
International Vermiculite Co.	Girard, IL	20 - 49	mineral wool
Koos Inc.	Kenosha, WI	100 - 249	agricultural chemicals

Table 18. Estimates for Vermiculite Transportation from Exfoliation Plant

	Exfoliated vermiculite (percent of total)		
End use	Bag	Bulk	Use at Plant
Aggregates	24		12
Insulation	31		
Agricultural chemical carrier	1	3	13
Growing media	7		7
Other uses	1		1
TOTAL	64	3	33

Source: JRB 1982.

Table 19. Summary of Estimated Population Exposure to Vermiculite

Population	Number of Establishments	Total Number of Persons	Number of Persons Exposed	Comments
I. OCCUPATIONAL				
A. Mines and millers of vermiculite	4	490 - 548		EIS data base 1980 & Versar estimate
B. Importers and exporters of vermiculite				
C. Exfoliators of vermiculite	50	1,694 - 1,979		EIS data base 1980 & Versar estimate
D. Users of unexfoliated vermiculite				
1. Steel workers				
• Furnacemen, smeltermen and pourers	27		76	NOHS data base 1980
• Metal molders	19		863	NOHS data base 1980
• All iron and steel foundry workers		195,000		NOHS data base 1980
2. Manufacturers of gypsum wallboard				
• See I.C.				
(a) Wholesale/retail traders of wallboard				
(b) Installers of wallboard				
• See I.E. 1.(a)				
E. Users of exfoliated vermiculite				
1. Producers of lightweight aggregates				
• See I.C.				
(a) Users of plasters, concretes, and aggregates containing vermiculite				
• Construction laborers	622		10,753	NOHS data base 1980
• Cement and concrete finishers	40		440	NOHS data base 1980
• Brick and stone masons	184		3,000	NOHS data base 1980

Table [illegible]

Population	Number of Establishments	Total Number of Persons	Number of Persons Exposed	Comments,
containing vermiculite				
(1) Users of pesticides and fertilizers				
• Nurserymen		> 3,400		Amer. Assoc. Nurserymen* 1981
• Greenhouse employees				
• Gardeners and groundskeepers	18		666	NOHS data base 1980
• Landscape contractors				
? • Agricultural workers: family		299,000		Bureau of Census 1980
• Agricultural workers: wage laborers	78		470	NOHS data base 1980
(2) Users of horicultural media				
• See I.E.3.(a)(1)				
• Florists	29,400	88,000		Bureau of Census 1980
(3) Users of cattle feed				
(4) Users of hatchery and poultry litter				
(b) Wholesale/retail traders of agricultural/horticultural products containing vermiculite				
• Hardware stores	26,500	112,800		Bureau of Census 1980
• Lawn and garden stores	15,500	27,000		Bureau of Census 1980
• Drug stores	44,400	440,000		Bureau of Census 1980
• Food stores		2,000,000		Bureau of Census 1980
• Feed/farm suppliers				Bureau of Census 1980
• General merchandise retailers		2,200,000		Bureau of Census 1980

Table 19. (continued)

Population	Number of Establishments	Total Number of Persons	Number of Persons Exposed	Comments
• Enamel				
• Ink				
• Plastics		145,000		Bureau of Census 1980
• Rubber		587,000		Bureau of Census 1980
• Paper				
• Fabrics				
• Plywood				
(2) Miscellaneous users of vermiculite products				
• Welders				
• Workers exposed for industrial premixes				
• Workers exposed to vermiculite sound insulation				
(3) Miscellaneous wholesalers/retailers of vermiculite products				
• See I.E.3.(b)				
• Pet stores				
5. Transporters of vermiculite				
(1) Truck drivers		1,900,000	129	Bureau of Census 1980 NOHS data base 1980
(2) Ship and dock workers				
(3) Rail workers				
• Freight handlers	33		108	NOHS data base 1980
(4) Warehousemen				

II. TRANSPORTATION AND STORAGE SPILLS

Table 19. (continued)

Population	Number of Establishments	Total Number of Persons	Number of Persons Exposed	Comments,
B. Water				
C. Land				

[a] All available and pertinent data are entered in the table; no entry indicates that no data are available.

* Personal communication between Debra Dillard of AAN and Pat Wood of Versar, November 2, 1981

† Personal communication between Susan Thomas of ACNP and Pat Wood of Versar, November 19, 1981.

‡ Personal communication between Betty Lerch of RI and Pat Wood of Versar, November 17, 1981.

Vermiculite is probably no longer used in the U.S. as a carrier for commercial pesticides and agricultural fertilizers. However, it is still a common ingredient in lawn and garden fertilizers as used by gardeners and groundskeepers, landscapers, nurserymen, and homeowners. About three-fourths of these mixtures are formulated at the exfoliating plant.

Vermiculite is also commonly used in growing media. Half of the vermiculite so used is formulated by the distributor into soil and soilless premixes; of this, 75 percent is shipped to greenhouses and the rest retailed to the consumer. The other half is bagged as is and shipped from the exfoliator to the distributor as "horticultural grade" vermiculite. It is probably not rebagged. It is used mainly as a mulch and soil conditioner, for hydroponics, and for packing bulbs and seeds for transportation. Of this horticultural grade sold, 50 percent is sold to landscapers, 30 percent to greenhouses, 15 percent to nursery and garden centers, and 5 percent to retail consumers (JRB 1982).

Vermiculite has minor agricultural uses in livestock feed, hatchery and poultry litter, and seed encapsulation. Few persons are expected to be exposed via these uses.

(4) Retail. Vermiculite has a number of consumer uses, and may be offered for sale in virtually any kind of store that sells merchandise for the home. It is also used in window displays.

(5) Castable refractories and firebricks. Vermiculite has refractory uses in aluminum and ferrous metal foundries as a component of molding sands and insulating cements and for other uses. Vermiculite-containing firebricks are used in high temperature furnaces and in other applications as listed in Table 19.

The above figures are based on the assumption that vermiculite insulation has been installed only during the past ten years. It is possible that the insulation has been used for a longer period of time but no confirmation was available.

7.2.2 Lawn and Garden Fertilizers

Market research (Simmons 1978) indicates that 33.8 percent of the U.S. population buys lawn and garden fertilizers each year (74.4 million persons based on 1980 population figures). The percentage of lawn fertilizers containing vermiculite is not known. Ortho and O.M. Scott are known to produce fertilizers containing vermiculite. Estech General has reported that vermiculite was removed from their Vigoro product line a few years ago (JRB 1982). Approximately 32 million households kept gardens in 1976 and 1977 (EPA 1980b). It may be assumed that fertilizer is used in all gardens, but again it is not known what proportion of garden fertilizers contain vermiculite.

7.2.3 Houseplants

The number of Americans who own at least one houseplant is not known but probably includes the vast majority of the population. The percentage of houseplant potting soils that contain vermiculite was not known. The majority of houseplant owners probably buy plants that are already potted and keep them indefinitely without repotting. If the soil does contain vermiculite, it is probably kept fairly moist, is rarely (if ever) disturbed, and would therefore not be a significant source of potential exposure. A small fraction of houseplant owners are hobbyists who buy significant quantities of premixed soil or who mix their own soil, often using bagged horticultural vermiculite. They would be exposed to vermiculite during mixing and repotting. Persons who cultivate succulents or who frequently use root cuttings would use the most vermiculite.

There are at least 3,000 owners of hobby greenhouses (Encyclopedia of Associations 1980) whose exposure to vermiculite should be comparable to that of greenhouse employees occupationally exposed.

levels of asbestos fibers. St. Louis was chosen as a representative site and was used in the ATM-SECPOP model (see Section 5.3.2) estimating ambient exposure from exfoliation. In the ATM-SECPOP results, all persons within 50 km were exposed to some asbestos. For the purposes of this exposure assessment, it was not possible to count the populations within 50 km of each site accurately. Instead, 1980 Census data (Bureau of Census 1981) were obtained for most of the 47 cities. Table 20 lists these data. The total number of persons ambiently exposed to asbestos from vermiculite exfoliation is estimated to be 13,147,496. Section 8 will discuss the level to which each subpopulation within that total is exposed.

The procedure used to estimate this population is limited, and the figures obtained must be considered approximations. The limitations include:

- Data were unavailable for three sites: Beltsville MD; Kearney, SC; and Enoree, SC. Maps indicate that these are small towns. A population of 1000 was assumed for each.
- It was not possible, within the scope and resources of this study, to determine the exfoliation plants' actual locations, to see whether nearby towns might be affected.
- It was assumed that the total reported population within a town would be exposed to some extent. ATM results indicate that fibers are dispersed to a 50 km radius, and it is unlikely that any city enumerated by the Census would exceed those bounds.
- It was assumed that asbestos is present as a contaminant in the vermiculite processed at all of the exfoliation plants. Actually, some vermiculite is not contaminated with asbestos.

It is not possible to determine the number of persons exposed to asbestos from vermiculite transport or disposal; in many cases they would be the same persons exposed via mining, milling, or exfoliation, since disposal and transport would be localized around these industrial sites.

No significant ambient exposure via water or land would be expected. Section 5, summarizing the fate and transport of asbestos fibers and exposure pathways, shows that water and land are not important sources of exposure to asbestos from vermiculite.

