



Instituto Tecnológico
GeoMinero de España

INVESTIGACIÓN DE DIATOMITAS EN EL SUR DE ALBACETE

TOMO III

ANEXO B

**ESPECIFICACIONES DE LOS
DIFERENTES USOS DE LA
DIATOMITA**



MINISTERIO DE INDUSTRIA, COMERCIO Y TURISMO

11334

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nations. Consumption in the Communist Bloc is probably very close to production, estimated to be 550,000t in 1986.

4.1 Consumption by type of diatomite

Numerous diatomite products are marketed, many of them processed for specific applications. Major producers can also supply material to meet the needs of individual customers. There are three main types of diatomite, classified according to the degree of beneficiation; natural, calcined and flux-calcined. Calcined and flux-calcined materials are classified as activated diatomite in the trade tables.

Particle size increases with the degree of beneficiation. Natural diatomite, which has the smallest average particle size, is used in some filter applications, and in fillers. Calcined and flux-calcined diatomite are used primarily in filter applications.

4.1.1 Natural diatomite

Since it is the shape and structure of the diatom skeleton which sets diatomite apart from other forms of silica, and which gives it its unique properties, great care must be taken during beneficiation to preserve this structure. Such size reduction methods as grinding or ball milling would render the mineral useless for most of its more important applications.

Since crude diatomite typically contains as much as 40% water, and frequently over 60%, primary crushing to aggregate size is followed by simultaneous milling and drying as the suspended diatomite particles are carried in a stream of hot gases. The initial beneficiation process results in the separation of the powder into various particle sizes, the removal of waste impurities and the expulsion of absorbed water.

Diatomite products so processed, without further beneficiation, are bagged and marketed as "natural" milled products.

4.1.2 Calcined diatomite

Calcined diatomite is obtained by heat treatment of the natural powder in rotary kilns. The diatomite is heated to incipient fusion at 1000°C, a process which removes organic matter, shrinks and hardens the individual particles, and also sinters some of the material into small clusters, thereby adjusting particle size distribution. The resulting product has a pink cast, caused by the oxidation of iron present in the crude material. Calcined diatomite has a mean particle size of between 2.5 and 7 microns.

4.1.3 Flux-calcined diatomite

Heat-treatment of natural diatomite with the addition of a flux, usually between 3% and 10% of soda ash, salt or sodium hydroxide, yields the flux-calcined grades. The process further adjusts particle sizes, reducing surface area, changing surface texture and converting clay materials to aluminium silicate slag, thereby changing the colour to true white. Flux-calcined diatomite has a mean particle size varying from 5 to 40 microns, according to grade and application.

4.2 Consumption of diatomite by end-use

Diatomite is used in a wide variety of industrial applications, owing to its unusual particle structure and chemical inertness. The most important use is as a filter-aid in the separation of suspended solids from fluids in the brewery, food, pharmaceutical, water, oil and chemical industries. Filter-aids account for 69% of the diatomite sold in the USA, and for about 60% of European demand. Two other important end-uses are as a filler in paints, paper and plastics, and as insulation in refractories and furnaces. Minor applications include pesticide carriers, industrial absorbents, fertilizer coating and caking agents, and abrasives.

Table 31: USA: Consumption of diatomite by end-use 1964 to 1987
(000t)

	<u>Filtration</u>	<u>Fillers and additives</u>	<u>Others</u>	<u>Total</u>
1964	186	110	99	395
1965	188	111	128	426
1966	193	105	122	420
1967	215	99	134	448
1968	215	103	112	430
1969	222	92	69	383
1970	234	93	76	403
1971	209	78	67	354
1972	227	88	75	390
1973	238	83	72	393
1974	231	100	106	437
1975	209	93	88	390
1976	236	100	106	442
1977	236	147	68	451
1978	259	143	50	452
1979	297	168	32	497
1980	286	150	32	468
1981	281	167	28	476
1982	278	137	13	428
1983	265	146	18	429
1984	281	154	19	454
1985	290	159	18	467
1986	303	77 17%	72 16%	452
1987	329	76 16%	72 15%	477

Source: USBM Mineral Facts and Problems
Table 32
Roskill estimates

After falling by 3% to 451,610t in 1986, US apparent consumption rose by nearly 6% to 477,000t in 1987.

Table 32: USA: Diatomite sold or used (1), by principal end-use, 1973 to 1987 (% of US production)

	<u>Filtration</u>	<u>Fillers</u>	<u>Insulation</u>	<u>Others(2)</u>	<u>Total</u>
1973	61	20e	4	15e	100
1974	60	20e	5	15e	100
1975	60	20e	4	16e	100
1976	60	20e	5	15e	100
1977	59	20e	5	16e	100
1978	63	23	3	11	100
1979	65	21	3	11	100
1980	66	21	3	10	100
1981	64	23	2	11	100
1982	68	19	1	12	100
1983	66	21	3	10	100
1984	67	22	1	10	100
1985	66	21	1	12	100
1986	67	17	3	13	100
1987	69	16	2	13	100

e = estimated

(1) Includes exports

(2) Includes abrasives (1981 and 1982), absorbents, additives and silicate admixtures.

Source: US Bureau of Mines Minerals Yearbook
Roskill estimates

4.2.1 Filtration

Filtration is an important process in the clarification and purification of a wide variety of commercial products. The unaided use of a filter mesh, or septum, as a filtration medium traps only relatively large particles, which then clog the openings and retard the flow of liquid. The use of filter-aids such as diatomite overcomes these shortcomings. Filter-aids are finely divided materials which, when added to the liquid to be filtered, help control the flow and removal of solids. There is no chemical interference with the liquid being filtered, so the process of filtration is a purely mechanical one.

Filtration by diatomite does not involve the use of traditional static filter bed technology. Rather, a precoat of diatomite is laid over a permeable base, or septum (filter cloth, porous paper or wire mesh), so that the diatomite cake acts as a filter medium. The permeability of the septum is such that the passage of diatomite particles is prevented without restricting the flow of filtered liquid. The amount of diatomite used in precoating

is usually 10-15 lbs per 100ft² of filter area. Additional diatomite is added to the effluent as a body feed to keep the impurity particles apart and prevent early blockage of the filter base. Once a high back pressure is formed due to congestion of the media, the flow is stopped and the filter cake removed by backwashing. A new precoat is applied and the process begins again.

Diatomite precoats are used in both vacuum and pressure filters. Vacuum filtration uses a rotating horizontal drum which is partially submerged in a basin containing the precoat slurry. A vacuum is applied from within the drum which draws the precoat onto the septum, forming a uniform filtration layer. Then the effluent and diatomite body are introduced in to the basin and filtration takes place. Excess filter cake is removed by a blade as the drum rotates.

Precoat pressure filters are usually vertical or horizontal cylinders containing vertical or horizontal base plates. Only the horizontal plates must be cleaned by backwashing; with vertical filter plates, the precoat falls off when the flow stops.

Precoat filtration is most commonly used for beer, wine, liquors, oils, waxes etc. Water purification is a relatively minor application.

In a good filter-aid, the structure of the particles must be such that they will not pack together closely, but will form cakes that are 85% to 90% pores. This facilitates high initial liquid flow and provides pore spaces to trap and contain the filterable solids, while leaving a high percentage of channels open for flow.

A small surface area is important, as the viscous shear of the liquid over the surface area of the filter-aid particles creates resistance to flow. As fine particles reduce flow, due to their higher surface area, and coarse particles reduce clarity, the narrowest possible range of particle sizes (within a given grade of a series of filter-aids) is to be desired. Some coarse particles are necessary to allow precoating on coarse wire and synthetic screens, but the percentage needed is very small and does not have a detrimental effect on flow-rate or clarity.

Diatomite fulfils all of these requirements and has been used as a filter aid for over 50 years. Diatomite is an amorphous form of silica containing a small amount of microcrystalline material, and diatomite filter-aids are processed at temperatures ranging from 800°C to 1100°C. The typical properties of ranges of diatomite filter-aids produced by the Manville Products Corp. and Grefco Inc. are shown in Tables 33 and 34.

At the 8th Industrial Minerals International Congress in 1988, delegates from Chile outlined a simple procedure to evaluate whether a given diatomaceous ore can be processed to obtain quality filter aids. Four tests were proposed: two physical and two chemical ones. The physical tests measure filter-cake permeability and density while the chemical tests monitor levels of critical contaminants (CaO, Fe₂O₃)

Table 33 Typical properties of Celite diatomite filter aids (1) (2)

Grades	Colour	Fibra-Cel/ Diatomite Blend Equiv- alent (3)	Median Pore Size in Microns	Approx. P@ 1 gal./ sq.ft./min. with 0.15 lb./ sq.ft. Precoat	Estimated Gal./sq.ft./hr. Water, 6 in. Precoat 24 in.Hg. P	Perme- ability -Darcies*	Density lbs./ft. ³		150 Mesh % Retained	% Mois- ture as Shipped	pH Max.	% Solu- bles
							Dry	Wet				
<u>Fibra Cel</u>	Gray	1	1.5	3.2	*	.09	7.0	16	2	3.0	7.0	0.15
505	Pink	3		2.0	*	.1	8.0	23		1.0	7.0	0.15
577	Pink	2	2.5	1.2	*	.2	8.0	18	2	0.5	7.0	0.10
<u>Standard</u>												
<u>Super-Cel</u>	Pink	5	3.5	0.7	10	0.5	8.0	18	4	0.5	7.0	0.10
512	Pink	6	5.0	0.4	20	0.9	8.0	19	7	0.5	7.0	0.10
<u>Hyllo</u>												
<u>Super-(el)</u>	White	7	7.0	0.1	50	2.0	9.0	18	6	0.1	10.0	0.15
501	White	8	9.0	0.07	65	2.5	9.5	18	8	0.1	10.0	0.15
503	White	9	10.0	0.06	130	3.5	9.5	18	9	0.1	10.0	0.15
535	White	10	13.0	0.03	240	5.5	12.0	19	10	0.1	10.0	0.15
545	White	11	17.0	0.02	370	8.5	12.0	19	12	0.1	10.0	0.15
550	White	12		0.015	600	15.0	18.0	21	14	0.1	8.0	0.15
560	White	13	22.0	0.005	1400	30.0	19.5	20	40	0.1	10.0	0.15

(1) 'Celite' is the trade name used by Johns-Manville for their filter-aid products.

(2) As expressed, these are typical or estimated physical properties, not specifications, and should be used accordingly.

(3) Fibra-Cel grades are designated by a number plus a letter (i.e., Fibra-Cel 7F). The number refers to the equivalent grade of Celite filter-aid and the letter to the percent Cellulose in multiples of 2½%; i.e., A=2½%, B=5%, C=7½%, etc.

* Not applicable.

Source: Johns-Manville company literature.

Table 34 Typical properties of Dicalite diatomite filter-aids (1)

Grade	Relative Flow rate	Density lbs/ft ³		Density kg/m ³		Screen analysis % retained 150 mesh	Colour	pH	Specific gravity	H ₂ O absorption	% Ignition loss
		Loose wt.	Filter cake	Loose wt.	Filter cake						
<u>Calcined</u>											
215	100	8.0	-	128	-	-	Pink	7.0	2.25	190	0.5
Superad	120	8.0	22.0	128	352	1	Pink	7.0	2.25	190	0.5
UI	145	8.0	-	128	-	-	Pink	7.0	2.25	190	0.2
Speedflow	200	10.0	23.0	160	368	4	Pink	7.0	2.25	200	0.3
231	325	9.0	23.0	144	368	4	Pink	7.0	2.25	220	0.4
<u>Flux-calcined</u>											
Special speedflow	350	9.0	21.5	144	344	5	White	10.0	2.35	240	0.2
Speedplus	700	10.0	21.1	160	338	5	White	10.0	2.35	240	0.2
Speedex	1030	14.0	22.0	224	352	8	White	10.0	2.35	240	0.2
4200	1800	16.0	23.0	256	368	12	White	10.0	2.35	230	0.2
4500	1925	16.0	23.0	256	368	13	White	10.0	2.35	240	0.2
5000	2050	19.0	24.0	304	384	20	White	10.0	2.35	230	0.1
6000	2500	20.0	24.0	320	384	35	White	10.0	2.35	230	0.1

(1) Dicalite is the trade-name used by Grefco Inc. for their filter-aid products.

Source: Industrial Minerals, April 1982 and Dicalite Filtration Bulletin B-16.

Table 35 Commercial applications of different grades of diatomite filter-aid

Type	Mean particle size (microns)	Approximate relative flow rate	Typical applications
Natural	Less than 2.5	100 or less	Polish filtration of beer, wine and other liquids requiring brilliant clarity.
Calcined	2.5 to 7.0	100 to 300	<p>Industrial: Alcohol, tallow, tar oil, lube oil, phosphoric acid, paper mill, sulphate liquor, driers (cobalt, lead and manganese tallates) palm oil, varnishes, waxes.</p> <p>Pharmaceutical: Hormones, pyrogens, vitamins, agar, shaving lotion, rocnelle salts.</p> <p>Food processing: Beer, wine, skim milk, citric acid, cane sugar, lemon juice, olive oil, vinegar molasses, pectin.</p>
Flux-calcined	5.5 to 13.0	300 to 1,000	<p>Industrial: Clarification of fats, lanolin, latex removal, sodium chloride, sulphite liquor, soda ash, linseed oil, tallow, driers, magnesium chloride, sodium silicate, tall oil, lube oil, sulphuric acid, tung oil, soya oil, transformer oil, paper mill liquors, pyroxylin solution, hemp oil, dopes, fuel oil, mucilage, aluminium hydroxide floc, paints lacquers, Soln's dye, wax.</p> <p>Pharmaceutical: Palm oil, alginate liquors, streptomycin, Bitters shaving lotion.</p> <p>Food processing: Phosphoric acid, lemon juice, citrus pulp, malt syrup, beet, cane sugar, beer, citric acid, citrus pulp, grape juice, cottonseed oil, wine (rough), pectin, molasses, coconut oil, drinking water.</p>
Flux-calcined	13.0 to 40.0	1,500 to 2,500	<p>Industrial: Pyroxylin solution, Soln's Dye, linseed oil, lube oil, rayon liquor, acetate liquors, dopes, lacquers, varnish, glue and glycerine resins, aluminium hydroxide floc, wax.</p> <p>Food processing: Wort beer, lime juice, grape juice, corn glutel, orange juice.</p> <p>Swimming pool water.</p>

Source: Company literature.

and average levels of soluble substances. It is claimed that these tests are usually sufficient to determine the filter-aid potential of the ore. (1)

(1) A more detailed review of the testing process appears in the paper "Aptitude of diatomaceous ore for filter-aid processing", 8th Industrial Minerals International Congress 1988, by C. Theune H and J. Bellet P, Empresa de Programacion y Sistemas Eprom Limitada, Santiago, Chile.

Filtration requirements range from the very high clarity needed in the polishing of beer and wine, through to the filtering of swimming-pool water. The processes vary according to the application, but ultimately the objective of all industrial filtration is to obtain the optimum compromise between clarity and flow rate. The selection of the appropriate grade of diatomite for a specific filtration process is only one of a number of variables. There are, for example, many types of filtration vessels, some suitable for heavier, more viscous suspensions (e.g. rotary drum vacuum filters) and others for lighter liquids.

Table 35 summarises some of the end-uses for filter diatomite and gives a rough indication of the grade of diatomite required. The flow rates shown are relative, with the natural grade of diatomite taken as the base of 100, and are estimated from company literature. Further details of some of the more important uses are given below.

Filtration applications represent by far the major end-use for diatomite. The US Bureau of Mines estimate that in 1987, 412,000t of diatomite were used for filtration purposes, out of a total US demand of 477,000t.

