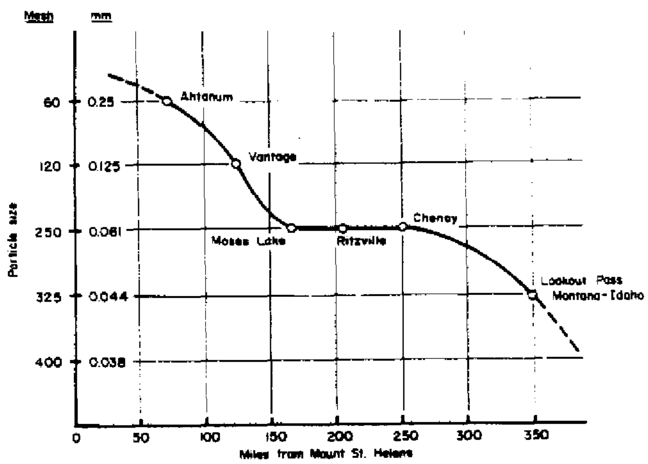

Fig. 4. Average ash particle size along Mount St. Helens-Lookout Pass transect.

the volcano the average size is also 0.061 mi (250 mesh); at Lookout Pass the ash averaged 0.044 mm (325 mesh).

Particle size distribution curves of ash samples collected along the transect show normal curves with decreasing particle sizes as distances increase from Mount St. Helens, which one would expect from normal gravitational settling of coarse dense particles near their source.

Color

The color of the ash ranges from light- to medium-gray. Its reflected light values range from 77 (Ritzville ash) to 40 (Vantage ash). Variations in the color of the ash are caused mainly by different amounts of black magnetite and dark-green to black hypersthene and hornblende. Ash with high glass-feldspar content tends to be light gray, whereas ash containing up to 10% combined magnetite and ferromagnesian minerals tends to be medium gray.

Chemistry

To date, numerous chemical analyses have been run on St. Helens ash from many sites throughout the Northwest. Analyses show that the chemical composition of the ash is not much different than the chemical composition of ashes from the past eruptions. For comparative purposes, the composition of several ashes along the St. Helens-Lookout Pass transect are presented. Also shown is the average of 25 samples at widely distributed sites in the Northwest and analyses of pumice, dacite, and andesite from Mount St. Helens prior to the May 18 eruption. Based on norm calculations the chemical composition of the ash corresponds to rocks of dacitic composition.

In addition to analyses of common oxides of the ash, some samples have been analyzed for as many as 20 trace elements. Analyses of ten common trace elements are shown. Also shown for comparison are element analyses for an andesitic rock and analyses of certain elements for ashes of six eruptions of St. Helens. As can be seen in this figure, concentrations of chromium, cobalt, and arsenic are slightly greater than that of an average andesitic rock. Because of high tourmaline contents of rocks in the vicinity of St. Helens, boron is higher than average. Although the area, 7 to 12 mi north-northeast of St. Helens contains significant copper mineralization, the copper content of the ash is lower than that of an average andesitic rock. Trace element analyses of ashes from six eruptions occurring from March 27 to August 7, 1980, reveal only slight differences, with the exception of the July 22 eruption. Ash from this eruption showed zinc concentrations of around ten times that of the other eruptions, whereas antimony concentrations are seven times as great as other eruptions. A slight increase in fluorine also occurred in the July 22 eruption.

Density

The density of the ash varies, depending mainly on its mineral composition. Coarse ash and dark ash tend to be denser because of the presence of heavy minerals such as magnetite, hypersthene, and hornblende. Loose dry ash in the 250 mesh range has densities of 0.62 to 0.90. The density of compacted dry ash ranges from 1.2 to 2.55. Water saturated ash has an average density of 1.78.