Table 21. Summary of Inhalation Exposure to Asbestos in Vermiculite

Population	Number of Persons Exposed[a]	Exposure Level[b] f/cc	Exposure Level[b] $\mu g/m^3$	Duration[c] (hrs/wk)	Comments
I. Occupational					
A. Miners and millers of vermiculite	~250	ND-9.7		43.0	Number of persons exposed estimated as one-half total employment.
B. Importers and exporters of vermiculite	unknown	unknown			
C. Exfoliators of vermiculite	1694-1979	ND-0.48		41.5	
D. Users of unexfoliated vermiculite					
1. Steel workers	919	unknown			
2. Manufacturers of gypsum wallboard	unknown	unknown			
(a) Wholesale/retail traders of gypsum wallboard	unknown	unknown			
(b) Installers of wallboard	unknown	unknown			

Table 21. Summary of Inhalation Exposure to Asbestos in Vermiculite (continued)

Population	Number of Persons Exposed[a]	Exposure Level[b] f/cc	Exposure Level[b] $\mu g/m^3$	Duration[c] (hrs/wk)	Comments
3. Producers of agricultural and horticultural products containing vermiculite	unknown	ND-0.48		41.8	Based upon most recent data from O.M. Scott.
(a) Users of agricultural/horticultural products containing vermiculite	>1136	ND		32.7	Level based on most recent O.M. Scott data.
(b) Wholesale/retail traders of agricultural/horticultural products containing vermiculite	unknown	unknown			
4. Producers of minor vermiculite-containing products					
(a) Producers and users of vermiculite filters for pollution control	unknown	unknown			
(b) Producers and users of oil-well drilling muds	unknown	unknown			

Table 21. Summary of Inhalation Exposures to Asbestos in Vermiculite (continued)

Population	Number of Persons Exposed[a]	Exposure Level[b] f/cc	Exposure Level[b] µg/m³	Duration[c] (hrs/wk)	Comments
III. Consumers					
A. Homeowners insulating attics with loose-fill vermiculite	188,000		7,200	8	Time-weighted average concentration estimate; one-time 8-hr exposure.
B. Users of lawn and garden fertilizers					Time-weighted average concentration estimate; once yearly exposures.
(1) lawn application	<74,400,000		4.4	4	
(2) garden application	<32,000,000		28	1	
C. Users of houseplant potting soil with vermiculite	>3000	unknown			
D. Users of vermiculite-based kitty litter	unknown	unknown			
E. Users of vermiculite in barbecue grills	<74,400,000	unknown			
IV. Disposal	unknown	unknown			
V. Food	unknown	unknown			
VI. Drinking water	unknown	unknown			

(2) Exfoliators of Vermiculite. Exfoliation of vermiculite leads to atmospheric emissions from process equipment and during handling. Uncontrolled emissions to the air within an exfoliation plant may lead to occupational exposure, while process vents to the outside lead to exposure via ambient air.

The actual number of persons exposed in the workplace to asbestos from exfoliation is not known; estimates range from 1,694 to 1,979 employees at 52 plants. Fiber levels within the exfoliation area vary between nondetectable and 0.48 f/cc. The higher exposure levels that have been recorded in the past are no longer encountered because of the installation of improved dust collection devices and enclosures (see Table 11).

(3) Transporters of Vermiculite. The number of persons involved in transportation of vermiculite is unknown; the NOHS survey identified 129 truck drivers and 108 rail workers exposed to asbestos from vermiculite transport (Table 21). It is probable that a large number of workers handling vermiculite in transport are unaccounted for.

Exposure during transport may be significant. Based upon personnel samples taken at one mine, truck drivers may be exposed to 0.3 f/cc. Rail workers are potentially exposed to high fiber counts resulting from the transfer of beneficiated vermiculite from railroad cars to exfoliation facilities. Fiber counts may range from 0.22 to 245.0 fibers/cc when handling Libby vermiculite. Warehouse workers handling the exfoliated product have been monitored with personal samplers. Results indicate that no exposure arose from warehouse handling of vermiculite, but it is likely that accidental spills occur with some regularity and lead to exposure during cleanup operations.

(4) Commercial and Industrial Users. This population includes formulators of consumer products and users of exfoliated and unexfoliated

vermiculite. Few data are available to quantify asbestos exposures within this group. Parts I.D. and I.E. of Table 21 present the available data. In some cases, product formulation data were not distinct from exfoliation data and the same figures were used for both worker subpopulations. This was the case for producers of lightweight aggregates, producers of vermiculite insulation, and producers of agricultural and horticultural products.

Table 22 lists the occupational subpopulations for which no data were available, and makes a qualitative statement of potential exposure.

8.1.2 Consumer Exposure

Consumer exposure has been calculated for three types of products: use of vermiculite loose-fill insulation in attics, use of lawn care products, and garden fertilizer application. The other consumer uses of vermiculite are not expected to lead to high exposure to asbestos; asbestos fibers either affect a very small population or they are not expected to be released during use.

(1) Consumer Installation of Loose-Fill Vermiculite Insulation. It has been estimated that the attics in 940,000 homes have been insulated with vermiculite in the last ten years (see Section 7.2.1). At the rate of 94,000 homes per year, and assuming that the job requires two people, approximately 188,000 consumers are exposed each year.

The estimates of asbestos concentrations in an average attic are seen in Section 6.5. The average exposure level is 7,200 $\mu g/m^3$ for the 8-hour period.

Once in place, vermiculite attic insulation would probably not lead to subsequent consumer exposure. The type of attic in which vermiculite is used is ordinarily isolated from the rest of the home and is not regularly entered.

(2) Consumer Use of Garden Fertilizer. As seen in Section 6.5, asbestos levels can be estimated to reach 57 $\mu g/m^3$ during application of garden fertilizer; a time-weighted average of 28 $\mu g/m^3$ represents the mean exposure

level. It is assumed that it takes one hour to fertilize the average garden and that it is done once yearly.

The proportion of garden fertilizers containing vermiculite and the proportion of contaminated mineral are unknown, but it is known that 32 million households had gardens in 1976 and 1977 (USEPA 1980b). If each gardener uses asbestos-contaminated vermiculite-based fertilizer, then approximately 32 million persons are exposed to 28 $\mu g/m^3$ asbestos during fertilizer use.

(3) Consumer Use of Lawn Care Products. This worst-case exposure scenario is based upon the "box model" estimated concentrations developed in Section 6.5. This analysis should be interpreted with caution in light of O.M. Scott's monitoring of air during use of their products, which detected no asbestos fibers (see Table 11). Each consumer might breathe a time-weighted asbestos concentration of 4.4 $\mu g/m^3$, for four hours once yearly.

Approximately 74.4 million Americans buy lawn and garden fertilizers each year. Again, the percentage buying asbestos-containing vermiculite products is unknown.

8.1.3 Ambient Exposure

Ambient exposure to asbestos from vermiculite is assumed to arise from two types of point sources: mines and exfoliation plants. This exposure is via releases into ambient air; water and land are not significant exposure sources (see Section 5.2).

(1) Ambient Exposure Near Mines and Mills. Approximately 4680 persons live in the three towns with vermiculite mines. All are probably exposed to asbestos fibers from controlled and uncontrolled emissions. Monitoring data collected at points around mines and mills indicate that levels of asbestos range from undetected to 0.5 fibers/cc. A full-time resident could be exposed to this level 24 hours per day. The respirable fraction of this level has not

unloading is probably very small because of the relatively low release rates; exposure to the transportation workers during loading and unloading is considered to be an occupational exposure and is discussed in Section 8.1.1 above.

Disposal comprises primarily landfilling solid wastes from mining, beneficiation, exfoliation, and processing, and also includes discarded end products (JRB 1982). Releases of vermiculite and asbestos from landfills are thought to be negligible. Wastewater from mining, beneficiation, and exfoliation is recycled (JRB 1982). Minor amounts of vermiculite and asbestos are released from water treatment operations at permanent vermiculite concrete plants (JRB 1982). Because water-mediated exposure to asbestos from vermiculite is not thought to be a significant route, and because the aqueous releases of vermiculite and asbestos are insignificant compared to air releases covered in the occupational, consumer, and ambient scenarios, this exposure pathway is considered to be negligible.

As discussed in Section 5.2.2, asbestos is not expected to be accumulated; therefore, food is not considered to be an applicable exposure scenario.

Drinking water could contain asbestos from waterborne releases from vermiculite processing and use. Releases to water from all sources are considered negligible (JRB 1982). Fate processes do, however, result in some intermedia transfer of asbestos from the atmospheric and land environments to surface water. The available data are inadequate to support a quantitative estimate of exposure from ingestion of drinking water, but it is considered unlikely that this exposure route is significant compared to the occupational, consumer, or ambient exposures discussed above.

8.1.5 Integrated Worst Case Exposure Scenario

The geographic distribution of vermiculite point sources and the widespread use of some vermiculite products indicate that individual exposure may come from numerous sources. This facilitates the creation of a plausible

Table 23. Worst-Case Individual Exposure Level Profile

Source of Exposure	Exposure level[a]
Working in an exfoliation plant 2,000 hours yearly	0.48 fibers/cc
Living in city with exfoliation plant 8,736 hours yearly	0.025 $\mu g/m^3$
Fertilizing garden once yearly for one hour	28 $\mu g/m^3$
Fertilizing lawn once yearly for four hours	4.4 $\mu g/m^3$
Insulating attic for 8 hours once in lifetime	7,200 $\mu g/m^3$

[a] Exposure levels from Table 21.