4.2.1.1 Water treatment and purification

Diatomite filter-aids are used in the purification of water and in the treatment of waste water. The degree of treatment varies considerably, but, for most purposes, conventional primary and secondary treatment, involving such processes as sedimentation, chlorination and chemical precipitation and flocculation, is insufficient. Therefore, tertiary treatments are needed. These involve filtration using sand, granulated activated carbon, mixed-media filters or diatomite.

4.2.1.1.1 Silica sand filters

Silica sand is the most common filter medium used in water treatment. In the conventional rapid filters used in potable water treatment plants, the filter consists of a graded gravel base overlaid by sand sized between 0.35 and 0.60 mm and with a maximum uniformity coefficient of 1.7. Although rapid filtration can remove 50% of solid impurities, some water needs further treatment. In the case of potable water this involves the use of slow filters which are similar to rapid filters but cover a larger area and use finer sand. Owing to the finer grain of sand clogging is common and frequent backwashing is necessary.

In Europe, most producers of silica sand filters work to the West German DIN 19623 standard which is outlined below.

Table 36: Main specifications of the West German DIN 19623 silica sand filtration standard

Silica content:	at least 96% SiO ₂	
Grain size distribution :	0.4 - 0.63mm to	Not more than 5% under-and oversized particles
	0.7 - 1.25mm	
Coefficient of uniformity :	1.0 - 1.25mm to	Not more than 10% under- and oversized particles
	25 - 35mm	
Coefficient of uniformity :	1.5 maximum	
Density :	2,500-2,670 kg/m ³	
Shape :	Must be a natural sand- no crushed quartzites due to the formation of large % of fines from the breakdown of angular nature	

Source: Industrial Minerals, September 1985

The filters outlined above rely on gravity; however, silica sand is also used in pressure filters. These consist of a filter media, a supporting bed, an underdrain system and flow control mechanisms, but differ from gravity filters in that they are totally enclosed and rely on pressure to achieve high flow rates. Filtration capacities are usually between 200 and 600 gpm (gallons per minute) at a filter rate of 3 gpm/foot².

A typical sand found in pressure filters is shown in the table below.

Table 37: Analysis of a typical sand found in pressure filters

<u>Thickness (inches)</u>	<u>Medium</u>	<u>Particle size</u>
12	Sand	0.45 - 0.50 mm
10	Sand	0.80 - 1.20 mm
4	Gravel	$\frac{1}{4}$ - inch
4	Gravel	$\frac{1}{2}$ - inch
8	Gravel	1 - $\frac{1}{2}$ inch
4	Gravel	1 $\frac{1}{2}$ - 1 inch

Source: Industrial Minerals, September 1985

Manganese green sand is also used for filtration purposes but to improve flavour rather than remove toxins. It is used principally in those regions where the water has a high iron content. Inversand Co. in Clayton, New Jersey are the world's sole producers, and export approximately 20% of their annual production to Asia, Europe and Latin America.

The bulk of the demand for filtration sand is from the slow and rapid gravity filters used in the filtration of potable waters by public authorities. Filtration plants of this nature may contain thousands of tonnes of filter media and last for ten years with only minor replenishment. The pattern of demand is, therefore, rather erratic. Consumption of sand by industrial filter manufacturers is much less than by municipal authorities but fluctuates less. These manufacturers produce gravity and pressure filters used in, for example:

- the removal of suspended solids and colour from surface waters for potable and industrial applications
- filtration of water prior to ion exchange treatment
- filtration of industrial process waters for recovery and recirculation
- removal of organic matter from cooling systems

The largest of the pressure filters may hold up to one tonne of sand, whereas the smaller swimming pool filters use only 50 kilogrammes. US consumption of filtration sand was 230,000t, 380,000t and 144,000t in 1981, 1982 and 1983 respectively, reflecting the variable nature of demand. Between 35,000 and 45,000 tpa are reported to be used in swimming pools.

4.2.1.1.2 Granulated Activated Carbon filters

Granulated Activated Carbon (GAC) is used both in the treatment of drinking water and in the purification of industrial and municipal wastewater. It may be used either as a primary treatment, or as the final tertiary stage in the purification process.

GAC used in water treatment has a surface area of between 900 and 1150 m²/gm for maximum adsorption and a wide range of pore sizes, including macropores for the adsorption of higher molecular weight substances. Fine mesh sizes are used, with at least 95% passing a 325 mesh. Dosage rates depend on the type of carbon used and the level of impurities but are generally low.

The main use of GAC in treating drinking water is the removal of organic compounds such as chloroform and trihalomethanes. US regulations restrict concentrations of chloroform and other trihalomethanes to 0.1 mg/litre of water in municipal water systems serving more than 75,000 people.

4.2.1.1.3 Mixed-media filters

More effective pressure filtration is obtained by the use of mixed-media filters. These comprise different materials of different densities, graded so that the coarsest material is at the top and progressively smaller particles are towards the base. The finer material tends to have the highest density. This prevents hydraulic grading during backwashing. Materials commonly used in mixed-media filters are listed in the table below.

Table 38: Materials commonly used in mixed-media filters

	<u>Effective size (mm)</u>	<u>Sp. Grav.</u>
Anthracite	0.7 - 1.7	1.4
Sand	0.3 - 0.7	2.6
Garnet	0.4 - 0.6	3.8
Magnetite	0.3 - 0.5	4.9

Anthracite is used both on its own and in conjunction with sand. The Unifilt Corporation, in Zelienople, Pennsylvania are the major US manufacturers of anthracite for water filtration. They believe that the angularity of anthracite particles allows them to catch more pollutants than rounder sands. The city of Los Angeles used anthracite supplied by Unifilt in the Aqueduct Filtration Project.

Mixed-media filters benefit from higher flow rates and larger filtration runs than their mono-medium counterparts, and also consume less backwash water. Anthracite-sand-garnet beds operate at around 5-8 gpm/foot². This form of filtration is, however, expensive since garnet costs a great deal more than ordinary filtration-grade sand. Mixed-media filtration is, therefore, unsuited to use by municipal water authorities, although it is gaining popularity with manufacturers of pressure filters, particularly in the USA which has its own supplies of garnet. US demand for filter-grade garnet amounted to 7,100t in 1983.

4.2.1.1.4 Diatomite filters

Whilst silica sand is by far the most widely used filtration medium, it is only effective at extracting solids greater than 10-20 microns. Where sub-micron solid particle polishing is required, diatomite is used. The market for diatomite in water treatment is most highly developed in the USA, largely due to the presence of indigenous supplies and resultant lower prices. The main uses are in the treatment of industrial process waters and in swimming-pool filtration. The purification of potable water is a relatively minor application. Drinking water supplies are treated in some areas of the USA, where the nature of the water demands it, but reported consumption only amounts to between 13,500 and 18,000 tpa and is subject to seasonal variation.

Some interest has been shown in the treatment of drinking water liable to be contaminated with the parasitic growth Giardia, which cannot be extracted by sand filters, and test plants were reported to have been commissioned in Wyoming and Colorado. However, no reports of their progress have been received.

The US military uses diatomite in portable filtration units for drinking water.

However, drinking water filtration is largely the domain of graded sand filters. When these are inadequate, chemical treatments can be used to coagulate the impurities, removing the need for a finer filter. If the impurity content is low ('thin' water), or merely discolours the water, a solid may be added to increase the weight and so facilitate filtration. This is normally bentonite or a similar clay, not diatomite.

In Europe the use of diatomite in water treatment is limited, being restricted to situations where water purification is critical, such as in the recycling of process waters in the food, chemical and electroplating industries. There is little or no demand for diatomite precoat filters used in the treatment of drinking water, although export markets exist in Africa and the Middle East.

A growing market exists in the offshore filtration of sea water prior to its injection into partially-spent oil reservoirs for enhanced oil recovery methods.

Swimming pool filters represent a significant end-use for diatomite in the USA, in competition with sand filters. In recent years, around 45% of domestic (private) pool filter demand has been met by diatomite, compared to 50% for sand filters and 5% for textile-based cartridge filters. An average pool uses 75-100 lbs of diatomite a year. Some competition from expanded perlite has been reported in this market, due to a significant cost advantage, but this material is less efficient and available in far fewer grades.

Australia is the world's second major swimming pool market, with upwards of 200,000 pools. Demand for diatomite as a pool filter is probably about 3,000 tpa.

The UK has about 70,000 pools (all types) but consumes very little diatomite in filtration. No diatomite is used in municipal pools. In common with the rest of Europe, sand represents by far the major filter medium since it provides adequate water clarity at comparatively low cost.

Spa pools, otherwise known as whirlpool baths, rarely use diatomite as a filter medium. The larger, commercial pools mostly use sand and the domestic models are usually fitted with cartridge filters.

4.2.1.1.5 Changes in demand for filters in water treatment

The use of filters in water purification grew considerably during the 1970s, especially in the USA and Europe. In the USA alone, consumption of all types of filters in water purification increased from 254,000t in 1970 to 435,430t in 1980, a rise of 58%. This was the result of high energy costs and increasingly stringent government controls on pollution which stressed the need to recycle and purify water.

It is believed that the Safe Drinking Water Act of 1986 will have an effect on the filter industry as a whole. The Act contains a filtration rule which requires the installation and use of filter-media in the unfiltered water plants which provide drinking water for 22% of the population.

The Water Pollution Control Acts Amendment was passed in the USA in 1977, and pollution standards have since been set by the World Health Organisation and a number of European governments. As such standards become more widely accepted there will be an increase in the use of water treatment materials. Frost and Sullivan have predicted that US capital spending by federal, state and local government on water supply and wastewater treatment will increase by over 30% between 1987 and 1995. Similarly, the New York market research company Find/SVP have predicted a rise in the total market for water purification systems from US\$3.1 billion in 1986 to US\$7.7 billion (at constant prices) in 1995 which, when adjusted for inflation, represents a US\$5 billion market.

In Europe, the French water company, Lyonnaise des Eaux have joined with the Danish company DDS (De Danske Sukkerfabrikker) and the Canadian company Zenon to develop a water filtration process using ultrafiltration membranes. A subsidiary of DDS, DDS Filtration, will supply equipment to the European market while Zenon aim to supply the North-American and Japanese markets. Lyonnaise des Eaux have also established a joint-venture company, Water Services, with the construction company John Laing PLC to identify opportunities in the UK's water industry.

The rise in the use of silica sand will probably involve a greater emphasis on higher technology pressure systems. A growth in the use of garnet and magnetite is likely. There will be growth in consumption of diatomite for water treatment but most of this growth will be concentrated in the USA.

4.2.1.2 Sugar and Sweeteners

The first large scale industrial use of diatomite filter-aids was reported in 1899 for filtering raw sugar liquors, and sugar processing remains an important end use for diatomite. However, the market for diatomite lies chiefly in liquid sweetener production.

Sugar is the commercial name applied to sucrose derived from the sugar cane, the sugar beet and, to a lesser extent, from sorghum and the sugar maple.

World production of cane sugar and beet sugar is of the order of 100 mill.tpa and other sweeteners are produced in smaller quantities. The trend in sugar production since 1979/1980 is shown in Table 39.

Table 39: World production and consumption of sugar, 1979/80 to 1987/88 (million tonnes)

	<u>Production</u>	<u>Consumption</u>	<u>Stocks at Year-end</u>
1979/80	84.8	89.9	25.2
1980/81	88.1	89.4	24.3
1981/82	100.8	92.2	32.9
1982/83	100.5	94.0	38.9
1983/84	98.0	96.2	39.8
1984/85	100.4	98.4	40.3
1985/86	98.9	100.3	37.9
1986/87	103.9	103.7	37.1
1987/88	103.5	105.4	34.6

Source: F.O. Licht

World sugar statistics do not generally include data on other caloric sweeteners, which are derived from a starch source (usually maize). The broad term 'caloric sweetener' may, however, be used to include cane and beet sugar. Until recently, starch products comprised two types: glucose syrups (called corn syrups in the USA) and pure glucose in liquid or crystalline form (sometimes called dextrose). However, the discovery of the enzyme glucose isomerase, which converts glucose to isoglucose (or fructose), has led to a rapidly expanding market for liquid high fructose corn syrup (HFCS) containing 55%-90% fructose. Production of all three types can involve diatomite. Liquid sucrose and glucose mixtures are also produced.

There is a growing tendency for sugar to be replaced by HFCS and high-intensity sweeteners, such as aspartame, particularly in the

USA. Corn products as a whole account for 65% of the US industrial nutritive sweeteners market, although applications of liquid corn sweeteners are believed to be nearing saturation point.

World production of HFCS amounts to about 6 mill. tpa, of which the bulk is consumed in the USA. Table 40 shows that US consumption of HFCS was 10.2 bill. lb (sugar equivalent) in 1985. This figure is forecast to rise to 13.5 bill. lb by 2005, an increase of 3.3 bill. lb. Consumption of sucrose (sugar) is expected to fall by 5.8 bill. lb during the same period.

Table 40: USA: Forecast of consumption of all sweeteners and non-metabolized polysaccharides (bill.lb sugar equivalent)

	<u>1985</u>	<u>2005</u>	<u>Change</u>
Sucrose	14.8	9.0	-5.8
HFCS	10.2	13.5	+3.3
Other corn syrups, inc. glucose	5.1	5.6	+0.5
Solid fructose	0.012	1.0	+0.988
Selected non-metabolized polysaccharides	0.025	0.300	+0.275
High-intensity sweeteners (all)	4.0	11.6	+7.6

Source: Reach Associates, Inc. report: Aspartame and other sweeteners - update 1987.

The use of high-intensity sweeteners will have the highest growth; 7.6 bill.lb between 1985 and 2005. Annual worldwide sales of these sweeteners amount to over US\$900 million, with aspartame (which is 200 times sweeter than sucrose) accounting for over 90% of US sales and 80% of world sales (around US\$750 million). Low-calorie versions of popular canned drinks, such as Diet Coke and Diet Pepsi, represent approximately 75% of the world aspartame market.

In the USA, aspartame is produced and sold under the name "NutraSweet" by G.D. Searle, part of Monsanto. However, Searle's aspartame patent for Europe is due to expire during 1988 and that for the USA in 1992. Many companies are therefore researching new, improved ways of producing aspartame or developing alternative high-performance sweeteners. One such company is Hoechst Celanese. Their acesulfame-K sweetener ("Sunette") has already been approved by the Food and Drugs Administration (FDA) for use in dry foods, and a proposal to use "Sunette" in baked goods and liquids is being considered. The first "Sunette" products should appear on the US market in 1989.

US consumption of caloric sweeteners amounted to 130 lb/person (sucrose equivalent) in 1985, but is expected to fall to 110 lb/person by 2005. However, consumption of all sweeteners, including caloric and high-intensity sweeteners, is forecast to rise to 155 lb/person.

The market for diatomite lies chiefly in liquid sweetener production, but there is little information available about the proportion of the total sweetener market held by liquid products. Liquid sweeteners are used almost entirely in food processing and other industrial uses. Almost 80% of all US, Japanese and West German sweeteners are used industrially, but the figure is only 50% for France, and 10-25% for developing countries. About 35% of industrial sugar deliveries in the USA are liquid, but only about 15% in the EEC and less than 10% in Japan. A much higher proportion of starch products are liquid - about 75% in the USA - and increased production of HFCS will further increase the liquid proportion. All liquid sweeteners account for about 45% of the total industrial sweetener market in the USA.

4.2.1.3 Beer and Wine

Another important filtration use for diatomite is in the production of alcoholic beverages.

4.2.1.3.1 Beer

Filter-aids such as diatomite are used in the filtration of most beers, with the exception of cask-conditioned draught beers produced in the UK. Manville have estimated that 4 oz (approximately 112g) of diatomite are needed for the production of one 36-gallon barrel (164 litres) of beer, although one UK brewer has reported the lower figure of 3.1 oz/barrel. The average level of use is probably around 3.5 oz/barrel.