Solubility and acidity

Particles of the ash are insoluble in water, but water becomes slightly acidic when it comes in contact with the ash. On initial exposure to distilled water, pH values are slightly acidic, but approach neutral within a few hours. The acidity of water that has been in contact with ash is about the same or slightly less than that of rain or snow. Ranges of acidity of water leachates ranged from 5.2 to 7.2, the average being 6.5.

Magnetism

The presence of 1 to 5% by weight of magnetite makes much of the ash magnetic. The magnetite occurs as dustlike grains in the different minerals that comprise the ash, and very little of the magnetic fraction of the ash consists entirely of magnetite. Very fine-grained particles of magnetite have been noted to collect on magnetic components of equipment, and in some cases has caused electrical equipment to malfunction.

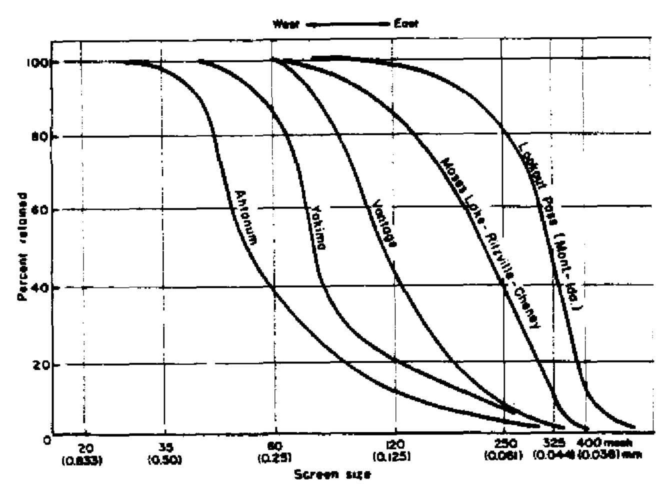

Fig. 5. Particle size distribution curves along Mount St. Helens-Lookout Pass transect.

Table 2. Weight percentages of major oxides in Mount St. Helens ash, May 18, 1980, eruption.

	A	B	C	D	E	F	G
SiO_2	63.30	68.20	67.20	63.96	64.30	63.16	67.40
Al_2O_3	17.40	17.20	16.30	17.55	18.20	18.22	17.08
Fe_2O_3	5.59	4.22	3.76	4.79	4.20	4.69	4.79
CaO	5.74	4.77	4.20	4.92	4.80	5.24	3.27
Na_2O	4.49	4.42	4.52	4.62	4.80	4.06	4.21
MgO	2.80	1.61	1.48	2.08	2.00	2.30	1.16
K_2O	1.25	1.60	1.66	1.49	1.45	1.16	1.67
TiO_2	0.83	0.63	0.58	0.64	0.60	0.18	---
P_2O_5	0.33	0.37	0.37	0.18	---	0.14	0.18
MnO	0.092	0.067	0.064	0.090	---	Tr	Tr

A - Yakima ash (Fruchter and others, 1980, p. 1117).
B - Spokane ash (Fruchter and others, 1980, p. 1117).
C - Missoula ash (Fruchter and others, 1980, p. 1117).
D - Average of 25 samples in Washington
E - Mount St. Helens pumice (Wozniak and others, 1980, p. 130).
F - Mount St. Helens hypersthene andesite (Verhoogen, 1937, p. 293).
G - Mount St. Helens dacite (Verhoogen, 1937, p. 293).

Abrasiveness

The presence of magnetite, feldspar, and ferromagnesian minerals, which have hardnesses ranging from 5 to 6.5 on Mohs scale of hardness, makes the ash moderately abrasive. It readily scratches material such as paint, plastic, glass, and iron and has proved to shorten the lifetime of bearings in many types of equipment that come in contact with the ash.

Absorption and compaction

The absorptive properties of the ash have yet to be fully investigated. Some ash has the ability to absorb up to 30% of its weight in water. Compaction tests reveal that loose dry ash in the 250 mesh range will compact to around 40% of its original thickness under only 10 psi; at 1,000 psi the ash will compact to about 50%; and at 10,000 psi it will compact to almost 60%.