ENVIRONMENTAL POLLUTION BY ASBESTOS PRESENT IN VERMICULITE ORE

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Abstract

Raw vermiculite ore after exfoliation at high tempratures provides a low density material with excellant thermal and acoustical insulation properties, as well as a water storage enhancer in soil. The ore slated for mining in Louisa County, Virginia was found to contain two types of asbestos minerals, actinolite and chrysotile. Mining and milling of such ore may result in occupational as well as environmental contamination of air and water. Potential health hazards may also be associated with the use of asbestos-contaminated vermiculite consumer products, such as horticultural media and animal litter.

Two vermiculite firms, W.R. Grace & Co. and Virginia Vermiculite are seeking open pit mining permits for mining of vermiculite ore in the Green Springs, Virginia area. Historic Green Springs Inc., an environmental group with historic interests, has engaged in litigation with the mining board consequent to approval of two temporary permits. Both firms have confidently stated that there is no trace of asbestos in the proposed mining sites. A laboratory study was performed, by A.D. Little Inc., for W.R. Grace & Co., on ore samples from the same general location. The conclusions reached were that vermiculite, hornblende, and hydrobiotite were the major constituents and that the presence of tremolite was doubtful.

The mining and subsequent widespread use of such vermiculite ore raises the possibility of environmental contamination by the asbestos minerals present - chrysotile and tremolite/actinolite. These minerals have known human disease potential (1), being both carcinogenic and fibrogenic.

The structure of vermiculite consists of a central octahedrally coordinated layer of (Mg, Fe) ions between two inward pointing sheet of linked SiO_4 tetrahedra, giving an emperical chemical formula of $(Mg,Ca)_1(Mg,Fe^{+3},Al)_6((Al,Si)_8\ O_{20})\ (OH)_4 \cdot 8H_2O$. Geologically, vermiculite may be formed by two principal processes; one is in the region of contact between acid intrusives and basic or ultra-basic rocks. The second type of occurence is as an alteration product of biotite either by weathering or hydrothermal action (2). In the Green Springs area, the deposits of hornblende gabbro and gneiss are sufficiently near the surface to allow weathering alteration to for vermiculite.

Methods

Fourty court-sanctioned core samples, indexed by number were taken in the Green Springs area. Six of these samples were fowarded to the Environmental Sciences Laboratory for mineralogical analysis. This included examination by polarizing optical microscope, x-ray diffraction, transmission electron microscope, and scanning electron microscope with microchemical capabilities.

Raw ore samples were prepared for the optical microscope using conventional techniques of mineral fragment observation. Mineral properties and optical constants of each of the samples were measured. These included; color, morphology, cleavage traces, indicies of refraction, relief, birefringance, extinction angle, and pleochroism.

Six samples were prepared for the transmission electron microscope (TEM) by the wipe-out technique (see append.1). Along with these samples, three amphibole standards were also prepared. Actinolite, tremolite, and hornblende were selected because of their possible occurence in the samples.

Two grids from each were scanned at 20,000K. Because the fibril morphology of chrysotile is so unique, this mineral species may be identified by this method alone (3) (4). These fibers were sized and counted, and their mass concentration in the samples were calculated (see table 1). The amphibole minerals, however, needed further characterization after initial identification by selected area electron diffraction techniques on the TEM (see fig. 1 and append.) (5).These amphibole fibers were mapped for study under the scanning electron microscope (SEM).

The SEM, coupled with an energy dispersive x-ray detector, enabled semi-qualitative analyses of the mapped amphibole fibers and standards. It was necessary, because of the low emission of the light elements, to calibrate our instrument by including chemically analyzed standards in our analyses. Eight fibers of each standard and sample were analyzed and spectra recorded using a DEC PDP 11 computer. Vermiculite particles were included from each sample for comparison purposes.

An area, was recorded for each sample and standard, that straddled the center of each x-ray energy peak of magnesium, aluminum, silicon, potassium, calcium, and iron. Another area was subtracted which was representative of the background noise. Crude percentages were calculated for each element from the corrected areas. Using this data three component graphs for all the fibers were made up containing Mg:Ca:Al and Mg:K:Al (see fig. 2). The chemically analyzed actinolite fibers were also plotted on seperate three components containing the same systems.

For a quantative measurement, the samples were prepared for the x-ray diffractometer. The sonicated samples remaining from the wipe-out precedure were elutriated on a clean glass slide, taking care to concentrate the sample in the region of the incident beam. Each of the samples were continuously scanned through the 5-65 degrees 2θ region, where θ is the dispersion angle. The peak positions as a function of degrees 2θ were recorded and correlated using the ASTM x-ray powder data files.

To further quantify this, the samples were prepared for step-scanning by the filter mount method (see append. 1) (6). The diagnostic reflection of tremolite was step-scanned over a goniometric interval of 10.00-11.10 degrees 2θ. This interval proved sufficient to define a peak-to-background ratio (6). A digital printout of elapsed time in the fixed-count mode was used to prepare precise positions and profiles of these reflections. The area of which was determined using a compensating polar planimeter.

For comparison, binary systems containing talc and tremolite were prepared. Percentages of 25, 50, and 75% tremolite in talc were continuously scanned over the 5-65 degrees 2θ range (see fig. 3). However, because of orientation and microabsorption effects (7), a curve containing standards below ten percent tremolite in talc had to be prepared.

Results

Based on observations from the optical microscope, it was found that amphibole minerals were present in all the samples. The estimated percentages ranged from a trace quantity (about 1% or less) up to major constituents of the sample (>50%). The observed variance in asbestos content of the samples is a function of various geological factors. The close similarities and overlap of indicies of refraction of the amphibole minerals precluded positive identification by this technique.

The electron beam instruments enabled the identification of the particular species of amphibole mineral present. Using the microchemical capabilities of the SEM, it was possible to detect which cations were present in substitution. A graphic interpretation of the elemental percentages yielded actinolite as the major amphibole species present. The transmission electron microscope also allowed identification and quantitation of the fibrous serpentine mineral, chrysotile (see table 1).

The determination of the presence of amphibole minerals by optical microscopy was confirmed by the continuous scan mode of x-ray diffractometry. Amphibole phases were found in five of the six samples. Step-scanning of the diagnostic reflection (in the angular interval 10.0-11.1 2θ) permitted determination of the percentages of actinolite listed in table 1.

Summary

Mining and milling of this ore may pose a potential hazard to the miners and their families. A possible environmental hazard also exists by ambient air and water contamination resulting from this operation. It is suggested that other vermiculite ores be thoroughly studied to discern the content and hazards inherent in their production. Also that protective measures be employed in production areas already in progress.

The results of this study have been brought to the attention of the appropriate regulatory agencies, Occupational Safety and Health Administration and the Mining Enforcement and Safety Agency. It is their intention to monitor all vermiculite processing plants in the country for asbestos levels.

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CHEMICAL HAZARD INFORMATION PROFILE*
Environmental Protection Agency

DRAFT

Chemical: Vermiculite

CAS #: 1318-00-9

Date of Report: 9/21/79

CHIP Equivalent:

Rationale for CHIP Selection: Report of "bloody pleural effusion" in workers at vermiculite plant - in FYI submission.

Comments:

High exposure potential; demonstrated human toxicity, not on TSCA inventory - should have been included as a natural product.

* This report represents a preliminary investigation of the subject chemical's potential for injury to human health and the environment and therefore may not reflect all available information on the subject chemical. Any recommendations based on this report are tentative and should not be construed as final Agency policy with respect to the subject chemical.

DRAFT

Vermiculite 1318-00-9

Vermiculite, a hydrated magnesium -aluminum -iron silicate has a platelet-like crystalline structure with pseudo- hexagonal characteristics. For commercial purposes crude vermiculite is heated to "exfoliated" vermiculite. When heated vermiculite is capable of expanding 6-20 times its original size. Exfoliation takes place in vertical furnaces with temperatures ranging between 1600°F and 2000°F. When the water composition of vermiculite is heated to high temperatures the pressure of steam forces the laminar apart at right angles to the cleavage planes in an accordian-like form. Air spaces develop throughout the heated vermiculite thus its great bulk, low thermal capacity and high insulation value. (Otis, 1958)[1]

Vermiculite is a secondary mineral found in Montana, Wyoming, Colorado, Virginia, North and South Carolina and South Africa. The commercially significant deposits are located in Libby, Montana and South Africa. (Otis, 1958)

Vermiculite is soft, smooth, and resilient. It is soluble in hot concentrated sulfuric acid and insoluble in water and organic solvents. (Hawley, 1978)[2]

There are nineteen varieties of vermiculite known. Only the varieties vermiculite and jeffersite have been mined commercially. Although there is some disagreement as to whether vermiculites constitute a distinct chemical species, x-ray studies confirm that the diffraction patterns of vermiculite differ from true micas or chlorite. (Otis, 1958)

Molecular formula:	$3MgO\ Fe_2Al_2O_3\ 3SiO_2$
Hardness (Mohs scale)	1.5-3.0
Specific gravity	2.30-2.80
Melting point	2,425°F - 2,480°F

Production/Use

Uses of Vermiculite

insulating material
light weight concrete aggregate
additive of ferilizer
seed bed for plants
insecticide carrier
absorbent in the removal of strontium-90 from milk
removal of phosphates from wastewater
filler for paint, rubber, and plastics
animal feed additive
litter for hatcheries
packing material

(Hawley, 1977)[2]

Free world production of Crude - Vermiculite
Production (short tons)

	1974	1975	1976	1977
U.S.	341,000	330,000	300,000	320,000
S. Africa	200,000	230,000	250,000	255,000
other	12,000	12,000	12,000	12,000

(Riedl, 1977)[3]

Users:

Information on users of vermiculite is scant although O.M. Scott & Sons of Marysville, Ohio reports purchases of crude vermiculite from W.R. Grace, Libby, Montana and South Africa for usage in their lawn care products.

