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Development Document for Interim Final Effluent Limitations Guidelines and New Source Performance Standards for the

CLAY, CERAMIC, REFRACTORY AND MISCELLANEOUS MINERALS VOL. III

MINERAL MINING AND PROCESSING INDUSTRY

Point Source Category

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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DEVELOPMENT DOCUMENT
for
EFFLUENT LIMITATIONS GUIDELINES
and
STANDARDS OF PERFORMANCE

MINERAL MINING AND PROCESSING INDUSTRY

VOLUME III

Clay, Ceramic, Refractory and Miscellaneous Minerals

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SECTION I

CONCLUSIONS

For purposes of establishing effluent limitations guidelines and standards of performance, and for ease of presentation, the mineral mining industry has been divided into three segments to be published in three volumes: minerals for the construction industry; minerals for the chemical and fertilizer industries; and clay, ceramic, refractory and miscellaneous minerals. This division reflects the end use of the mineral after mining and beneficiation. In this volume covering clay, ceramic, refractory, and miscellaneous minerals, the 21 minerals are grouped into 17 production subcategories for reasons explained in Section IV.

Based on the application of best practicable technology currently available, 11 of the 17 production subcategories under study can be operated with no discharge of process generated waste water pollutants to navigable waters. With the best available technology economically achievable, 12 of the 17 production subcategories can be operated with no discharge of process generated waste water pollutants to navigable waters. No discharge of process generated waste water pollutants to navigable waters is achievable as a new source performance standard for all production subcategories except kaolin (wet), feldspar (wet), talc minerals (flotation), garnet, and graphite. Mine drainage and contaminated plant runoff are considered separately for each subcategory.

This study included 21 clay, ceramic, and refractory minerals of Standard Industrial Classification (SIC) categories 1452, 1453, 1454, 1459, 1496, and 1499 with significant waste discharge potential as listed below with the corresponding SIC code.

1. Bentonite (1452)
2. Fire Clay (1453)
3. Fuller's Earth (1454)
   A. Attapulgite
   B. Montmorillonite
4. Kaolin and Ball Clay (1455)
5. Feldspar (1459)
6. Kyanite (1459)
7. Magnesite (Naturally Occurring) (1459)
8. Shale and other Clay Minerals (1459)
   A. Shale
   B. Aplite
9. Talc, Soapstone, Pyrophyllite, and Steatite (1496)
10. Natural Abrasives (1499)
    A. Garnet
    B. Tripoli
11. Diatomite (1499)
12. Graphite (1499)
13. Miscellaneous Non Metallic Minerals (1499)
    A. Jade
    B. Novaculite

SECTION II

RECOMMENDATIONS

The recommended effluent limitations guidelines and the suggested technologies are listed in Table 1. pH should be maintained between 6.0 and 9.0 units at all times.

The pretreatment limitations will not limit total suspended solids, unless there is a problem of sewer plugging, in which case 40 CFR 128.131(c) applies. Limitations for parameters other than TSS are recommended to be the same for existing sources as best practicable control technology currently available and for new sources as new source performance standards.

Table 1

Recommended Limits and Standards for the Mineral Mining and Processing Industry

The following apply to process waste water except where noted

Subcategory	BPCTCA max. avg. of 30 consecutive days	BPCTCA max. for any one day	BATEA and NSPS max. avg. of 30 consecutive days	BATEA and NSPS max. for any one day
Bentonite, Fire clay, Montmorillonite, Attapulgite Kyanite, Magnesite, Shale, Aplite, Tripoli (dry processing), Diatomite, Jade & Novaculite	No discharge		No discharge	
Mine drainage (non-acid)		TSS 35 mg/1**		TSS 35 mg/1
Mine drainage (acid)	TSS 35 mg/1 Dis Fe 0.3 mg/1	TSS 70 mg/1 Dis Fe 0.6 mg/1	TSS 35 mg/1 Dis Fe 0.3 mg/1	TSS 70 mg/1 Dis Fe 0.6 mg/1
Kaolin				
Dry processing	No discharge		No discharge	
Wet processing	Turbidity 50 JTU TSS 45 mg/1 Zn 0.25 mg/1	Turbidity 100 JTU TSS 90 mg/1 Zn 0.50 mg/1	Turbidity 50 JTU TSS 45 mg/1 Zn 0.25 mg/1	Turbidity 100 JTU TSS 90 mg/1 Zn 0.50 mg/1
Mine drainage (ore slurry pumped)	Turbidity 50 JTU TSS 45 mg/1	Turbidity 100 JTU TSS 90 mg/1	Turbidity 50 JTU TSS 45 mg/1	Turbidity 100 JTU TSS 90 mg/1
Mine drainage (ore dry transported)		TSS 35 mg/1		TSS 35 mg/1
Ball Clay				
Dry processing	No discharge		No discharge	
Wet processing	TSS 0.17 kg/kkg	TSS 0.34 kg/kkg	No discharge	
Mine drainage (non-acid)		TSS 35 mg/1		TSS 35 mg/1
Mine drainage (acid)	TSS 35 mg/1 Dis Fe 0.3 mg/1	TSS 70 mg/1 Dis Fe 0.6 mg/1	TSS 35 mg/1 Dis Fe 0.3 mg/1	TSS 70 mg/1 Dis Fe 0.6 mg/1
Feldspar				
Non-Flotation plants	No discharge		No discharge	
Flotation plants*	TSS 0.6 kg/kkg F 0.175 kg/kkg	TSS 1.2 kg/kkg F 0.35 kg/kkg	TSS 0.6 kg/kkg F 0.13 kg/kkg	TSS 1.2 kg/kkg F 0.26 kg/kkg
Mine drainage		TSS 35 mg/1		TSS 35 mg/1
Talc, Steatite, Soapstone and Pyrophyllite				
Dry processing & Washing plants	No discharge			
Flotation and HMS plants	TSS 0.5 kg/kkg	TSS 1.0 kg/kkg	TSS 0.3 kg/kkg	TSS 0.6 kg/kkg
Mine drainage		TSS 35 mg/1		TSS 35 mg/1
Garnet	TSS 0.4 kg/kkg	TSS 0.8 kg/kkg	TSS 0.25 kg/kkg	TSS 0.5 kg/kkg
Mine drainage		TSS 35 mg/1		TSS 35 mg/1
Graphite (process and mine drainage	TSS 10 mg/1 Total Fe 1 mg/1	TSS 20 mg/1 Total Fe 2 mg/1	TSS 10 mg/1 Total Fe 1 mg/1	TSS 20 mg/1 Total Fe 2 mg/1

pH 6-9 for all subcategories
No discharge - No discharge of process waste water pollutants
kg/kkg - kg of pollutant /kkg of product
*kg of pollutant/kkg of ore processed
BPCTCA - Best practicable control technology currently available
BATEA - Best available technology economically achievable
NSPS - New source performance standard.
Dis - Dissolved
**No TSS limit (BPCTCA) recommended for montmorillonite mine drainage at this time.

SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

The United States Environmental Protection Agency (EPA) is charged under the Federal Water Pollution Control Act Amendments of 1972 with establishing effluent limitations which must be achieved by point sources of discharge into the navigable water of the United States.

Section 301(b) of the Act requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best practicable control technology currently available as defined by the Administrator pursuant to Section 304(b) of the Act. Section 301(b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best available technology economically achievable which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) to the Act. Section 306 of the Act requires the achievement by new sources of a Federal standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants. Section 304(b) of the Act requires the Administrator to publish within one year of enactment of the Act, regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operation methods and other alternatives. The regulations proposed herein set forth effluent limitations guidelines pursuant to Section 304(b) of the Act for the clay, ceramic, refractory and miscellaneous minerals segment of the mineral mining and processing industry point source category.

Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b) (1) (A) of the Act, to propose regulations establishing Federal standards of performances for new sources within such categories. The Administration published in the Federal Register of January 16, 1973 (38 F.R. 1624), a list of 27 source categories. Publication of an amended list will constitute announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources within the mineral mining and processing industry. The list will be amended when proposed regulations for the mineral mining and processing industry are published in the Federal Register.

SUMMARY OF METHODS

The effluent limitations guidelines and standards of performance proposed herein were developed in a series of systematic tasks. The Mineral Mining and Processing Industry was first studied to determine whether separate limitations and standards are appropriate for different segments within a point source category. Development of reasonable industry categories and subcategories, and establishment of effluent guidelines and treatment standards requires a sound understanding and knowledge of the mineral mining and processing industry, the processes involved, waste water generation and characteristics, and capabilities of existing control and treatment methods.

This report describes the results obtained from application of the above approach to the mining of clay, ceramic, refractory, and miscellaneous minerals segment of the mineral mining and processing industry. Thus, the survey and testing covered a wide range of processes, products, and types of wastes.

The products covered in this report are listed below with their SIC designations:

a. Bentonite (1452)
b. Fire Clay (1453)
c. Fuller's Earth (1454)
d. Kaolin and Ball Clay (1455)
e. Feldspar (1459)
f. Kyanite (1459)
g. Magnesite (1459)
h. Shale and other clay minerals, N.E.C. (1459)
i. Talc, Soapstone and Pyrophyllite (1496)
j. Natural abrasives (1499)
k. Diatomite mining (1499)
l. Graphite (1499)

m. Miscellaneous Non-metallic minerals, N.E.C. (1499)

Any of the above minerals which are processed only (3295) are also included.

Categorization and Waste Load Characterization

The effluent limitation guidelines and standards of performance proposed herein were developed in the following manner. The point source category was first categorized for the purpose of determining whether separate limitations and standards are appropriate for different segments within a point source category. Such subcategorization was based upon raw material used, product produced, manufacturing process employed, and other factors. The raw wastes characteristics for each subcategory were then identified. This included an analysis of (1) the source and volume of water used in the process employed and the sources of waste and waste waters in the facility; and (2) the constituents of all waste waters including harmful constituents and other constituents which result in degradation of the receiving water. The pollutants of waste waters which should be subject to effluent limitations guidelines and standards of performance were identified.

Treatment and Control Technologies

The full range of control and treatment technologies existing within each subcategory was identified. This included an identification of each control and treatment technology, including both in facility and end of process technologies, which are existent or capable of being designed for each subcategory. It also included an identification of the amount of pollutants (including thermal) and the characteristics of pollutants resulting from the application of each of the treatment and control technologies. The problems, limitations and reliability of each treatment and control technology were also identified. In addition, the non water quality environmental impact, such as the effects of the application of such technologies upon other pollution problems, including air, solid waste, noise and radiation were also identified. The energy requirements of each of the control and treatment technologies were identified as well as the cost of the application of such technologies.

Data Base

The data for identification and analyses were derived from a number of sources. These sources included EPA research information, published literature, qualified technical consultation, on site visits and interviews at numerous mining and processing facilities throughout the U.S., interviews and meetings with various trade associations, and interviews and meetings with various regional offices of the EPA. All references used in developing the guidelines for effluent limitations and standards of performance for new sources reported herein are included in Section XIII of this report. Table 2 summarizes the data base for the various subcategories sutdied in this volume.

Facility Selection

The following selection criteria were developed and used for the selection of facilities.

Discharge effluent quantities

Facilities with low effluent quantities or the ultimate of no discharge of process waste water pollutants were preferred. This minimal discharge may be due to reuse of water, raw material recovery and recycling, or to use of evaporation. The significant criterion was minimal waste added to effluent streams per weight of product manufactured. The amounts of wastes considered here were those added to waters taken into the facility and then discharged. If different processes are used by industry to achieve this low level of pollution further subcategorization was considered.

Land utilization

The efficiency of land use was considered.

Air pollution and solid waste control

Exemplary facilities must possess overall effective air and solid waste pollution control where relevant in addition to water pollution control technology. Care was taken to insure that all facilities chosen have minimal discharges into the environment and that these sites do not exchange one form of pollution for another of the same or greater magnitude.

TABLE 2

DATA BASE

Subcategory	No. Plants	Visited	No. Plants Data Available	Verification Sampling
Bentonite	37	2	2	*
Fire Clay	81	9	9	*
Fuller's Earth				
Attapulgite	10	4	5	2
Montmor.	4	3	3	3
Kaolin Dry		4	4	*
Kaolin Wet	37 total	6	7	0
Ball Clay	12	4	4	0
Feldspar				
Wet	5	5	5	5
Dry	2	2	2	*
Kyanite	3	2	2	*
Magnesite	1	1	1	*
Shale and Common Clay	129	10	20	*
Aplite	2	2	2	*
Talc Minerals				
Dry	27	12	20	*
Washing	2	1	2	*
HMS, Flotation	4	4	4	4
Natural Abrasives				
Garnet	3	2	2	0
Tripoli	4	2	4	*
Diatomite	9	3	3	*
Graphite	1	1	1	0
Misc. Minerals				
Jade	est. 10	1	1	*
Novaculite	1	1	1	*
Total	est. 384	70	94	15

*There is no discharge of process waste water in the subcategories under normal operating conditions.

Effluent treatment methods and their effectiveness

The facilities selected have in use the best currently available treatment methods, operating controls, and operational reliability. Treatment methods considered included basic process modifications which significantly reduce effluent loads as well as conventional treatment methods.

Facility facilities

All facilities chosen had all the facilities normally associated with the production of the specific product(s) in question. Typical facilities generally were facilities which have all their normal process steps carried out on site.

Facility management philosophy

Facilities were preferred whose management insists upon effective equipment maintenance and good housekeeping practices. These qualities are best identified by a high operational factor and facility cleanliness.

Geographic location

Factors which were considered include facilities operating in close proximity to sensitive vegetation or in densely populated areas. Other factors such as land availability, rainfall, and differences in state and local standards were also considered in so far as those locations with strict standards usually result in exemplary facility performance.

Raw materials

Differences in raw materials purities were given strong consideration in cases where the amounts of wastes are strongly influenced by the purity of raw materials used. Several facilities using different grades of raw materials were considered for those minerals for which raw material purity is a determining factor in waste control.

Diversity of processes

On the basis that all of the above criteria are met, consideration was given to installations having a multiplicity of manufacturing processes. However, for sampling purposes, the complex facilities chosen were those for which the wastes could be clearly traced through the various treatment steps.

Production

On the basis that other criteria are equal, consideration was given to the degree of production rate scheduled on water pollution sensitive equipment.

Product purity

For cases in which purity requirements play a major role in determining the amounts of wastes to be treated and the degree of water recycling possible, different product grades were considered for subcategorization.

GENERAL DESCRIPTION OF INDUSTRY BY PRODUCT

Clays and other ceramic and refractory materials differ primarily because of varying crystal structure, presence of significant non-clay materials, variable rations of alumina and silica, and variable degrees of hydration and hardness. This industry, together with ore mining and coal mining, differs significantly from the process industries for which effluent limitation guidelines have previously been developed. The industry is characterized by an extremely variable raw waste load, depending almost entirely upon the characteristics of the natural deposit. The prevalent pollutant poblem is suspended solids, which vary significantly in quantity and treatability.

For the purpose of this section we will define clay as a naturally occurring, fine-grained material whose composition is based on one or more clay minerals and contains impurities. The basic formula is $Al_2O_3SiO_3.xH_2O$. Important impurities are iron, calcium, magnesium, potassium, and sodium which can either be located interstitially in the hydrous aluminum silicate matrix or can replace elements in the clay minerals. As it may be imagined there is a infinite mixture of clay minerals and impurities, and a solution for nomenclature would seem insurmountable. The problem is solved somewhat haphazardly by classifying a clay according to its principal clay mineral (kaolin-kaolinite), by its commercial use (fire clay and fuller's earth) or by its properties (plastic clay). Much clay, however, is called just common clay. Some of the principal clay minerals are kaolinite, montmorillonite, attapulgite, and illite.

Kaolinite consists of alternating layers of silica tetrahedral sheets and alumina octahedral sheets. Imperfections and differences in orientation within this stacking will lead to differences in the kaolinite mineral.

Each unit within the montmorillonite stack is composed of two silica tetrahedral sheets sandwiching a alumina octaheldral sheet. Because of the unbalanced forces between sucessive units, polar molecules such as water can enter and distribute the changes. This accounts for the swelling properties of montmorillonite bearing clays. The presence of sodium, calcium, magnesium and iron between units will also affect the degree of swelling.

The unit structure of attapulgite is comprised of two silica chains liked by octahedral groups of hydroxyls and oxygens containing aluminum and magnesium. The emperical formula is $(Mg,Al)_5\ Si_8O_{22}(OH)_4 \cdot 4H_2O$.

The unit structure of illite resembles that of montmorillonite except that aluminum ions replace some of the silicon ions. The resultant charge imbalance is neutralized by the inclusion of potassium ions between units.

Most clays are mined from open pits, using modern surface mining equipment such as draglines, power shovels, scraper loaders, and shale planers. A few clay pits are operated using crude hand mining methods. A small number of clay mines (principally underclays in coal mining areas) are underground operations employing mechanized room and pillar methods. Truck haulage from the pits to processing facilities is most common, but other methods involve use of rail transport, conveyor belts, and pipelines in the case of kaolin. Recovery is near 100 percent of the minable beds in open pit mines, and perhaps 75 percent in the underground operations. The waste to clay ratio is highest for kaolin (about 7:1) and lowest for miscellaneous clay (about 0.25:1).