As in most filtration uses, perlite competes with diatomite in the production of beer. However, diatomite is usually preferred by brewers since it provides greater clarity, and probably accounts for 60% of demand for filter-aids in this market. Synthetic filter-aids are only rarely used.

Although the UK is one of the larger beer-producing nations, accounting for around 6.5% of world output, the use of diatomite is not as great as might be expected. In recent years, cask-conditioned draught beers have claimed an ever-increasing share of the market and, as a result, consumption of filtered beers has probably fallen.

Table 41 shows world production of beer between 1975 and 1985. The eleven countries listed accounted for an average of 66.6% of total output during this period. Differences in beer types and filtration practices make it impossible to obtain a detailed breakdown of diatomite consumption in individual countries. However we estimate total world consumption to be in the range of 30,000 to 35,000 tpa.

Table 41: World: Production of beer in selected major countries⁽¹⁾
1975 to 1985 (million hectolitres)⁽²⁾

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Canada	22	22	22	22	24	23	23	23	23	24	23
China	...	3	4	4	5	7	10	12	16	22	31
Czechoslovakia	23	23	22	22	24	23	24	25	25	24	22
France	23	25	24	23	23	21	22	22	22	20	19
East Germany	20	21	22	22	23	24	24	25	25	25	24
West Germany	88	91	90	87	88	89	91	91	91	87	88
Japan	40	37	43	44	47	46	46	48	51	46	49
Mexico	20	19	22	23	25	27	29	28	24	26	27
UK	65	66	65	66	67	65	62	60	60	60	60 ^e
USA(3)	185	180	168	195	216	228	227	228	229	229	229
USSR	57	59	62	64	63	61	63	65	66	65	66
Others(4)	242	275	286	283	295	299	324	327	328	306	307
Total	785	821	830	855	900	913	945	954	960	934	945

% of total
accounted for
by major
producers 69.1 66.5 65.5 66.9 67.2 67.2 65.7 65.7 65.8 67.2 67.5

e = estimate

- (1) Countries producing more than 20 million hectolitres in 1984
(2) 1 hectolitre = 100 litres
(3) 1975 and 1976: Year ends June 30th
1977 to 1983: Year ends September 30th
(4) Comprising 117 countries

Source: UN Industrial Statistics Yearbooks, 1982 and 1985

4.2.1.3.2 Wine

Less information is available on the use of filter-aids in wine-making, although diatomite is known to be used. World production of wine is shown in Table 42. Between 1977 and 1985, the ten major producers accounted for an average 85% of total output. The two leading producers, Italy and France, accounted for around 45% of world output in 1985. It is thought that filter-aids are used more extensively in countries whose wine industry is geared to production of cheaper brands intended for mass consumption, such as Italy and Spain.

The use of diatomite in wine filtration faces competition from

expanded perlite and bentonite clays, although the superior clarity afforded by diatomite ensures its dominant position.

Table 42: World: Production of wine 1977-1985 (mill. hectolitres)⁽¹⁾

	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1980</u>	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>
Argentina	23	20	26	23	22	25	25	19	17
France(2)	53	58	84	70	57	80	69	64	70
West Germany(3)	10	7	7	5e	8e	11e	13e	9e	6e
Italy(3)	64	72	85e	87	71	73	83	71	66
Portugal	7	7	11	10	9	10	8	8	10
Romania	9	8	9	8	10	13	10	10	5
South Africa	5	3	3	4	4	8	9	8e	8
Spain	22	30	42	40	37	44	36	36	33
USA(4)	16e	18e	18e	18	15	19	14	16	17
USSR	31	25	29	32	34	35	35	34	27
Others(5)	<u>48</u>	<u>48</u>	<u>52</u>	<u>54</u>	<u>49</u>	<u>51</u>	<u>47</u>	<u>46</u>	<u>43</u>
Total	<u>288</u>	<u>296</u>	<u>366</u>	<u>351</u>	<u>316</u>	<u>369</u>	<u>349</u>	<u>321</u>	<u>302</u>

e = estimated

(1) 1 hectolitre = 100 litres

(2) Includes grape must

(3) Source: Food and Agriculture Organisation (FAO), Rome

(4) Twelve months ending 30 June of year stated

(5) Comprising 43 countries

Source: UN Industrial Statistics Yearbook, 1985.

4.2.1.4 Vegetable and animal oils and fats

Diatomite filter-aids are also used in the food processing sector in the production of edible oils derived from animal or vegetable sources. These are collectively known as glyceride oils.

Most crude fats or vegetable oils cannot be consumed without further treatment because they contain gum, phosphatides, pigments from the seed, meal particles and free fatty acids. Therefore, a refining process is necessary. The oils are treated with a strong alkali or caustic solution to precipitate impurities, they are washed with water, stirred with fullers' earth to remove pigments, and filter-aids are used for further refining. After filtering and blowing with air or steam to remove entrained oil, the filter cake is discarded and the residual neutralised, bleached oil in the cake is removed by solvent extraction.

Table 43 : World: Production of selected vegetable and animal oils and fats, 1974 to 1985 (mill.t)

	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1980</u>	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>
Lard	4.4	4.3	3.9	4.0	4.1	4.4	4.4	4.5	4.3	4.5	4.6	4.6
Butter	6.4	6.5	6.6	6.8	6.9	6.9	7.0	6.9	7.2	7.7	7.6	7.6
Margarine and Imitation Lard	8.1	8.2	8.7	8.9	9.1	9.3	9.5	9.5	9.5	9.8	10.3	10.5
Aquatic animal oils and fats	1.5	1.5	1.4	1.4	1.5	1.6	1.4	1.5	1.6	1.4	1.8	1.7
Crude animal oils and fats	5.3	4.9	5.4	5.9	6.0	6.1	6.3	6.2	6.6	6.6	6.4	6.6
Refined Soya bean oil	4.4	4.3	5.0	5.5	6.0	6.2	6.5	6.9	7.1	7.5	7.4	7.6
Refined Cotton seed oil	1.2	1.1	0.8	1.0	1.1	1.0	1.0	1.0	1.4	1.3	1.0	1.2
Refined Groundnut oil	0.5	0.4	0.5	0.4	0.4	0.3	0.2	0.3	0.3	0.3	0.3	0.3
Refined Olive oil	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.3
Other refined vegetable oils	4.7	5.1	4.9	5.1	5.1	5.4	5.3	5.7	6.0	6.1	5.9	6.2
Total	<u>36.6</u>	<u>36.5</u>	<u>37.4</u>	<u>39.2</u>	<u>40.4</u>	<u>41.4</u>	<u>41.8</u>	<u>42.7</u>	<u>44.2</u>	<u>45.5</u>	<u>45.5</u>	<u>46.6</u>

Source: UN Industrial Statistics Yearbooks 1982 and 1985

The quantity of filter-aid required in this end-use varies with the grade and colour of the oil, and an average figure would be misleading; the range varies from 0.5% to 2% of the feed. Alternative materials to diatomite in this end-use include acid-activated or neutral clays.

World production of animal and vegetable oils and fats grew steadily between 1974 and 1985 (Table 43). Soya bean oil is the major product and is the world's principal source of vegetable oil. The second largest source is palm oil, of which about 10 mill. tpa are produced. Figures for the production of palm oil are not listed separately in Table 43, but are probably included in "Other vegetable oils".

The biggest world producers of vegetable oils are Argentina, Brazil, Canada, China, India, Indonesia, Italy, Malaysia, Nigeria, the Philippines, the USA and the USSR. The US Department of Agriculture (USDA) have predicted that world oilseeds production will rise to 202 mill.t for 1987/1988. US production is expected to rise by only 1% but production in the rest of the world is expected to rise by 5% to 142 mill.t in 1988. US exports for 1987-88 are forecast at 21 mill.t by the USDA and oilseeds demand in other countries is expected to rise.

In the past, it was normal for crude oils to be processed in the consuming countries (i.e. industrialised countries) which, therefore, would account for the bulk of demand for filter-aids. However, there is now a growing tendency for the oil-producing countries to refine their output before export to increase its value. This is particularly true of Malaysia, the world's biggest producer of palm oil.

Oil palm is the source of one of the world's most prolific and economic oil crops. One hectare of oil palm has an annual yield of between 4 and 5t of palm oil and 400 to 500 kg of palm kernel oil. After refining and fractionation, the oil is normally used for edible purposes, although use of the oil in oleochemical production is increasing. In 1987, the ASEAN countries (Indonesia, Malaysia, the Philippines, Singapore and Thailand) produced around 6 mill.t of crude palm oil, accounting for over 70% of world palm oil production (see Table 44). ASEAN is also the world's largest producer of palm kernel oil (700,000t in 1987) and coconut oil (2.2 mill.t in 1987).

A considerable amount of research has been carried out, and is still being carried out, into finding ways to convert palm oil, a dietary staple in the Third World, into a valuable food product for sale to industrialised countries. Production of palm oil is rising substantially, and producers are attempting to develop new markets to prevent the price falling.

One of the processes developed involves a bed of diatomaceous earth coated with the enzyme lipase over which the palm oil, dissolved in solvents, flows. Lipase is one of a family of enzymes found in the human intestine which break down food fats. This method is used by

Table 44 : Production of palm, palm kernel and coconut oils in the ASEAN region, 1983-1992 (000t)

Palm Oil	1983	Production		1986	1987	1988	Forecasts		1991	1992
		1984	1985				1989	1990		
Malaysia	3,018	3,830	4,133	4,544	4,598	4,953	5,229	5,475	5,720	5,973
Indonesia	983	1,278	1,216	1,148	1,339	1,727	1,970	2,217	2,458	2,707
Philippines	20	26	30	35	37	40	44	47	51	54
Thailand	56	81	89	94	115	125	140	160	170	180
ASEAN	4,077	5,215	5,468	5,821	6,089	6,845	7,383	7,389	8,399	8,914
World production	5,417	6,347	6,925	7,505	8,176					
ASEAN % of world production	75.3	82.2	79.0	77.6	74.5					

Palm Kernel Oil	1983	Production		1986	1987	1988	Forecasts		1991	1992
		1984	1985				1989	1990		
Malaysia	381	429	528	596	553	619	653	684	714	746
Indonesia	76	98	119	130	133	173	197	222	246	271
Philippines	-	-	-	-	-	-	-	-	-	-
Thailand	5	9	7	6	10	10	11	13	15	16
ASEAN	462	536	654	732	696	802	861	919	975	1,033
World production	764	831	945	1,051	1,022					
ASEAN % of world production	60.5	64.5	69.2	69.7	68.1					

Coconut Oil	1983	Production		1986	1987	1988	Forecasts		1991	1992
		1984	1985				1989	1990		
Malaysia	63	45	51	55	59		32	28	24	22
Indonesia	557	492	755	782	626	750	800	850	900	950
Philippines	1,216	819	1,006	1,610	1,464	1,450	1,525	1,600	1,650	1,700
Thailand	-	-	-	-	-	-	-	-	-	-
ASEAN	1,836	1,356	1,812	2,447	2,149	2,236	2,357	2,478	2,574	2,672
World production	2,605	2,102	2,638	3,304	2,720					
ASEAN % of world production	70.5	64.5	68.7	74.1	79.0					

Source: 1983-1987: Oil World
 1988-1992: PORIM (Palm Oil Research Institute of Malaysia)

Tables quoted from "Performance Chemicals" April 1988

Table 45 : USA: Production of fats and oils which are likely to be decolourised
1971 to 1987 (million lbs)

Year	Baking and frying fats	Soya bean salad and cooking oils	Other salad and cooking oils	Margarine	Glycerine (refined)	Total
1971	3,515	2,630	870	2,296	340	9,651
1972	3,533	3,033	972	2,361	353	10,152
1973	3,636	2,838	1,056	2,359	359	10,248
1974	3,702	3,143	968	2,398	349	10,560
1975	3,687	3,005	942	2,399	264	10,297
1976	3,913	3,344	999	2,630	321	11,207
1977	3,841	3,317	1,036	2,535	286	11,015
1978	4,002	3,809	1,027	2,456	291	11,585
1979	4,215		5,107	2,403	364	12,089
1980	4,215		5,180	2,039	344	11,778
1981	4,283	4,317	1,052	2,574	298	12,524
1982	4,379	4,263	1,087	2,596	230	12,555
1983	4,363	4,659	1,116	2,451	265	12,854
1984	4,793	4,529	996	2,481	282	13,081
1985	4,304	4,722	1,220	2,603	321	13,170
1986	4,237	4,741	1,295	2,789	295	13,357
1987p	4,530	5,069	1,263	2,550	279	13,691

p = preliminary

Source: Current Industrial Reports: Fats and Oils

different organisations for different reasons. In the oil-producing countries, the aim is to produce cooking oils capable of standing on supermarket shelves in Europe without hardening. Unilever, on the other hand, seek to find a substitute for the expensive food fat cocoa butter which is widely used in the manufacture of chocolate. World supply of cocoa butter is insufficient to meet the demands of the chocolate industry.

Conventional methods of changing the fatty acid composition of palm oil take several days and produce a number of unwanted side-products. The use of enzymes, however, is far more efficient since they can be targeted, resulting in a process period of only a few hours.

In 1985, the Malaysian government were reported to be investigating the possibility of converting palm oil to fuel for diesel engines, using a process called transesterification. This involved reacting vegetable oil with alcohol in the presence of a catalyst to produce esters that are less viscous than neat oils, but still thicker than diesel. However, the cost of production was found to be almost five times higher than that of agricultural diesel. Research into this project is now being conducted by the Palm Oil Research Institute of Malaysia (PORIM).

Table 45 shows US production of fats and oils between 1971 and 1987. The slow but steady growth in output (except in 1980) would suggest a similar pattern in demand for diatomite and other filter-aids. In the UK, sales of oils and fats have been in decline during the 1980s (Table 46). This is due largely to falling demand for oil seed cake and meal.

It is to be expected that vegetable oils will gain a greater share of the market than animal oils, particularly in domestic and commercial cooking. This is due to medical reports that the low proportion of saturated fats in vegetable oils makes them less of a health risk.

Continued growth in world production of vegetable oils is likely to result in increased demand for diatomite filter-aids. However, the trend towards in-situ refining of crude oils by the producers themselves will cause a shift in the pattern of demand for filter-aids. The industrialised countries' share of total consumption will fall whereas countries such as Malaysia will account for a greater proportion.

Manville market a filter-aid which, it is claimed, improves the quality of cooking oil and increases its life by about 50%. Called 'Microsweet' this filter-aid is a blend of a Celite diatomite filter-aid and synthetic calcium and magnesium silicates. The physical properties of 'Microsweet' are given in the table below:

Table 46 : UK: Sales of organic oils and fats by UK manufacturers 1982 to 1988

	(000t)						1st
	1982	1983	1984	1985	1986	1987	quarter 1988
Vegetable and seed oils (excluding lubricating oils):							
Unrefined (including partly processed)							
Unhydrogenated	248	227	264	186	244	286	93
Hydrogenated	4	1	1	0	0	1	-
Refined:							
Unhydrogenated	501	523	443	533	716	745	206
Hydrogenated	148	123	162	169	161	130	37
Fish and marine animal oils (excluding lubricating oils):							
Unrefined	5	3	3	2	-	-	-
Refined	164	149	170	195	149	58	13
Refined inedible animal (other than marine animal) oils, fats and greases (excluding tallow):	5	4	5	4	9	6	2
Acid oils (excluding fatty acids):	56	53	49	56	57	57	13
Edible emulsifiers:	6	6	6	6	5	6	...
Total	1,137	1,089	1,103	1,151	1,341	1,289	364

Source: Business Monitor PQ 4116

Table 47: Physical properties of the "Microsweet" filter-aid

Colour	Off-white
Bulk density, lb/ft ³	15.4
Wet density, lb/ft ³	20.0
Retained on 150 mesh, %	8.0
Retained on 325 mesh, %	28.0
pH, 10% water slurry	9.6
Specific gravity	2.3
Oil retention	100.0
Moisture, %	2.5
Average particle size	35.0

Source: Company literature

4.2.1.5 Industrial Oils

Diatomite may be used in the refining of industrial oils, but it is probable that consumption of filter-aids in this industry has declined considerably in recent years, due to the development of refining techniques which eliminate the need for extensive secondary purification or bleaching. For instance, hydrogenatic plants and catalytic cracking have replaced lube-oil percolation towers and Gray process gasoline treatment units.