- Chemical Week Buyers Guide, 1979 lists suppliers of vermiculite[4]

Filter, - Media, Ind.
Grace, W.R. & Co.
Southwest Vermiculite Co., Inc.

Toxicity

Hunter and Thomson, 1973 administered 25 mg in 0.2 ml physiological saline of vermiculite or asbestos via intraplural injections to female CFY rats (50 rats/substance). Rats were maintained for 104 weeks or until death or culling for humane reasons. Vermiculite was purchased from the Palabora Mining Company Limited, South Africa. It cannot be determined from this study if there was any contamination of asbestos in the vermiculite.

The following table gives the percentage particle size of Asbestos and Vermiculite

Hunter and Thompson, 1975[5]

Size range (μm)

Material		≤2	2-5	6-10	11-15	16-20	>20
Rhodesian chyrosite asbestos	a	71.53		17.86	5.20	2.14	3.2[illegible]
	b	78.7	15.2	2.8		3.3	
Vermiculite	a	37.23	55.84	3.46	2.16	0.87	0.44

a: Estimations made by microscopy

b: From UICC (Union Internationale Contre le Cancer) data sheet [illegible]

Rats injected with vermiculite had a survival rate equivalent to or slightly superior to that of saline controls, whereas a higher mortality rate of chrysotile asbestos treated rats was a direct result of treatment.

A high incidence of mammary and pituitary gland tumors was observed in vermiculite or saline treated rats. This pathology also occurred in rats treated with asbestos but debility caused by mesotheliomata tended to reduce the number of rats at risk of developing mammary or pituitary gland tumors.

Among rats killed at week 104, macroscopically visible lung masses were confined to chrysotile asbestos treated rats. Tumors classified as mesotheliomata were observed in asbestos treated rats (21 out of 40 descedants and 2 out of 8 killed at week 104) Descendants treated with chrysotile asbestos showed macroscopic evidence of severe pulmonary damage including abcess formation, extensive fibrous adhesions between the visceral and parietal pleura in 31 out of 40 rats and suspected lung tumors in 21 out of 40 rats. Fibrous pleural adhesions were also noted in 13 out of 25 descendants in the group treated with vermiculite, but adhesions were not seen in the control rats.

The authors note that although vermiculite shares many of its chemical components with various types of asbestos, the particles were amorphous unlike the fibrous particles of asbestos.

No other toxicity studies concerning vermiculite could be found in the available literature.

It should be noted that some researchers believe that for fibrous materials, fiber size rather than chemical composition determines the biological effect.[6,7].

O.M. Scott and Sons Company report 4 workers at their Marysville, Ohio fertilizer plant who work with vermiculite experienced bloody pleural effusions. For 20 years O.M. Scott & Sons has relied on vermiculite as an inert carrier on which fertilizer and pesticide chemicals would be applied to form finished products. Raw vermiculite is mined and classified in Libby, Montana and South Africia and shipped to the Marysville plant. In the Trionized where there are approximately 50 workers, the vermiculite is exfoliated.

Company samples of the vermiculite have shown the presence of asbestos in Libby, Montana vermiculite but not in the South African ore. The samples have also generally shown that asbestos (in the form of tremolite) is present in the crude ore but not in the expanded vermiculite. It has recently been reported that asbestos levels are in accordance with OSHA standards. However earlier samples taken by the company reported high levels of asbestos (up to 245 fibers/cc) during railroad car unloading. It is not known whether all the fibers were asbestos since further microscopy has identified other fibers and cleavage fragments.[8]

Listed below are analysis of chest x-rays and pulmonary function data for workers at O.M. Scott and Co. at the Marysville, Ohio plant. Tables and discussion were provided by physicians contracted by OSHA. This information was compiled January, 1979.

In a personal communication with OSHA representative, Dr. Victor Alexander, it has been learned that an additional 3 workers have experienced bloody pleural effusions. OSHA has also contracted for another more extensive study to examine workers in the Scott plant. The study with a preliminary final report is expected to be completed by January, 1980.

Scott Chemical Company

(Table 1) The overall prevalence of pleural and/or interstitial abnormalities, among workers whose chest x-rays were reviewed, was approximately twice as great in the trionized process compared to both maintenance and packaging workers, without taking into consideration age or length of employment (seniority).

(Table 3) Overall, the proportion of pleural and/or interstitial abnormalities increased with length of employment for all departments. On a departmental basis, the increase in proportion of abnormalities was noted in the trionized process and mainteance departments, but peaked in the 10-19 year seniority group in the packaging department.

(Tables 4 and 5) The proportion of abnormal chest x-rays increased with age.

(Table 6) The proportion of obstructive changes on pft increased with age for workers in the packaging and maintenance departments. Evidence of restrictive changes in the absence of obstructive changes increased with age only among workers in the trionized process. Smoking histories were not available.

IV. BACKGROUND

Exposure to asbestos-contaminated vermiculite in the workplace and during mining operations.

In December 1978, O.M. Scott and Sons submitted information to EPA regarding serious health problems experienced by workers who were processing asbestos-contaminated vermiculite in their chemical fertilizer plant in Marysville, Ohio.[10]. The original submission indicated that bloody pleural effusions had been detected in 4 of 350 employees; symptoms and clinical findings in the employees were similar to those found in individuals with asbestos-related diseases. Subsequent follow-up studies initiated by OSHA[11] revealed that the prevelance of health problems among employees at O.M. Scott and Sons was greater than originally expected. Thirty-two cases of pleural and/or interstitial abnormalities were detected by chest x-rays and/or spirometric measurements (x-rays were taken for 125 of 221 workers).

The cause of the disease was most probably due to inhaled asbestos dust. Monitoring data revealed that prior to the installation of more stringent safety controls in 1976, plant employees were occasionally acutely exposed to airborne asbestos. One air sample taken in the unloading area was found to contain 245 fibers/cm^3. Subsequent microscopic studies have identified other types of fibers and cleavage products in addition to asbestos. Similar high fiber levels have been reported elsewhere. A plant in St. Paul, Minnesota which also processes vermiculite containing asbestos was found to have peak levels as high as 163 fibers/cm^3.[12]

Although adverse health effects developed by workers at O.M. Scott & Sons appear to be caused by asbestos exposure, other factors cannot be discounted. Since little data exists for health effects from pure vermiculite (fibrous or nonfibrous), it is possible that cleavage fragments or fibers of vermiculite itself caused the effects. Free silica present in the dust is another possible toxicant. Alternatively, fertilizer and pesticide chemicals, which are coated onto the vermiculite surface in the production process, may have adhered onto the fibers that were inhaled and could have contributed to the adverse health effects. Further studies would have to investigate these possibilities. At this time, the only known toxic chemical to which the workers were exposed is asbestos.

The source of asbestos contamination may have resulted from the use of vermiculite from Grace mines in Libby, Montana. Grace acknowledged the presence of asbestos in the vermiculite from that mine in 1971.[13] In 1977, an EPA study reported the presence of substantial amounts of asbestiform amphibole fibers in the tailings (residues) from mining and milling operations.[14] During beneficiation, impurities in the raw vermiculite ore are physically separated by a "wet" process in which adhering clay and other impurities are removed by washing. However, attempts to remove all impurities have been unsuccessful and tremolite asbestos remains as a contaminant in the vermiculite. The current asbestos concentration in ore leaving the Libby mines has reportedly been reduced to 0.5%.[15]

In the past, mining employees had been exposed to asbestos-containing fiber levels in excess of the current OSHA 8-hour TWA standard of 2 fibers/cm^3.[7] Current levels in the ambient air surrounding the Libby mines range from 0.3 to 2.6 fibers/cm^3.[7] Equipment operators are exposed to levels of 0.6-1.8 fibers/cm^3,[16] and workers in loading areas are exposed to fiber levels in the range from 0.2 to 5 fibers/cm^3.[17] To date lung scarring has been noted in some employees[8] and there were two reported cases of "dust related lung diseases" in 1979.[18] NIOSH is currently conducting a thorough study on adverse health effects of Libby miners.[19]

Release of Asbestos from Vermiculite Products or End Uses

In addition to workers, a substantial number of consumers and product end-users are potentially exposed to asbestos from asbestos-contaminated vermiculite. Although no data exists to substantiate this premise, engineering calculations have shown that levels of asbestos release into the atmosphere during end use may not be negligible.[20]. Figure 1 diagrams the estimated amounts of asbestos released during mining, production and use of vermiculite. The greatest source of current asbestos release to air is during the exfoliation process. At present exfoliation is estimated to release 140 kkg/yr of asbestos, or 58 percent of the total airborne releases. The second major source of airborne asbestos is the mining and milling process, which is estimated to release 102 kkg/yr, or 42 percent of the total. Vermiculite end uses account for less than 1 percent of total airborne releases. Although the quantitites of asbestos released during end-use are small in comparison to the mine and workplace, the aggregate risk to the consumer or product end user may be large in view of the large number of people exposed. Moreover, users may be particularly vulnerable and unprotected due to ignorance of the potential hazard.