Processing of clays ranges from very simple and inexpensive crushing and screening for some common clays to very elaborate and expensive methods necessary to produce paper coating clays and high quality filler clays for use in rubber, paint, and other products. Waste material from processing consists mostly of quartz, mica, feldspar, and iron minerals.

Clays are classified into six groups by the Bureau of Mines, kaolin, ball clay, fire clay, bentonite, fuller's earth, and miscellaneous clay. Halloysite is included under kaolin in Bureau of Mines statistical reports. Specifications of clays are based on the method of preparation (crude, air separated, water washed, delaminated, air dried, spray dried, calcined, slip, pulp, slurry, or water suspension), in addition to specific physical and chemical properties.

The 1972 production and employment figures for the clay, ceramic, refractory and miscellaneous minerals industries were derived either from the Bureau of the Census (U.S. Department of Commerce) publications or the Commodity Data Summaries (1974) Appendix I to Mining and Minerals Policy, Bureau of Mines, U.S. Department of the Interior. These figures are tabulated in Table 3.

BENTONITE (SIC 1452)

Bentonites are fine-grained clays containing at least 85 percent montmorillonite. The swelling type has a high sodium ion concentration which causes a material increase in volume when the clay is wetted with water, whereas the nonswelling types usually contain high calcium ion concentrations. Standard grades of swelling bentonite increase from 15 to 20 times their dry volume on exposure to water. Specifications are based on pertinent physical and chemical tests, particularly those relating to particle size and swelling index. Bentonite clays are processed using the following processes: weathering, drying, grinding, sizing, and granulation. The supply-demand relationships for bentonite and other clays for 1968 are shown in Figure 1.

The principal uses of bentonites are drilling muds, catalyst manufacture, decolorizing agents, and foundry use. However the properties within the bentonite group vary such that a single deposit cannot serve all the above mentioned functions. Because of the high montmoillonite content bentonites are an important raw material in producing fuller's earth. The distinction between these two clays is not clearly defined except by end usage.

The bentonites found in the United States were deposited in the Cretaceous age as fine air-borne volcanic ash. Advancing salt water seas and groundwater had resulted in cationic exchangead addition of iron and magnesium. The placement of the relatively large sodium and calcium ions between the silica and alumina sheets in the basic montimorillonite lattice structure are responsible for the important property of swelling in water. Sodium bentonite is principally mines in Wyoming while calcium bentonite is found in many states, but principally Texas, Mississippi and Arizona.

FIRE CLAY (SIC 1453)

The terms "fire clays" and "stoneware clays" are based on refractoriness or on the intended usage (fire clay indicating potential use for refractories (hence they are also called refratory clays), and stoneware clay indicating use for such items as crocks, jugs, and jars). Their most

TABLE 3

1972 U.S. Production and Employment Figures For Clay, Ceramic, Refractory, and Miscellaneous Minerals

Sic Code	Product	Production kkg (tons)	Employment
1452	Bentonite	2,150,000 (2,767,000)	900
1453	Fire clay	3,250,000 (3,581,000)	500
1454	Fuller's Earth	896,000 (988,000)	1,200
1455	Kaolin	4,810,000 (5,318,000)	3,900*
1455	Ball clay	612,000 (675,000)	
1459	Feldspar	664,000 (732,000)	450
1459	Kyanite	Est. 108,000 (Est. 120,000)	165
1459	Magnesite	Withheld	Unknown
1459	Aplite	190,000 (210,000)	Unknown
1459	Crude common Clay	41,840,000 (46,127,000)	2,600
1496	Talc		
1496	Soapstone	1,004,000	950
1496	Pyrophyllite		
1499	Abrasives		
	Garnet	17,200 (19,000)	Unknown
	Tripoli	80,000 (88,000)	Unknown
1499	Diatomite	522,000 (576,000)	500
1499	Graphite	Withheld	54
1499	Jade	107 (118)	Unknown
1499	Novaculite	Withheld	15

* includes ball clay

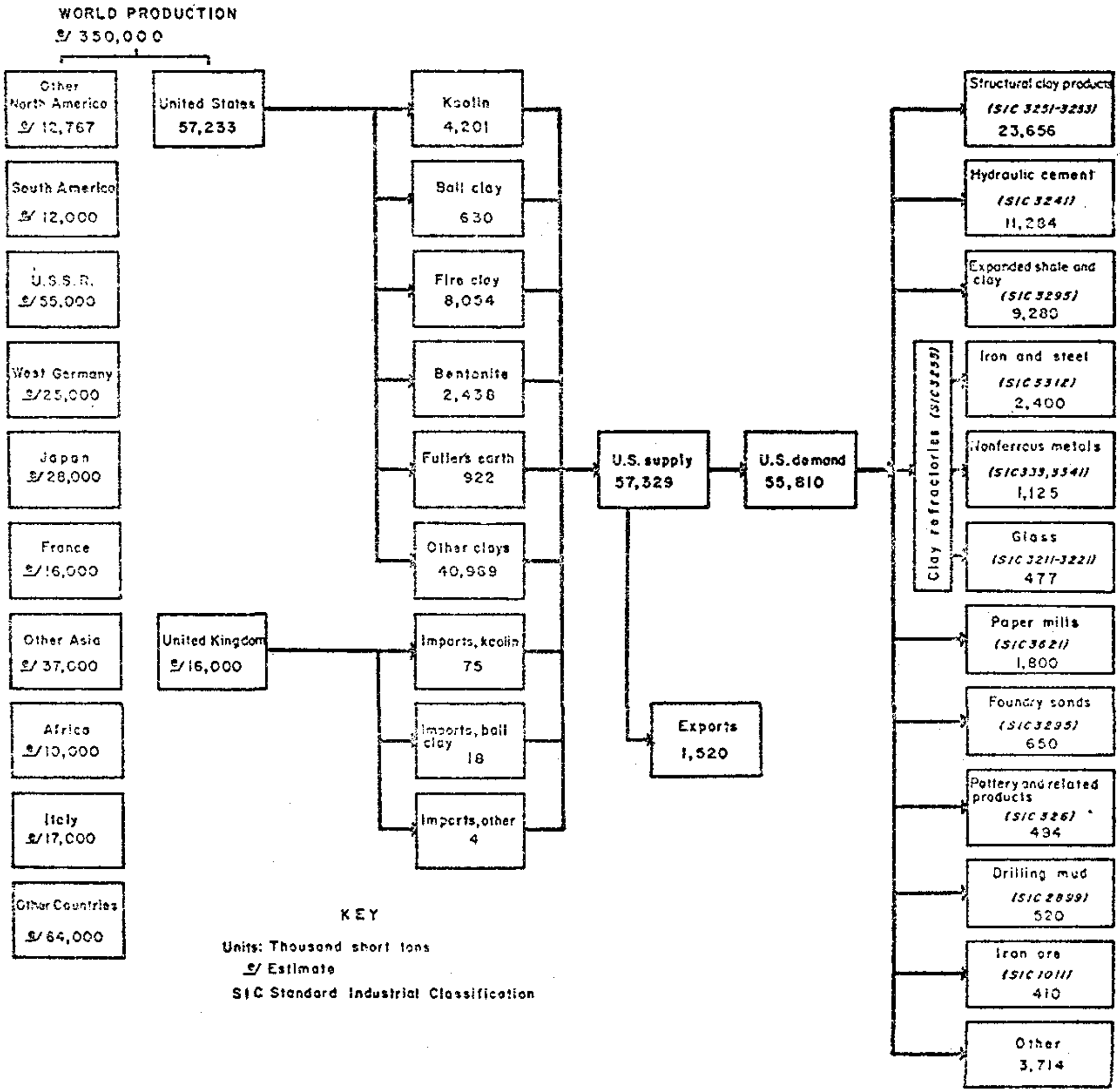


Figure 1. Supply–Demand Relationships for Clays, 1968.

notable property is their high fusion points. Fire clays are principally kaolinitic containing other clay minerals and impurities such as quartz. Included under the general term fire clay are the diaspore, burley, and burley flint clays. Fire clays are usually plastic in nature and are often referred to as plastic clays, but flint clays are exceedingly hard due to their high content of kaolinite. The fired colors of fire clays range from reds to buffs and grays. Specifications are based on pertinent physical and chemical tests of the clays, and of products made from them. In general the higher the alumina content the higher the fusion point. Impurities such as lime and iron lower the fusion point. Fire clays are mined principally in Missouri, Illinois, Indiana, Kentucky, Ohio, West Virginia, Pennsylvania and Maryland. The fire clays are processed by crushing, calcining and final blending.

FULLER's EARTH (SIC 1454)

The term "fuller's earth" is derived from the first major use of the material, which was for cleaning wool by fullers. Fuller's earths are essentially montmorillonite or attapulgite for which the specifications are based on the physical and chemical tests of the products. As previously mentioned the distinction between fuller's earth and bentonite is in the commercial usage. Major uses are for decolorizing oils, edible fluids, and cat litter. The fuller's earth clays are processed by blunging, extruding, drying, crushing, grinding and finally sizing according to the requirements of its eventual use.

KAOLIN AND BALL CLAY (SIC 1455)

Kaolin is the name applied to the broad class of clays chiefly comprised of the mineral kaolinite. Although the various kaolin clays do differ in chemical and physical properties the main reason for distinction has been commercial usage. Both fire clay and ball clay are kaolin clays. That portion of the kaolin clays term kaolin is mined in South Carolina and Georgia and is used as fillers and pigments. Ball clays consist principally of kaolinite, but have a higher silica to alumina ratio than is found in most kaolins in addition to larger quantities of mineral impurities, the presence of minor quantities of montmorillonite and, often, much organic material. They are usually much finer grained than kaolins due to their sedimentary origin and, in general set the standards for plasticity of clays. Ball clays are mined in western Kentucky, western Tennessee and New Jersey. Specifications for ball clays are based on methods of preparation (crude, shredded, air floated) and pertinent physical and chemical tests, which are much the same as those for kaolin. The prinicpal use for ball clay is in whitewares (e.g. china).

MISCELLANEOUS CLAYS

The last Bureau of Mines category of clays, is the miscellaneous clay category. Miscellaneous clay may contain some kaolinite and montmorillonite, but usually illite predominates, particularly in the shales. There are no specific recognized grades based on preparation, and very little based on usage, although such a clay may sometimes be referred to as common, brick, sewer pipe, or tile clay. Specifications are based on the physical and chemical tests of the products.

Most of the environmental disturbance related to clay mining and processing is concerned with miscellaneous clays, which are used mostly for making heavy clay construction products, lightweight aggregates, and cement. The environmental considerations are significant, not because the waste products from clay mining are particularly offensive, but because of the large number of operations and the necessity for locating them in or near heavily populated consumption centers. The principal environmental factors involved are dust, noise, and unsightly or incongruous appearance. Inadequate long range area planning has often contributed to the environmental disturbance in the past, but the growing awareness of the need for orderly development of area resources should result in improvements in the future.

Environmental disturbances in kaolin mining and processing are of major concern in central Georgia, where most of the high quality filler grades are produced. Although the clay mining for the most part is not in areas of high population density, the mined areas are extensive, and large amounts of materials are generated. On occasion, flash floods may dump significant quantities of clay wastes into local streams, and although the wastes are not reactive, temporary overloading of the streams might be harmful to some types of marine life. Steps are being taken to alleviate the undesirable conditions by rapid rehabilitation of mined areas and by using the waste materials as fill.

FELDSPAR (SIC 1459)

Feldspar is a general term used to designate a group of closely related minerals, especially abundant in igneous rocks and consisting essentially of aluminum silicates in combination with varying proportions of potassium, sodium, and calcium. The feldspars are the most abundant minerals in the crust of the earth. The principal feldspar species are orthoclase or microcline (both $K_2O \bullet Al_2O_3 \bullet 6SiO_2$), albite ($Na_2O \bullet Al_2O_3 \bullet 6SiO_2$), and anorthite ($CaO \bullet Al_2O_3 \bullet 2SiO_2$). Specimens of feldspar closely approaching the ideal compositions are seldom encountered in nature, however, and nearly all potash feldspars contain significant proportions of soda. Albite and anorthite are really the theoretical end members of a continuous compositional series known as the plagioclase feldspars, none of which, moreover, is ordinarily without at least a minor amount of potash.

Originally, only the high potash feldspars were regarded as desirable for most industrial purposes. At present, however, in many applications the potash and the soda varieties, as well as mixtures of the two, are considered to be about equally acceptable. Perthite is the name given to material consisting of orthoclase or microcline, the crystals of which are intergrown to a variable degree with crystals of albite. Most of the feldspar of commerce can be classified correctly as perthite. Anorthite and the plagioclase feldspars are of limited commercial importance.

Until a few decades ago virtually all the feldspar employed in industry was material occurring in pegmatite deposits as massive crystals pure enough to require no treatment other than hand cobbing to bring it to usable grade. More recently, however, stimulated by the often unfavorable location of the richer pegmatite deposits relative to markets and by the prospect of eventual exhaustion of such sources, technological advances have created a situation in which more than 90 percent of the total current domestic supply is extracted from such feldspar bearing rocks as alaskite and from beach sands. A large part of the material obtained from beach sands is in the form of feldspar silica mixtures that can be used, with little or no additional processing, as furnace feed ingredients in the manufacture of glass. In fact, this use is so prominant that feldspathic sands are considered in volume II of this document under industrial sands.

Nepheline syenite is a feldspathic, igneous rock which contains little or no free silica, but does contain nepheline ($K_2O \bullet 3Na_2O \bullet 4Al_2O_3 \bullet 9SiO_2$). The valuable properties of nepheline are the same type as those of feldspar, therefore, nepheline syenite, being a mixture of the two, is a desirable ingredient of glass, whiteware and ceramic glazes and enamels. A high quality nepheline syenite is mined in Ontario, Canada, and is being imported into the U.S. in ever increasing quantities for ceramics manufacture. Deposits of the mineral exist in the U.S. in Arkansas, New Jersey, and Montana, but mining occurs only in Arkansas, just outside of Little Rock. There, the mineral is mined in open pits as a secondary product to crushed rock. Since this is the only mining of this material in the U.S. and posses few if any environmental problems, it will not be considered further.

Rocks that are high in feldspar and low in iron and that have been mined for the feldspar content have received special names, for instance aplite (found near Piney River, Virginia), alaskite (found near Spruce Pine, North Caroline) and perthite. The major feldspar producing states are North Carolina, Calfironia, the New England states, Colorado and South Dakota.

Feldspar and feldspathic materials in general are mined by various systems depending upon the nature of the deposits being exploited. Because underground operations entail higher costs, as long as overburden ratio will permit and unless land use conflicts are a decisive factor, most feldspathic rocks will continue to be quarried by open pit procedures using drills and explosives. Feldspathic sand deposits are mined by dragline excavators.

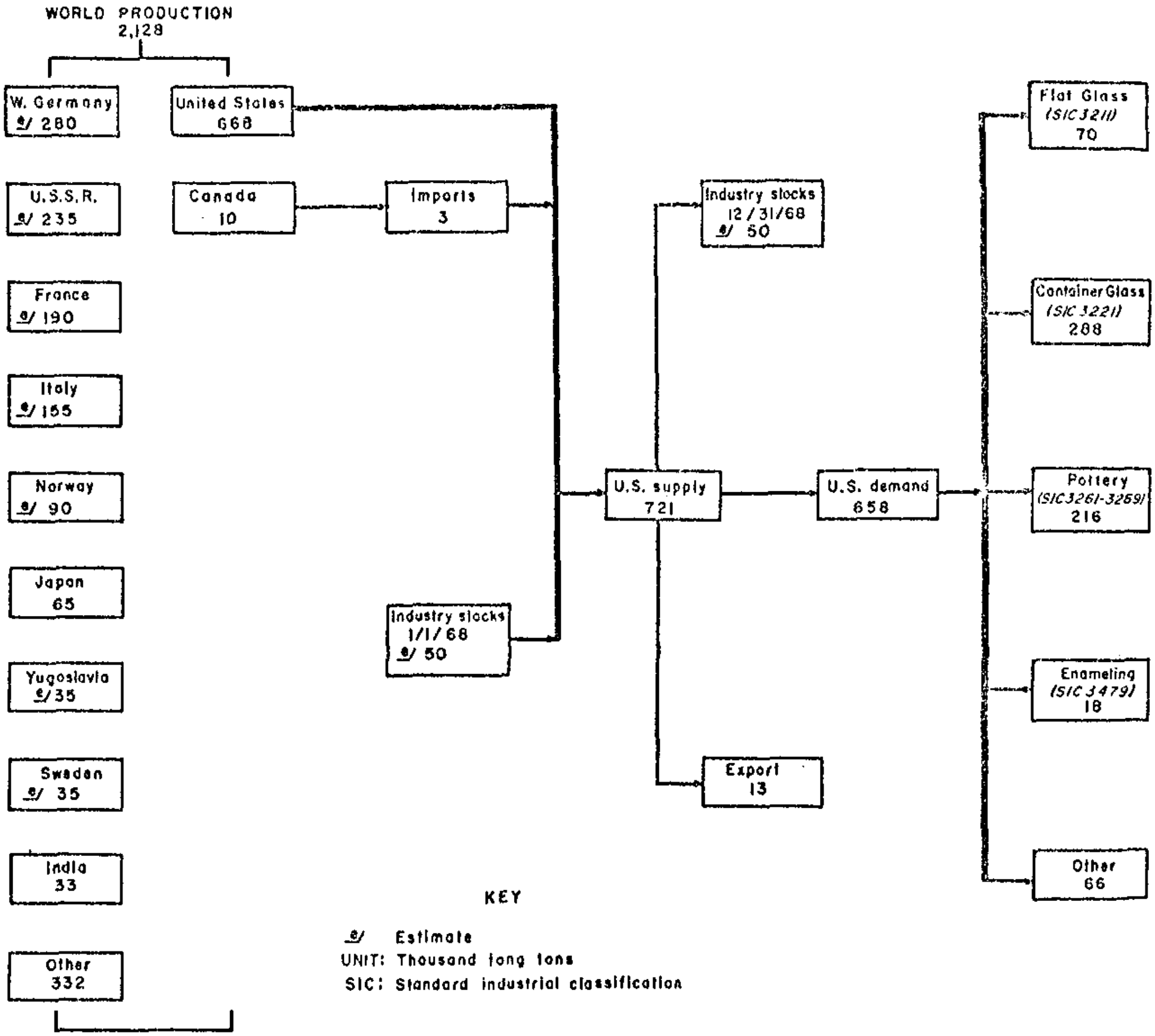
High grade, selectively mined feldspar from coarse structured pegmatites can be crushed in jaw crushers and rolls and then subjected to dry milling in flint lined pebble mills.