Moreover, US consumption of filter-aids in this industry is probably considerably higher than in Europe where alternative methods of solvent refining are considered to be more attractive economically.

Within the broad category of industrial oils, diatomite is used mainly in the refining of white oils and electrical oils, and fairly rarely for lube-oils. Although a good filter-aid, diatomite has only a limited bleaching action, and active clays such as sepiolite and sodium montmorillonite (bentonite) are frequently preferred on these grounds.

4.2.1.6 Chemical and Pharmaceutical uses

The dry-cleaning industry uses diatomite in the purification of solvents. With the growth of coin-operated dry-cleaning machines, filter manufacturers had until recently concentrated on automatic units, such as single-charge filters with automatic filter-feed and throwaway cartridges. However, difficulties in complying with solvent pollution laws have hampered growth in this potentially significant market for filter-aids and the use of coin-operated machines is in decline.

The pharmaceutical industry uses diatomite filters where it is necessary to remove solids in processes involving fermentation. The transportation of phosphoric acid for use in fertilizers is made more economic by the prior removal of solids, which produces a high concentrate. Diatomite filter-aid is commonly used in this application.

4.2.2 Fillers

Mineral fillers, extenders and pigments are used in the manufacture of many products including: paint, paper, plastics, carpet backing and rubber. Almost any rock can be pulverised and used as a filler but some satisfy the required specifications particularly well. Fillers can be separated into two groups; functional and non-functional. Functional fillers are those which play a role in the final performance of the product, whilst non-functional fillers are usually included to extend the other ingredients, thereby reducing costs. Non-functional fillers tend to have less stringent specifications than functional fillers, making substitution between materials fairly easy. The aspects of a product or production process most commonly modified by fillers are given below:

- cost reduction
- colour or brightness
- fire resistance
- thermal conductivity
- electrical conductivity
- density
- flowability
- hardness
- strength
- viscosity
- texture

The reduction of production costs is seen as the most important application for fillers.

A filler should ideally be soft, grit-free, insoluble and inert, and have a high refractive index, low specific gravity, small particle size and suitable particle shape and size distribution. Consistency in size distribution is particularly important since the filler may, in some cases, constitute 50% of the final product. The relative importance of other properties depends on the end-use. Colour, for example, is critical in paints, paper and plastics, whilst chemical purity is a major consideration if the filler is to be used in combination with acids or in a low pH process environment.

The properties of diatomite make it suitable for use as a functional filler in a wide range of industries. The particle structure has led to its use as a flattening agent in the paint industry, and as an anti-blocking agent in polyethylene film.

Table 48 : USA: Properties of diatomites sold in filler applications

	<u>Paper</u>		<u>Paint</u>		<u>Conditioning agent</u>		<u>Anti-blocking agent</u>	<u>Reinforcing agent</u>
	<u>Cylinder machine production</u>	<u>Fourdrinier production</u>	<u>High flatting</u>	<u>Low lustre stir-in</u>	<u>Toxicant extender</u>	<u>Fertiliser coating</u>	<u>Polyethylene</u>	<u>Rubber</u>
Loose wt./m ³	0.11	0.12	0.13	0.12	0.12	0.13	0.15	0.14
Wet density, t/m ³	0.32	0.36	0.32	0.30	0.36	0.31	0.33	0.38
Moisture content, %	4.0	3.0	0.5	0.1	4.0	3.3	0.1	0.3
Retained on 0.104 mm. % wt	-	0.1	Trace	0	0.1	0.1	0	0.1
Retained on 0.043 mm. % wt	8.0	0.4	1.2	Trace	0.4	3.0	Trace	0.7
Oil absorption. % wt	210	180	145	160	180	190	160	150
Colour	Grey	Grey	White	White	Grey	Grey	White	Pink
Brightness, TAPPI	65	63	88	89	63	59	90	60
Hegman	-	-	1	4	-	-	5	-
Sheen	-	-	12	15	-	-	30	-
Specific gravity (apparent)	2.0	2.0	2.3	2.3	2.0	2.0	2.3	2.2
pH	6.6	6.2	8.7	9.5	6.2	7.1	9.8	6.5
Resistivity, ohms	3,000	3,000	13,000	7,400	3,000	4,000	6,500	30,000
Refractive index	1.42	1.42	1.48	1.48	1.42	1.42	1.48	1.44
Surface area, sq.m.perg.	20-30	20-30	0.7-3.5	0.7-3.5	20-30	20-30	0.7-3.5	4-6
Porosity, %	65-85	65-85	65-85	65-85	65-85	65-85	65-85	65-85
Particle size range u	8-1	4-1						
Valley Iron Abrasion mg	440	170	850	495	170	410	390	300

Source: Industrial Minerals, April 1982.

Diatomite is also used in the production of cat-litter, pesticide carriers, and in pitch control for the paper industry, due to its high absorptive capacity (up to 2.5 times its weight in water). The high silica content (as much as 94%) of certain grades means that diatomite is inert to most chemical reactions and resistant to extremely high temperatures (with a softening point of around 1,430°C). These grades can therefore be used as catalyst carriers and insulating materials. Refined natural milled diatomite is used as an abrasive in some silver polish formulations, while flux-calcined grades are used in automobile polishes and toothpastes. Diatomite is also used as a filler in resin/polymer production (to introduce lighter colours), and in rubber production (as a semi-reinforcing agent). A detailed analysis of the properties of diatomite used for filler applications in the USA is given in Table 48.

C.H. Kline and Co. estimate that in 1986, 10.3 mill.t of industrial minerals valued at almost US\$2.7 bill. were consumed for extender and filler applications in North America. (Table 49). This represents an average annual growth of 9% from 1981. This growth is expected to continue, with the market projected to reach US\$3.1 bill. by 1990. However, diatomite fillers account for a very small percentage of this market (between 1 and 2%). Table 50 shows US consumption of diatomite for filler and extender purposes.

Table 49: North America: Estimated sales of extender and filler minerals 1981, 1982, 1985, 1986, 1987 and 1990 (US\$mill)

	<u>1981</u>	<u>1982</u>	<u>1985</u>	<u>1986</u>	<u>1987</u>	<u>1990</u>
Titanium Dioxide	1,100	1,180	1,400	1,500	1,600	1,700
Kaolin	300	360	700	600	570	600
Calcium Carbonate	100	140	200	250	250	300
Silica	100	110	150	150	160	170
Talc	70	40	70	70	70	100
Others	<u>100</u>	<u>100(1)</u>	<u>180</u>	<u>160</u>	<u>150</u>	<u>250</u>
Total	<u>1,770</u>	<u>1,930</u>	<u>2,700</u>	<u>2,730</u>	<u>2,800</u>	<u>3,120</u>

(1) Diatomite accounted for around 10% of sales of other extender and filler minerals in 1982

Source: C.H. Kline & Co./Roskill estimates

Table 50: USA: Consumption of diatomite for fillers and extenders
1983-1987 (t)

1983	133,000
1984	145,000
1985	156,000
1986	136,000
1987	159,000

Source: USBM Minerals Yearbook

Nearly half of total filler sales in the USA in 1982 went into the paper industry. Paper is probably still the main end-use for diatomite fillers.

Paper is also the main application in Western Europe, accounting for 62% of the 7 mill.t of fillers estimated to have been consumed in 1984. However, 60% of demand for fillers in paper is met by kaolin which is also by far the most commonly used material in the other major uses like paint and plastics. Between them, paper and paint account for over 75% of the market for fillers and extenders in Western Europe. However, there is a growing trend in the paper industry towards the use of alkaline paper making systems. This will lead to increased use of ground calcium carbonate as a filler.

4.2.2.1 Paper

Fillers are used in the paper industry to reduce cost and provide certain properties that cannot be achieved with pulp alone. A paper filler should ideally be white, soft, free from grit, insoluble and inert, and have a high refractive index, relatively low specific gravity, small particle size and suitable particle shape and size distribution.

The major property imparted to the paper is opacity. Paper consists of sheets of cellulose fibres formed on a fine-wire screen from a dilute aqueous suspension and bonded together as the sheet is dried.

Minerals are used to fill the interstices between the fibres to reduce 'showthrough' (where printing is visible on the reverse of the sheet) and improve the reception of printing or writing ink. Generally, the effectiveness of the filler is increased by a reduction in particle size, although the particle size distribution is also a factor and should not necessarily be uniform.

A high refractive index also increases opacity and brightness. A filler should also be as white as, or whiter than, the fibre used to maintain or improve colour, and have good brightness (measured as the

percentage of light of specified wavelengths reflected by the material).

The filler should also be soft and have a flat particle shape so that it can be formed into a smooth sheet by calendaring. A smooth sheet is both an aesthetic requirement and necessary to ensure good printing characteristics.

The other requirements for paper fillers reflect the need for a material which can be used efficiently and without adverse effect on the paper-making process. Softness and freedom from gritty particles are needed to minimise machine wear while the filler should be inert so as not to interfere with sizing (a treatment which reduces water penetration and is especially important for lithographic papers).

It is important that the filler is retained on the wire with the fibre when it is dried, to ensure good sheet formation and minimise dusting and wastage of the filler. The properties which affect filler performance in this respect are solubility and specific gravity which should both be low, and suitability for application with a starch or resin binder. Insolubility is especially important in mills with open water systems where there would be high losses of a soluble filler. Fillers with a high specific gravity may also tend to become concentrated on one side of the sheet, and make it difficult to produce an opaque lightweight paper. Increasing postal charges are creating a significant trend in demand towards lightweight papers.

The most widely used paper fillers are kaolin, calcium carbonate, titanium dioxide and talc. The 1986 US consumption figures for these fillers are given in Table 51.

Table 51: USA: Consumption of major paper fillers 1986 (000t)

Kaolin	3,310
Calcium carbonate	590
Titanium dioxide	190
Talc	<u>130</u>
Total	<u>4,220</u>

Source: Falmouth Associates Inc.

Calcium sulphate, barium compounds and perlite are also used, but to a lesser extent. An outline of filler use in the various types of paper is given in Table 52.

The use of diatomite as a filler in paper is relatively new, its first use having been as a pitch control agent.

Pitch trouble is caused by the resinous material which is

present in timber and not completely removed by the pulp washing process. During the paper-making process, small particles of pitch tend to agglomerate, adhere to machinery surfaces and clog the web, causing thin spots and other faults in the sheet. The incidence of pitch trouble can be related to many factors which affect both the amount of pitch present and its tendency to agglomerate. For instance, trees felled in spring and summer have a relatively high pitch content. Pitch trouble cannot, therefore, be eliminated and must be controlled by one of two methods: dispersion or adsorption. Dispersion methods, where pitch is maintained in a colloidal state by organic chemical additions, are logical in a mill with an open water system where pitch and dispersants are discharged, but are problematic in the closed systems increasingly required by effluent discharge regulations, because the pitch and dispersants accumulate. As a result, adsorption methods are finding increasing favour.

Table 52: Types of paper and filler use

<u>Paper types</u>	<u>Properties</u>	<u>Filler</u>
<u>Examples</u>	<u>Extent and reason for filler use</u>	<u>Loadings</u>
Newsprint Newspapers	Adequate for printing Limited, less than 20% to reduce cost and modify surface	4- 6
Uncoated printings and writings Coated printings and writings Books, magazines, box lining, duplicating, stationery, air mail, etc.	Suitable for printing Almost always filled to reduce cost and modify surface Almost always filled to reduce cost.	10-15
Construction paper and paperboard Papers, felts and for insulation	Strength Very small deliberate additions	8-10
Household and Sanitary Towelling, napkins, tissues, industrial wiper stock	Absorbency strength, disposability Very small deliberate additions	8-10

Special thin paper Condenser, capacitor and cigarette papers	Low weight Small deliberate additions	20
Vegetable parchment greaseproof and glassine		
Greaseproof paper	Resistance to oil, grease and water, strength, translucence	8-10
	Some special filler use, small total market	10
Liner board, Fluting paper and paperboard		
Solid boxboard and corrugated papers boards	Whiteness Some filler to increase opacity and brightness	10
Sack Kraft Paper sacks (cement, fertilizers, etc.	Strength Very small deliberate additions	8-10
Other Kraft wrapping paper Other paper bags groceries, etc.	Strength Unlikely to be filled	8-10
Folding boxboard Boxes	Softness, scoring and folding characteristics, suitable for printing Widely filled to modify surface	8-10
Straw paper and paperboard Boxes	Softness, scoring and folding characteristics, suitable for printing Small market	8-10

Other

Including non-folding boxboard for shipping cases	Various Softness, scoring and folding characteristics, suitable for printing Limited market	8-10
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Source: OECD definition of products, in The Pulp and Paper Industry (OECD, Paris), and industry sources

Pitch control by adsorption involves adding an inert ultra-fine mineral to the stock at an early stage in the pulping process (it is a preventative rather than curative technique). The adsorption agents used have a high effective surface area of an organophilic nature onto which pitch can be adsorbed and so lose its ability to adhere to other pitch particles. There are considerable economic advantages to this method, since both the pitch control agent and the adsorbed pitch are retained in the finished product, and increase its weight. Moreover, an effective pitch control agent allows the amount of green fresh wood used to be increased, which reduces pulpwood storage costs.

In addition to having a large organophilic surface area, pitch control agents should also be hydrophobic, electrically neutral, non-abrasive, unaffected by the pH, temperature or chemical balance of the pulping system and continue to function as long as the organophilic surfaces are unsaturated.

Diatomite, bentonite, talc and other clays are all used as pitch control agents. Diatomite's low density and good suspension properties result in excellent retention on the sheet. This is affected by the grade of diatomite, method of addition and the type of pulp, but may be as high as 95% in paperboard.

The quantity of diatomite used varies between 0.5% for pitch control and 15% in some boards or moulded paper products. Typical levels for other products are shown in Table 53 below.

Table 53: Quantity of diatomite used in selected paper products
(% of body weight of finished product)

<u>Product</u>	<u>% diatomite</u>
Fruit wrappers and carbonizing tissue	1
Newsprint	2-4
Offset printing paper	2-4
Milk cartons	3-5
Chip board	4
Liner and filling of folding boxboard	3-10

Source: Paper Loading Materials, Technical Association of the Pulp and Paper Industry, Monograph Series No. 19 (New York: 1958)

There are no definitive specifications for diatomites suitable for use in paper, but the following table gives some indication of the type of material used.