V. REGULATORY STATUS

This section reviews the authorities and actions of Federal agencies as they relate to control of health risks from exposure to vermiculite. A number of federal agencies have issued regulations to control exposure to asbestos. Two agencies have issued regulations that control human exposure to asbestos-contaminated vermiculite. This chapter gives a summary of these regulations and gives information on the extent to which they may control exposure to asbestos-contaminated vermiculite. It also speculates on whether laws administered by the agencies might be used to develop regulations to control asbestos-contaminated vermiculite in the future. Where possible, the potential effect of these regulations is estimated.

Consumer Product Safety Commission (CPSC)

CPSC can regulate asbestos in consumer products under two acts. The Consumer Product Safety Act[21] gives CPSC the general responsibility to protect the public from unreasonable risks of injury, illness, or death associated with consumer products. The Federal Hazardous Substances Act[22] gives CPSC the mandate to regulate hazards presented by the presence or use of toxic and other hazardous substances in the household. CPSC has used the Consumer Product Safety Act to ban two consumer products that contain asbestos: artificial members and spackling compound.[23] Neither product is associated with the vermiculite industry.

CPSC has announced that it is using its regulatory authority to begin a comprehensive investigation of the use of asbestos in other consumer products. As stated in an October 17, 1979 Advance Notice of Proposed Rulemaking (ANPRM), CPSC's general approach will be to seek to eliminate "all non-essential uses of asbestos in consumer products from which asbestos fibers are released during reasonably forseeable conditions of use, including misuse."[24] The ANPRM solicited general information on consumer products that contain asbestos, and stated that the Commission intended to issue general and special orders in the future to require some firms to submit information on specific products. The ANPRM included a list of approximately 100 products and classes of products that contain asbestos. One item that appeared on the list was "potting materials (vermiculite)." The Commission later published a general order requiring firms to submit information on 16 asbestos-containing products. Vermiculite does not appear on the list of products that are subject to this general order.[25] The regulation of the use of asbestos-contaiminated vermiculite for potting materials appears to be possible given the broad nature of CPSC mandate under the Consumer Product Safety Act and the seriousness of the health effects of asbestos. However, it appears that the Commission has decided to seek information first, about products in which asbestos is intentionally added rather than about vermiculite products in which asbestos is present as a contaminant.

DECISION PAPER

for

ASBESTOS-CONTAMINATED VERMICULITE

Prepared by

Albert Colli
William Stigliani
Kirk Johnson

Chemical Control Division
Office of Toxic Substances

February 1981

The inadvertent presence of asbestos in materials (i.e. contamination) appears to be broader in scope than the Commission previously assumed. It is likely that the CPSC will address asbestos contamination as a separate issue.

CPSC also has the authority under the Consumer Product Safety Act[26] to require firms to label a product to identify its contents.[26] However, it is not clear whether the Commission will choose to use this authority. When CPSC regulated spackling compounds and artificial embers, the Commission stated that there was no safe level of exposure to asbestos and that "only banning these products can adequately protect the public from unreasonable risks of injury associated with them."[27] CPSC may decide that it would be inconsistent to propose a labeling rule after taking such a strong stand against asbestos with the ban rule.

In short, CPSC appears to have the authority to ban or to require labeling of asbestos-contaminated vermiculite and other consumer products that contain asbestos. The question is whether the Commission will choose to use this authority. It appears somewhat doubtful that CPSC will regulate asbestos-containing vermiculite, at least in the near future, but this possibility does exist. Whether any action that CPSC takes would have a widespread effect throughout the vermiculite industry depends on the number of products that CPSC can regulate. Vermiculite products can be thought of as belonging in one of three categories: those that are exclusively consumer products, those that are used for both consumer and industrial uses, and those that are used only for industrial uses. We have little information on how many products fall in each category. On the basis of the information we do have about the end uses of vermiculite, it appears likely that CPSC would not be able to regulate the bulk of asbestos-contaminated products; these would have to be controlled by other agencies.

<u>Department of Transportation</u> (DOT)

Under the authority of the Hazardous Materials Transportation Act[28], DOT has issued a regulation to control the transportation of asbestos. The regulation states that so-called "commercial asbestos" must be contained in airtight packaging or bags when it is shipped by freight containers, motor vehicles, and other modes of transportation.

This regulation is not applicable to asbestos-contaminated vermiculite. The reason is DOT's definition of commercial asbestos: "any material or product containing asbestos that has commercial value because of its asbestos content."[29] Clearly, this regulation was meant to cover products to which asbestos is added intentionally, rather than those where it occurs as a contaminant. According to a DOT spokesman, in order for the regulation to be applicable to vermiculite, vermiculite would have to be placed on DOT's list of hazardous materials in its own right, without considering the health effects of asbestos.[30] Because so little is known about the health effects of vermiculite, the chances of this occuring are undoubtedly slim.

The amount of asbestos that is released into the environment during transportation is very small, about 1% of the air releases and .03% of all releases.[31] Any control of these emissions would have to come from another Act (TSCA, for example, which offers life cycle control).

Food and Drug Administration (FDA)

FDA implements several laws that have been used to control asbestos. However, because vermiculite is neither a food nor a drug, these laws are not applicable to asbestos-contaminated vermiculite.

Occupational Safety and Health Administration (OSHA)

OSHA has used the Occupational Safety and Health Act's[32] broad mandate to provide a safe environment for workers by issuing a regulation containing two major provisions controlling asbestos exposure in the workplace. The first is an exposure standard. The second is a labeling requirement.

OSHA's current exposure standard, an 8-hour time-weighted average of 2 fibers of asbestos per cubic centimeter (f/cc) of air or a peak concentration of 10 f/cc, applies to "employment performed in a workplace" as stated in the Act.[33]

OSHA's workplace standard for asbestos does not apply to mines. Theoretically, the standard protects workers along the remainder of the life cycle of vermiculite, i.e., at mills and exfoliation plants, and where vermiculite is processed. Realistically, however, it is difficult to imagine the standard being enforced at many of these latter sites. For example, it i doubtful that employers at greenhouses where vermiculite is usec as a soil conditioner run their businesses with the asbestos standard in mind. Few employers besides those involved in the initial stages of vermiculite processing know that vermiculite often contaminated with asbestos.

Preliminary information that we have received indicates th the OSHA fiber limits can be exceeded at plants where vermiculi is processed, particularly during exfoliation.[34] However, both OSHA and EPA have stated publicly that no safe level of exposur to asbestos has been determined. In fact, OSHA has stated tha its current exposure standard in not sufficient to protect wor health.[35] It appears, then, that OSHA's authority may not off workers sufficient protection in all circumstances, and that a case could be made for using a different authority to reduce workplace exposures to asbestos.

OSHA's second major provision in the regulation deals wi labeling. The regulation requires that warning labels be affixed to "all [asbestos-containing] raw materials, mixtures, scrap, containers, except that no label is required where asbestos fibers have been modified by a bonding agent, coating, binder, or other material so that during any reasonably forseeable use, handling, storage, disposal, processing, or transportation, no airborne concentrations of asbestos fibers in excess of the [OSHA exposure limits] will be released."[36] The standard also states the warning message that the label must give.[37] This labeling provision appears to be applicable to asbestos-contaminated vermiculite. However, we are aware of no manufacturers of vermiculite who currently label their product to show that it contains asbestos. There appear to be at least two reasons why.

First, the OSHA regulation does not require manufacturers to label. It leaves to a manufacturer the decision of whether an item will be labeled. As long as a manufacturer believes that the use (handling, storage, etc.) of a product will not create fiber levels above the OSHA standard, he or she is not compelled to label it. Second, there is the possibility that some manufacturers of asbestos-contaminated vermiculite are not complying with the OSHA regulation by failing to label vermiculite that they know creates exposures greater than the OSHA limits.

It seems, then, that although OSHA's labeling standard applies to vermiculite plants, it is not strong enough to compel owners and operators of these plants to label their product with a warning about asbestos.

OSHA proposed a general labeling rule on January 16, 1981.[38] This rule would require labeling of various classifications of hazardous materials. It would apply to "a consituent substance in an amount of at least 0.1% (by weight) which is known to be a carcinogen".[39] However, the propsed standard would exempt from the labeling requirements those substances that are subject to an other OSHA labeling standard. Therefore, asbestos would not be subject to this proposed labeling requirements. Also, there is some question as to whether OSHA's broad labeling rule will be promulgated in its present form, or at all, because of a shift in national priorities.

<u>Mine Safety and Health Administration</u> (MSHA)

Under the Federal Metal and Nonmetallic Mine Safety Act[40], MSHA has issued a regulation to limit exposure of miners to asbestos.[41] The regulation sets limits for the allowable time-weighted average and peak concentrations of asbestos to which miners can be exposed. These concentrations are identical to the OSHA standard. MSHA's regulation is applicable to asbestos-contaminated vermiculite mines[42] and affects directly the approximately 260 miners in the vermiculite industry. Any future regulation (the most foreseeable one would be another revision of the workplace standard to match a revised OSHA standard) would continue to be applicable to these miners. A regulation issued by MSHA does not control exposures to workers or the general public past the mining stage.