Feldspar ores of the alaskite type are mostly beneficiated by froth flotation processes. The customary procedure begins with primary and secondary comminution and fine grinding in jaw crushers, cone crushers, and rod mills, respectively. The sequence continues with acid circuit flotation in three stages, each stage preceded by desliming and conditioning. The first flotation step depends on an amine collector to float off and remove mica, and the second uses sulfonated oils to separate iron bearing minerals. The third step floats the iron- and mica free feldspar with another amine collector, leaving behind a residue that consists chiefly of quartz.

The supply demand relationships for feldspar in 1968 are shown in Figure 2.

KYANITE (SIC 1459)

Kyanite and the related minerals --- andalusite, sillimanite, dumortierite, and topaz --- are natural aluminum silicates which can be converted by heating to mullite, a stable refractory raw material with some interstitial glass also being formed. Kyanite, and alusite and sillinanite have the basic formula $Al_2O_3.SiO_2$. Dumortierite contains boron, and topaz contains fluorine,



KEY

e/ Estimate
UNIT: Thousand long tons
SIC: Standard industrial classification

Figure 2. Supply-Demand Relationships for Feldspar, 1968

both of which vaporize during the conversion to mullite ($3Al_2O_3 . 2SiO_2$).

With exception of the production of a small amount of by product kyanite sillimanite from Florida heavy mineral operations, the bulk of domestic kyanite production is derived from two mining operations in Virginia, operated by the same company, and one in Georgia. The mining and process methods used by these producers are basically the same. Mines are open pits in which the hard rock must be blasted loose. The ore is hauled to the nearby facilities in trucks where the ore is crushed and then reduced in rodmills. Three stage flotation is used to obtain a kyanite concentrate. This product is further treated by magnetic separation to remove most of the magnetic iron in a high iron fraction which is wasted. Some of the concentrate is marketed as raw kyanite, while the balance is further ground and/or calcined to produce mullite.

Florida beach sand deposits are worked primarily for zircon and titanium minerals, but the tailings from the zircon recovery units contain appreciable quantities of sillimanite and kyanite, which can be recovered by flotation and magnetic separations. Production and marketing of Florida sillimanite kyanite concentrates started in 1968.

The kyanite producers are located in areas of low population density, and since the waste minerals generated by mining and processing of kyanite ore are relatively inert, and settle rapidly, they present no appreciable environmental problem. The land area involved in kyanite operations is not extensive.

The production and uses of kyanite and related minerals are shown in Figure 3.

MAGNESITE (SIC 1459)

Magnesium is the eighth most plentiful element in the earth and, in its many forms, makes up about 2.06 percent of the earth's crust. Although it is found in 60 or more minerals, only four, dolomite, magnesite, brucite, and olivine, are used commercially to produce its compounds. Currently dolomite is the only domestic ore used as principal raw material for producing magnesium metal. Sea water and brines are also principal sources of magnesium, which is the third most abundant element dissolved in sea water, averaging 0.13 percent magnesium by weight. Extraction of magnesium from sea water is so closely associated with the manufacture of refractories that it will be discussed in the clay and gypsum products category.

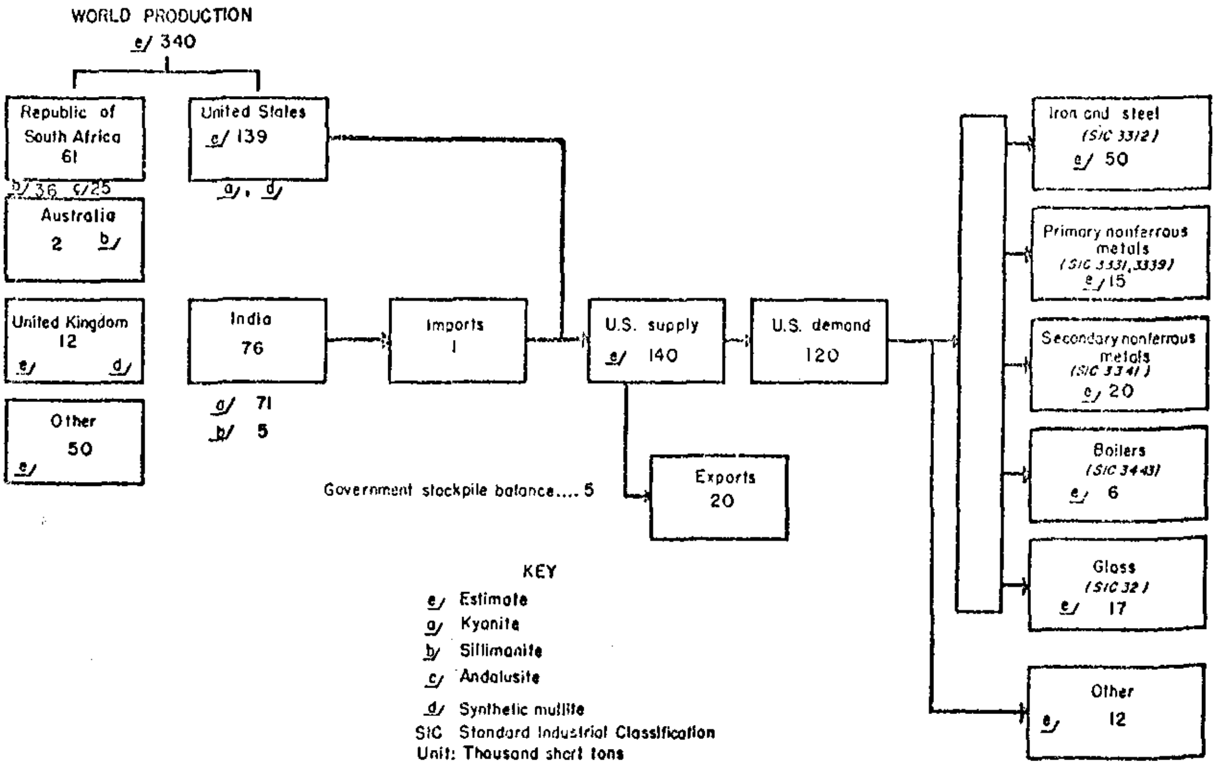


Figure 3. Supply-Demand Relationship for Kyanite and Related Minerals, 1968

Dolomite, the double carbonate of magnesium and calcium and a sedimentary rock commonly interbedded with limestone, extends over large areas of the United States. Most dolomites are probably the result of replacement of calcium by magnesium in preexisting limestone beds. Magnesite, the natural form of magnesium carbonate, is found in bedded deposits, as deposits in veins, pockets, and shear zones in ferro-magnesium rocks, and as replacement bodies in limestone and dolomite. Significant deposits occur in Nevada, California, and Washington. Brucite, the natural form of magnesium hydroxide, is found in crystalline limestone and as a decomposition product of magnesium silicates associated with serpentine, dolomite, magnesite, and chromite. Olivine, or chrystolite, is a magnesium iron silicate usually found in association with other igneous rocks such as basalt and gabbro. It is the principal constituent of a rock known as dunite. Commercial deposits are in Washington, North Carolina, and Georgia.

Evaporites are deposits formed by precipitation of salts from saline solutions. They are found both on the surface and underground. The Carlsbad, New Mexico, and the Great Salt Lake evaporite deposits are sources of magnesium compounds. The only significant commercial source of magnesium compounds from well brines is in Michigan, although brines are known to occur in many other areas. This form of mining is included in the clay, gypsum, ceramics and refractory products report since it is closely related to refractories manufacturing.

Selective open-pit mining methods are being used to mine magnesite at Gabbs, Nevada. This facility is the only known U.S. facility that produces magnesia from naturally occurring magnesite ore.

Magnestie and brucite ore are delivered from the mines to gyratory or jaw crushers where it is reduced to a minus 5 inch size. It is further crushed to minus 2.5 inches and conveyed to storage piles. Magnesite ore is either used directly or beneficiated by heavy media separation or froth flotation. Refractory magnesia is produced by blending, grinding and briquetting various grades of magnesite with certain additives to provide the desirable refractory product. The deadburning takes place in rotary kilns which develop temperatures in the range of 1490-1760°C (2700 to 3200°F).

When the source of magnesia is sea water or well brine, the waters are treated with calcined dolomite or lime obtained from oyster shell by calcining, to precipitate the magnesium as magnesium hydroxide. The magnesium hydroxide slurry is filtered to remove water, after which it is conveyed to rotary kilns fired to temperatures that may be as high as 1850°C (3,360°F). The calcined product contains approximately 97 percent MgO.

The principal uses for magnesium compounds follow:

Compound and grade	Use
Magnesium oxide:	
Refractory grades	Basic refractories.
Caustic-calcined	Cement, rayon, fertilizer, insulation, magnesium metal, rubber, fluxes, refractories, chemical processing and manufacturing, uranium processing, paper processing.
U.S.P. and technical grades	Rayon, rubber (filler and catalyst), refractories, medicines, uranium processing, fertilizer, electrical insulation, neoprene compounds and other chemicals, cement.
Precipitated magnesium carbonate	Insulation, rubber, pigments and paint, glass, ink, ceramics, chemicals, fertilizers.
Magnesium hydroxide	Sugar refining, magnesium oxide, pharmaceuticals.
Magnesium chloride	Magnesium metal, cement, ceramics, textiles, paper, chemicals.

Basic refractories used in metallurgical furnaces are produced from magnesium oxide and accounted for over 80 percent ot total domestic demand for magnesium in 1968. Technological advances in steel production required higher temperatures which were met by refractories manufactured from high purity magnesia capable of withstanding temperatures above 1930°C (3,500°F).

SHALE AND OTHER CLAY MINERALS N.E.C. (SIC 1459)

SHALES

Shale is a soft laminated sedimentary rock in which the constituent particles are predominantly of the clay grade. Just as clay possesses varying properties and uses, the same can be said of shale. Thus, the word shale does not connote a single mineral, inasmuch as the properties of a given shale are largely dependent on the properties of the originating clay species.

Mining of shales depends on the nature of the specific deposit and on the amount and nature of the overburden. Some deposits are mined underground, however, the majority of shale deposits are worked as open quarries.

Shales and common clays are used interchangeably in the manufacture of formed and fired ceramic products and are frequently mixed prior to processing for optimization of product properties. This type of product consumes about 70 percent of shale production. Certain impure shales (and clays) have the property of expanding to a cellular mass when rapidly heated to 1000 - 1300°C. On sudden cooling, the melt forms a porous slag like material which is screened to produce a lightweight concrete aggregate (60-110lb/ft.[3]). Probably 20 25 percent of the total market for shale goes into aggregate production.

APLITE

Aplite is a granitic rock of variable composition with a high proportion of soda or lime soda feldspar. It is therefore useful as a raw material for the manufacture of container glass. Processing of the ore is primarily for the purpose of obtaining sufficient particle size reduction and for removing all but a very small fraction of iron bearing minerals.

Aplite of sufficient quality is produced in the U.S. from only two mines, both in Virginia (Nelson County and Hanover County). The aplite rock in Hanover County has been decomposed so completely that it is mined without resort to drilling and/or blasting.

TALC, STEATITE, SOAPSTONE AND PYROPHYLLITE (SIC 1496)

The mineral talc is a soft, hydrous magnesium silicate, $3MgO \cdot 4SiO_2 \cdot H_2O$. The talc of highest purity is derived from sedimentary magnesium carbonate rocks; less pure talc from ultra basic igneous rocks.

Steatite has been used to designate a grade of industrial talc that is especially pure and is suitable for making electronic insulators. Block steatite talc is a massive form of talc that can be readily machined, has a uniform low shrinkage in all directions, has a low absorption when fired at high temperature, and gives proper electrical resistance values after firing. Phosphate bonded talc which is approximately equivalent to natural block can be manufactured in any desired amount. French chalk is a soft, massive variety of talc used for marking cloth.

Soapstones refer to the sub steatite, massive varieties of talc and mixtures of magnesium silicates which with few exceptions have a slippery feeling and can be carved by hand.

Pyrophyllite is a hydrous aluminum silicate similar to talc in properties and in most applications, and its formula is $Al_2O_3 \bullet 4SiO_2 \bullet H_2O$. It is principally found in North Carlina. Wonderstone is a term applied to a massive block pyrophyllite from the Republic of South Africa. The uses of pyrophyllite include wall tile, refractories, paints, wallboard, insecticides, soap, textiles, cosmetics, rubber, composition battery boxes and welding rod coatings.

During 1968 talc was produced from 52 mines in Alabama, California, Georgia, Maryland, Montana, Nevada, New York, North Carolina, Texas, and Vermont. Soapstone was produced from 13 mines in Arkansas, California, Maryland, Nevada, Oregon, Virginia, and Washington. Pyrophyllite was produced from 10 mines in California and North Carolina. Sericite schist, closely resembling pyrophyllite in physical and chemical properties, was produced in Pennsylvania and included with pyrophyllite statistics.

The facility size breakdown is as follows:

Numbers of Facilities	Production tons/yr
6	< 1,000
22	1,000 - 10,000
20	10,000 - 100,000
3	100,000 - 1,000,000

Slightly more than half of the industrial talc is mined underground and the rest is quarried as is soapstone and pyrophyllite. Small quantities of block talc also are removed by surface method. Underground operations are usually entirely within the ore body and thus require timber supports that must be carefully placed in talc operations because of the slippery nature of the ore.

Mechanization of underground mines has become common in recent years, especially in North Carolina and California where the ore body ranges in thickness from 10 to 15 feet and dips 12 to 19 degrees from horizontal. In those mines where the ore body suffers vein dips of greater than 20 degrees, complex switch backs are introduced to provide the gentle slopes needed for easier truck haulage of the ore. At one quarry in Virginia, soapstone for decorative facing is mined in large blocks approximately 1.2 by 2.4 by 3.0 m (4 by 8 by 10 ft) which are cut into slices by gang saws with blades spaced about 7.6 cm (3 in) apart. In the mining of block talc of crayon grade, a minimum of explosive is used to avoid shattering the ore; extraction of the blocks being accomplished with hand equipment to obtain sizes as large as possible.

When mining ore of different grades within the same deposit, selective mining and hand sorting must be used. Operations of the mill and mine are coordinated, and when a certain specification is to be produced at the mill, the desired grade of ore is obtained at the mine. This type of mining and/or hand sorting is commonly used for assuring the proper quality of the output of crude talc group minerals.

Roller mills, in closed circuit with air separators, are the most satisfactory for fine grinding (100 to 325 mesh) of soft talcs or pyrophyllites. For more abrasive varieties, such as New York talc and North Carolina ceramic grade pyrophyllite, grinding to 100 to 325 mesh is effected in quartzite or silex lined pebble mills, with quartzite pebbles as a grinding medium. These mills are ordinarily in closed circuit with air separators but some times are used as batch grinders, especially if reduction to finer particle sizes is required.

Talc and pyrophyllite are amenable to processing in an additional microgrinding apparatus. Microgrinding or micronizing is also done in fluid system with subsequent air drying of the product.

The production and uses of talc, soapstone and pyrophyllite are shown in Figure 4.