Radioactivity

Radioactivity has been detected in the ash, but is no more than exists in average crustal rocks. To date, chemical analyses have not shown the presence of U_3O_8, and the radioactive properties of the ash are not generally detectable by radiation detection instruments commonly used in the field.

Possible Uses of Mount St. Helens Ash

Although over thirty depositions of pumicite from volcanic eruptions of the past occur in the state, material from these deposits has not been utilized since 1957. Throughout the world, volcanic ash has been put to as many as forty different uses, but to date, ash mined in Washington has been used only as (1) pozzolan, (2) scouring powder, (3) mechanics soap, and (4) dusting powder for brick molds. With the exception of pozzolan, it is doubtful that Mount St. Helens ash will be used in large amounts for the other mentioned uses, as the market for them is rather small. As such, it is best to consider uses that would require large amounts of ash, preferably within short distances of existing stockpiles in eastern Washington. Uses considered for St. Helens ash are presented.

Construction Uses

Pozzolan

Pozzolan is defined as an artificial or natural, fine, siliceous and aluminous compound which will, at atmospheric temperatures, form cementitious compounds upon combination with water and calcium hydroxide, or hydrated lime. Silica in the amorphous form reacts more readily with calcium hydroxide than crystalline silica which makes volcanic ash a perfect pozzolan.

A 10 to 40% replacement of portland cement by pozzolan in concrete mixes imparts several advantageous properties to the concrete. The greatest benefit associated with this replacement is economic. Delivered portland cement averages $70 per yard; delivered pozzolan averages $50. During construction of Priest Rapids Dam on the Columbia River, pumicite was mined from a local basalt flow interbed. Forty-three thousand tons of pozzolan were added to 142,500 tons of portland cement at a 30% reduction in delivered cost of portland cement.

Portland Cement Association, the U.S. Army Corps of Engineers, the Civil Engineering Department of the University of Washington, and Pozzolanic Northwest have analyzed the ash for its pozzolanic properties. Specifically, they examined the effect of ash in strength development of mortar cubes when the ash is used as a partial cement replacement or as a partial substitute for sand; the pozzolanic activity of the ash when mixed with lime or portland cement; and alkali reactivity by measuring mortar expansion.

Table 3. Possible uses of 1980 Mount St. Helens ash.

CONSTRUCTION
Pozzolan
Lightweight aggregate
Sewer lagoon lining
Stabilized fill
Ash-component pavement
Asphalt mineral filler
FILLERS
Paint, rubber, plastics, gypsum products, and linoleum
ABRASIVES
Sand-blasting medium
Grinding stones
CERAMICS
Bricks, glass, and glazes
MISCELLANEOUS
Waste treatment
Dust abatement
Filters
Carrying and nonsticking agents
Absorbents

These analyses demonstrate that Mount St. Helens ash has moderate pozzolanic properties. In combination with hydrated lime, the pozzolanic activity index at seven days ranges from compressive strength failures of 139 psi at Yakima to 632 psi at Spokane. Minimum ASTM requirements for compressive strength failure is 800 psi. The activity index increases with progressive distance from Mount St. Helens, a reflection of decreasing particle size. At Yakima fineness is 721 cm^2/g, as determined by Blaine apparatus, while at Spokane ash fineness is 2626 cm^2/g. The minimum ASTM specification for fineness of pozzolan is 5000 cm^2/g. Fineness is the primary factor in pozzolanic activity because the pozzolanic reaction rate increases with decreasing particle size.

The real criteria regarding suitability of the ash as a pozzolan is whether or not it meets all ASTM standards. Considering the variability of the ash in its physical properties from site to site, extensive testing would be required at each location before its use would be considered.