Federal Trade Commission (FTC)

At present, FTC has no regulations that apply to asbestos. However, the Commission is investigating the possibility of using the Federal Trade Commission Act to require manufacturers to label asbestos-contaminated vermiculite to alert purchasers to the presence of asbestos. Section 5 of the Act enables FTC to take action to prevent "unfair and deceptive trade acts or practices."[43] FTC might argue that not alerting a consumer to the presence of respirable asbestos in a product is unfair and deceptive within the meaning of the Act. FTC's investigation is still in the most germinal stages. An FTC spokesman has said that the Commission will probably regulate asbestos-contaminated vermiculite only if other agencies do not do so.[44] If the Commission issued a labeling requirement, it would only affect manufacturers of vermiculite that is present as a consumer product.[45]

Environmental Protection Agency (EPA)

EPA currently has no regulations that apply to asbestos-contaminated vermiculite. The Agency has issued a number of regulations to control asbestos. Under the Toxic Substances Control Act, EPA along with CPSC has issued an ANPRM that announced that the Agency was seeking to control commercial and industrial uses of asbestos.

The vast majority of the air emissions, liquid effluent, and solid waste resulting from vermiculite processing is created during mining, milling, and exfoliation. These three stages are estimated to account for 99% of the air emissions, 99% of the liquid waste, and 99% of the solid waste of asbestos. GCA estimates that the liquid effluent and the solid waste that are generated at vermiculite plants do not appear to result in significant releases.[46] A far more serious problem is created by air emissions.

To help control these air emissions under the Clean Air Act, the Agency could simply add "vermiculite plants" to the list of stationary sources already subject to the no visible emissions requirement of the National Emission Standards for Hazardous Air Pollutants (NESHAPs) regulation. There are two points that should be considered. First, the no visible emission requirements were promulgated after the Agency decided that a more conventional technology-based standard would be inappropriate for asbestos because of the problems associated with measuring asbestos emissions.[47] Second, Dr. William Nicholson of Mt. Sinai Hospital in New York has stated that this no visible emission standard allows fiber levels well in excess of the OSHA standard to be released into the environment.[48] It may be advisable to consider more stringent controls than those possible with the current NESHAPs regulation.

State Regulation

The Occupational Safety and Health Act allows States to submit plans for developing safety and health standards to OSHA. If these plans are approved, States are authorized to issue and enforce the standards, which must be at least as stringent as federal standards.[49] A number of States have used these provisions of the Act to develop standards for workplace exposure to asbestos. These are often identical to the federal standard of 2 f/cc 8-hour TWA, 10 f/cc peak.

To our knowledge, only one State, Minnesota, has used its authority to enforce a workplace standard for asbestos at a vermiculite plant. In November 1980, an inspector from Minnesota's Department of Labor and Industry responded to a complaint filed by an employee at the MacArthur Company in St. Paul. The inspector took a number of air samples as a boxcar of vermiculite was being unloaded and concluded that fiber levels in the plant exceeded both the ceiling and 8-hour TWA concentrations allowable by law.[50] Presumably, the State is taking action to rectify conditions at this plant.

Because of this case, other States and OSHA might be pursuaded to inspect vermiculite plants for violations of the asbestos standard. EPA might consider recommending (perhaps through OSHA) that State occupational safety and health departments add vermiculite plants to their lists of asbestos facilities that they already inspect.

Summary

Table 1 is a summary of the extent to which existing and potential regulations offer control of asbestos-contaminated vermiculite. The regulations that exist have not been successful in minimizing exposure of workers and the general public to asbestos-contaminated vermiculite.

VI. Regulatory Options Analysis

A preliminary evaluation of the costs and effectiveness of various control options was conducted by GCA under contract to OPTS.[50] Most of the options chosen could be implemented under the TSCA. In some cases other authorities may be more appropriate to implement an option.

A series of engineering assumptions was made in this preliminary study because there was insufficient data available to complete the work otherwise. The goal was to develop preliminary information to determine whether rulemaking proceedings should be initiated as opposed to detailed information to support proposed and final rules. The analysis in this study should be regarded as tentative and subject to revision when more definitive data becomes available.

The regulatory control options evaluated by GCA are described below:

Option 1 - Restrict the Level of Asbestos in Crude Vermiculite

This option would place a limit on the level of asbestos allowed in crude vermiculite produced or consumed in the United States. Currently, the average asbestos concentration of crude vermiculite produced by Grace, the largest domestic supplier, is reported to be 0.5 percent by weight. Two alternative beneficiating processes which are estimated to lower the concentration to asbestos levels of 0.1 and 0.25 percent are considered.

The 0.1 percent asbestos level is to be achieved by dissolving the tremolite out of the vermiculite by acid leaching at elevated temperatures and pressures. Although this process has not been used with vermiculite, the successful separation of tremolite from talc caused GCA to hypothesize that it could be used to beneficiate vermiculite.[50]

The 0.25 percent level is believed to be attainable by using a process patented by the Zonelite Corporation for beneficiating vermiculite. In this process a concentrated salt solution is used to partially exfoliate vermiculite and lower its density so that the heavier gangue minerals can be separated gravimetrically.

Option 2 - Restrict the Level of Asbestos in Exfoliated Vermiculite

This option will place a limit on the level of asbestos allowable in exfoliated vermiculite. It is assumed that asbestos content is directly proportional to the surface area per unit volume of each grade because asbestos-rich dust will be retained at the surface of exfoliated vermiculite. The level of asbestos in vermiculite will thus be greater for the finer product grades. The analysis presumes that industry would respond to 0.25 percent limit in exfoliated vermiculite by curtailing the production of grade 5(2a). If a 0.13 percent limit on asbestos concentration was imposed it is presumed that industry would terminate production of grades 4 and 5(2b). GCA assumes[49] that the finely divided dust associated with vermiculite was richer in asbestos than the coarser material and that efficient screening of the exfoliated vermiculite would reduce the asbestos content of the vermiculite to 0.08 percent (2c).

Option 3 - Restrict the Release of Asbestos to the Workplace During Vermiculite Processing

A lower limit on the asbestos concentration in the workplace would be required by this option. The current level of control is 2.0 fibers per cubic centimeter (f/cc) of air averaged over an 8 hour-day with peak concentrations limited to 10 f/cc. This option would reduce the level of control to 0.5 f/cc. averaged over an 8 hour-day.

Option 4 - Restrict the Manner in Which Asbestos-Contaminated Wastes are Disposed

This regulatory control would require that all asbestos-contaminated wastes generated during mining, milling and exfoliation be disposed of in such a way as to reduce asbestos releases to the environment and minimize human exposure. Solid and liquid wastes generated during mining, beneficiation, and exfoliation of vermiculite contain concentrated asbestos fiber. Dust collected by air pollution control devices and solid waste material generated during crushing, screening and destoning steps would be properly handled and disposed of to minimize environmental release. Liquid wastes containing asbestos would be discharged to tailings ponds. When full they would be covered with soil and seeded over.

Option 5 - Ban the Use of Asbestos-Contaminated Vermiculite

This option has been defined in a manner as to ban all vermiculite. There is evidence that one or more of the asbestos minerals may be present in all deposits of vermiculite.

Option 6 - Ban the Use of Vermiculite for Specific Uses

A ban on selected uses of vermiculite would be implemented by this option. For example, the use of vermiculite for attic insulation may be of particular concern because the material is applied by people in confined areas. Also, the risks to human health associated with the use of raw vermiculite should be investigated thoroughly because it contains higher levels of asbestos.

grades. The analysis presumes that industry would respond to 0.25 percent limit in exfoliated vermiculite by curtailing the production of grade 5(2a). If a 0.13 percent limit on asbestos concentration was imposed it is presumed that industry would terminate production of grades 4 and 5(2b). GCA assumes[49] that the finely divided dust associated with vermiculite was richer in asbestos than the coarser material and that efficient screening of the exfoliated vermiculite would reduce the asbestos content of the vermiculite to 0.08 percent (2c).

Option 3 - Restrict the Release of Asbestos to the Workplace During Vermiculite Processing

A lower limit on the asbestos concentration in the workplace would be required by this option. The current level of control is 2.0 fibers per cubic centimeter (f/cc) of air averaged over an 8 hour-day with peak concentrations limited to 10 f/cc. This option would reduce the level of control to 0.5 f/cc. averaged over an 8 hour-day.

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Option 7 - Require Firms Mining or Exfoliating Vermiculite to Report

This option requires record keeping and reporting to EPA. It provides a means of tracing the flow of asbestos-containing vermiculite throughout its lifecycle, from production to end-use, including its intermediate transfers. This option will not result in any direct release reduction. It allows the government to gather information from the industry on a regular basis. Also, it may result in a risk reduction by making firms aware of the potential hazards.

Option 8 - Require all Substances Containing Vermiculite to be Labelled with Information on Asbestos Contamination

This option requires a warning label on all packages containing asbestos-contaminated vermiculite. It will serve to inform users of the possible asbestos hazards associated with its use.

Conclusions from Regulatory Options Analysis

Eight options for reducing the release of asbestos from contaminated vermiculite have been evaluated. Table 2 summarizes their effectiveness in reducing the release of asbestos and the costs associated with their implementation. Figures 2 through 6 illustrates the impacts of Options 1 and 2 in more detail.