NATURAL ABRASIVES (SIC 1499)

Abrasives consist of materials of extreme hardness that are used to shape other materials by grinding or abrading action. Such materials may be classified as either natural or synthetic (manufactured). Of interest here are the natural abrasive minerals which include cleamorid, corundum, emery, pumice, tripoli and garnet. Of lesser importance, other natural abrasives include feldspar, calcined clays,

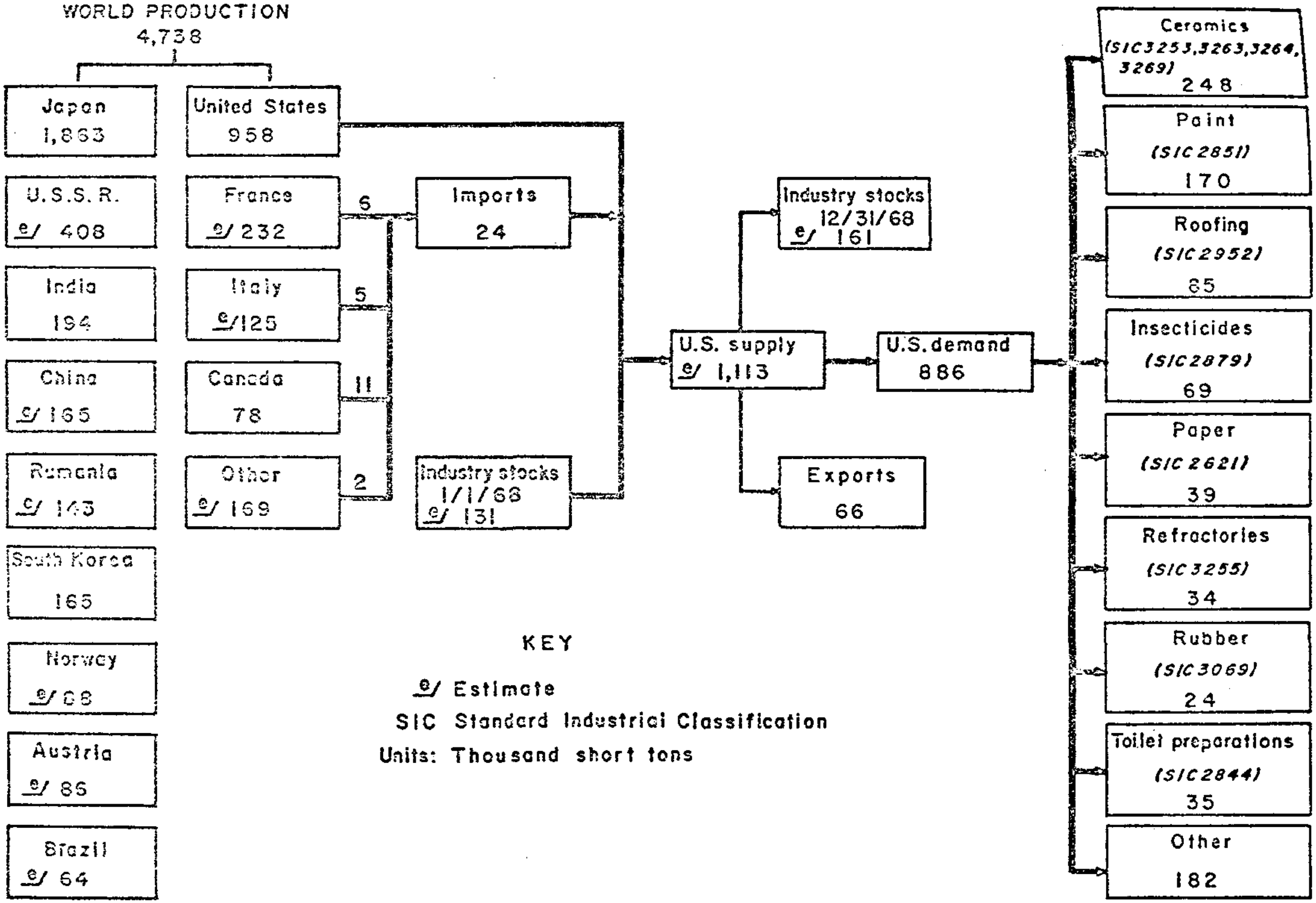


Figure 4. Supply-Demand Relationships for Talc, Soapstone, and Pyrophyllite, 1968

chalk and silica in its many forms such as sandstones, sand, flint and diatomite.

CORUNDUM

Corundum is a mineral with the composition Al_2O_3 crystallized in the hexagonal system which was formed by igneous and metamorphic processes.

Abrasive grade corundum has not been mined in the United States for more than 60 years. There is no significant environmental problem posed by the processing of some 2,360 kkg of corundum per year (1968 data); and further consideration will be dropped.

EMERY

Emery consists of an intimate admixture of corundum with magnetite or hematite, and spinel.

The major domestic use of emery involves its incorporation into aggregates as a rough ground product for use as heavy duty non skid flooring and for skid resistant highways. Additional quantities (25 percent of total consumption) are used in general abrasive applications.

Recent statistics show the continuing down turn in demand for emery resulting from the increasing competition with such artificial abrasives as Al_2O_3 and SIC. Production is estimated to be 11,000 kkg/yr (10,000 tons/yr). Emery was not considered further in this report because it was not deemed economically significant and no environmental problems were noted.

TRIPOLI

Tripoli is the generic name applied to a number of fine grained, lightweight, friable, minutely porous, forms of decomposed siliceous rock, presumably derived from siliceous limestones or calcareous cherts. Tripoli is often confused, in both the trade and technical literature, with tripolite, a diatomaceous earth (diatomite), found in Tripoli, North Africa.

The two major working deposits of tripoli are those in the Seneca, Missouri area and in southern Illinois. The Missouri ore resembles tripolite and was incorrectly named tripoli. The name has persisted and now has definite physical and trade association with the ore from the Missouri Oklahoma field. The material from the southern Illinois area is often refered to as "amorphous" or "soft" silica. In both cases the ore contains 97 to 99 percent

SiO_2 with minor additions of alumina, iron, lime, soda and potash. The rottenstone obtained from Pennsylvania is of higher density and has a composition approximately 60 percent silica, 18 percent alumina, 9 percent iron oxides, 8 percent alkalies and the remainder lime and magnesia.

Tripoli mining involves two different processes depending on the nature of the ore and of the overburden. In the Missouri Oklahoma area, the small overburden of approximately six feet in thickness coupled with tripoli beds ranging from 0.6 to 4.3m (2 to 14 ft) in thickness, lends itself to open pit mining. The tripoli is first hand sorted for texture and color, then piled in open sheds to air dry (the native ore is saturated with water) for three to six months. The dried material is subsequenly crushed with hammer mills and rolls.

In the southern Illinois field, due to the terrain and the heavy overburden, underground mining using a modified room-and-pillar method is practiced. The resulting ore is commonly wet milled after crushing to 0.63 to 1.27 cm (0.25 to 0.50 in) sizing, the silica is fine ground in tube mills using flint linings and flint pebbles in a closed circuit system with bowl classifiers. The resulting accurately sized product is thickened, dried and packed for shipment.

Tripoli is primarily used as an abrasive or as a constituent of abrasive materials for such uses as polishing and buffing of such materials as copper, aluminum, brass and zinc. In addition, the pulverized product is widely used as the abrasive element in scouring soaps and powders, in polishes for the metal working trades and as a mild mechanical cleaner in washing powders for fabrics. The pure white product from southern Illinois, when finely ground, is widely used as a filler in paint. The other colors of tripoli are often used as fillers in the manufacture of linoleum, phonograph records, pipe coatings and so forth.

Total U. S. production of tripoli in 1971 was of the order of 68,000 kkg, some 70 percent of which was used as abrasive, the remainder as filler.

GARNET

Garnet is an orthosilicate having the general formula $3RO \bullet X_2O_3 \bullet 3SiO_2$ where the bivalent element R may be calcium, magnesium, ferrous iron or manganese; the trivalent element x, aluminum, ferric iron or chromium, rarely titanium; further, the silicon is occasionally replaced by titanium.

The members of the garnet group of minerals are common accessory minerals in a large variety of rocks, particularly in gneisses and schists. They are also found in contact metamorphic deposits, in crystalline limestones; pegmatites; and in serpentines. Although garnet deposits are located in almost every state of the United States and in many foreign countries, practically the entire world production comes from New York and Idaho. The Adirondack deposit consists of an alamandite garnet having incipient lamellar parting planes which cause it to break under pressure into thin chisel edge plates. Even when crushed to very fine size this material still retains this sharp silvery grain shape----a feature of particular importance in the coated abrasive field.

The New York mine is a surface site worked by open quarry methods. The ore is quarried in benches about 10.7 m (35 ft) in height, trucked to the mill and dumped on a pan conveyor feeding a 61 - 91 cm (24 x 36 in) jaw crusher. The secondary crusher which is a standard 4 feet Symonds cone is in closed circuit with a 1-1/2 inch screen. The minus 3.8 cm (1 1/2 in) material is screened on a 10 mesh screen. The oversize from the screen goes to a heavy media separation facility while the undersize is classified and concentrated on jigs. The very fine material is treated by flotation. The combined concentrates, which have a garnet content of about 98 percent, are then crushed, sized and heat treated. It has been found that heat treatment, to about 700 to 800° C will improve the hardness, toughness, fracture properties and color of the treated garnets.

The only other significant production of garnets in the United States is situated on Emerald Creek in Benewah County, Idaho. This deposit is an alluvial deposit of alamandite garnets caused by the erosion of soft mica schists in which the garnets have a maximum grain size of about 4.8 mm (3/16 in). The garnet bearing gravel is mined by drag line, concentrated on trommels and jigs then crushed and screened into various sizes. This garnet is used mainly for sandblasting and as filtration media.

Approximately 45 percent of the garnet marketed is used in the manufacture of abrasive coated papers, about 35 percent in the glass and optical industries with the remainder for sand blasting and miscellaneous uses.

DIATOMITE (SIC 1499)

Diatomite is siliceous rock of sedimentary origin which may vary in the degree of consolidation but which consists mainly of the fossilized remains of the protective silica shells formed by diatoms, single celled non flowering microscopic facilities. The size, shape and structure of the individual fossils and their mass packing characteristics result in microscopic porous material of low specific gravity.

There are numerous sediments which contain diatom residues, admixed with substantial amounts of other materials including clays, carbonates or silica; these materials are classified as diatomaceous silts, shales or mudstones; they are not properly diatomite, a designation restricted to material of such quality that it is suitable for commercial uses. The terms diatomaceous earth and kieselgur are synonymous with diatomite; the terms infusorial earth and tripolite are considered obsolete.

Diatomaceous silica is the most appropriate designation of the principal component of diatomite; that is, the substance of the fossil silica shell is the major constituent of beneficiated diatomite of processed diatomaceous products. Commercially useful deposits of diatomite show SiO_2 concentration ranging from a low of 86percent (Nevada) to a high of 90.75 percent (Lompoc, California) for the United States producers; the SiO_2 content of foreign sources is somewhat lower. The remainder consists of alumina, iron oxide, titanium oxide, and lesser quantities of phosphate, magnesia, and the alkali metal oxides. In addition, there is usually some residual organic matter as indicated by ignition losses which are typically of the order of 4 to 5 percent.

The formation of diatomite sediments was dependent upon the existence of the proper environmental conditions over an adequate period of time to permit a significant accumulation of the skeletal remains. These conditions include a plentiful supply of nutrients and dissolved silica for colony growth and the existence of relatively quiescent physical conditions such as exist in protected marine estuaries or in large inland lakes. In addition, it is necessary that these conditions existed in relatively recent times in order that subsequent metamorphic processes would not have altered the diatomite to the rather more indurated materials such as porcelanite and the opaline cherts.

The upper tertiary period was the period of maximum diatom growth and subsequent deposit formation. The great beds near Lompoc, California are upper Miocene and lower Pliocene (about 20×10^6 years old); formations of similar origin and age occur along the California coast line from north of San Francisco to south of San Diego. Most of the dry lake deposits of California, Nevada, Oregon and Washington are of freshwater origin formed in later tertiary of Pleistocene (less than 12×10^6 years old.)

Currently, the only significant production of diatomite within the U.S. is in the western states, with California the leading producer, followed by Nevada, Oregon and Washington. Commonly, beds of ordinary sedimentary rocks such as shales, sandstones, or limestone overlie and underlie the diatomite beds, thus the first step in mining requires the removal of the overburden (which ranges from zero to about 15 times the thickness of the diatomite bed) by ordinary earth moving machinery. The ore is ordinarily dug by power shovels without the necessity of previous fragmentation by drilling or blasting although such operations may be carried out.

Initial processing of the ore involves size reduction by a primary crusher followed by further size reduction and drying (some diatomite ores contain up to 60 percent water) in a blower hammer mill combination with a pneumatic feed and discharge system. The suspended particles in the hot gases pass through a series of cyclones and a baghouse where they are separated into appropriate particle size groups.

The uses of diatomite result from the size (from 10 to greater than 500 microns in diameter), shape (generally spiny structure of intricate geometry) and the packing characteristics of the diatom shells. Since physical contact between the individual fossil shells is chiefly at the outer points of the irregular surfaces, the resulting compact material is microscopically porous with an apparent density of only 5 to 16 pounds per cubic foot for ground diatomite. The processed material has dimensional stability to temperatures of the order of 400° C. The domestic consumption of diatomite is shown in Figure 5.

GRAPHITE (SIC 1499)

Natural graphite is the mineral form of elemental carbon, crystallized predominately in the hexagonal system, found in silicate minerals of varying kind and percentage. The three principal types of natural occurrence of graphite are classified as lump, amorphous and crystalline flake; a classification based on major differences in geologic origin and occurrence.

Lump graphite occurs as fissure filled veins wherein the graphite is typically massive with particle size ranging from extremely fine grains to coarse, platy intergrowths or fibrous to acicular aggregates. The origin of vein type deposits is believed to be either hydrothermal or pneumatolytic since there is no apparent relationship between the veins and the host rock. A variety of minerals generally in the form of isolated pockets or grains, occur

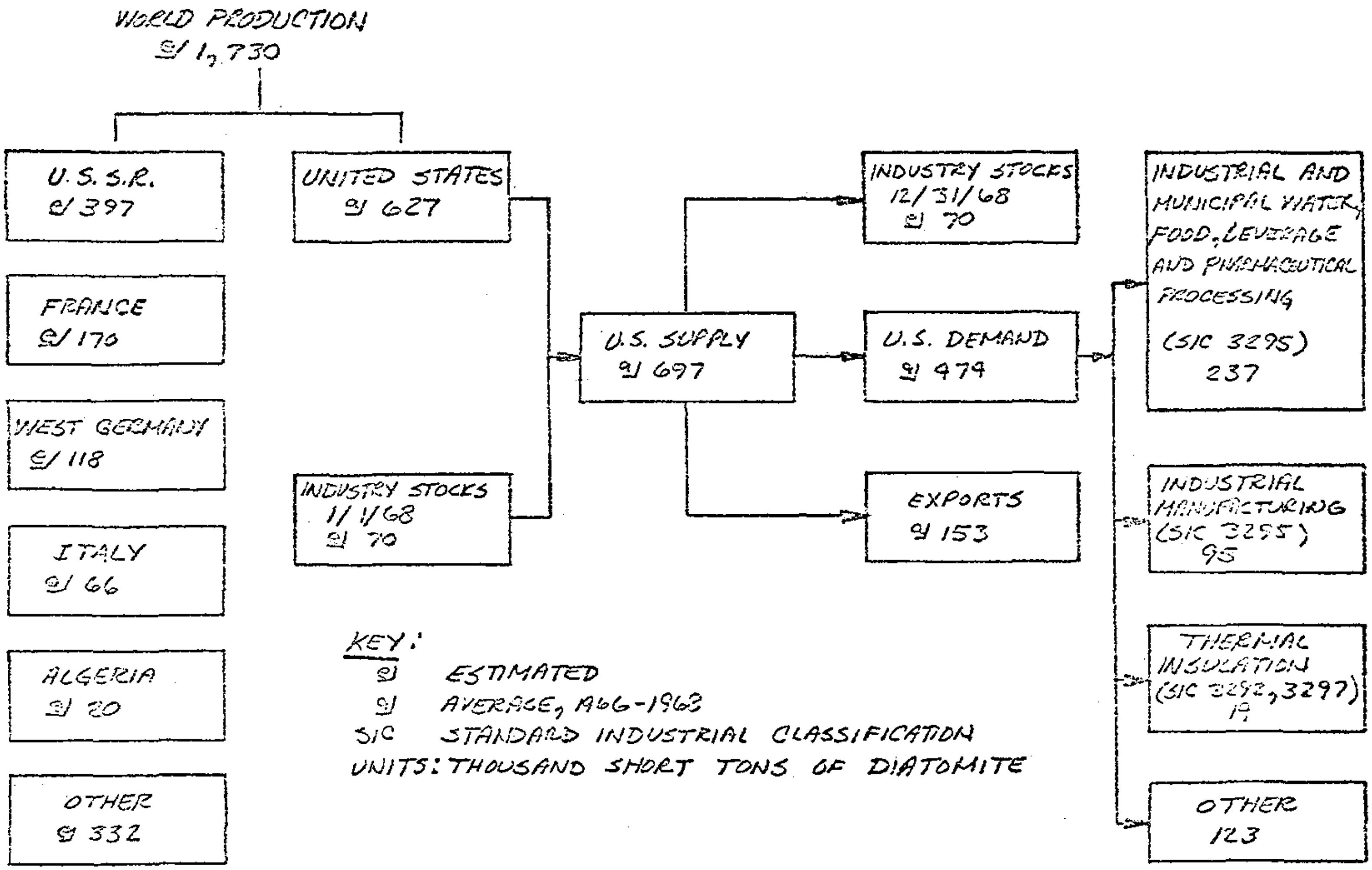


Figure 5. Supply-Demand Relationships for Diatomite, 1968

with graphite, including feldspar, quartz, mica, pyroxene, zircon, rutile, apatite and iron sulfides.