Table 54: Properties of diatomites used in paper manufacture

	<u>Natural</u>	<u>Calcined</u>
Specific gravity	1.95-2.05	2.30-2.36
Moisture, maximum	6.0%	1.0%
Retention on 325-mesh screen max.	1-6%	1-15%
Apparent density, loose, lb./cu.ft	8-12	8-12
Cake density, lb./cu.ft	18-30	18.30
Brightness	59-75	85-95
Colour	Brown to white	White
Relative abrasion, mg.	40-175	200-1000
Surface area, nitrogen adsorption method, sq.m./g.	20-37.3	1.6-4.0
Oil adsorption (Gardner Coleman)	140-180	100-250
Chemical analysis		
SiO ₂	80-90%	80-90%
Al ₂ O ₃	3.0-7.0%	3.0-7.0%
Fe ₂ O ₃	1.0-3.0%	1.0-3.0%
CaO	0.3-3.0%	0.3-3.0%
MgO	0.1-1.0%	0.1-1.0%
Ignition loss, etc.	4.0-7.5%	0.5-1.5%
Particle size distribution, microns		
Over 40	0- 4%	0-5%
40 to 20	3-10%	1-11%
20 to 10	5-20%	10-30%
10 to 6	14-32%	15-30%
6 to 2	30-46%	20-55%
Under 2	15-32%	4-20%

Source: Paper Loading Materials, Technical Association of the Pulp and Paper Industry, Monograph Series No. 19 (New York: 1958) p.81

Diatomite satisfies the basic requirement for a pitch control agent, but talc is more effective, cheaper and more widely used. In paperboard, the addition of diatomite improves the dispersion and retention of fibres, and increases drainage. A faster, more uniform vapour release allows the options of increased production rates or reduced steam consumption. In fine papers, improved sheet formation is diatomite's major advantage, but it is also used as a filler to comply with weight and thickness requirements, and to reduce costs by replacing expensive sulphite pulp. In addition, it improves pigment retention, and enhances the brightness of titanium dioxide pigments.

It has been found to be advantageous to keep the internal mineral content as low as possible in order to preserve the strength of the paper, and to apply additional pigments to the surface of the paper. Papers with complete fibre coverage have controlled ink absorbency and even surface characteristics. The pigments used are usually clay and/or calcium carbonate. Diatomite is used to give a matt finish in paper coating formulations and, in combination with

Table 55 : OECD: Production of paper divided by type, 1982 (000t)

	Newsprint	Other P & W	Construction	Household	Wrapping	Other	Total
Austria	181.8	660.6	...	114.9	734.1	15.2	1,706.6
BLEU	98.5	416.8	21.2	100.7	171.4	19.3	827.9
Denmark	...	135.3	...	13.2	130.0	...	278.5
Finland	1,500.5	2,170.9	4.8	167.3	1,785.3	266.4	5,895.2
France	248.0	2,065.0	8.0	273.0	2,430.0	103.0	5,127.0
West Germany	660.0	3,070.5	58.1	597.3	3,028.9	368.4	7,783.2
Greece	25.0	135.0	...	54.0	53.0	13.0	280.0
Ireland	-	10.0	...	...	20.0	...	30.0
Italy	198.0	1,683.4	...	166.5	2,186.7	339.1	4,573.7
Netherlands	148.5	490.6	40.1	120.7	803.8	7.4	1,611.1
Norway	668.0	249.5	6.1	21.7	322.0	36.5	1,304.0
Portugal	...	95.7	...	35.5	301.2	64.8	497.2
Spain	92.6	703.3	...	136.7	1,449.5	301.7	2,683.8
Sweden	1,323.0	991.7	...	283.5	3,082.3	247.2	5,927.7
Switzerland	210.0	257.0	...	80.0	335.0	5.0	887.0
Turkey	143.6	85.6	...	2.4	217.6	88.0	537.2
UK	85.0	903.8	...	411.5	1,511.6	257.3	3,169.2
Canada	8,116.0	1,480.0	200.0	360.0	2,183.0	267.0	12,606.0
USA	4,573.1	13,888.0	...	4,201.7	16,960.7	4,230.9	43,854.4
Japan	2,580.0	4,017.0	223.0	1,297.0	6,740.0	2,535.0	17,392.0
Australia	307.2	193.4	...	107.4	847.4	3.2	1,457.6
New Zealand	322.1	36.8	...	39.7	307.7	16.6	722.9
Total	21,480.9	33,739.9	561.3	8,584.9	45,601.2	9,184.0	119,152.2

Source: OECD

Table 56: OECD: Production of paper divided by type, 1984 (000t)

	<u>Newsprint</u>	<u>Other P & W</u>	<u>Construction</u>	<u>Household</u>	<u>Wrapping</u>	<u>Other</u>	<u>Total</u>
Austria	198.9	762.2	-	95.8	827.5	37.7	1,922.1
BLEU	102.0	434.0	-	45.0	237.0	50.0	868.0
Denmark	-	159.3	-	15.0	177.6	-	351.9
Finland	1,878.3	2,970.4	1.4	160.6	1,986.2	324.7	7,321.6
France	264.5	2,247.7	7.8	227.2	2,622.6	195.8	5,565.6
West Germany	721.0	3,778.3	48.2	614.6	3,437.8	557.4	9,157.3
Greece	7.0	69.5	-	89.2	78.5	80.8	325.0
Ireland	-	-	-	-	20.0	-	20.0
Italy	206.8	2,005.1	-	176.3	2,004.1	329.8	4,722.1
Netherlands	181.1	574.7	46.0	149.1	925.3	5.8	1,882.0
Norway	840.0	298.0	1.0	22.0	363.0	38.0	1,562.0
Portugal	-	106.8	-	42.1	348.0	75.0	571.9
Spain	124.2	736.2	-	181.5	1,564.5	344.0	2,950.4
Sweden	1,506.9	1,333.7	-	259.3	3,509.5	259.7	6,869.1
Switzerland	231.0	303.0	-	86.0	366.0	-	986.0
Turkey	152.4	112.3	-	11.0	413.5	7.9	697.1
UK	235.7	1,023.9	-	431.0	1,641.4	255.2	3,587.2
Canada	9,014.0	1,943.0	200.0	367.0	2,529.0	368.0	14,421.0
USA	5,025.0	16,444.0	-	4,464.0	33,830.0	2,341.0	62,104.0
Japan	2,553.4	4,551.1	221.6	1,074.0	7,664.0	3,280.5	19,344.6
Australia	378.0	222.0	-	125.0	805.0	-	1,530.0
New Zealand	242.0	38.0	-	41.0	308.0	65.0	694.0
Total	23,862.2	40,113.2	526.0	8,676.7	65,658.5	8,616.3	147,452.9

Source: OECD: "The Pulp and Paper Industry".

Table 57: OECD: Production of paper divided by type, 1985 (000t)

	<u>Newsprint</u>	<u>Other P & W</u>	<u>Construction</u>	<u>Household</u>	<u>Wrapping</u>	<u>Other</u>	<u>Total</u>
Austria	241.2	849.6	-	94.6	905.2	36.4	2,127.0
BLEU	109.0	416.0	-	41.0	238.0	37.0	841.0
Denmark	-	136.9	-	13.8	171.0	-	321.7
Finland	1,810.8	3,166.8	0.5	160.8	1,972.8	333.3	7,445.0
France	263.6	2,124.0	7.1	245.2	2,510.9	192.1	5,342.9
West Germany	721.5	3,908.3	39.3	628.3	3,452.1	428.6	9,178.1
Greece	7.7	82.2	-	101.1	77.2	96.5	364.7
Ireland	-	-	-	-	20.0	-	20.0
Italy	177.8	1,940.1	...	200.2	1,917.2	351.6	4,586.9
Netherlands	191.1	561.7	40.4	149.3	956.0	6.3	1,904.8
Norway	877.0	284.0	7.0	26.0	388.0	22.0	1,604.0
Portugal	-	93.0	-	35.0	356.0	58.0	542.0
Spain	134.4	712.3	...	193.1	1,532.5	341.0	2,913.3
Sweden	1,594.3	1,364.4	-	263.6	3,519.3	261.0	7,002.6
Switzerland	232.0	323.0	-	90.0	369.0	5.0	1,019.0
Turkey	146.1	115.7	3.5	18.3	394.6	18.4	696.6
UK	351.8	1,022.0	-	403.7	1,647.8	255.9	3,681.2
Canada	8,991.0	2,141.0	-	422.0	2,894.0	-	14,448.0
USA	4,924.0	16,478.0	-	4,482.0	32,519.0	2,537.0	60,940.0
Japan	2,592.0	4,747.0	245.0	1,089.0	8,404.0	3,392.0	20,469.0
Australia	372.0	256.0	-	109.0	883.0	-	1,620.0
New Zealand	298.0	48.0	-	41.0	316.0	67.0	770.0
Total	24,035.3	40,770.0	342.8	8,807.0	65,443.6	8,439.1	147,837.8

Source: OECD: "The Pulp and Paper Industry".

Table 58: OECD: Per capita consumption of paper and board, 1957, 1967 and 1974 to 1985 (kgs per capita)

	1957	1967	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
USA	186.9	232.4	264.9	223.3	245.5	256.6	270.2	277.0	264.5	268.8	249.4	268.3	288.4	282.8
Sweden	100.0	171.0	218.0	210.3	216.1	182.6	187.6	216.3	216.9	199.4	205.2	228.1	245.8	241.6
Finland	72.0	122.8	135.8	150.0	193.2	183.3	188.9	226.3	244.1	279.6	228.6	243.3	287.7	275.2
Canada	126.0	154.0	193.2	147.6	180.9	176.9	193.8	202.5	193.7	199.7	181.2	193.5	201.0	191.1
New Zealand	-	-	144.9	138.5	115.1	133.7	130.0	147.5	126.2	131.3	160.0	145.7	201.1	239.2
Norway	69.6	108.3	121.5	124.2	123.2	120.0	130.0	144.6	118.9	129.0	121.5	121.1	136.3	141.3
Netherlands	69.0	108.0	152.2	123.6	141.5	142.7	148.1	158.6	154.8	154.2	150.7	157.8	170.9	171.0
Australia	-	-	150.6	120.0	125.7	127.5	114.6	117.7	138.3	142.4	149.2	122.8	136.3	149.4
Denmark	66.0	115.7	145.1	119.7	127.4	127.8	139.3	145.1	149.4	142.3	165.7	170.5	183.5	181.1
Japan	31.4	87.7	140.4	117.6	132.8	134.6	141.7	151.2	153.5	142.5	145.8	155.0	160.0	168.8
West Germany	63.5	98.2	131.9	112.3	133.2	137.4	142.9	156.4	155.3	156.0	151.7	160.0	176.3	174.1
Switzerland	78.0	126.8	155.3	110.2	131.5	143.4	150.1	159.7	167.1	164.9	154.8	162.9	173.1	177.7
UK	80.0	115.6	143.3	108.0	124.1	124.6	130.7	135.5	122.3	125.9	120.4	125.6	134.4	136.9
Belgium	55.0	83.4	145.9	100.7	126.1	122.1	133.4	143.9	138.5	141.2	143.3	150.7	157.1	155.7
France	51.8	79.6	115.1	89.2	105.7	105.4	110.5	117.1	115.8	115.5	116.0	119.1	123.9	118.8
Austria	37.4	59.8	99.9	84.8	97.1	98.5	98.1	105.9	113.7	110.0	108.0	110.1	124.2	133.0
Ireland	38.3	65.9	99.5	72.9	82.5	89.0	83.3	96.2	72.6	58.7	56.3	77.1	24.0	54.9
Italy	23.0	56.0	79.8	61.4	81.0	77.1	83.5	93.0	92.8	88.3	87.9	86.0	93.7	91.8
Spain	14.2	30.2	64.5	56.6	61.2	63.6	59.4	62.9	71.4	70.2	74.0	72.8	78.1	76.7
Greece	10.0	22.2	30.6	43.4	44.6	43.2	45.6	53.2	52.1	59.4	48.5	59.2	53.7	56.5
Portugal	9.0	20.2	41.9	29.4	26.7	38.2	35.3	41.5	35.8	42.0	41.9	55.8	44.3	43.0
Turkey	16.8	7.2	7.7	10.2	11.3	9.2	12.8	7.9	12.9	12.5	12.5	12.2	15.5	14.5

Source: OECD "The Pulp and Paper Industry".

water and titanated lithopone, is sometimes used for the hiding power and uniform appearance it produces.

There are no published statistics on the use of diatomite in papermaking. However, Tables 55, 56 and 57 show OECD production (1982, 1984 and 1985) of the types of paper in which diatomite is likely to be used.

In Europe, diatomite is probably used more extensively in those countries with local supplies. Larger quantities of diatomite are likely to be used in the North American paper industry, especially as a pitch control agent for fruit-wrapping and other tissues.

OECD per capita consumption of paper and board between 1957 and 1985 is shown in Table 58. The growth in consumption has been linked to increasing levels of literacy and resultant growth in the use of printed matter, particularly in advertising. The highest rates of growth in consumption have been experienced by Portugal, Greece and Spain, which have only recently been included in the list of industrialised countries by the OECD.

4.2.2.2 Paint

The most important filler end-use for diatomite is as an extender and flattening agent in paint. However, it is not a major paint extender compared to minerals such as talc, calcium carbonate, kaolin, silicas, mica and barytes.

Paints are composed of binders (oils), solvents (water or synthetic organic materials) and pigments. Pigments are small crystalline particles and the term includes both materials which determine the colour of the paint (such as titanium dioxide) and extenders (such as diatomite) which reduce overall material costs. Mineral extenders can account for up to 25% of the total weight of a paint, while representing only 5% of the cost. However, 10%-20% of the weight is a more typical level.

Diatomite is added to paint for a number of reasons, but the most important is flattening efficiency. Simply, diatomite alters the texture of a paint, resulting in surface irregularity which disrupts specular (mirror-like) reflection. Few other functional fillers can match the ability of diatomite to combine flattening efficiency with economy. The efficiency of diatomite lies in its reduction of gloss at solids-to-binder ratios that do not sacrifice film performance. Since the coatings industry buys raw materials by weight and sells finished products by volume, diatomite's high bulking value also makes it cost-effective.

Other benefits of using diatomite include improved touch-up characteristics, burnish resistance, ease of wetting, and good stain removal. The finer grades of diatomite offer better stain removal, and the coarser grades, better abrasion resistance. The highly

irregular particle size and shape contribute to good sanding qualities, "tooth" for topcoat adhesion (useful in primers) and fast solvent release. An interesting point is that the diffuse reflectivity imparted by irregular diatoms makes them good candidates for extending traffic paints which require good night-time reflectivity.

The choice of the optimum diatomite grade for flattening efficiency depends on several factors: the desired reduction of gloss and sheen, the type of dispersion equipment used and the final film smoothness required. Smoothness is the factor on which the selection is usually based to the greatest extent. For interior flat wall paints, a medium flux-calcined (Hegman 2) grade is most suitable. For semi-gloss enamel paints, a fine flux-calcined (Hegman 4) is recommended for its high flattening ability and easy dispersibility. The flattening efficiency of the fine and extra-fine flux-calcined grades (Hegman 5 and 6) provides low pigment-to-binder ratios, making these grades suitable for high-performance industrial finishes and pigmented coil coatings.

The physical properties of diatomite important to its use in coatings are given in Table 59.

Table 59: Properties of diatomite used in coatings

<u>Product</u>	<u>Hegman</u>	<u>Colour</u>	<u>Screen, 325 % Retained</u>	<u>O/A Rub-out Lbs/100 Lbs</u>	<u>Average PSD Microns</u>
Coarse. fc	0	white	14	130	16
Coarse. n	0	grey	4	155	8
Medium. fc	2	white	1.5	110	7
Medium. n	3	grey	0.5	135	3
Fine. fc	4	white	Tr.	105	5
Fine. n	5	white	Tr.	105	5
Extra fine. fc	5½	white	Tr.	100	4

fc = flux-calcined
n = natural

Source: American Paint & Coatings Journal, March 17th, 1986.

Four major factors affect gloss and sheen in a paint system: particle shape, oil absorption, particle structure and particle size distribution. The particle structure of diatomite allows the absorption of oil into the structure whilst permitting the particles to act individually and form voids between themselves to absorb more oil. When diatomite particles are broken and reduced by attrition, their structures are destroyed and they become discrete particles whose oil absorption is merely a function of their external surface area. The British Standard BS1795 suggests an oil absorption value for diatomite of 60-100g/100g.