Specific conclusions are as follows:

- The quantity of asbestos in raw vermiculite may be reduced by 44 to 56% of present levels through more effective processing at the mine (Option 1). The costs increase by a factor of seven in improving the efficiency of asbestos removal from 44% ($8/kkg) to 56% ($53/kkg) at Grace's Libby mine. (For comparison, GCA estimates a cost of $1.37/kkg to ship vermiculite 100 km.)

- Implementing Option 1 would cause a significant reduction in airborne asbestos release during exfoliation, and would cause a somewhat smaller decrease in releases from the end-uses.

- Restricting the level of asbestos in exfoliated vermiculite (Option 2) primarily affects releases from vermiculite end-uses. Although the effect of the option on total release is small, the reduction of airborne asbestos releases from the uses of vermiculite range from 10% to 75% depending upon the level of controls that are imposed.

TABLE 2 ESTIMATED IMPACT OF IMPLEMENTATION OF REGULATORY CONTROL OPTIONS

Option	Level of restriction or control measure	Release Reduction: Air Release (%)	Release Reduction: Total (%)	Release Reduction: Total kkg/yr	Population	Estimated vermiculite cost increase ($/kkg)	COMMENT
1. Restrict the level of asbestos in raw vermiculite	a. To a level of 0.1% (Acid Leaching).	56	9.8	875	W, G	35 to 70 42 to 84 116 to 233 147 to 294	Cost increases are for W.R. Grace, Montana, W.R. Grace, S.C., Virginia Vermiculite, and Patterson Vermiculite, S.C., respectively
	b. To a level of 0.25% (Salt Treatment).	44.4	7.6	674	W	5 to 11 7 to 14 16 to 33 20 to 40	Same as above
2. Restrict the level of asbestos in exfoliated vermiculite	a. To a level of less than 0.25% in any grade or 0.12% average	10.4	1.8	202	W, G	13	This option assume - Grade 5 would no longer be marketed.
	b. To a level of less than 0.13% in any grade or 0.07% average.	74.8	58.0	5,083	W, G	43	This option assumes Grades 4 and 5 would no longer be marketed
	c. To a level of less than 0.21% in any grade or 0.08% average.	64.0*	0.2	21	G	S	This option assumes screening to seperate asbestos after exfoliation.
3. Restrict release of asbestos to the workplace during vermiculite processing.	To a level of 0.5 fiber/cc.	75.0	1.3	118	W	28	Only a fraction of the cost affects the vermiculite concentrate price - the remainder affects exfoliated vermiculite price.
4. Restrict the manner in which asbestos contaminated vermiculite wastes are disposed.	Containerize solid waste; dispose of all wastes in secure landfills	S	2.6	230	W, G	0.2	NESHAPS asbestos regulations describe waste handling procedures. An additional price increase of $1.97 per kkg of exfoliated vermiculite would result from this option.
5. Ban asbestos-contaminated vermiculite.	Asbestos contamination defined by most sensitive test available - detection limit below 0.2%	100	100	8,845	W, G	N/A	Vermiculite production and use will be discontinued.

TABLE 2 (continued)

Option	Level of restriction or control measure	Release Reduction: Air Release (%)	Release Reduction: Total (%)	Release Reduction: Total kkg/yr	Population	Estimated vermiculite cost increase ($/kkg)	COMMENT
6. Ban specific vermiculite applications	6.a. Ban vermiculite concrete aggregate.	35*	2.1*	1.4	W, G	N/A	
	6.b. Ban vermiculite plaster and premix aggregate	53.0*	2.7*	1.8	W, G	N/A	
	6.c. Ban vermiculite attic insulation and packing	0.1*	0.2*	0.1	W, G	N/A	
	6.d. Ban vermiculite blockfill insulation	2.1*	0.5*	0.3	W, G	N/A	
	6.eBan use of vermiculite as steel and foundry insulation	12.0*	10*	6.8	W, G	N/A	
	6.f. Ban vermiculite for horticultural use and soil premixes.	1.8*	79*	52	W, G	N/A	
	6.g. Ban vermiculite's use as an agricultural carrier	0.1*	0.3*	0.2	W, G	N/A	
	6.h. Ban vermiculite's use in gypsum board.	1.7*	1.8*	1.2	W, G	N/A	
	6.i. Ban vermiculite's miscellaneous uses.	26*	2.4*	1.6	W, G	N/A	
7. Require firms mining or exfoliating vermiculite to report	Reporting by 4 mines, 52 exfoliation plants.	S	2.6	230	W, G	0.2	
8. Require substances containing vermiculite to be labeled with information on	Same as above	S	S	S	W,G	<0.1	

Source: GCA, op. cit., p.193.
* Reduction in air releases only
Notes: N/A = Not applicable
S = Small
W = Worker
G = General Population

VIII. ALTERNATIVE CONTROL STRATEGIES

Section V of this document contains a discussion of the non-TSCA options that could be used to control asbestos-contaminated vermiculite. It notes that several federal agencies have the authority to control exposure to asbestos-contaminated vermiculite, but that this control is piecemeal and does not extend throughout the life cycle. Furthermore, it appears that none of the agencies will take further action to regulate exposures in the near future.

Section VI contains a discussion of the major ways that EPA could control asbestos-contaminated vermiculite under TSCA. TSCA appears to offer much more definitive control of the problem and could be used to reduce exposures throughout the life cycle.

In Section VII, the major technical problems associated with control of asbestos-contaminated vermiculite are discussed so that they can be considered in the decision regarding control strategy for this chemical.

In this Section the results of Sections V, VI and VII will be used to present alternative strategies for controlling asbestos-contaminated vermiculite. These have emerged from an examination of EPA's authority under TSCA and other acts, the acts administered by other agencies, and a number of non-regulatory options. At the present stage of knowledge there appears to be five major alternatives for EPA in designing such a strategy.

They are:

ALTERNATIVE 1	Take no action at this time;
ALTERNATIVE 2	Gather information;
ALTERNATIVE 3	Pursue voluntary controls with the vermiculite industry;
ALTERNATIVE 4	Pursue a rule under TSCA requiring labeling of asbestos-contaminated vermiculite;
ALTERNATIVE 5	Take action under section 6 of TSCA to control asbestos-contaminated vermiculite.

The advantages and disadvantages of each alternative are discussed below. These alternatives are not mutually exclusive.

ALTERNATIVE 1: Take no action at this time

PRO

- EPA resources may be freed to control other chemicals.
- A rule to control asbestos-contaminated vermiculite may complicate EPA's rulemaking to control industrial and commercial uses of asbestos.
- The technical problems associated with measuring low levels of asbestos in vermiculite and resulting exposure levels will make development of a rule difficult.
- A rule may have particularly adverse effects on the national economy because domestic supplies of vermiculite may contain higher levels of asbestos than foreign sources.

CON

- People may continue to develop adverse health effects from exposure to asbestos-contaminated vermiculite if we take no action.
- If EPA does not take action under TSCA, it is unlikely that any other agency will take new action to control this problem, at least in the near future.*
- Industry's current controls, which limit contamination to an average of about 0.2% asbestos by weight, may not offer adequate protection because large numbers of microscopic asbestos fibers may be released at that level.

Estimated Resource Requirements:

No additional resources would be expended by this alternative.

* For a more complete discussion, see Section 4.

ALTERNATIVE 2: Gather Information

PRO
- We do not have sufficient information to determine the extent of the risk to human health from asbestos-contaminated vermiculite.
- We do not have definitive information on the rate of asbestos release from exfoliated vermiculite and the human exposure resulting from the use of vermiculite products.
- We do not know the efficiency of technological controls to remove asbestos from vermiculite.
- We need additional information to determine whether control actions on this chemical will have adverse effects on the national economy.

CON
- A regulatory investigation may be the most effective means for us to gather enough information on health risk and economic consequences to determine whether a regulation is warranted.
- Although we lack definitive information, we have enough information to initiate some type of rulemaking.
- OPTS's limited resources might be better spent to control other chemicals.

Estimated Resource Requirements:

It is estimated that 60 person months and $900,000 will be required to complete the work outlined in Section XI.

ALTERNATIVE 3: Pursue voluntary controls with the vermiculite industry.

PRO

- If the industry agreed to make the changes we thought necessary voluntarily, it could obviate the need for a rule and save us a great deal of time and resources.
- Meeting with the industry would be relatively easy because it is small.

CON

- The risk to human health may still be unacceptable after the voluntary controls have been established.
- Asbestos appears in veins at random so that the level of asbestos contamination depends upon selective mining as well as technological contols. Adequate protection of the public may require regulatory monitoring and record keeping to ensure compliance.
- Grace has known about the contamination of its vermiculite for a number of years but may not have taken measures to control the problem adequately.

Estimated Resources Requirements:

The alternative of encouraging the use of voluntary controls by industry would have minimum resource requirements associated with it. The action would involve gathering and analyzing information from industry, and working with them to obtain the most stringent controls possible. Resource requirements are estimated to be 4 person months with no extramural support.

ALTERNATIVE 4: Pursue a rule under TSCA requiring labeling of asbestos-contaminated vermiculite.