Amorphous graphite, which is fine grained, soft, dull black, earthy looking and ususally somewhat porous, is formed by metamorphism of coalbeds by nearby intrusions. Although the purity of amorphous graphite depends on the purity of coalbeds from which it was derived, it is usually associated with sandstones, shales, slates and limestones and contains accessory minerals such as quartz, clays and iron sulfides.

Flake graphite, which is believed to have been formed by metamorphism from sedimentary carbon inclusions within the host rocks, commonly occurs disseminated in regionally metamorphosed sedimentary rocks such as gneisses, schists and marbles.

The only domestic producer is located near Burnet, Texas and, mines the flake graphite by open pit methods utilizing an 5.5 m (18 ft) bench pan. The ore is hard and tough and thus requires much secondary blasting. The broken ore is hauled by motor trucks to the mill.

Because of the premium placed upon the mesh size of flake graphite, the problem in milling is one of grinding to free the graphite without reducing the flake size excessively; this is difficult because during grinding, the graphite flakes are cut by quartz and other sharp gangue materials, thus rapidly reducing the flake size. However, if the flake can be removed from most of the quartz and other sharp minerals soon enough, subsequent grinding will usually reduce the size of the remaining gangue, with little further reduction in the size of the flake. Impact grinding or essentially pure flake in a ball mill reduces flake size rather slowly, the grinding characteristics of flake graphite under these conditions being similar to those of mica.

Graphite floats readily and does not require a collector; hence, flotation has become the accepted method for beneficiating disseminated ores. Although high recoveries are common, concentrates with acceptable graphitic carbon content are difficult to attain and indeed with some ores impossible. The chief problem lies with the depression of the gangue minerals since relatively pure grains of quartz, mica, and other gangue minerals inadvertently become smeared with fine graphite, making them floatable resulting in the necessity for repeated cleaning of the concentrates to attain high grade products. Regrinding a rougher concentrate reduces the number of cleanings needed. Much of the natural flake either has a siliceous skeleton (which can be observed when the carbon is burned) or is composed of a layer of mica between outer layers of graphite making it next to impossible to obtain a high grade product by flotation. The supply demand relationships for 1968 are shown at Figure 6.

MISCELLANEOUS NON-METALLIC MINERALS, N.E.C. (SIC 1499)

JADE

The term jade is applied primarily to the two minerals jadeite and nephrite, both minerals being exceedingly tough with color varying from white to green. Jadeite, which is a sodium aluminum silicate ($NaAlSi_2O_6$) contains varying amounts of iron, calcium and magnesium is found only in Asia. Nephrite is a tough compact variety of the mineral tremolite ($Ca_2Mg_5Si_8O_{22}(OH)_2$) which is an end member of an isomorphous series where in iron may replace the magnesium. In the U.S. production of jade minerals is centered in Wyoming, California and Alaska.

NOVACULITE

Novaculite is a generic name for massive and extensive geologic formations of hard, compact, homogenous, microcrystalline silica located in the vicinity of Hot Springs, Arkansas. There are three strata of novaculite --- lower, middle, and upper. The upper strata is not compacted and is a highly friable ore which is quarried, crushed, dried and air classified prior to packaging. Chief uses are as filler in plastics, pigment in paints, and as a micron sized metal polishing agent.

WHETSTONE

Whetstones, and other sharpening stones, are probably produced in small volume across the U.S. wherever deposits of very hard silaceous rock occur. However, the largest center of sharpening stone manufacture is in the Hot Springs, Arkansas, area. This area has extensive outcropping deposits of very hard and quite pure silica, called "Novaculite", which are mined and processed into whetstones. Most of the mining and processing is done on a very small scale by individuals or very small companies.

The total production in 1972 of all special silica stone products (grinding pebbles, grindstones, oilstones, tubemill liners, and whetstones) was only 2,940 kkg (3,240 tons), with a value of $670,000. This production and value is neither economically nor environmentally significant and will not be treated further in this report.

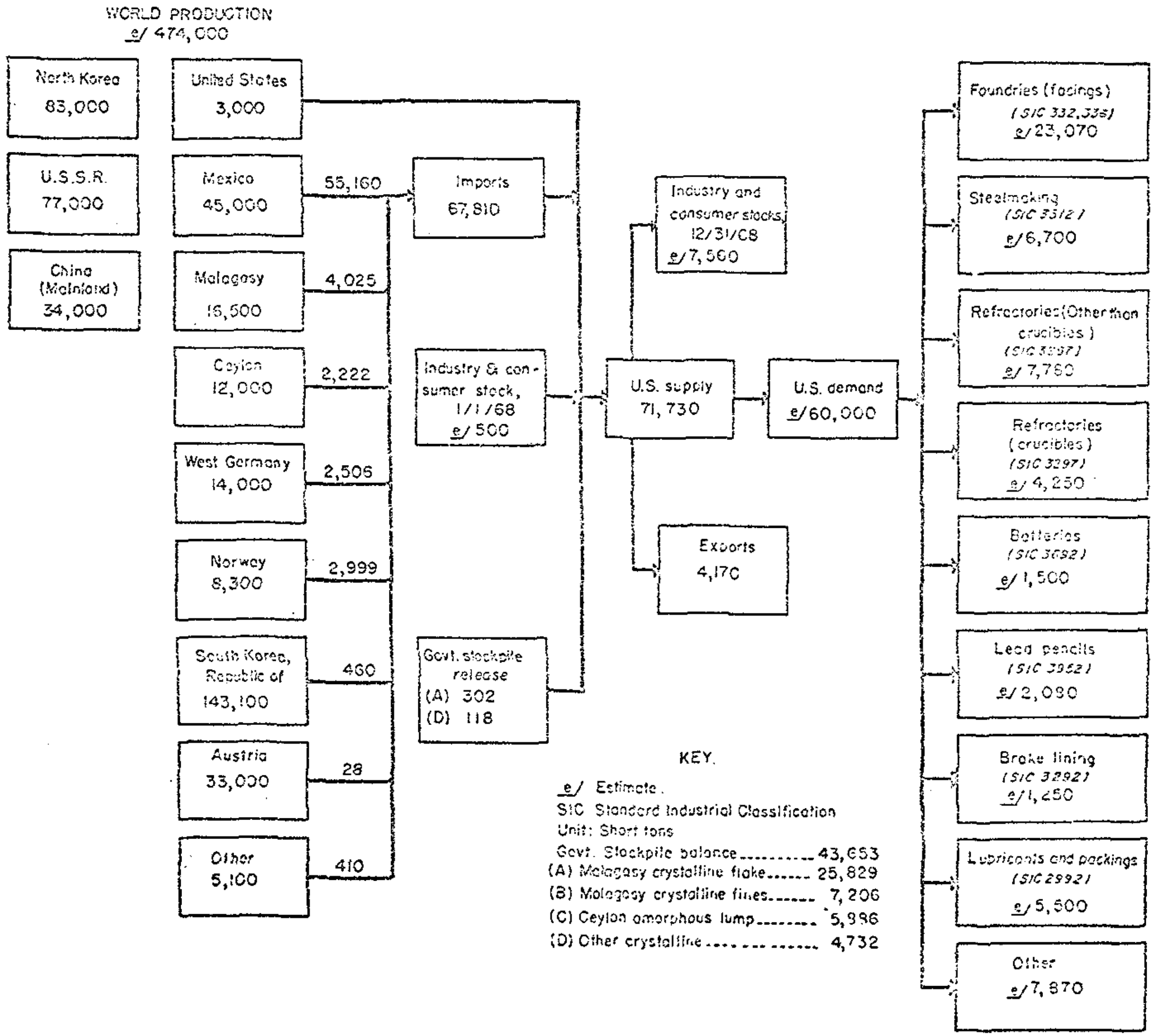


Figure 6. Supply-Demand Relationships for Natural Graphite, 1968

SECTION IV

INDUSTRY CATEGORIZATION

INTRODUCTION

In the development of effluent limitations guidelines and recommended standards of performance for new sources in a particular industry, consideration should be given to whether the industry can be treated as a whole in the establishment of uniform and equitable guidelines for the entire industry or whether there are sufficient differences within the industry to justify its division into categories. For this segment of the mineral mining and processing industry, which includes 21 mineral types, the following factors were considered as possible justifications for industry categorization and subcategorization:

1) manufacturing processes;

2) raw materials

3) pollutants in effluent waste waters;

4) product purity;

5) water use volume;

6) facility size;

7) facility age; and

8) facility location.

INDUSTRY CATEGORIZATION

The first categorization step was to segment the mineral mining and processing industry according to product use. Thus, Volume I is "Mining of Minerals for the Construction Industry," Volume II is "Mining of Minerals for the Chemical and Fertilizer Industries," and this volume, Volume III, is "Mining of Clay, Ceramic, Refractory and Miscellaneous Minerals."

The reason for this division is twofold. First, the industries in each volume generally have the same waste water treatment problems. Secondly, this division results in development documents that are not so big that the reader may reaily forget earlier points as he reads from section to section.

The first cut in subcategorization was made on a commodity basis. This was necessary because of the large number of commodities and in order to avoid insufficient study of any one area. Furthermore, the economics of each commodity differs and an individual assessment is necessary to insure that the economic impact is not a limiting factor in establishing effluent treatment technologies. Table 4 lists the 17 subcategories in this report.

FACTORS CONSIDERED

Manufacturing Processes

Each commodity can be further subcategorized into three very general classes - dry crushing and grinding, wet crushing and grinding (shaping), and crushing and beneficiation (including flotation, heavy media, et cetera, where such differences exist. Each of these processes is described in detail in Section V of this report, including process flow diagrams pertinent to the specific facilities using the process.

Raw Materials

The raw materials used are principally ores, which vary across this segment of the industry and also vary within a given deposit. Despite these variations, differences in ore grades do not generally affect the ability to achieve the effluent limitations. In cases where it does, different processes are used, as is the case for feldspar and subcategorization is better applied by process type as described in the preceeding paragraph.

Product Purity

The mineral extraction processes covered in this report yield products which vary in purity from what would be considered a chemical technical grade to an essentially analytical reagent quality. Product purity was not considered to be a viable criterion for categorization of the industry. Pure product manufacture usually generates more waste than the production of lower grades of material, and thus could be a basis for subcategorization. As is the case for variation of ore grade discussed under raw materials above, pure products usually result from different beneficiation processes, and subcategorization is applied more advantageously there.

TABLE 4

Commodity	Industry SIC Code	Subcategory
Bentonite	1452	No further subcategorization
Fire clay	1453	No further subcategorization
Fuller's earth	1454	Attapulgite Montmorillonite
Kaolin and ball clay	1455	Dry Kaolin Mining and Processing Kaolin Mining and Wet Processing for High-Grade Product Ball Clay - Dry Processing Ball Clay - Wet Processing
Feldspar	1459	Feldspar Wet Processing Feldspar Dry Processing
Kyanite	1459	No further subcategorization
Magnesite	1459	No further subcategorization
Shale & Common Clay, NEC	1459	Shale Aplite
Talc Minerals Group	1496	Talc Minerals Group, Dry Process Talc Minerals Group, Ore Mining & Washing Talc Minerals Group, Ore Mining, Heavy Media and Flotation
Natural Abrasives	1499	Garnet Tripoli
Diatomite	1499	No further subcategorization
Graphite	1499	No further subcategorization
Misc. Minerals, Not elsewhere classified	1499	Jade Novaculite

Facility Size

For this segment of the industry, information was obtained from more than 90 different mineral mining sites. Capacity varied from as little as 2 to 6,800 kkg/day. The variance of this factor was so great that facility size was not felt to be useful in categorizing this segment of the industry. Furthermore setting standards based on pounds pollutant per ton production minimizes the differences in facility sizes. The economic impact on plant size will be addressed in another study.

Facility Age

The newest facility studied was less than a year old and the oldest was 90 years old. There is no correlation between facility age and the ability to treat process waste water to acceptable levels of pollutants. Also the equipment in the oldest facilities either operates on the same principle or is identical to equipment used in modern facilities. Therefore, facility age was not an acceptable criterion for categorization.

Facility Location

The locations of the more than 90 mineral mining and processing sites studied are in twenty states spread from coast to coast and north to south. Some facilities are located in arid regions of the country, allowing the use of evaporation ponds and surface disposal on the facility site. Other facilities are located near raw material mineral deposits which are highly localized in certain areas of the country. In general the principal factor within facility location affecting effluent quantity or quality is the amount of precipitation and evaporation. Appropriate consideration of these factors was taken where applicable, most notably mine pumpout and storm runoff.

SECTION V

WATER USE AND WASTE CHARACTERIZATION

INTRODUCTION

This section discusses the specific water uses in the clay, ceramic, refractory, and miscellaneous minerals segment of the mineral mining and processing industry, and the amounts of process waste materials contained in these waters. The process water raw waste loads are given in terms of kilograms per metric ton of either product produced or ore processed. The specific water uses and amounts are given in terms of liters per metric ton of product produced or ore mined. For each of the facilities contacted in this study. The treatments used by the mining and processing facilities studied are specifically described and the amount and type of water borne waste effluent after treatment is characterized.

The verification sampling data measured at specific facilities for each subcategory is included in this report where industry data and data from other sources is lacking.

SPECIFIC WATER USES

Waste water originates in the mineral mining and processing industry from the following sources.

(1) Non-contact cooling water
(2) Process generated waste water
- wash water
- transport water
- scrubber water
- process and product consumed water
- miscellaneous water

(3) Auxiliary processes water

(4) Storm and ground water - mine water
- storm runoff

Non-contact cooling water is that cooling water which does not come into direct contact with any raw material, intermediate product, by-product or product used in or resulting from the process or any process water. Such water will be regulated by general limitations applicable to all industries.

Process generated waste water is that water which, in the mineral processing operations such as crushing, washing beneficiation, comes into direct contact with any raw material, intermediate product, by-product or product used in or resulting from the process.

Auxiliary process water is that used for processes necessary for the manufacture of a product but not contacting the process materials. For example, water treatment regeneration is an auxiliary process. Such water will be regulated by general limitations applicable to all industries.

The quantity of water usage for facilities in the clay, ceramic, refractory and miscellaneous minerals segment of the mineral mining and processing industry generally ranges from zero to 2,200,000 l/day (0 to 580,000 gal/day). In general, the facilities using very large quantities of water use it for heavy media separation and flotation processes and, in some cases, wet scrubbing and non-contact cooling.

Non-Contact Cooling Water

The largest use of non-contact cooling water in this segment of the mineral mining industry is for the cooling of equipment, such as kilns, pumps and air compressors.

Contact Cooling Water

Insignificant quantities of contact cooling water is used in this segment of the mineral mining industry. When used, it usually either evaporates immediately or remains with the product.

Wash Water

This water is process water because it comes into direct contact with either the raw material, reactants or products. Examples are ore washing to remove fines and filter cake washing. Waste effluents can arise from these washing sources, due to the fact that the resultant solution or suspension may contain impurities or may be too dilute a solution to reuse or recover.

Transport Water

Water is widely used in the mineral mining industry to transport ore to and between various process steps. Water is used to move crude ore from mine to facility, from crushers to grinding mills and to transport tailings to final retention ponds. Transport water is process water.

Scrubber Water

Particularly in the dry processing of many of the minerals in this industry, wet scrubbers are used for air pollution control. These scrubbers are primarily used on dryers, grinding mills, screens, conveyors and packaging equipment. Scrubber water is process water.

Process and Product Consumed Water

Process water is primarily used in this industry during blunging, pug milling, wet screening, log washing, heavy media separation and flotation unit processes. The largest volume of water is used in the latter two processes. Product consumed water is often evaporated or shipped with the product as a slurry or wet filter cake.

Miscellaneous Water

These water uses vary widely among the facilities with general usage for floor washing and cleanup, safety showers and eye wash stations and sanitary uses. The resultant streams are either not contaminated or only slightly contaminated with wastes. The general practice is to discharge such streams without treatment or combine with process water prior to treatment.

Another miscellaneous water use in this industry involves the use of sprays to control dust at crushers, conveyor transfer points, discharge chutes and stockpiles. This water is usually low volume and is either evaporated or absorbed in the ore. The water uses so described are process waters.

Auxiliary Processes Water

Auxiliary process water include blowdowns from cooling towers, boilers and water treatment. The volume of water used for these purposes in this industry is minimal. However, when they are present, they usually are highly concentrated in waste materials.

Storm and Ground Water

Water will enter the mine area from three natural sources direct precipitation, storm runoff and ground water intrusion. Water contacting the exposed ore or disturbed overburden will become contaminated.

Storm water and runoff can also become contaminated at the processing site from storage piles, process equipment and dusts that are emitted during processing.