Lightweight Aggregate

A lightweight aggregate is defined as any solid material used in the manufacture of concrete that weighs less than standard sand and gravel aggregrate. Volcanic ash from Mount St. Helens averages 55 lbs/cu ft, while clean sand averages 90 lbs/cu ft, and gravel averages 100 lbs/cu ft. One cubic yard of concrete requires 1,800 lbs of ash versus 3,000 lbs for a conventional sand and gravel mixture.

The properties of prime importance to lightweight aggregate are: (1) uniformity in all properties to prevent costly, time consuming changes in mixing formulations; (2) color consistency, especially in concrete products that will show, such as precast wall panels; and (3) chemical stability to prevent deterioration of the product. The ready-mix concrete industry is accustomed to consistent, reliable aggregate supplies. They do not feel that the ash represents such a supply because of inconsistencies in particle size and color. The ash from Yakima west to the volcano has the best potential as aggregate because this is where it is coarsest, in the fine- to medium-sand range, with 70% retained on 60-mesh sieves. This particle size is within ASTM specifications for lightweight aggregate grain sizes.

Sewer Lagoon Lining

The town of Othello, Adams County, Washington, has 25 acres of sewer lagoon to which they intend to add another 25 to 50 acres. The settling ponds are lined with bentonite to prevent leakage of organic waste through the highly fractured basalt bedrock they overlie. When the May 18 ashfall occurred, interest developed in the feasibility of substituting ash for bentonite. Bentonite's installed cost has been $250 per ton; to be competitive, ash would have to be made available at $1000 per ton. Ritzville, 50 road miles distant from Othello, is the nearest ash source with a 13,000 cubic yards stockpile of uncovered, uncontaminated ash.

The engineering firm responsible for the design and construction of the new sewer lagoons, Brown and Caldwell Engineers, Seattle, are gathering information on the physical and engineering properties of the ash to present to their construction subcontractors, who will make the final decision regarding its use.

Ash-Component Pavements

In Oregon, volcanic ash-sand aggregate has been mined and mixed onsite with asphalt, then applied directly to soil road bases. Because the ash-asphalt mixture is not highly abrasion-resistent, a thin cap of resistant aggregate chips were embedded in the top of the mixture. Ash can also be used as a mineral filler in asphalt because the amorphous silica component counteracts the hydrophilic reaction of some aggregates.

Natural pozzolans have also been used in conjuction with lime-cement-pozzolan-filler (LCPF) pavements. The LCPF mixture is combined with water to form a paste that is compacted with normal paving equipment to a relatively high-density mass that hardens to a rigid pavement with 1-year compressive strength from 750 to 2,000 psi. LCPF pavements have been used as bases or sub-bases ranging in thickness from 6 to 40 inches. Their benefit is in support of the static load. Because they do not hold up to surface abrasion and are subject to infiltration of surface water, they are capped with a few inches of wearing surface.

For secondary access roads, such as those required for logging in the St. Helens devastated zone, LCPF pavements could be mixed onsite. As in the case of all road construction, laboratory analyses of aggregate are vital, and in fact will soon be undertaken by the Federal Highway Administration's Materials Laboratory in Vancouver, Washington.

Stabilized Fills

Problems associated with any fill involving the use of fine-grained material are internal and external erosion, liquefaction, surface and ground water contamination, and slope instability. The physical properties to be considered in evaluation of a substance for fill material are grain size, density, compaction characteristics, shearing strength, and permeability.

The ash progresses from a fine to medium sand at Yakima to a coarse silt at Moses Lake-Ritzville. Specific gravity averages from 0.88 g/cc (55 lbs/ft^3) when loose and dry to 1.8 g/cc (112 lbs/ft^3) when water saturated. This places the ash in the size and density range of most conventional fill materials.

Due to angularity of ash particles it compacts well, especially when wet. Yakima ash shows greatest initial compaction due to its larger grain size. The ash absorbs up to 30% of its weight in water· shear strength decreases substantially as the maximum water-absorption percentage is approached. Optimum compaction of the ash would be achieved by taking advantage of its pozzolanic properties by mixing it with lime and water, then packing it with a vibrating roller to bring the angular particles into maximum interlocking structure.