Diatomite is most effective when used in conjunction with other extenders. In semi-gloss enamels, a combination of talc and diatomite will have better flexibility than talc alone, since the same flattening is achieved with less pigment. In flat enamel, the addition of 10 lbs of fine flux-calcined diatomite per 100 gallons of pigment reduces sheen from 30 to 15, as shown below.

	<u>Alkyd Flat Enamel</u> <u>Lbs/100 Gal</u>	<u>Lbs/100 Gal</u>
TiO ₂	200	200
CaCO ₃	300	300
Fine Flux-Calcined Diatomite	0	10
60° gloss	10	8
85° sheen	30	15
Hegman	4.5	4

Source: American Paint & Coatings Journal, March 17th, 1986.

The British Standard BS1795 sets out the following physical and chemical specifications for diatomite and other silica extenders used in paint (Table 60).

Table 60: British Standard (BS1795) for silica extenders in paint

Physical specifications:

Extender	Grade	Residue on sieve (max. %)			Particle size distribution (min. %)			
		125 m	63 m	45 m	20 m	20 m	5 m	2 m
No. 12 & No. 13	a	40.0	-	-	-	-	-	-
	b	2.0	25.0	60.0	-	-	-	-
	c	-	0.5	5.0	70	-	10	-
	d	-	-	0.1	-	-	95	-
No. 14 & No. 15	a	-	-	15.0	70	10	-	-
	b	-	-	5.0	75	20	5	-
	c	-	-	1.0	80	30	10	-
	d	-	-	1.0	90	50	30	-
No. 18	a	-	2.0	5.0	80	50	20	-

Chemical specifications:

	No. 12	No. 13	No. 14	No. 15	No. 18
% SiO ₂	80-98	98	70-80	80	97
Volatile matter 105°C. %	0.5	0.5	12	2	12
Loss on ignition, % max.	5.0	0.2	15.0	1.0	8.0
Matter soluble in water, %	0.5	0.5	1.0	1.0	-
pH of aqueous solution	7-10	7-8.5	6.5-10	6.5-10	3.5-8

- Extender No. 12: Silica (quartzite) type 1. Natural.
- Extender No. 13: Silica (quartzite) type 2. Natural.
- Extender No. 14: Kieselguhr, type 1. Diatomaceous siliceous earth.
- Extender No. 15: Kieselguhr, type 2. Diatomaceous siliceous earth.
- Extender No. 18: Silica, synthetic, hydrated.

The types of paint in which diatomite is used are shown in Table 61, together with the reasons for selection and the grade of diatomite used. The coatings industry only uses the natural (off-white) and flux-calcined (white) grades of diatomite. Calcined diatomite is not used because of its pink colour.

Table 61: Use and properties of diatomites in paints, divided by coating type

<u>Finish Coating type</u>	<u>Required Hegman fineness</u>	<u>Estimated grade of diatomite (medium particle size, microns)</u>		<u>Useful properties</u>
		<u>Flux-calcined</u>	<u>Natural</u>	
Masonry paints	0.1	16.0	7.7	Colour and sheen uniformity, flatting
Traffic paints	0.1	16.0-7.6	7.7	Fast solvent release. Diffuse reflectivity, abrasion resistance.
Primer paints	1-3	7.6	7.7-3.0	Good top coat adhesion, good sanding adhesion.
Flat wall paints	1-2	7.6	3.0	High flatting efficiency.
Exterior house paints	1-2	7.6	3.0	High flatting efficiency.
Maintenance paints	1-2	7.6	3.0	Efficient flatting, good application properties.
Eggshell enamels	3-5	6.8	-	Gloss and sheen control.
Semi-gloss enamels	4-5	6.8	-	High flatting efficiency.
Industrial finishes	5-7	5.5	-	Very high flatting efficiency permits low pigment:binder ratio.
Flat varnishes and lacquers	5-5	5.5		Efficient flatting.

Source: Based on Manville company literature.

Table 62: USA: Production of paint, varnish and lacquer 1979-1987
(000KL)

	<u>Architectural coatings</u>	<u>Product Finishes OEM</u>	<u>Special Purpose Coatings</u>	<u>Total</u>
1979	1,786.3	1,328.6	439.5	3,554.4
1980	1,661.4	1,195.8	509.9	3,367.0
1981	1,578.5	1,179.1	489.4	3,247.0
1982	1,491.4	1,059.5	488.7	3,039.6
1983	1,639.4	1,113.3	493.2	3,245.9
1984	1,731.0	1,270.7	548.9	3,550.6
1985	1,809.0	1,333.9	550.4	3,693.3
1986	1,896.8	1,323.0	515.6	3,735.3
1987e	1,972.1	1,370.3	522.4	3,864.8

e = estimate

Source: "Current Industrial Reports, M28F" and estimates by Rauch Associates 1986.

Table 63: World production of paint 1981-1985 (000t)

	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>
Algeria	91	100	...	...	...
Argentina	131	118	119	125	104
Austria	...	...	18e	19e	...
Belgium	114	113	113	123	120
Czechoslovakia	163	162	166	166	171
Denmark	85	85	32	37	39
Finland	94	75	75	78	...
France(1)	...	506	483	479	493
East Germany	383	333	380	398	397
West Germany	1,173	1,132	1,158	1,168	1,161
Hungary	139	141	140	139	141
India(2)	96	108	113	120	140
Japan	1,555	1,574	1,618	1,803	1,847
Mexico	220	217	179	201	222
Netherlands	213	209	213	225	233
Norway	62	61	62	63	...
Portugal	79	82	82	76	74
Spain	87	77	91	...	...
Sweden	131	134	134	140	134
UK(3)	743	735	331	760	776
USSR	3,209	3,167	3,325	3,431	3,509
Yugoslavia	<u>209</u>	<u>191</u>	<u>200</u>	<u>294</u>	<u>303</u>
Total (countries listed)	<u>8,976</u>	<u>9,318</u>	<u>9,031</u>	<u>9,844</u>	<u>9,863</u>

e = estimate

... = not available

- (1) Source: Annuaire de Statistique Industrielle 1986
Ministere de l'Industrie, des P et T et du Tourisme
- (2) Production by large or medium-scale establishments only
- (3) Sales of manufacturers employing 25 or more persons

Source: UN Industrial Statistics Yearbook 1985.

Table 62 shows production of paint, varnish and lacquer in the USA from 1979 to 1987, and Table 63 shows paint production in the other major producing countries from 1981 to 1985. The peak in production in 1979 was the result of high demand from the automobile and building sectors (the two major end-uses for paint). The recession in the early 1980s was responsible for a fall in output due to its effect on automobile sales and house building. However, since 1983 production has recovered, and the average annual growth in paint shipments in both Europe and the USA is estimated to be around 1%.

Table 64: World paint sales by market sector 1986 (%)

Decorative	49
Automotive	5
Autorefinish	4
Can	3
Other	39

Source: ICI

Table 64 shows the distribution of world paint sales by market sector in 1986. The largest sector is that for decorative coatings, which accounts for 49% of total sales. 30% of this figure represents sales made to individuals for domestic use, while the remainder is sold to trade painters for internal and external decorative architectural purposes.

Automotive coatings, including original equipment manufacture (OEM) and refinish, account for around 9% of the total market. This sector offers considerable potential for water-based coatings, which reduce solvent emissions and improve working conditions, and also offer considerable cost savings on raw material. The refinish market is dominated by Hoechst, BASF and ICI, who have invested heavily in new production facilities to ensure consistency of product, as well as in research and development.

Coil and strip coatings (6%) are used in "white goods" such as cookers and refrigerators, other engineering products and can manufacture. Controlled application means there is little wastage, making this sector a highly profitable one.

Powder coatings represent approximately 2% of total sales. They reduce the need for solvents and offer more precise applications than other paints. Some producers have estimated growth of between 10 and 15% in the powder coatings industry within the next few years.

Other sectors of the paint and coatings market include wood coatings and varnishes, marine paints, fungicidal paints, heat-resistant coatings, fluorescent markings, high-performance anti-corrosive paints, and temporary coatings.

Table 65: USA: Consumption of selected fillers and extenders in the paint industry, 1972 to 1986 (000t)

	<u>Titanium Dioxide</u>	<u>Talc(1)</u>	<u>Kaolin</u>	<u>Barytes</u>	<u>Mica</u>	<u>Other Clays</u>	<u>Total</u>
1972	391	158	115	42	24	5	735
1973	425	162	122	47	34	5	795
1974	...	143	237	44	30	6	460
1975	307	128	104	32	20	7	598
1976	330	171	192	45	19	7	764
1977	361	181	150	50	29	9	780
1978	388	174	159	55	19	10	805
1979	395	215	168	34	17	10	839
1980(2)	327	234	177	36	16	10	800
1982	274	155	197(3)	...	14	17	657
1985	390	138	188(3)	...	17	15	748
1986	447	163	231(3)	...	20	23	884

(1) Includes pyrophyllite 1972-1975

(2) In addition, in 1980, 18,000t of diatomite were consumed in the US paint industry

(3) Includes ball clay

Source: C.H. Kline: Guide to the Paint Industry 1981
Rauch Guide to the US Paint Industry 1984 and 1987
USBM Minerals Yearbooks

Table 65 shows the consumption of selected fillers and extenders in the US paint industry between 1972 and 1986. Titanium dioxide, talc and mica are used mainly in exterior paints, while kaolin is used in interior emulsion paints. The main use for barytes is in corrosive-resistant paints.

There has been substantial growth in the filler/extender market since 1972. The European market has grown by around 87%, largely due to increased calcium carbonate loading levels for cost-reducing purposes. Growth in the US market has been slower, around 15%, as US paint producers have had to reduce the use of certain grades of tremolitic talc for health and safety reasons.

Titanium dioxide accounts for approximately 45% of total filler consumption in the US paint industry, and calcium carbonate occupies a similar position in the European market. Both are used mainly to reduce costs but also to add opacity and whiteness.

C.H. Kline have estimated that around 18,000t of diatomite were consumed by the US paint industry in 1980, less than 2% of total filler consumption. In 1987, Rauch Associates estimated diatomite consumption in the US paint industry to be around 24,000 tpa. The bulk of this diatomite is used in flat architectural paints.

Demand for paint is not expected to increase rapidly: a growth rate of 1-2% per year could reasonably be expected. The consumption of different kinds of coatings will, of course, be affected by different factors.

Demand for architectural coatings, for example, will be limited by the level of house building which in turn will depend on interest rates, mortgage rates and land prices. The price of land is particularly important in Japan. However, these same factors can cause greater demand for paint in the DIY market.

Consumption of highway paints depends very largely on the budgeting decisions taken by authorities responsible for road marking. In any case, the consumption of such paints is falling as formulation improvements are making them more durable.

The consumption of extenders in the paint industry is likely to increase in order to reduce production costs. However, demand for diatomite is unlikely to increase at the same rate as other minerals, largely due to its higher cost. Diatomite will probably be used in conjunction with another small-particle, but cheaper extender, such as talc.

The prices of diatomite and competitive materials are covered in Section 6.

4.2.2.3 Plastics

A wide variety of fillers, including synthetic fibres, wood flour and other organic materials and minerals, are used in plastics. They divide into two categories: bulk fillers, which reduce the quantity of expensive plastic resin needed, and functional fillers, which impart desirable physical, electrical or processing properties to the plastic.

Diatomite is used as a filler in plastics as it both reduces cost and modifies properties. Diatomite imparts good heat resistance and surface finish to the product, reduces mould shrinkage and improves water and abrasion resistance. Highly refined diatomite is used in the production of polyethylene films as an abherent (anti-blocking agent). Abherents are substances that prevent or reduce adhesion of a material to itself or to another material, and are mainly used in casting, moulding, surface release coatings, transfer coatings and packaging.

No separate figures for the consumption of diatomite in plastics are available, but demand in both Europe and the USA is probably less than 20,000 tpa.

Table 66 below shows some of the important properties of

minerals used in the plastics industry.

Table 66: Important properties of mineral fillers used in plastics

<u>Property</u>	<u>Desired characteristics</u>
Density	Low density preferred to reduce added weight and maximize resin saving
Colour	High degree of whiteness usually required
Hardness	Hard minerals cause abrasion on processing equipment, but can be beneficial in product
Particle size and shape	Very fine particles usually required, size distribution important, fibrous minerals reinforce system
Absorption	Absorption of resin increases filling cost and mixture viscosity
Moisture	Free moisture and moisture absorption should be low
Dispersion	Good dispersion and 'wetting out' needed; affected by particle size and use of surface treatment

Source: Kriens, J., Industrial Minerals Fillers/Extenders in Plastics, in Proceedings of the Third 'Industrial Minerals' International Congress 1978.

Density is the most important factor, as it determines the reduction in resin weight that can be achieved. Fillers have densities up to three or four times greater than resins, and occupy a proportionally smaller volume for a given weight. The density of diatomite, at 2.00 to 2.33 g/cm³ is, as shown below, slightly lower than that of most other mineral fillers. Flux-calcined (white) diatomite has the highest density and natural (off-white) diatomite the lowest.

Table 67: Densities of major mineral fillers and resins

<u>Filler</u>	<u>Density (g/cm³)</u>
Calcium carbonate	2.7
Limestone	2.8
Kaolin	2.6
Talc	2.8
Mica	2.8 to 3.0
Wollastonite	2.9
Silicas	2.65
Asbestos	2.4 to 2.6
Diatomite	2.00 to 2.33

The bulking value, (the volume filled by a given weight of filler), is the reciprocal of the density. The bulking value of diatomite is, therefore, high compared to other mineral fillers, between 0.43 cm³/g, and 0.50 cm³/g.

Compounding with mineral fillers is the most widely used and least expensive method of modifying plastics. Studies by Kline & Co. (of Fairfield, New Jersey, USA) show a loss of momentum in plastics consumption over the past nineteen years, but an annual rise in the consumption of mineral fillers by the plastics industry over the same period. In Europe, consumption has increased at an average annual rate of 7%, from 278,000t in 1972 to 650,000t in 1985, and some fillers (notably talc and silicas) have increased by over 20% during this period. Between 1967 and 1985, US production of PVC, polyester, polypropylene and nylon (which account for over 90% of demand) increased by 8% per year, while mineral filler consumption rose by 13% per year. From 1977 to 1985, mineral filler consumption by the US plastics industry increased at an average rate of 19% per year.

Mineral fillers are mainly used in the production of polyvinyl chloride (PVC), phenolics, nylon, epoxy plastics and unsaturated polyesters. US consumption of fillers in plastics is shown in Table 68.

Table 68: USA: Consumption of mineral fillers in the plastics industry
1985-1987 (000t)

	<u>1985</u>	<u>1986</u>	<u>1987(1)</u>
Carbonates (2)	1,230	1,280	1,340
Kaolin	77	86	95
Mica	10	11	14
Microspheres (3)	8	9	10
Minerals (4)	170	181	188
Organics (5)	86	86	90
Silica (6)	43	45	48
Talc	64	68	73
Others (7)	<u>4</u>	<u>4</u>	<u>5</u>
Total	<u>1,692</u>	<u>1,770</u>	<u>1,863</u>

(1) estimated

(2) Calcium carbonate, chalk, limestone

(3) Includes glass, ceramic and PVDC spheres and bubbles

(4) Wollastonite, silicates, others

(5) Agricultural waste products, including shell and wood flours and corn cobs

(6) Includes novaculite, sand, quartz

(7) Includes cork, perlite

Source: "Modern Plastics International" September 1987
Kline & Co., Fairfield, New Jersey, USA
Supplier and industry sources

Consumption of mineral additives by the European plastics industry is shown in Table 69 below.