PROCESS WASTE CHARACTERIZATION

The mineral products are discussed in the Standard Industrial Classification Code numerical sequence in this section. For each mineral product the following information is given:

-- a short description of the processes at the facilities studied and pertinent flow diagrams;

-- raw waste load data per unit weight of product or raw material processed;

-- water consumption data per unit weight of product or raw material processed;

-- specific facility waste effluents found and the post-process treatments used to produce them.

BENTONITE (SIC 1452)

Process Description

Bentonite is mined in dry, open pit quarries. After the overburden is stripped off, the bentonite ore is removed from the pit using bulldozers, front end loaders, and/or pan scrapers. The ore is hauled by truck to the processing facility. There, the bentonite is crushed, if necessary, dried, sent to a roll mill, stored, and shipped, either packaged or in bulk.

Dust generated in drying, crushing, and other facility operations is collected using cyclones and bags. In facility 3030 this dust is returned to storage bins for shipping. A general process flowsheet is given in Figure 7.

Raw Waste Load

Waste is generated in the mining of bentonite in the form of overburden, which must be removed to reach the bentonite deposit. Waste is also generated in the processing of bentonite as dust from drying, crushing, and other facility operations.

Water Use

There is no water used in the mining or processing of bentonite.

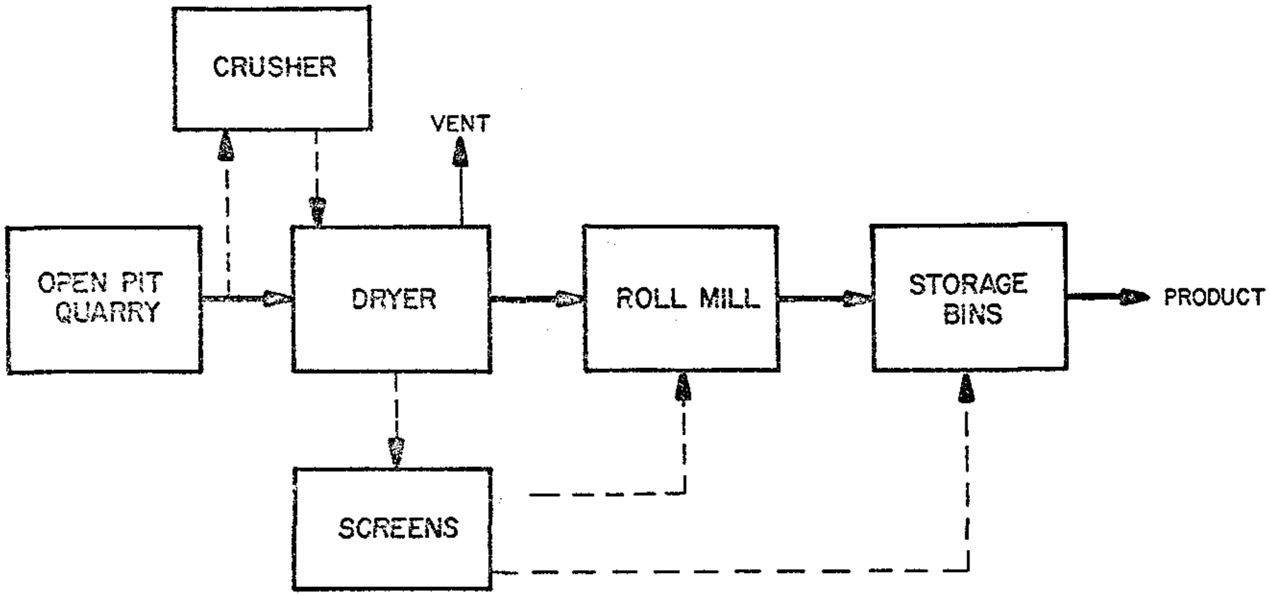


FIGURE 7.
BENTONITE MINING AND PROCESSING

Waste Water Treatment

Since there is no water used in bentonite mining or processing, no waste water is generated.

Effluent and Disposal

There is no discharge of any waste water from bentonite operations. The solid overburden removed to uncover the bentonite deposit is returned to mined-out pits for land disposal and eventual land reclamation. Dust collected from processing operations is either returned to storage bins as product or it is land-dumped.

FIRE CLAY (SIC 1453)

Fire clay is principally kaolinite but usually contains other minerals such as diaspore, boehmite, gibbsite and illite. It can also be a ball clay, a bauxitic clay, or a shale. Its main use is in refractory production and only the mining is covered here. Due to the similarity in all types of clay mining, this section will also serve for common clay mining and processing

Process Description

Fire clay is obtained from open pits using bulldozers and front-end loaders for removal of the clay. Blasting is occasionally necessary for removal of the hard flint clay. The clay is then transported by truck to the facility for processing. This processing includes crushing, screening, and other specialized steps, for example, calcination. There is at least one case (facility 3047) where the clay is shipped without processing. However, most of the fire clay mined is used near the mine site for producing refractories. A general process diagram is given in Figure 8.

Raw Waste Load

The solid waste generated in fire clay mining is overburden which is used as fill to eventually reclaim mined-out areas. Mine pumpout is the only other waste in this subcategory.

Water Use

There is no water used in fire clay mining. However, due to rainfall and ground water seepage, there can be water which accumulates in the pits and must be removed. Mine pumpout is intermittent depending on frequency of rainfall and geographic location. Flow rates are not generally available. In many cases the facilities provide protective earthen dams and ditches to prevent intrusion of external storm runoff in the clay pits. No process water is used in the mine.

Waste Water Treatment

There is no process waste water. In some cases, settling ponds are employed to reduce the amount of suspended solids in the mine pumpout before discharge. Usually, mine pumpout is discharged to a nearby body of water, to a watershed, or is evaporated on-land.

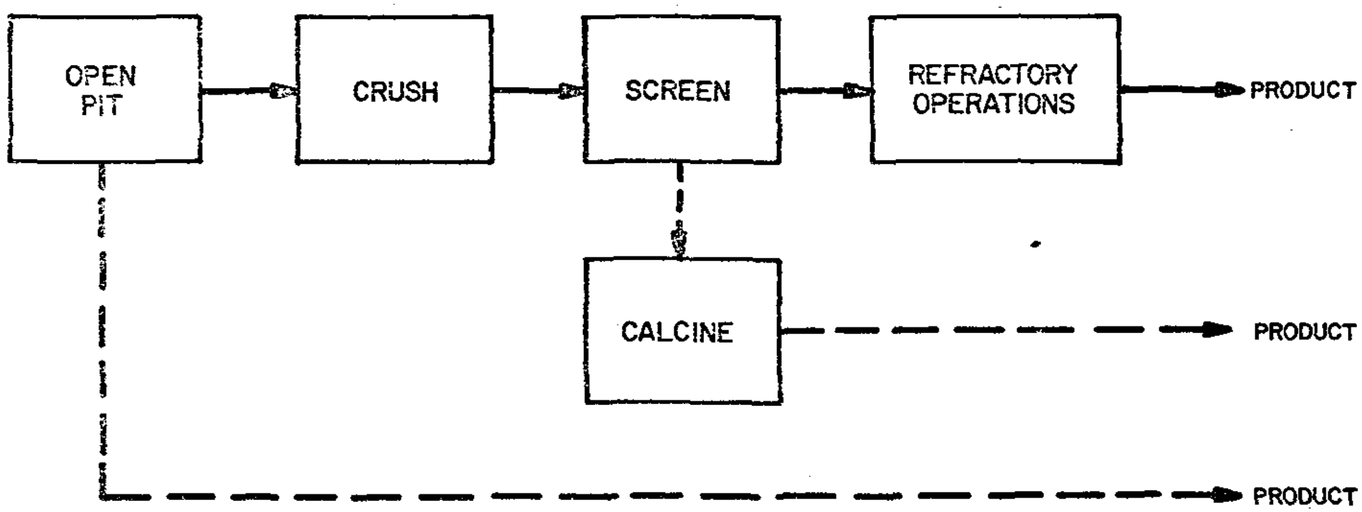


FIGURE 8.
FIRE CLAY MINING AND PROCESSING

Effluent and Disposal

There is no discharge of process waste waters. Mine pumpout is discharged either after settling or with no treatment. The effluent quality of mine pumpout at a few mines are as follows:

Mine	Treatment	pH	TSS mg/l	Total Fe mg/l
3083	Pond	7.25	3	
3084	Lime & Pond	6.5	26.4	
3087	lime, combined with other waste streams	4.0	45	
3300	None	6.0-6.9	4	
3301	None	6.9	2	
3302	None	8.3	30	
3303	None	7.0	1	
3307	None	9.2	5	
3308	Pond	5.0	16	20
3309	Pond	4.2		80
3310	None	3.0	16	

FULLER'S EARTH (SIC 1454)

Fuller's Earth is a clay, usually high in magnesia, which has decolorizing and absorptive properties. Production from the region that includes Decatur County, Georgia, and Gadsden County, Florida, is composed predominantly of the distinct clay mineral attapulgite. Most of the Fuller's Earth occurring in the other areas of the U.S. contains primarily montmorillonite. Six facilities, representing 83 percent of the total U.S. production of Fuller's Earth, provided the data for this section.

ATTAPULGITE

Process Description

Attapulgite is mined from open pits, with removal of overburden using scrapers and draglines. The clay is also removed using scrapers and draglines and is trucked to the facility for processing. Processing consists of crushing and grinding, screening and air classification, pug milling (optional), and a heat treatment that may vary from simple evaporation of excess water to thermal alteration of crystal structure. A general process diagram is given in Figure 9.

Raw Waste Load

Dusts and fines are generated from drying and screening operations at facility 3060. This slurried waste is sent to worked-out pits which serve as settling ponds. In the last year the ponds have been enlarged and modified to allow for complete recycle of this waste water. The ponds have not yet totally filled, however the company anticipates no problems. There is no discharge at this time of process water. At facility 3058 waste is generated from screening operations as fines which until presently were slurried and pumped to a settling pond. With the installation of new reconstituting equipment these fines are recycled and there is no discharge of process water. The settling pond however is maintained in event of breakdown or the excessive generation of fines. Facility 3088 also has installed recycle ponds recently and anticipates no trouble. Facility 3089 uses a dry micro-pulsair system for air pollution control, therefore there is no discharge of process water. According to the company they are within state air pollution requirements.

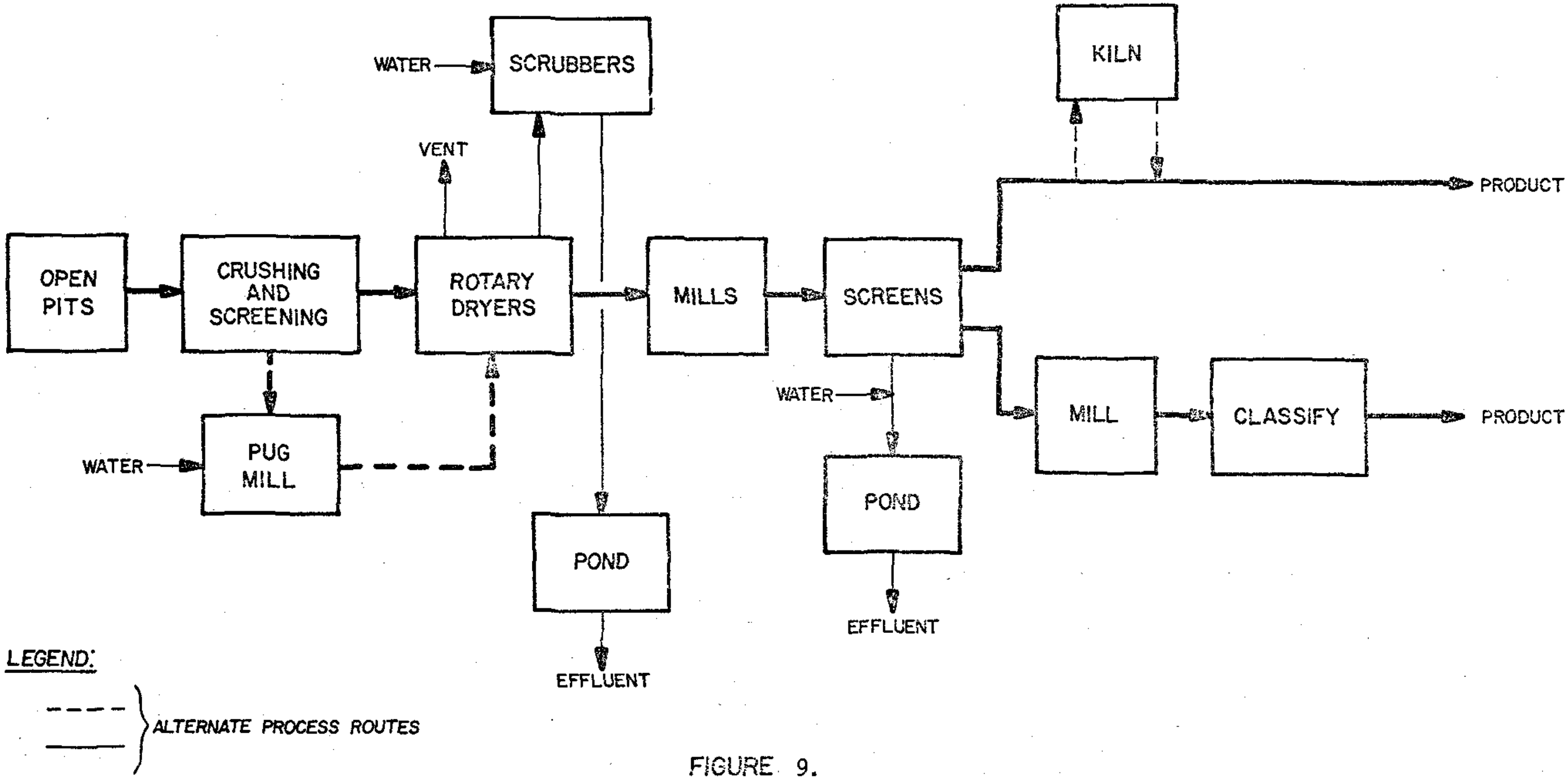


FIGURE 9.
FULLER'S EARTH MINING AND PROCESSING
(ATTAPULGITE)

Water Use

No water is used in the mining, but rain and ground water do collect in the pits, particularly during the rainy season. This type of clay settles rapidly and mine pumpout is generally clear except when overburden gets into the water. Only one company, 3089, uses settling ponds for treatment of dry weather mine pump-out. No company attempts to treat wet weather mine pump-out or surface runoff. Untreated creek water serves as source and make-up for facilities 3058 and 3060. Water is used by facility 3058 for cooling, pug milling, and during periodic overload for waste fines slurrying. This slurrying has not occurred since installation of a fines reconstitution system. However it is maintained as a back-up system. Facility 3060 also uses water for cooling and pug milling, and, in addition, uses water in dust scrubbers for air pollution control. There is no recycle of process water at either facility, all being evaporated, sent to ponds, and/or eventually discharged. Typical flows are:

	l/kkg of product (gal/ton) 3058	3060
Intake:		
Make-up	460 (110) includes average intermittent needs	total unknown
Use:		
cooling	184 (44)	unknown amount
waste disposal and dust collection	230 (55) intermittent	345-515 (82-122)
pug mill	46 (11)	42 (10)
Consumption:		
cooling water discharge	none	unknown
process discharge	none	none
evaporation	230 (55)	42 (10)
Total	460 (110)	unknown

Waste Water Treatment

Mine pumpout at facilities 3060 and 3058 is discharged without treatment. Facility 3089 uses two settling ponds in series to treat mine pumpout, however they do not attempt to treat wet weather mine pumpout. Bearing cooling water at facility 3060 is pumped directly back to the creek, with no treatment, while water used in pugging and kiln cooling is evaporated in the process. Scrubber waters are directed to settling ponds before recycle to the scrubber. At facility 3058 cooling and pug mill water is evaporated in the process.

Effluent and Disposal

Facilities 3060 and 3088 at the present time have recycle ponds. However, due to evaporation and possibly seepage little or no actual recycling is occurring at this time. Facilities 3058 and 3087 use dry air pollution equipment and fines reconstituters; therefore they have no discharge.

MONTMORILLONITE

Montmorillonite wastes present more of a settling problem in water than attapulgite wastes. The information presented below is based on 3 of 4 facilities in this subcategory. This represents over 80 percent of the U.S. montmorillonite production.

Process Description

Montmorillonite is mined from open pits. Overburden is removed by scrapers and/or draglines, and the clay is draglined and loaded onto trucks for transport to the facility. Processing consists of crushing, drying, milling, screening, and, for a portion of the clay, a final drying prior to packaging and shipping. A general process diagram is given in Figure 10.

Raw Waste Load

Solid waste generated in mining montmorillonite is overburden which is used as fill to reclaim worked-out pits. Waste is generated in processing as dust and fines from milling, screening, and drying operations. The dust and fines which are gathered in bag collectors from drying operations are hauled, along with milling and screening fines, back to the pits as fill. Slurry from scrubbers is sent to a settling pond with the muds being returned to worked-out pits after recycling the water. There are no data available on the amount of these solid wastes.