Permeability of the ash decreases with compaction and increases with grain size. Besides slight initial solubility with water and an accompanying slight increase in pH, the ash is essentially chemically inert and does not undergo deterioration upon exposure to the atmosphere. Water percolating through these landfills is unlikely to pick up significant quantities of any chemical that could negatively impact surface or group water supplies.

Fillers

Most fillers are inert silicates very similar in physical and chemical properties to Mount St. Helens ash. For this reason, the possible substitution of volcanic ash for common fillers by Washington State paint, rubber, plastics, and gypsum products industries was investigated.

The primary industry specification for fillers is chemical inertness. Common fillers are 99% pure SiO_2 while the ash is only 64%. The iron oxide content of the ash (5% average) poses problems in all paint products except those where it is used as a primary pigment or in oil-base interior paints. A few tenths of one percent of trace elements, such as copper, cobalt, or nickel, can hinder curing time, aging, and quality of rubber products. Cobalt can also affect stability of plastics products.

Particles size and shape is also critical for fillers. The averge filler grain size is 2.5 microns for paint, 1 to 5 microns for rubber, and 2 to 30 microns for plastics. The larger grain sizes represented by the ash would dilute rubber and make paint and plastic products grainy. Ash angularity would counteract its reinforcement properties in rubber, reduce workability in paints, and abrade application and mixing equipment. In plastics, particle angularity can be positive or negative, depending on intended product use. Production of rubber erasers could take advantage of ash angularity and abrasiveness; however, there are no eraser industries in the Northwest. The Navy has used rubberized paint with pumicite filler to prevent skidding on ship decks.

An application for which coarse ash particles is desirable is in casting of plastic novelty items such as ashtrays or synthetic marble countertops where large particle size adds strength and the light weight of the ash (0.9 gm/cm^3) is an asset. Coarse particle size also allows its use in concrete epoxy, as a substitute for sand, in situations where it is necessary to bond new concrete castings to old.

Another carefully controlled filler specification is color, especially in coating products such as texture paint or in paper products. Brightness ratings for the most desirable fillers are in the 90s Reflected light values for Mount St. Helens ash range from 77 at Ritzville to 40 at Vantage.

Apparently the ash does not pose any physical or chemical problems for use in wallboard, but the supply of gypsum in the Northwest is plentiful and cheap so that there are no economic inducements to replace it with other fillers.

Abrasives

At least two grinding wheel manufacturers have evaluated the potential use of Mount St. Helens ash in their products. Pacific Grinding Wheel Company, Marysville, Washington, has produced some promotional hones from a mixture of 15% ash and 85% aluminum oxide, clay, feldspar, and slip. Results of industry evaluations indicate that the ash is too soft and friable, and has too low a melting point to be compatible with standard abrasive products.

Industral abrasive densities range from 35 to 200 lbs/cu ft, depending upon the use for which they are intended. St. Helens ash has low density (55 lbs/cu ft) by comparison.

Ash particle surfaces are riddled with broken vesicles with sharp, thin readily broken walls. The glass jackets that enclose many mineral crystals are readily separated upon impact. The combination of these features make the ash very friable.

Abrasives industries process all materials in kilns to fuse them at high tempratures. The rugged vesicular surface of the ash quickly fuses into a rounded blob that makes it essentially useless as an abrasive. Tests have demonstrated that the ash fuses at 1800°F, a melting point too low to make it a viable replacement for established grinding wheel binding agents.

Although the ash contains only 3% or less crystalline silica, and therefore does not pose a silicosis hazard, it does not appear to be a viable sand blasting medium because of its fine particle size and friability. For more delicate polishing purposes, such as china and furniture finishing, artwork, and jewelry, the fine-grained ash in the 300 mesh range probably could be used in very limited tonnages. Much use has been made of pumicite as abrasive filler in scouring powders, mechanics soap, and toothpaste.