Table 69: Europe: Consumption of mineral additives in the plastics
industry, 1981 and 1985 (000t)

	<u>1981</u>	<u>1985</u>
Carbonates	1,100	1,255
Talc	50	75
Asbestos	15	10
Silicas	20	40
Other minerals (including diatomite)	<u>17</u>	<u>25</u>
Total	<u>1,202</u>	<u>1,405</u>

Source: Plastics Consultancy, June 1983

The use of chemically modified minerals has enabled more mineral fillers to be used as functional additives, and it is believed that growth in this sector will outpace the growth of mineral-filled plastics by the end of the 1980s. Demand for mica, surface-treated kaolin and wollastonite has been forecast to rise by over 10% per year, due to the significant property improvements they give when added to specific resins.

Consumption of plastics in the USA and Western Europe is shown in Tables 70 and 71. In both cases, an increase in demand for polyethylene since the beginning of the 1980s can be seen. This may well have caused growth in demand for diatomite as an abherent.

Table 70: USA: Sales of plastics by type, 1977 to 1987 (000t)

	<u>Polyethylene</u>		<u>Vinyls</u>	<u>Polypropylene</u>	<u>Others(2)</u>	<u>Total</u>
	<u>High density</u>	<u>Low(1) density</u>				
1977	1,617	2,949	2,858	1,226	5,882	14,532
1978	1,893	3,249	2,641	1,389	5,271	14,443
1979	2,224	3,552	2,953	1,770	7,369	17,868
1980	1,997	3,394	2,604	1,689	6,533	16,217
1981	2,129	3,416	2,697	1,766	6,904	16,912
1982	2,284	3,494	2,810	1,647	6,088	16,323
1983	2,594	3,657	3,166	2,029	7,254	18,700
1984	2,701	3,821	3,547	2,186	7,952	20,207
1985	3,024	3,991	3,506	2,395	8,224	21,140
1986	3,198	4,004	3,836	2,650	8,664	22,352
1987	3,560	4,322	4,147	2,945	9,302	24,276

(1) Includes LLDPE

(2) Includes (1987 figures in 000t)

ABS (543), Acrylics (303), Nylon (214), Polystyrene (2,210), and Polyester thermoplastic - PBT, PET, (819)

Source: Modern Plastics International

Table 71: Western Europe (1): Consumption of plastics by type
1977 to 1987 (000t)

	<u>Polyethylene</u>		<u>Vinyl</u>	<u>Poly- propylene</u>	<u>Others(3)</u>	<u>Total</u>
	<u>High density</u>	<u>Low(1) density</u>				
1977	1,200	3,300	3,330	910	3,500	12,240
1978	1,288	3,484	3,560	1,056	3,706	13,094
1979	1,465	3,972	3,938	1,250	3,935	14,560
1980	1,364	3,745	3,750	1,200	3,745	13,804
1981	1,365	3,433	3,353	1,346	3,620	13,117
1982	1,372	3,531	3,570	1,393	3,114	12,980
1983	1,527	3,764	3,845	1,582	4,023	14,741
1984	1,639	3,862	3,820	1,858	4,274	15,453
1985	1,819	3,953	3,992	2,028	4,402	16,194
1986	2,019	4,403(2)	3,980	2,283	4,694	17,379
1987p	2,275	4,622(2)	4,207	2,561	4,926	18,591

p = preliminary

(1) Figures are estimates and include: Austria, Belgium, Denmark, Finland, France, West Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and UK.

(2) Includes LLDPE

(3) Includes (1987 figures in 000t): ABS (451), Acrylics (171), Nylon (281), Polystyrene (1,892) and reinforced thermoplastics (915)

Source: Modern Plastics International (January issues)

4.2.2.4 Agrochemicals

4.2.2.4.1 Pesticides

Mineral fillers are widely used as carriers and diluents in insecticides, herbicides and fungicides because, in their concentrated form, pesticides are difficult to distribute uniformly, and, undiluted, they may have harmful effects on the plants.

The toxic chemicals are first mixed with a carrier to make the concentrate easier to store, transport, and handle prior to application. The carrier must be highly absorptive, dispersible in liquids so it can be sprayed, and inert and compatible with the active ingredient. Fineness and low abrasiveness are important to avoid clogging and excess wear of nozzles. The most suitable fillers are diatomite, fuller's earth, kaolin, talc, gypsum, lime, perlite,

pyrophenyllite, sepiolite and attapulgite. Diatomite and perlite are the most inert of these materials, but some agrochemical formulators consider perlite too abrasive.

There are three main types of pesticide: granules, wettable powders, and liquid formulations. Diatomite is used fairly extensively in granules and wettable powders.

Many factors affect the selection of a carrier for granules. The carrier's density affects the product's performance in different weather conditions. The hardness of the carrier must be such that it will not break-down (and so clog the application), but not so abrasive as to cause excessive wear on machinery. Some agrochemicals are unstable on certain carriers, while the cost of the carrier is also a consideration. Generally, however, formulators consider the technical feasibility of using a particular carrier first, because the products are expensive and the relative cost of carrier candidates will not greatly affect choice.

Similarly the choice of carrier for wettable powders is determined by many factors, among which are the stability of the formulation's active ingredients, and the effect of storage. Powders are sold to farmers and then dispersed in liquid, and must resist agglomeration and be readily dispersible.

Mineral fillers may also be used as a diluent, which is further mixed with the formulation to facilitate spraying. Absorbency is not so important for diluents, but they must have a fine particle size and low abrasiveness. They should also act as a conditioning agent, ensuring that the formulation is free-flowing.

Anything between 5% and 60% diatomite may be included in wettable powder formulations, and typical levels are 40% to 50%.

Although diatomite is used quite widely in pesticides, the tonnages involved are far less than for fuller's earth, and probably less than for kaolin and talc. Detailed figures for the use of diatomite in pesticides are not available. However, the consumption of competitive minerals used as dry carriers and diluents by the US pesticide industry is given in Table 72.

Table 72: USA: Consumption of minerals used in dry carrier and diluent applications in pesticide formulations, 1974-1986 (000t)

	<u>Talc and pyrophyllite</u>	<u>Fuller's earth</u>	<u>Bentonite</u>	<u>Kaolin</u>	<u>Other clays</u>	<u>Total</u>
1974	43	163	22	26	...	254
1975	38	180	3	29	1	251
1976	40	186	2	31	14	273
1977	43	177	3	20	14	257
1978	36	164	4	30	15	249
1979	42	181	4	42	∅	269
1980	35	164	5	44	...	248
1981	38	167	3	73	...	281
1982	24	152	5	27	...	208
1983	16	139	7	16	...	178
1984	20	196	6	38	...	260
1985	17	233	1	61	...	312
1986	16	149	5	19	3	192

Source: US Bureau of Mines Minerals Yearbooks

The use of diatomite in pesticides is likely to vary according to local availability and company size. Large agrochemical companies operating on an international scale will use it more extensively than small companies operating in countries where it is less readily available. In general, calcined and flux-calcined grades of diatomite are used in pesticides (and other agrochemicals) because the high moisture content and lower stability of crude diatomite renders it unsuitable.

The variation in the proportion of the total accounted for by each material in Table 72 indicates that some switching between minerals takes place. It also seems likely that each filler is more or less suitable for use in certain formulations. Some variations in levels of consumption are caused by differences in the tonnages of the various pesticides which are produced from year to year in response to changes in demand, caused by variations in the area devoted to various crops, and by variations in the degree to which they are affected by pests and weeds each year.

The main producers of pesticides are Japan, the USA and the UK. Together with France and West Germany, these countries are reported to account for over 80% of total world production. Japanese production of pesticides by type is shown in Table 73.

Table 73: Japan: Production of pesticides by type, 1982 to 1985 (t)

	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>
Insecticides	185,646	202,976	209,593	206,148
Fungicides	120,119	117,717	129,976	126,911
Insecticide-fungicides	67,788	71,583	78,834	79,356
Herbicides	<u>148,382</u>	<u>154,181</u>	<u>149,546</u>	<u>162,199</u>
Total	<u>521,935</u>	<u>546,457</u>	<u>567,949</u>	<u>574,614</u>

Source: Japan Chemical Annual

Detailed statistics for the production of pesticides by type in the USA are not available. However, output of all pesticides in 1986 amounted to 535,000t.

Table 74: USA: Production and sales of pesticides, 1974-1982 (000t)

	<u>Production</u>	<u>Sales</u>
1974	643	619
1975	727	602
1976	619	541
1977	630	573
1978	642	590
1979	648	621
1980	666	638
1981	649	586
1982	505	520
1983	463	460
1984	540	502
1985	563	463
1986	535	426

Source: United States International Trade Commission Synthetic Organic Chemicals

In 1986, the world end-user agrochemical market totalled US\$17.4 billion. In real terms, this represents an increase of 1% since 1985, compared with a rise of 3.2% during the previous year. The US share of the market fell from 30% in 1985 to 26.5% in 1986. This was due to the worsening US farm economy. A percentage breakdown of the 1986 market by product and producing area is given in Table 75.

Table 75: World agrochemical production, 1986 (%)

<u>Product</u>		<u>Producing area</u>	
Herbicides	44	USA	26
Insecticides	31	Western Europe	25
Fungicides	19	Far East	22
Others	6	Eastern Europe (1)	10
		Latin America	9
		Other regions	8

(1) including USSR

Source: British Agricultural Association

The Japanese share of the market rose from 13% in 1985 to 15% in 1986. However, although production of pesticides in Japan has increased during the 1980s, domestic sales have fallen. The biggest decline has been in the use of insecticides and this can be linked to growing environmental pressures to restrict the use of pesticides. In addition, more attention is being paid to obtaining the optimum effect from these chemicals by spreading them in a more efficient way and by determining the best time to apply them.

Table 76: Japan: Domestic sales of pesticides by type, 1980, 1985 and 1986 (000t)

	<u>1980</u>	<u>1985</u>	<u>1986</u>
Insecticides	252.5	201.7	194.6
Fungicides	155.6	117.9	111.2
Insecticide- fungicides	74.7	74.0	74.6
Herbicides	166.6	152.4	151.7
Others	<u>...</u>	<u>3.6</u>	<u>4.2</u>
Total (1)	<u>649.4</u>	<u>549.9</u>	<u>536.2</u>

(1) Columns may not add to total shown due to independent rounding.

Source: Japan Chemical Week.

In the USA and the UK, herbicides account for a much larger proportion of pesticide demand than in Japan. This is largely due to a more rapid acceptance of non-selective herbicides such as paraquat and Roundup. However, the herbicide share of the market is estimated to have fallen from 44.5% in 1985 to 43.7% in 1986. This was a result of reduced acreages of maize, cotton, and to a lesser extent oilseeds, in the USA, leading to large reductions in demand.

It is likely that the bulk of diatomite consumed in the pesticides industry is used in the production of insecticides.

European Chemical News (October 9, 1984) forecast that the market for pesticides in Western Europe will be worth US\$2.75 billion in 1990, rising to US\$3.52 billion and US\$4.93 billion in 1995 and 2000 respectively. Market saturation and increasingly stringent government regulations will probably ensure that the growth in demand for pesticides in developed countries will be lower than in developing countries, especially in the Far East and Eastern Europe.

4.2.2.4.2 Fertilizers

A variety of minerals are used as diluents in the manufacture of fertilizers. The industry requires that the mineral is chemically inert and that it has satisfactory bulk density and low abrasive levels. The mineral fillers are used to facilitate dispersion. The most suitable fillers are diatomite, fuller's earth, kaolin, talc, gypsum, lime, perlite, pyrophyllite, sepiolite and attapulgite. Diatomite is the most inert of these carriers.

Table 77 : World: Production of nitrogenous, phosphate and potash fertilizers (1972/73 to 1985/86 divided by region (mill.t N, P₂O₅ and K₂O content)

	<u>1972/73</u>	<u>1973/74</u>	<u>1974/75</u>	<u>1975/76</u>	<u>1976/77</u>	<u>1977/78</u>	<u>1978/79</u>
Africa	1.8	1.7	1.9	1.8	1.8	1.9	2.0
North America	22.7	25.1	25.2	25.5	27.7	28.4	30.6
South America	0.7	0.8	1.0	1.2	1.6	1.8	1.9
Asia	11.1	11.7	13.1	13.8	14.5	17.3	19.8
Europe	29.1	30.4	31.7	29.5	31.2	32.7	34.6
Oceania	1.5	1.8	1.2	1.1	1.4	1.4	1.5
JSSR	14.8	16.1	17.9	21.6	22.1	23.0	23.2
Total (1)	<u>91.7</u>	<u>97.6</u>	<u>91.9</u>	<u>94.5</u>	<u>100.3</u>	<u>106.5</u>	<u>113.6</u>
Of which:							
nitrogenous	37.8	40.4	42.4	45.5	47.6	51.4	55.9
phosphate	23.7	24.9	25.7	25.7	27.7	29.6	31.6
potash	20.2	22.2	23.7	23.2	25.0	25.5	26.2
	<u>1979/80</u>	<u>1980/81</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>	<u>1984/85</u>	<u>1985/86</u>
Africa	2.0	2.4	2.6	3.0	3.2	3.4	3.5
North America	32.9	34.3	29.1	27.3	31.0	34.6	30.1
South America	2.1	2.5	2.1	2.1	2.1	2.6	2.6
Asia	23.0	25.0	25.9	27.3	29.5	32.4	32.5
Europe	35.8	34.7	33.3	33.1	34.5	35.6	34.4
Oceania	1.6	1.4	1.3	1.1	1.2	1.2	1.1
JSSR	21.6	24.3	25.3	26.2	28.9	30.0	32.2
Total (1)	<u>119.0</u>	<u>124.7</u>	<u>119.6</u>	<u>119.9</u>	<u>130.3</u>	<u>139.8</u>	<u>136.4</u>
Of which:							
nitrogenous	59.8	62.8	62.3	63.4	67.5	74.4	73.5
phosphate	33.5	34.5	31.7	32.1	34.9	36.6	34.6
potash	25.7	27.4	25.6	24.4	27.9	28.8	28.3

(1) Columns may not add to total shown due to independent rounding

Source: 1972/73-1979/80: UN Statistical Yearbook
 1980/81-1985/86: Food and Agriculture Organisation of the United Nations,
 Fertilizer Yearbook

The quantity of diatomite used in this application is not known. Fertilizers are included in the "Fillers and additives" category in the USBM statistics, and are likely to be only a small part of this category, probably no more than 20,000 tpa in the USA. This compares with an annual North American fertilizer output of over 30 mill. t. Diatomite is therefore used only to a very small extent as a filler in fertilizers.

Ammonium nitrate is the most hygroscopic of the common nitrogen fertilizers and is also highly soluble. Thus, if only a small amount of water is present, bridging crystals are formed between the granule surfaces during small changes in temperature. A coating of inert, moisture-absorbing material keeps the granules apart and inhibits re-crystallisation. Attapulgitic clay, diatomite, perlite and kaolin, in amounts of 2% to 3% by weight, are the usual conditioning agents added to achieve this.

Urea is much less hygroscopic than ammonium nitrate but a diatomite or other anti-caking agent is nevertheless frequently employed. In the manufacture of sulphur-coated urea, diatomite conditioner, in a quantity of 2% to 3% of total weight, is applied to the coated material to prevent caking and minimize floating in applications such as flooded rice fields.

Table 77 shows that world production of fertilizers increased by 67% between 1972/73 and 1985/86, providing a growing market for diatomite. Over the period, the relative importance of each of the three types of fertilizer changed little.

The slight decrease in production in the early 1980s was due to rising prices of energy and raw materials, and falling demand from Europe, the USA and Latin America. US demand for fertilizers fell from 21.5 mill.t (contained nutrient) in 1981 to 16.4 mill.t in 1983.

In 1986 and 1987, the world fertilizer industry experienced a general downturn. A very slow growth in demand, combined with increasing production resulted in falling prices. The EEC market was affected by rapidly increasing imports of fertilizers at prices low enough to suggest dumping. Consequently, a number of fertilizer producers in the EEC have been forced into reducing their output. This has led to an increasingly protectionist spirit in the market.