Water Use

There is no water used in the mining operations. However, rain water and ground water collect in the pits forming a murky colloidal suspension of the clay. This water is pumped to worked-out pits where it settles to the extent possible and is discharged intermittently to a nearby body

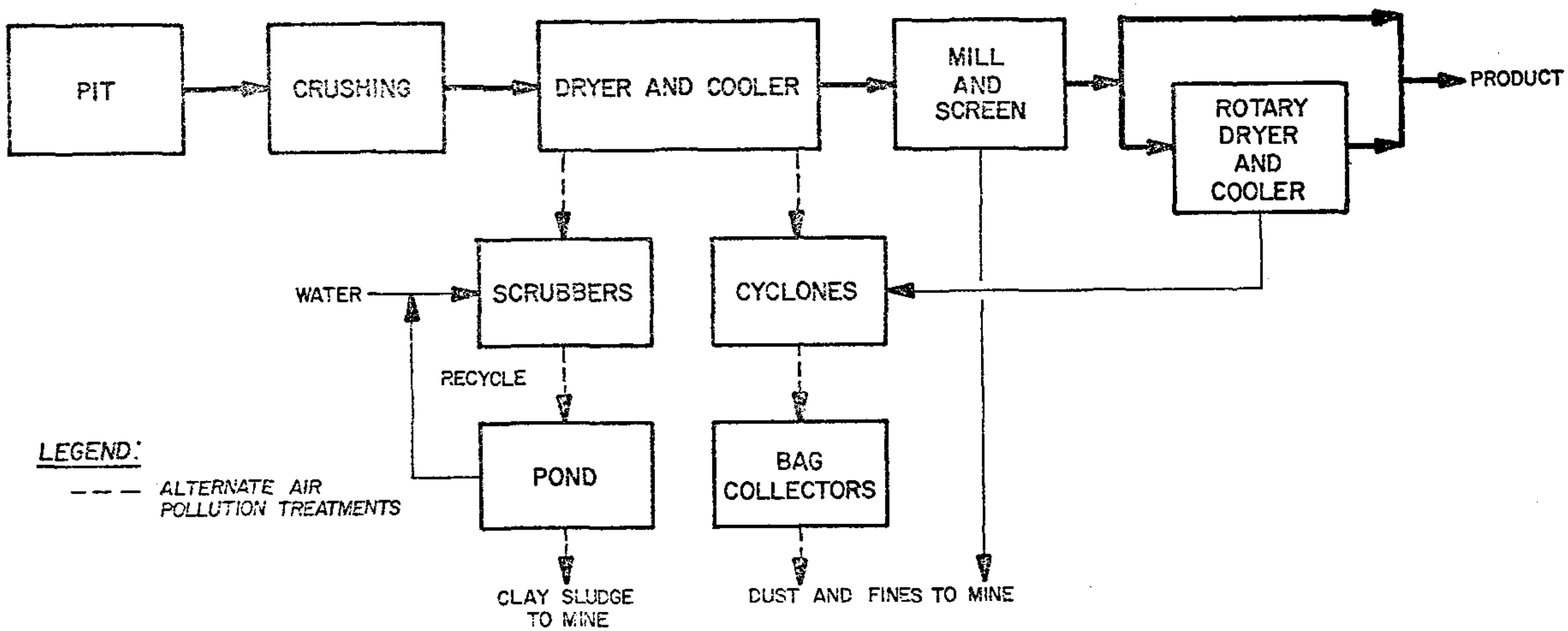


FIGURE 10.
FULLER'S EARTH MINING AND PROCESSING
(MONTMORILLONITE)

of water, except in the case of facility 3073 which uses this water as scrubber water makeup. The estimated flow is up to 1140 l/day (300 gpd).

Water is used in processing only in dust scrubbers. Typical flows are:

Facility	l/kkg product (gal/ton) 3059	3072	3073
Intake	1,930 (460)	500 (120)	143 (34)
Use:			
Dust Scrubbers	1,930 (460)	500 (120)	143 (34)
Consumption:			
Discharge	none	150 (36)	none
Evaporation plus Landfill of Solid Wastes	1,930 (460)	350 (84)	143 (34)

Facilities 3059 and 3073 recycle essentially 100 percent of the scrubber water.

Waste Water Treatment

Facilities 3059 and 3073 recycle essentially 100 percent of the scrubber water, while facility 3072 recycles only about 70 percent. Scrubber water must be kept neutral because sulfate values in the clay become concentrated, making the water acidic and corrosive. Facilities 3059 and 3073 use ammonia to neutralize recycle scrubber water, forming ammonium sulfate. Facility 3072 uses lime ($Ca(OH)_2$), which precipitates as calcium sulfate in the settling pond. To keep the scrubber recycle system working, some water containing a build-up of calcium sulfate is discharged to a nearby creek. However, facility 3072 intends to recycle all scrubber water by mid-1975. Mine pumpout presents a greater problem for montmorillonite producers than for attapulgite producers, due to the very slow settling rate of the suspended clay. Accumulated rain and ground water is pumped to abandoned pits for settling to the extent possible and is then discharged. A mine pumpout sample from facility 3059 (Versar data) had a TSS of 215 mg/l. At facility 3073 the pit water is used as makeup for the scrubber water.

Effluent and Disposal

There is no process discharge from facilities 3059 and 3073. Facility 3072 discharges a small amount of scrubber water after settling and lime treatment. This effluent contains 0.2 percent suspended solids and has a pH of 8. This effluent corresponds to an average TSS of 0.3 kg/kkg product. The settling pond muds at all three facilities are landfilled in worked-out pits.

KAOLIN (SIC 1455)

Kaolin is produced in mines in 17 states with Georgia accounting for the bulk (75%) of the U.S. production. Six kaolin mines and facilities distributed between eastern and western U.S. were contacted representing 48 percent of the total kaolin production in the U.S. Facilities were found having different water usages, so two subcategories are established for kaolin processing; wet for high grade product, and dry, for general purpose use.

DRY PROCESS

Process Description

The clay is mined in open pits using shovels, caterpillars, carry-alls and pan scrapers. Trucks haul the kaolin to the facility for processing. At facilities 3035, 3062, 3063 the clay is crushed, screened, and used for processing to refractory products. Processing at facility 3036 consists of grinding, drying, classification and storage. A general dry process diagram is given in Figure 11.

Raw Waste Load

There is no waste generated in the mining of the kaolin other than overburden, and in the processing, solid waste is generated from classification. No data is available on the amount of this waste.

Water Use

There is no water used in the mining or processing of kaolin at these four facilities. There is rainwater and ground water which accumulates in the pits and must be pumped out. The quantity of this mine pumpout is unknown.

Waste Water Treatment

There is no process waste water generated at any of the four facilities, but the mine pumpout is normally sent through a series of small settling ponds before discharge.

Effluent and Disposal

The solid waste generated is land-disposed on-site. There is no process effluent discharged. The mine pumpout is, in most instances, sent through a series of settling ponds to reduce the suspended solids.

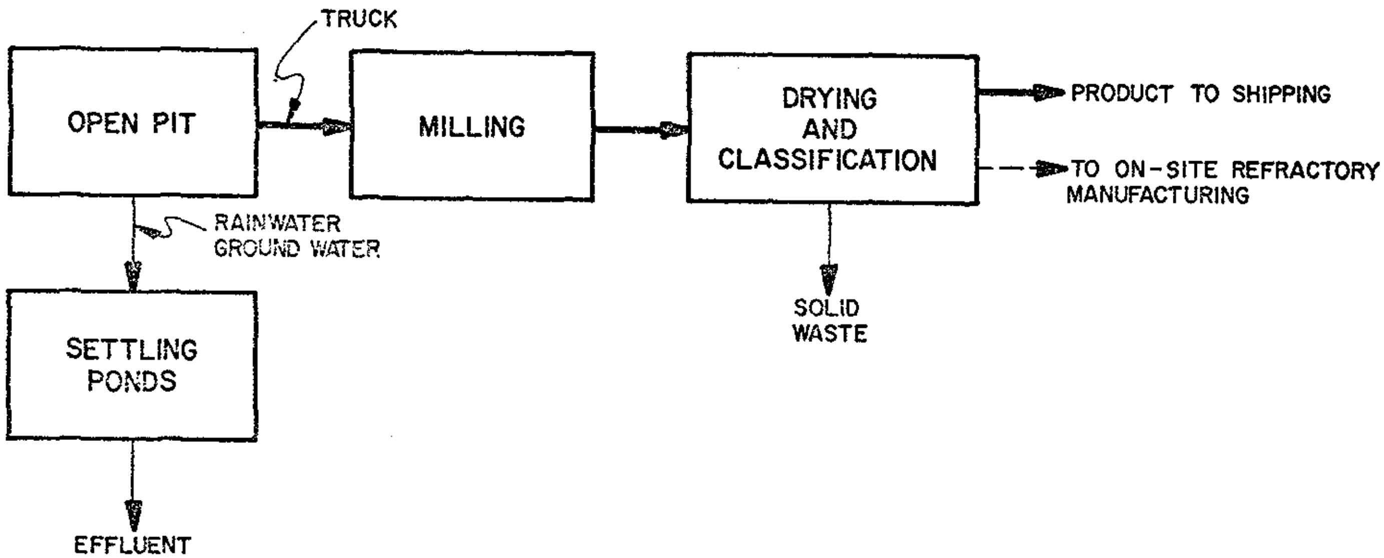


FIGURE 11.
DRY KAOLIN MINING AND PROCESSING
FOR GENERAL PURPOSE USE

WET PROCESS

Process Description

Sixty percent of the U.S. production of kaolin is by this general process.

Mining of kaolin is an open pit operation using draglines or pan scrapers. The clay is then trucked to the facility or, in the case of facility 3025, some preliminary processing is performed near the mine site including blunging or pug milling, degritting, screening and slurrying to pump the clay to the main processing facility. Subsequent operations are hydroseparation and classification, chemical treatment (principally bleaching with zinc hydrosulfite), filtration, and drying (via tunnel dryer, rotary dryer or spray dryer). For special properties, other steps can be taken such as magnetic separation, delamination or attrition (facility 3024). Also, facility 3025 ships part of the kaolin product as slurry (70% solids) in tank cars. A general wet process diagram is given in Figure 12.

Raw Waste Load

Waste is generated in kaolin mining as overburden which is stripped off to expose the kaolin deposit.

In the processing, waste is generated as underflow from hydroseparators and centrifuges (facility 3024), and sand and muds from filtration and separation operations. Zinc ion is carried through to waste water from the bleaching operations. The raw waste loads at these two facilities are:

Waste Material	kg/kkg product (lb/1000 lb) 3024	3025
zinc	0.37	0.5
dissolved solids	8	10
suspended solids	35	100

The dissolved solids are principally sulfates and sulfites and the suspended solids are ore fines and sand.

Water Use

Water is used in wet processing of kaolin for pug milling, blunging, cooling, and slurrying. At facility 3024, water is obtained from deep wells, all of which is chlorinated and most of which is used as facility process water with no

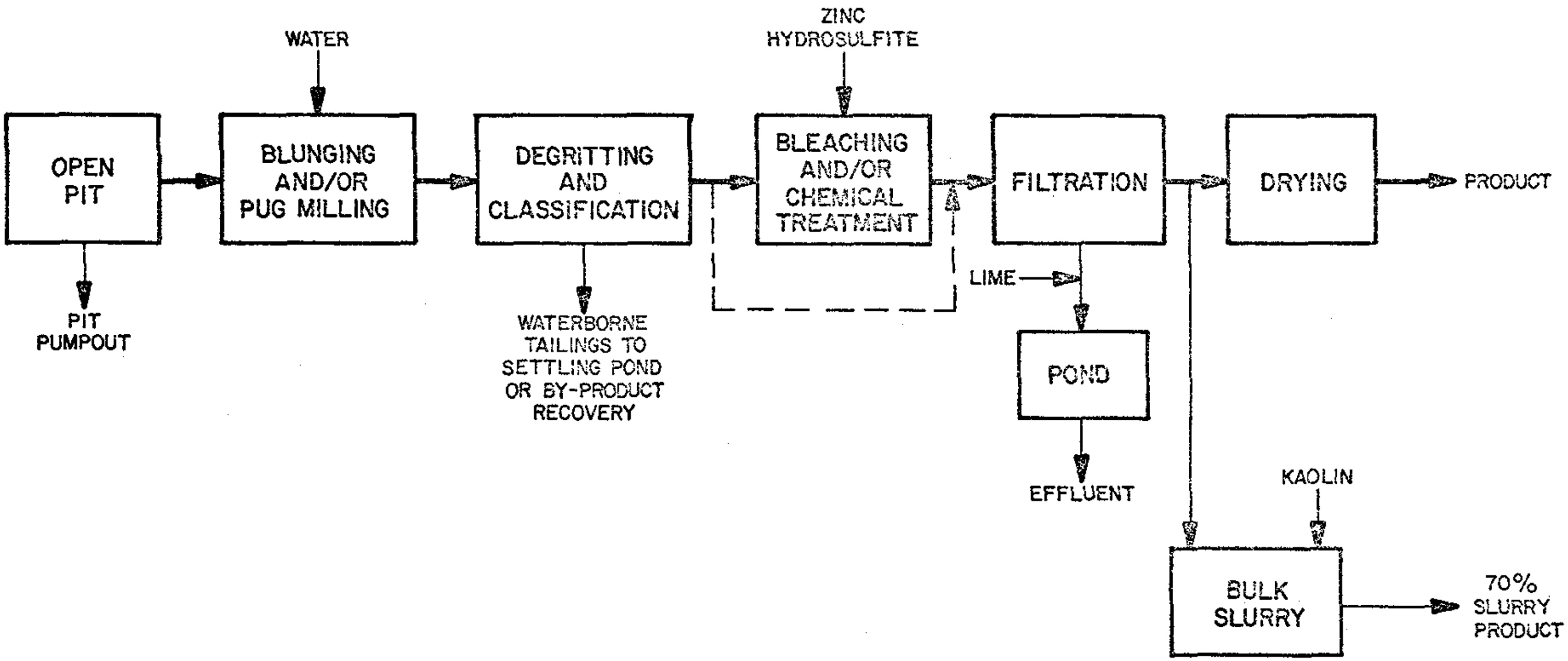


FIGURE 12.
WET KAOLIN MINING AND PROCESSING
FOR HIGH GRADE PRODUCT

recycle. Facility 3025 has a company-owned ground water system as a source and also incoming slurry provides some water to the process none of which is recycled. Typical water flows are:

	1/kkg product (gal/ton)	
	3024	3025
water intake	4,250 (1,020)	4,290 (1030)
process waste water	3,400 (810)	4,000 (960)
water evaporated, etc.	850 (210)	290 (70)

These facilities do not recycle their process water but discharge it after treatment. Recycle of this water is claimed to interfere with the chemical treatment.

Waste Water Treatment

Open pit mining of kaolin does not utilize any water. However, when rainwater and ground water accumulate in the pits it must be pumped out and discharged. Usually this pumpout is discharged without treatment, but, in at least one case, pH adjustment is necessary prior to discharge.

The facilities treat the ponds with lime to adjust pH and remove excess zinc which has been introduced as a bleaching agent. This treatment effects a 99.8% removal of zinc, 99.9% removal of suspended solids, and 80% removal of dissolved solids.

These facilities are considering the use of sodium hydrosulfite as bleach to eliminate the zinc waste.

Facilities with large ponds and a high freeboard have the capability of discontinuing discharge for one or more days to allow unusual high turbidities to decrease before resuming a discharge.

Effluent and Disposal

Solid wastes generated in kaolin mining and wet processing are land-disposed with overburden being returned to mined-out pits, and dust, fines, and other solids to settling ponds.

Waste waters are in all cases sent to ponds where the solids settle out and the water is discharged after lime treatment. A statistical analysis was performed on five Georgia kaolin treatment systems. Based on a 99 percent confidence level on the better fitting distribution of normal and logarithmic normal the following turbidities were achieved.

Facility	Turbidity, JTU or NTU long term average	daily maximum	monthly average maximum
3024	26.4	48.2	<43
3025	24.5	83	62.5
3314	58.2	202	
3315 (1)	32.9	140	113.7
3315 (2)	32.7	76.7	

Long term TSS data was not available. What TSS values were available were correlated with the corresponding turbidity values as follows:

Facility	TSS, mg/l 50 JTU(NTU)	100 JTU(NTU)
3024	45	90
3025	35	70
3315	50	100

The following mine drainage concentrations were measured.

Mine	TSS, mg/l	JTU
3074	10	
3080	10	
3081	10	
3311	22	
3312	7.4	
3313	41	
3316	95.2*	44.6*
3317		232*
3318		79.5*

*daily maximum achieved in 99 percent of samples

BALL CLAY (SIC 1455)

Ball clay is a plastic, white-firing clay used principally for bonding in ceramic ware. Four ball clay producers representing 40 percent of total U.S. ball clay production provided data for this section. There are twelve facilities in this category.

Process Description

After overburden is removed, the clay is mined using front-end loaders and/or draglines. The clay is then loaded onto trucks for transfer to the processing facility. Processing consists of shredding, milling, air separation and bagging for shipping. Facilities 5684 and 5685 have additional processing steps including blunging, screening, and tank storage for sale of the clay in slurry form, and rotary drying directly from the stockpile for a dry unprocessed ball clay. A general process diagram is given in Figure 13.