PRO

- A labeling rule could be promulgated expeditiously because of existing information on health effects resulting from exposure to asbestos.
- A labeling rule could probably be promulgated more rapidly than a more extensive rule.
- Although other agencies can require labeling (FTC, CPSC, OSHA), a labeling rule under TSCA may be more comprehensive.
- People are generally uninformed of the hazards of asbestos-contaminated vermiculite.

CON

- A labeling rule may jeopardize a larger control rule. ("Why control the problem further if labeled?")
- It may become necessary to solve the difficult technical problem of detecting low levels of asbestos in vermiculite before a labeling rule can be promulgated. ("How much asbestos does there have to be in vermiculite before it must be labeled?")
- Labeling is already required by OSHA and is under consideration by other agencies. The use of TSCA is unnecessary.

Estimated Resource Requirements:

The resource requirements to promulgate a rule to label the asbestos in vermiculite are estimated to be 6 person years and $200,000 in extramural contractual support. Only a portion of the work described in Section XI is required to support a labeling rule.

ALTERNATIVE 5: Take action under section 6 of TSCA to control asbestos contaminated vermiculite.

PRO

- TSCA offers the most comprehensive control of the asbestos-contaminated vermiculite problem.
- The long latency period associated with asbestos-related disease means that the full magnitude of the asbestos-contaminated vermiculite problem may not be determined in the near future. If we postpone action more people will be placed at risk.
- Once we solve the technical problems in controlling asbestos-contaminated vermiculite under TSCA, other asbestos-contaminated minerals may be easier to control.
- There are adequate substitutes for most uses of vermiculite.
- We have a great deal of information on the health effects of asbestos. If we can get reliable data on asbestos released from vermiculite, rulemaking will be greatly facilitated.

CON

- Industry should be given an opportunity to cooperate voluntarily before imposing regulatory controls that are costly to promulgate.
- Information should be gathered to determine the scope of the problem and the implications of rulemaking before initiating action.
- To develop a regulation for asbestos-contaminated vermiculite, staff resources may be diverted from other, more pressing problems.
- Controlling asbestos-contaminated vermiculite may help South African producers at the expense of domestic producers.
- With the current regulatory climate, it may be difficult to justify regulating vermiculite, a substance that many people do not consider a toxic chemical.

Estimated Resource Requirements:

The resources estimated to promulgate a rule to control asbestos-contaminated vermiculite under TSCA are 15 person years and $900,000 in extramural contractual support.

IX Recommendations:

We recommend that the following action be taken:

REJECT ALTERNATIVE 1 (No action)
If EPA doesn't control asbestos-contaminated vermiculite, no other agency will.

ACCEPT ALTERNATIVE 2 (Gather information)
More information should be gathered, but currently available information indicates that the problem is sufficient to warrant furthur action.

ACCEPT ALTERNATIVE 3 (Voluntary controls)
We should do everything possible to encourage conditions to reduce the risk to human health as we gather information to determine whether regulatory controls are required.

ACCEPT ALTERNATIVE 4 (Labeling rule)
A labeling rule is expeditious, cost-effective, and defensible.

POSTPONE ALTERNATIVE 5 (Regulatory control under TSCA)
We should gather information and evaluate the results of voluntary action before we commit to the development of more stringent regulatory controls.

A prudent strategy would combine Alternatives 2, 3 and 4. Alternative 5 should be postponed until additional information is gathered and the results of planned action are evaluated.

Information collected thus far indicates that asbestos-contaminated vermiculite poses a sufficient health problem as to warrant a near term regulatory proceeding to consider requiring hazard warning labels on vermiculite and vermiculite products that contain asbestos. People that use asbestos-contaminated vermiculite, or products that it contains, should be informed of the presence of asbestos so that they can protect themselves. Work has already begun to gather more definitive information in order to determine the need for imposing control of the release of asbestos from vermiculite by section 6 of TSCA. This work should continue and is outlined in Chapter XI. We should also encourage the vermiculite industry to minimize the release of asbestos fiber from vermiculite and we should monitor any change in release rate that may take place. OPTS should meet with other Federal agencies that can control asbestos-contaminated vermiculite (FTC, CPSC, OSHA, MSHA), particularly in order to coordinate any rule to require labeling. We should also exchange information and make sure that there is no duplication in planned activities. Although a labeling rule appears to be the most logical starting point for regulatory action, such a regulation should not preclude the possibility of more comprehensive action at a later date.

X. CONCLUSIONS

The following conclusions are made from information that is available at this time.

- The major domestic supply of vermiculite (at Libby, Montana) is contaminated with asbestos. Asbestos released from this material is the probable cause of adverse health effects developed by workers at a fertilizer plant where the material was used, and at the mine where the vermiculite is produced.

- Based upon present demand no domestic source of vermiculite could compensate for the quantity presently extracted from the Libby Montana mine.

- Control of asbestos contamination in vermiculite or asbestos exposure levels is complicated because most domestic sources of vermiculite may contain asbestos.

- Most of the asbestos contained in vermiculite is released during mining and exfoliation although the population exposed to the sources is relatively low. Much larger numbers of people are exposed to the lower levels of asbestos released from the use of exfoliated vermiculite.

- The asbestos content of vermiculite can be reduced by either technological controls or choice of supply.

- There are technical problems in accurately measuring trace quantities of asbestos in vermiculite.

- There are technically suitable and cost competitive substitutes for many of the uses of vermiculite.

- More information should be gathered, but available information indicates that the problem of asbestos-contaminated vermiculite warrants further action.

- Activities that are planned on asbestos-contaminated vermiculite should be coordinated with other Federal agencies.

XI. SUGGESTED FUTURE PLANS

A plan for a regulatory investigation of asbestos-contaminated vermiculite has been developed. This plan is based upon current information and is subject to revision when additional information becomes available.

The objective of the plan is to gather relevant information to determine whether asbestos-contaminated vermiculite poses an unreasonable risk. This determination is based upon balancing the risk to human health resulting from the release of asbestos against the cost to society for regulatory controls.

The major activities planned and the information to be obtained are described below.

- Information on asbestos-contaminated vermiculite will be gathered from sources within the government and any regulatory investigation planned will be coordinated with other appropriate government agencies.

- The mineralogy of major domestic and foreign vermiculite ore bodies and the raw vermiculite produced from these mines will be determined. Sufficient samples will be taken to characterize (1) the ore body, (2) each grade of raw vermiculite produced and (3) each grade of exfoliated vermiculite produced. Samples will be analyzed to determine the percentage and type of asbestos fiber, the nature of other fibrous materials present, and the existence of free silica. The fiber size distribution (strand diameter and length) will be determined for the fibrous materials present.

- Data on adverse health effects associated with asbestos-contaminated vermiculite will be studied to determine whether asbestos-exposure is the sole cause. The objective will be to determine whether other factors such as the presence of chemical agents or free silica in vermiculite may have contributed to the reported adverse health effects.

- The degree of human exposure to asbestos that results currently from the mining, processing, transport, use, and disposal of vermiculite will be determined. The relationship between the asbestos content of vermiculite and the release of asbestos into the air will be established. A model to predict the degree of human exposure to asbestos that would result at low levels of asbestos-contamination will be developed. This model may be used to estimate the risk of human health associated with restricting the asbestos-contamination of vermiculite to some reduced level.

- Diseases that may result from human exposure to asbestos-contaminated vermiculite will be identified together with the factors that modify the degree of risk posed by such exposure. Methods for predicting the risks resulting from exposure levels lower than those for which there are direct data will be developed. This information will be used, along with information on exposure, to estimate the risk to human health from asbestos-contaminated vermiculite.

- The risk to the population exposed to asbestos during the manufacture, processing, transport, use, and/or disposal of vermiculite will be estimated. This information will be used to determine what regulatory controls may be needed for asbestos-contaminated vermiculite.

- Methodology to monitor trace quantities of asbestos in vermiculite will be investigated and developed. The objective would be to establish sampling and measuring procedures that could be used to control extremely low levels of asbestos in commercial vermiculite. The investigation will: (1) establish recommendations for sampling the sources of vermiculite supply to ensure that the results are statistically valid, (2) identify or foster the development of test procedures for accurately measuring extremely low levels of asbestos in vermiculite, (3) determine the accuracy and reproductability of test procedures for measuring extremely low levels of asbestos in vermiculite, and (4) identify laboratories capable of adequately performing the measurements.

- Information on beneficiation technology to determine the lowest level of residual asbestos in vermiculite attainable by employing technological controls will be determined. Information on processes to separate asbestos from vermiculite has been requested from Grace, a known supplier of asbestos-contaminated vermiculite. If this information is not provided, the use of Section 8(a) of TSCA or subpoena will be investigated. Independent studies to determine the efficiency of separating asbestos from vermiculite will be instituted.

- Engineering controls under consideration for reducing the release of asbestos will be investigated and evaluated. The costs and the effectiveness of their use will be determined. The lowest level of asbestos-contamination attainable with technological controls will be established for each grade of vermiculite and costs associated with those controls will be determined. The cost and problems associated with measuring low levels of asbestos-contamination will be considered.

- The economic consequences of regulatory control of asbestos-contaminated vermiculite will be estimated. The impact of regulation on the vermiculite industry will be determined. The costs of various engineering controls will be established. The benefits derived from vermiculite and the availability of substitutes will be considered as far as possible. The effect on the national economy and small businesses will be estimated.

- An investigation will be performed to determine whether pure vermiculite can cause adverses health effects. This is a long range study that will depend primarily on the results from animal implantation studies.