However, growth is anticipated in the developing countries. Venezuela, for example, has become a significant importer of fertilizers, following the introduction of a new government programme for the development of the agricultural sector.

China is also considered to be a growing market for fertilizers. Agriculture has expanded rapidly in China, increasing the demand for fertilizers. This demand has compensated to a large extent for the loss of the Indian Market.

The 1986/87 slump made changes in the structure of the fertilizer industry necessary. There are now fewer producing

companies, costs have been cut and production capacity has been adjusted to the expected development of the market. The major producing companies (BASF, ICI, Kemira and Norsk Hydro) have invested heavily in the modernisation of production plant and have a relatively broad product range.

It is likely that demand for fertilizers will recover in the mid to long term. At the World Fertilizer Conference in September 1981, world production was projected to rise by over 40% in the next 20 years. The only way to increase crop productivity to maintain nutritional standards is by increasing the use and effectiveness of fertilizers. In March 1982, the Food and Agricultural Organisation of the United Nations forecast the average annual growth of fertilizer consumption would increase by 2-3% in industrialised countries, 6% in developing countries and 3-4% in centrally planned economies, until 1990/91. Although the slump in the fertilizer industry has made these forecasts seem rather optimistic, it is clear that in the long term demand for fertilizers will continue to grow, providing a small but significant market for diatomite.

4.2.2.5 Abrasives and polishes

Diatomite fillers are used in a wide range of polishes and cleaners. The hollow, thin-walled individual particle structure collapses under pressure to produce a very effective polishing action. The closely controlled particle size of each filler grade also assures the right degree of abrasiveness needed for any application. Fillers, like the Celite range (produced by Manville), can provide the gentle buffing action needed in a fine silver polish, the mild non-scratching abrasive needed in an automobile polish and the hard aggressive abrasion needed in a heavy duty metal cleaner. However, other minerals such as tripoli can also be used in this range of polishes. Table 78 shows the properties of diatomite used in abrasives in the USA.

Table 78: Properties of diatomite used in abrasives in the USA

	<u>Abrasives</u>		
	<u>Silver polish</u>	<u>Automobile polish</u>	<u>Buffing compound</u>
Loose wt.t/m ³	0.14	0.14	0.17
Wet density t/m ³	0.35	0.42	0.27
Moisture content %	4.1	0.1	0.5
Retained on 0.104 mm.% wt	Trace	0	5.6
Retained on 0.043 mm.% wt	0.3	0.1	19.6
Oil absorption % wt	190	120	185
Colour	Grey	White	White
Brightness TAPPI	64	91	86
Hegman	4½	3½	-
Sheen	50	50	-
Specific gravity (apparent)	2.0	2.3	2.3
pH	6.5	9.2	8.9
Resistivity, ohms	3.000	5.000	9.000
Refractive index	1.42	1.48	1.48
Surface area sq.m. per g.	20-30	0.7-3.5	0.7-3.5
Porosity %	65-85	65-85	65-85
Valley Iron Abrasion mg	140	375	1.900

Source: Industrial Minerals, April 1982.

4.2.2.6 Gas Cylinders

Diatomite is used in the mud mixture fillings of acetylene gas cylinders. The mineral sponge filling is added before the cylinders are filled with acetone, in which the acetylene gas is absorbed. Diatomite imparts high porosity, light weight, and structural strength to the mixture.

4.2.2.7 Concrete admixtures

Diatomite used as an admixture in concrete can eliminate excess water, improve water tightness and strength (by promoting a more uniform distribution of voids in the mixture), and yield an improved finished surface.

4.2.2.8 Asphalt and bituminous compositions

Fillers are used in asphalt and bituminous compositions to increase viscosity, melting point, hardness and resistance to mechanical stress and weathering. The choice of filler depends on the properties required.

In asphaltic and bituminous concrete and paving mixtures, the fillers most commonly used are limestone, other rock dusts, silicas, slate dust and impure clays.

For bituminous lacquers and enamels, increased hardness and melting point are important, and the more absorptive fillers such as diatomite are particularly suitable. They reduce "bleeding" and increase durability. In asphalt tiles, (where the filler content may be as high as 50%), asphalt flooring, bridge planking, expansion joints and mastics, various fine-ground fillers are used, including ground limestone, marble dust, ground serpentine rock, asbestos floats and diatomite. For moulded asphaltic products, fibrous materials such as cotton linters or amphibole asbestos are used together with finely divided materials, mainly diatomite and pyrophyllite. For asphaltic coatings on roofs, pipes, etc, diatomite is used to improve heat and weathering resistance, reduce blistering and cracking, and improve adhesion.

In the USA, there has been a noticeable trend away from the use of asbestos in asphalt products. This may lead to more diatomite being used in this industry.

4.2.2.9 Match heads

Diatomite fillers, added to the composition of match heads, function as flame retardants, since the porous diatomite absorbs and disperses the flammable material. This helps to prevent an undesirable excessive flame.

4.2.2.10 Rubber goods

Diatomite fillers are used as processing aids in a variety of rubber compounds, particularly in highly loaded low cost compounds containing large amounts of oil. By adding diatomite fillers to the oil as an absorbent, a quick mix is obtained. The silicone rubber compounds remain soft and easily millable, with good tensile strength and tear strength. Manville report that Celite fillers are used in amounts ranging from 10 to 20 parts per hundred parts of rubber.

4.2.2.11 Catalyst carriers

Diatomite fillers act as catalyst carriers in many industrial processes. They absorb liquid catalysts and the resultant mixture can be extruded or pelletised to make a strong packing for tall process vessels. Diatomite catalyst carriers have the following advantages:

- controlled surface area
- chemical inertness
- high porosity (up to 6 times greater than other carriers)
- thermal insensitivity up to 800°C
- high mechanical strength.

Examples of industrial processes using diatomite fillers as catalyst carriers include the hydrogenation process and the manufacture of sulphuric acid. The properties of Celite catalyst carriers manufactured by Manville are shown in Table 79.

4.2.2.12 Oil-well drilling

The addition of calcined moler to portland cement increases sea-water resistance. Moler is therefore used in the production of special cements for oil-well drilling, where it has the additional advantage of acting as an absorbent for oil spillages.

Increased drilling activity in the late 1970s and early 1980s caused a growth in the use of moler in special cements. However, the falling price of oil and resultant drop in drilling activity since early 1983 are likely to have reversed this trend.

4.2.3 Insulation

4.2.3.1 Heat insulation

Diatomite is an effective insulator as its highly porous structure makes it a poor conductor of heat. Moler, produced in Denmark, is especially suitable as an insulation material. Moler is an impure diatomite containing up to 30% clay, which makes it unsuitable for use in specialised applications like filters. However, the clay acts as a natural binder obviating the need for expensive

Table 79 : Properties of 'Celite' diatomite fillers used as catalyst carriers⁽¹⁾

	<u>Celite Grades</u>								<u>Micro-Cel</u>
	<u>410</u>	<u>408</u>	<u>F.C.</u>	<u>219</u>	<u>21-A</u>	<u>CS-22R</u>	<u>CAS-30KR</u>	<u>1200</u>	<u>L</u>
Form	¼"	5/32"			¼"	⅛"	⅛"	¼"	
	Pellet	Pellet	Powder	Powder	Pellet	Pellet	Pellet	Pellet	Powder
Surface Area m ² /gm	20	17	20	3	77	19	122	18	95
Pore Volume cc/gm	0.53	0.46	2.7	2.54	0.33	0.53	0.40	0.49	5.0
Vibrated density pcf	37	39	7.0	8.5	36	35	38	50	5.5
Water Absorption % by weight	53	58	260	200	74	65	66	60	450
Monsanto Hardness, kg	13	12	na	na	8	5	3	8	na
Pore Diameter Mean, μ	0.49	0.42	2.5	4.5	0.06	0.43	0.51	0.40	3.3
10% larger than % pore Volume	1.09	0.64	12.0	9.3	0.07	0.72	1.14	0.55	9.0
0.1μ	10.0	11.2	0	0	96.6	11.7	12.1	12.1	13
1.0μ	87.1	98.7	18	1	100	93.0	86.1	98.2	41
Chemical composition by wt									
SiO ₂	83.06%	84.00%	86%	92%	58.56%	82.68%	53.79%	84.51%	54%
CaO	1.04	0.91	0.5	0.5	16.74	0.79	0.68	0.76	25
Al ₂ O ₃	8.57	8.20	3.8	4.4	7.38	9.58	36.55	7.54	3.6
Fe ₂ O ₃	1.91	1.96	1.2	1.2	2.02	1.80	1.54	1.94	1.2
L.O.I. (1000°C)	3.30	2.50	3.6	0.2	12.80	3.6	7.0	3.1	9.1

(1) 'Celite' is the trade name for diatomite fillers produced by Johns-Manville.

Source: Johns-Manville company literature.

artificial binders or the addition of binding clays.

The principal use of diatomite as insulation is in industrial fireproofing, at operating temperatures of about 750°C, in the semi-refractory range.

As loose fill, diatomite powder can be placed in any hollow wall or space surrounding kilns, oven dryers and certain types of furnaces. Bonded with suitable binders and combined with other materials like asbestos and bentonite clays, firing produces insulating materials which can be formed in the shape of bricks, blocks, pipe covering and other shapes. Diatomite can also be incorporated into accessory insulating materials like mortars, aggregates and insulating boards and panels.

Materials with a wide range of physical properties are obtained by the addition of binder and other ingredients, and by the length of, and temperature at, firing. These properties are summarised in Table 80.

Table 30: Properties of diatomite insulating bricks

<u>Property</u>	<u>Range</u>
Thermal conductivity at 400°C (mean)	0.6 to 3.2 Btu
Maximum safe temperature	800°C to over 1,200°C
Cold crushing strength of 9 x 4½ x 3 inch bricks, on end	60 to 980 lbs/inch ²
Weight	27 to 77 lbs/cubic foot

In the choice of suitable insulating brick, the most important factor is the maximum safe temperature, as overheating causes shrinkage and cracking. Typical applications in the iron and steel, gas, electricity generating, glass and pottery, metallurgical, chemical and other industries lie in furnaces, kilns, high-pressure boilers, high-pressure steam lines, metallurgical furnaces, regenerators, flues and stacks. The insulation is frequently used with 85% magnesia or calcium silicate as a double-layer combination.

Diatomite insulating brick is used to back up refractories in furnace applications where there are no rapid changes in temperature. They are not suitable for direct exposure to flame but they have the advantage of high compressive strength and are frequently used under fire-brick in the floors of furnaces.

Calcined diatomite mixed with portland or calcium aluminate cement in a ratio of about 4:1 on a dry volume basis can be made into an insulating concrete in the semi-refractory range. Properly reinforced, this concrete is suitable for making into furnace and kiln doors, bases, and in some cases, such as core and jpanning ovens, the entire structure can be made of the insulating concrete.

Danish moler is probably the world's major source of insulating refractory material. The producers Skamol operate two plants with a combined annual capacity of 42,000 m³ of moler-based insulating bricks. Seven grades of material are produced, with densities ranging from 500kg/m³ to 820 kg/m³.

The only figures published concerning the consumption of diatomite for insulation purposes refer to the USA and Canada. Between 1985 and 1986, US domestic and export sales of diatomite for insulation purposes rose substantially in terms of quantity (from 3,800t to 17,000t), although the proportion of total diatomite consumption represented by these sales rose only slightly (from 1% to 3%). The 1985 drop in consumption was due to low demand from end-uses like the iron and steel, metallurgical and pottery industries, and because of restrictions placed on the use of asbestos, often a component of fire-resistant products, for pollution and health concerns. Canadian consumption of diatomite for insulation purposes rose by nearly 19% in 1985, to 3,162t. This figure represents 17% of total Canadian diatomite consumption.

Insulation is believed to account for a higher proportion of diatomite consumption in Europe, largely due to the suitability and availability of Danish moler.

Insulation should provide a growing market for diatomite. As fuel prices continue to rise and the need to conserve fossil fuels becomes greater, insulating refractories are likely to be built in greater quantities. However, manufacturers are not, as yet, convinced of their cost-effectiveness. Refractories, including insulating refractories, tend to have a high energy input and if the energy used in their production is greater than the energy saving achieved by their use, then there is clearly no point in using them.

4.2.3.2 Sound insulation

A wide variety of non-metallic mineral products, including vermiculite, expanded gypsum, magnesia, diatomite, asbestos, perlite, pumice, mineral wool and many others, are all effective sound insulators. These materials are all highly porous and act as sound absorbers by admitting sound waves which are then trapped and dissipated in the form of heat. In general, good heat insulators can be converted by suitable processing into good sound insulators, and the method of processing is more important in attaining the required sound insulating properties than is the choice of raw material.

4.2.4 Other uses

There are a number of other minor end-uses for diatomite. The tonnages involved in individual applications are small, but their total represents a significant market whose diversity ensures a stable demand. For example, diatomite is used as an anti-caking agent, and it is used to absorb radioactive waste. Miscellaneous end-uses for diatomite are listed in Table 81.

Table 81: Miscellaneous end-uses for diatomite

<u>Market</u>	<u>Application and properties</u>
Chalk	Tailor's and blackboard chalks
Chemicals	Chemical processing absorbent Packing for carboys and containers
Drilling muds	Increases viscosity where bentonite is not effective
Drying acid	Assists in drying where it is desirable to prevent caking or agglomeration
Dyes	Base for lakes and water-soluble dyes
Electrical	Filler in battery-box compositions and battery separators; Dielectrics
Explosives	Absorbent and anti-caking agent
Fire retardant	Fire-proofing material, smothering aid, packing for flammable products
Leather	Filler for real or imitation leather finishes
Mould wash	In foundry castings as a separation aid
Oral hygiene	Polishing agent in toothpaste and powder
Petroleum industry	Absorbent for acids, water and impurities
Printing	Filler in printing ink rollers to raise softening point. Used in roller core paint and in graphic art inks
Rubber	Sponge rubber products
Wax crayon	Adds strength. Aids in maintaining a universally high melting point.

4.2.4.1 Anti-caking agents

Diatomite is used as an anti-caking agent in animal feeds, especially in low fibre rations. However, only small amounts are consumed in this end-use. The presence of powdered or granular forms of limestone is often enough to enable the feed to flow freely, and the use of diatomite is restricted because of its high silica content. The diatomite products used in animal feeds are produced by the Danish company, Dansk Moler Industri A/S, in agreement with Ludolph Struve and Co.

Small amounts of diatomite are used as anti-caking agents in the manufacture of seasoning, baking powder, resin moulding powders, cosmetics, explosives, pigments and dyestuffs.

4.2.4.2 Waste disposal

Diatomite is used to absorb liquid radioactive wastes. The Manville Corporation have reported that the US Federal Government has recommended the use of diatomite to absorb low-level types of radioactivity.

4.2.4.3 Extraction of oil from diatomite

A diatomite deposit in the McKittrick area of central California is believed to contain up to 832 million barrels of oil. In 1983, Getty Oil Co. and Dravo Engineers Inc. completed a one month test of the Lurghi-Ruhrgas and Dravo solvent extraction processes in an attempt to determine the most economic method of recovering the oil. It was hoped that about 380 million barrels of heavy oil would be recovered.

The crushed diatomite is mixed with a hydrocarbon solvent to wash the oil from the ore. This produces a mixture of oil, solvent and water which is separated through a multistep process. The oil is transported in a pipeline to the refinery. The diatomite returns to its naturally occurring liquid content by the addition of water.

Manville were also interested in the operation with a view to processing the waste diatomite from the oil extraction process. However, after testing the material, they decided that the upgrading of the low-grade product was uneconomic, particularly since their Lompoc operation already had substantial production capacity for high-grade diatomite.