Ceramics

Bricks

The greatest potential use of Mount St. Helens ash to the brick industry is as an additive to building bricks and tiles. Clay was tested with 15% additions of fine ash from Moses

Lake and coarse ash from Portland, Oregon. The ash was mixed with water to a plastic state, extruded into test bars, dried, and fired for three hours at 1950°F or 2050°F. From 10 to 18 bars were broken by 3-point loading to determine moduli of rupture. The conclusion was that addition of the ash had little beneficial effect and in some instances lowered brick strength, probably due to reduced maturing strength associated with low firing temperatures.

The fact that the ash is not a clay, and therefore not plastic, prevents its use in the extrusion brick process. Clays in the Northwest tend to be nonplastic so that addition of ash would only reinforce this nonplasticity. Still another problem stems from the short firing range of the ash which makes the manufacture of a brick product difficult. The optimum condition involves a body mix that melts over a wide temperature range so that the proper amount of glass develops in the brick. Too much glass produces a soft, deformed brick; too little glass produces a weak one.

Ash bricks have been manufactured in the past at one-third of the cost of clay brick. Because of low ash density, brick products weigh up to one-third less than clay bricks, resulting in reduced transportation and handling costs. The product has excellent thermal and acoustical properties and is fire resistant and dimensionally stable.

Volcanic ash does not have application to manufacture of refractory bricks because of its chemical composition and its low melting point. Most refractory brick is manufactured from a very pure combination of aluminum oxide (60%) and crystalline silica (40%). Refractory temperatures involving this mixture range from 2000°F to 3800°F, well above the 1800°F melting point of the ash. Metallic trace elements are intolerable in refractory bricks above a few tenths or hundreths of one percent.

Glazes

Glazes are vitreous substances applied as coatings to finished pottery or enamelware. They are usually mixtures of native silicates such as Mount St. Helens ash, which is being used by artists in the state to glaze novelty pottery and ceramic items. The ash does not have potential for commercial glaze, however, because of the same lack of color control that prevents its use by commercial glass manufacturers. The iron content imparts a brown to black color that has artistic appeal, especially when the product is related to the cataclysmic eruption of Mount St. Helens.

Glass

Mount St. Helens ash has been considered for use in glass manufacture by several Washington State companies. While it is being used in small volumes for novelty items, no realistic use has been found by commercial glass manufacturers

The ash is excellent for conversion to the glassy state because up to 80% of it is composed of volcanic glass. Conversion to glass at lower temperatures is aided by addition of flux such as boric acid.

Mineralogical and chemical composition of the ash is the major factor considered by glass manufacturers. Feldspar acts as a flux in glass manufacture and brings alumina (Al_2O_3) into the melt which increases workability, inhibits devitrification, and increases chemical stability Clear bottle glass needs 1.5% alumina for strength.

Iron oxide in the ash prevents its commercial application to glass manufacture by imparting, along with manganese, magnesium, and nickel, a dark brown to black color. Commonly not over 0.05% total iron as Fe_2O_3 is allowed in commercial glass manufacture. Even in amber glass, such as beer bottle containers, a maximum of 0.1 to 0.15% is tolerated. This color control is not possible with inclusion of ash in glass products. Other impurities in the ash such as gravel particles also wreck the glassmaking process by not melting completely and setting up stresses in the glass. Uniform particle size of glassmaking substances is important because if a nonhomogeneous mixture is not well mixed, the particles can aggregate and cause the glass to run.

Miscellaneous Uses

Waste Treatment

Volcanic ash has been investigated for its effectiveness in the removal of inorganic phosphorus and organic pollutants from municipal sewage and polluted lakes.

For the first few days after the May 18 ashfall in Spokane, when the ash load in the municipal sewer system was high, sewer personnel bypassed the main components of their treatment plants and ran ash-laden sewage through two primary clarifiers only. As a result, total coliform level dropped to zero. The sheer mass of the ash, and its high specific gravity (2.6) relative to organic material, removed organic solids from suspension to a degree normally reserved for secondary waste treatment. Phosphorus in the sewage was absorbed by the ash; normal treatment removes up to 85% but the ash content caused 100% removal.

Liberty Lake, Spokane County, demonstrated an immediate drop to 1 to 1.5 pH units following the May 18 ashfall, with a decrease of 50% in total phosphorus and a massive decrease in the volume of algae, undoubtedly due to scavenging by fine ash particles. The lake resembled its appearance following alum treatment in 1974.

In a practical sense, ash could not be used in sewage treatment plants because it settles to the bottom of clarifiers and digesters and requires mechanical removal. Use of ash to control plant nutrients in natural standing bodies of water with eutrophication problems, however, seems to warrant further investigation.

Carrying and Noncaking Agents

Insecticide and fertilizer industries often use carrying agents to distribute, dilute, and gradually release chemicals to the environment. Some of these agents also double as noncaking agents. Because the glass fraction of St. Helens ash is fine-grained and vesicular, its use for this purpose was examined.

Properties of greatest significance to insecticide and pesticide carriers are chemical stability, high pH, and large particle surface area. The most common carriers, talc, diatomite, micronized clays and calcium silicates, are chemically stable agents. Apparently St. Helens ash, in combination with insecticides and pesticides, is chemically active. The 5% average iron content of the ash is detrimental because it acts as a catalyst in the chemical breakdown of organic insecticide constituents and therefore greatly diminishes product shelf life In addition, ash pH is too low.

St. Helens ash does not have any value in Washington as a carrying agent for fertilizers because transportation costs are so prohibitive that the industry has stopped using carriers Instead they either manufacture liquid fertilizer or combine dry fertilizer with filler material that provides additional soil-enriching elements. The ash does not contain the necessary 12% magnesium or 95% calcium the industry demands. Filler material with a maximum density of 60 lbs/cu ft and a grain size equivalent to BB shot (4 mm) is required. Because the ash is denser and finer than these specifications, it compacts and clogs the equipment used to spread it.

Filters

Volcanic ash has the high external particle porosity, surface area, and absorption properties that allow its use as a filtering agent. There are many filters on the market that are superior to ash, however, such as diatomite and bentonite, because of lower density, higher chemical stability, and very large internal porosity

Diatomite has a wet density of 17 lbs/cu ft compared to 112 lbs/cu ft for water-saturated St. Helens ash, a significant difference in light of the fact that heavy particles won't remain in suspension long enough to accomplish maximum filtration. Diatomite is 99 to 99 8% pure SiO_2 while St. Helens ash averages only 64% and contains accessory minerals such as magnetite that makes it much less chemically inert and severely restricts its use in the food industry. While the ash has great porosity associated with its bubble texture, it lacks the open internal latticework of diatomite and therefore its filtering properties are reduced.

Dust Abatement

Various governmental agencies have experimented with dust abatement compounds with varying degrees of success, including ash-lime mixtures, lignin sulfonate, calcium chloride and sodium chloride. Because of its immediate on-site availability, soil-lime enhancement potential and pozzolanic activity, the feasibility of using an ash-lime mixture was particularly attractive. Ash and lime are mixed with water, then sprayed onto gravel roadbeds and shoulders where it coats soil and gravel particles and set up to a hard crust. Investigation of ash-lime palliatives have indicated poor pozzolanic reaction, however, perhaps due to large ash grain size or the low percentage of lime that will go into solution. Penetration, cohesion, durability, and leachability of the ash-lime mixture are superior to the chloride compounds but inferior to lignin sulfonate which was given the best dust abatment rating by all investigators.

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