Raw Waste Load

Ball clay mining generates a large amount of overburden which is returned to worked-out pits for land reclamation. The processing of ball clay generates dust and fines from milling and air separation operations. These fines are gathered in baghouses and returned to the process as product. At the facilities where slurrying and rotary drying are done, there are additional process wastes generated. Blunging and screening the clay for slurry product generates lignite and sand solid wastes after dewatering. The drying operation uses wet scrubbers which result in a slurry of dust and water sent to a settling pond. There are no data available on the amount of wastes generated in producing the slurry or the dry product, but the waste materials are limited to fines of low solubility minerals.

Water Use

There is no water used in ball clay mining, however, when rain and ground water collects in the mine, there is an intermittent discharge. Mine pumpout is either discharged without treatment, or pumped to a settling pond before discharge to a nearby body of water. There is usually some diking around the mine to prevent run-off from flowing in. There are no flow rates or water quality data available on mine pumpout.

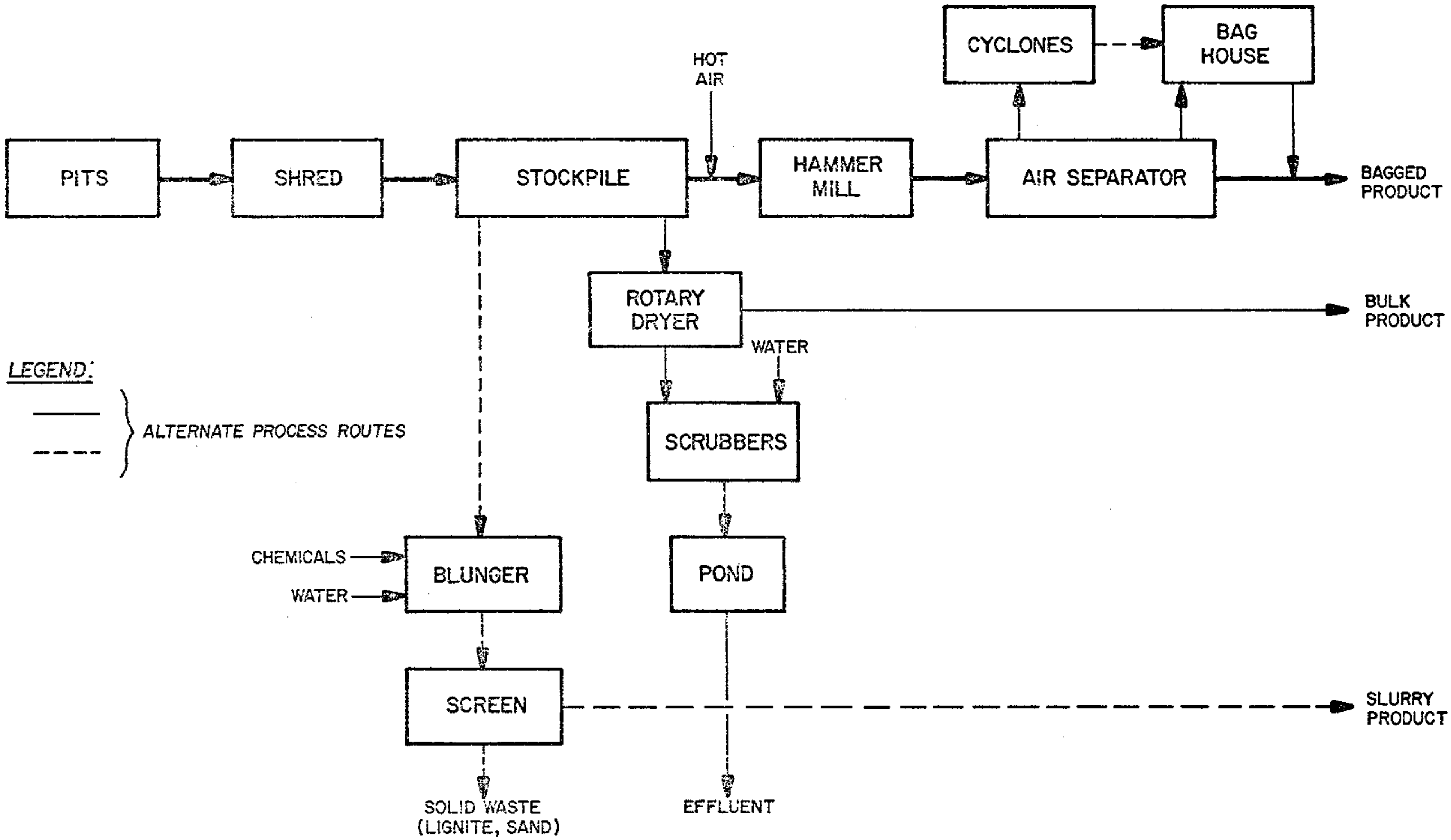


FIGURE 13.
BALL CLAY MINING AND PROCESSING

In ball clay processing, two of the facilities visited use a completely dry process. The others produce a slurry product using water for blunging, a product dried directly from the stockpile with water used for wet scrubbers, and/or the dry process product. Well water serves as the source for the facilities which use water in their processing. Typical flows are:

	l/kkg of product (gal/ton)		
	5684	5685	5689
Intake	total unknown	1,130 (270)	4,300 (1,030)
Use:			
Blunging	unknown	42 (10)	none
Scrubber	88 (21)	1,080 (260)	4,300 (1,030)

Water used in blunging operations is consumed both as product and evaporated from water material. Scrubber water is impounded in settling ponds and eventually discharged. Facilities 5685 and 5689 use water scrubbers for both dust collection from the rotary driers and for in-facility dust collection. Facility 5684 has only the former.

Waste Water Treatment

Mine pumpout is discharged either after settling in a pond or sump or without any treatment.

Scrubber water at these facilities is sent to settling ponds. In addition, facilities 5684 and 5689 treat the scrubber water with a flocculating agent which improves settling of suspended solids in the pond. Facility 5689 has three ponds of a total of 1.0 hectare (2.5 acres) area.

Effluent and Disposal

There are no data available on the quality of the intermittent mine pumpout from any of the ball clay producers visited.

Effluent discharged from the settling pond at facility 5685 has the following parameters: a pH of 6.4 and TSS of 400 mg/l. Total suspended solids at facility 5689 averages less than 40 mg/l. No data are available on effluent from facility 5684.

The amounts of process wastes discharged by these facilities are calculated to be:

facility	discharge, l/kkg of product (gal/ton)	TSS, kg/kkg of product (lb/1000 lb)
5684	88 (21)	------
5685	1,080 (260)	0.43
5689	834 (1,030)	0.17

There are two significant types of operations in ball clay manufacture insofar as water use is concerned: those having wet scrubbers, which have a waste water discharge, and those without wet scrubbers, which have no process waste water.

There is a discrepancy in discharge flow rates since not all the production lines in each facility have wet scrubbers. Baghouses are also employed by this industry.

Insofar as facilities having scrubbers is concerned, facility 5689 is exemplary in its treatment, discharging a low concentration of TSS and a moderate total amount.

FELDSPAR

Feldspar mining and/or processing has been sub-categorized as follows:

(1) flotation - dry quarries - flotation processing
(2) non-flotation - dry quarries - dry crushing and classification

Feldspathic sands are included in the Industrials Sands category in Volume I of this report.

FELDSPAR - FLOTATION

This subcategory of feldspar mining and processing is characterized by dry operations at the mine and wet processing in the facility. This is the most important subcategory of feldspar, since about 73 percent of the total tonnage of feldspar sold or used in 1972 was produced by this process.

Wet processing is carried out in five facilities owned by three companies. Data was obtained from all five of these facilities (3026, 3054, 3065, 3067, and 3068). A sixth facility is now coming into production and will replace one of the above five facilities in 1975.

Process Description

At all five facilities, mining techniques are quite similar: after overburden is removed, the ore is drilled and blasted, followed by loading of ore onto trucks by means of power shovels, draglines, or front end loaders for transport to the facility. In some cases, additional break-up of ore is accomplished at the mine by drop-balling. No water is used in mining at any location.

The first step in processing the ore is crushing which is generally accomplished at the facility, but may be accomplished at the mine (Facility 3068). Subsequent steps for all wet processing facilities vary in detail, but the basic flow sheet, as given in Figure 14, contains all the fundamentals of these facilities.

By-products from flotation include mica, which may be further processed for sale (Facilities 3054, 3065, 3067, and 3068), and quartz or sand (Facilities 3026, 3054, and 3068). At Facilities 3065 and 3067, a portion of the total flow to the third flotation step is diverted to dewatering, drying, guiding, etc., and is sold as a feldspathic sand.

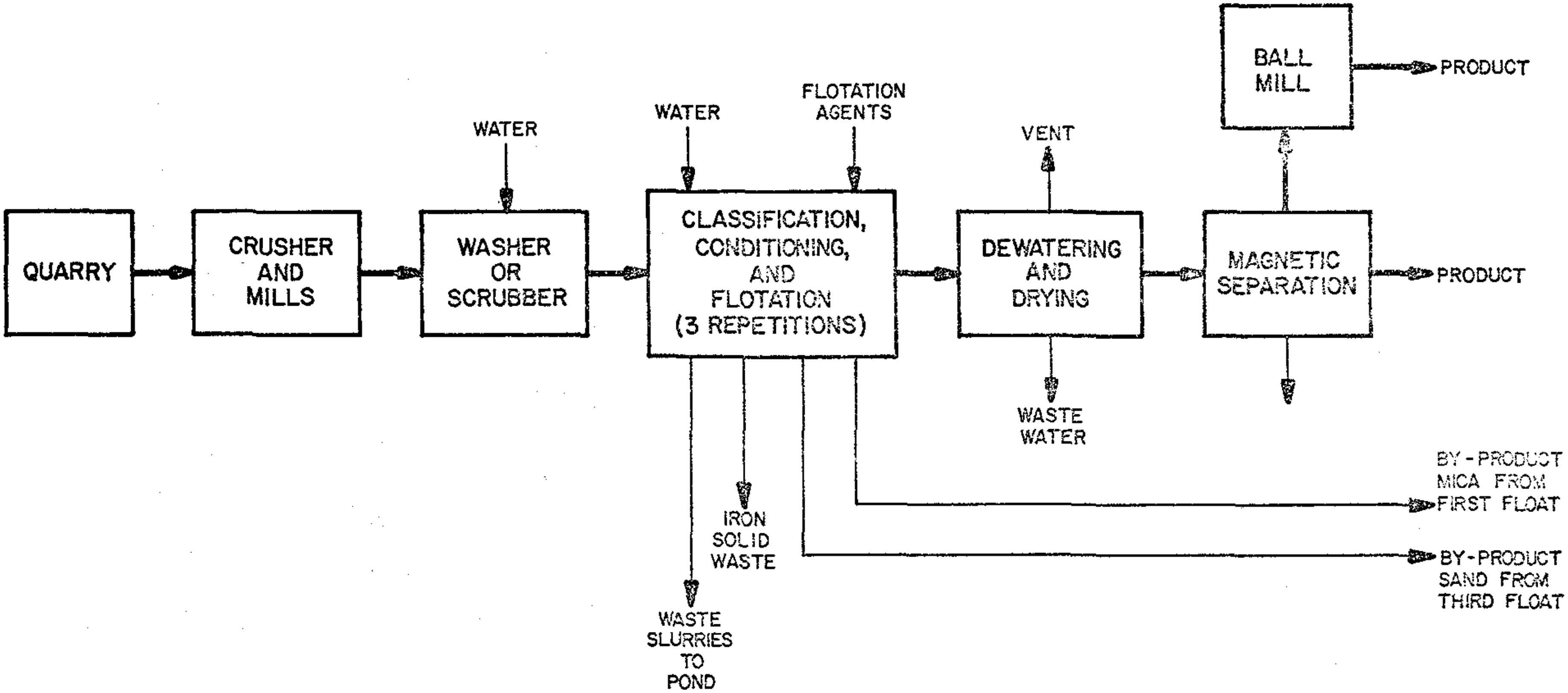


FIGURE 14.
FELDSPAR MINING AND PROCESSING
(WET)

Raw Waste Loads

Mining operations at the open pits result in overburden of varying depth. The overburden is applied to land reclamation of nearby worked-out mining areas.

Waste recovery and handling at the processing facilities is a major consideration, as large tonnages are involved. Waste varies from a low of 26 percent of mined ore at Facility 3065 to a high of 53 percent at Facility 3067. The latter value is considerably larger due to the fact that this facility does not sell the sand from its feldspar flotation. Most of the other facilities are able to sell all or part of their by-product sand. Typical flotation reagants used in this production subcategory contain hydrofluoric acid, sulfuric acid, sulfonic acid, frothers, amines and oils.

The raw waste data calculated from information supplied by these facilities are:

	kg/kkg of ore processed (lb/1000 lb)	
facility	ore tailings and slimes	fluoride
3026	270	0.22
3054	410	0.24
3065	260	0.20
3067	530	est. 0.25
3068	350	est. 0.25

These raw wastes are generally settled in ponds or sent to thickeners. The bulk of the solids and adsorbed organics would then be separated from the liquid containing dissolved fluoride and some suspended solids.

Water Use

Water is not used in the quarrying of feldspar. There is occasional drainage from the mine, but pumpout is not generally practiced.

Wet processing of feldspar does result in the use of quite significant amounts of water. At the facilities visited, water was obtained from a nearby lake, creek, or river and used without any pre-treatment. Recycle of water is minimal, varying from zero at several facilities to a maximum of about 17 percent at Facility 3026. The primary reason for little or no water recycle is the possible build-up of undesirable soluble organics and fluoride ion in the flotation steps. However, some water is recycled in some facilities to the initial washing and crushing steps, and some recycle of water in the fluoride flotation step is practiced at facility 3026.

Total water use at these facilities varies from 7,000 to 22,200 l/kkg of ore processed (1,680 to 5,300 gal/ton). Most of the process water used in these facilities is discharged. Some water is lost in tailings and drying. This is of the order of 1 percent of the water use at facility 3065.

The use of the process water in the flotation steps amounts to at least one-half of the total water use. The water used in the fluoride reagent flotation step ranges from 10 to 25 percent of the total flow depending on local practice and sand-to-feldspar ratio. Only two of these five facilities use any significant recycling of water. These are:

facility 3026 - 17 percent of intake (on the average)

facility 3067 - 10 percent of intake

Waste Water Treatment

Treatment at three facilities (3054, 3065, 3068) consists of pumping combined facility effluents into clarifiers, with polymer added to aid in flocculation. Both polymer and lime are added at one facility (3065). At the other two facilities, (3026, 3067) there are two settling ponds in series, with one facility adding alum (3026).

Measurements by EPA's contractor on the performance of the treatment system at facility 3026, consisting of two ponds in series and alum treatment, showed the following reductions in concentration (mg/l):

	TSS	Fluoride
waste water into system	3,790	14
discharge from system	21	1.3

Effluents and Disposal

The process water effluents after treatment at these five facilities have the following average quality characteristics:

facility	pH	mg/l	mg/l
3026	6.5-6.8	21*	8
3054	6.8	45	15*
3065	10.8*	349	23*
3067	7.5-8.0	35*	34*
3068	7-8	40-150	32

The asterisked values are Versar measurements in lieu of facility-furnished data not available. Facility 3065 adds lime to the treatment, which accounts for the higher than average pH.

The average amounts of the suspended solids and fluoride pollutants present in these waste effluent streams calculated from the above values are given in the following table together with the relative effluent flows.

	ore processed basis		
facility	flow, l/kkg (gal/ton)	TSS, kg/kkg (lb/1000 lb)	fluoride, kg/kkg (lb/1000 lb)
3026	14,600 (3,500)	0.31	0.12
3054	12,500 (3,000)	0.56	0.18
3065	11,000 (2,640)	1.1	0.25
3067	6,500 (1,560)	0.23	0.22
3068	18,600 (4,460)	0.7-2.8	0.6

The higher than average suspended solids content of the effluents from 3065 and 3068 is caused by a froth carrying mica through the thickerners to the discharges. Therefore, the waste treatment systems in these two facilities are not performing in an exemplary fashion. Facility 3026 is exemplary in regard to the levels of discharge of both suspended solids and fluoride. The fluoride content of the discharge is almost one-half of the raw waste load, whereas the other facilities discharge nearly all the fluoride raw waste. This facility uses alum to coagulate suspended solids, which may be the cause of the reduction in fluoride. Alum has been found in municipal water treatment studies (references 4 and 12) to reduce fluoride by binding into the sediment. The effectiveness of the treatment at 3026 to reduce suspended solids is comparable to that at facilities 3054 and 3067. All three of these facilities have exemplary suspended solids discharge levels for this subcategory.

The treatment at facility 3054 results in little or no reduction of fluoride, but good reduction of suspended solids. Nothing known about this treatment system would lead to an expectation of fluoride reduction.

The treatment at facility 3067 apparently accomplishes no reduction of fluoride, but its suspended solids discharge is significantly lower than average in both amount and concentration.

Based on these conclusions, facility 3026 is exemplary in regard to both suspended solids and fluoride discharges. In addition, facilities 3054 and 3067 exhibit exemplary reduction of suspended solids only.

Solid wastes are transported back to the mines as reclaiming fill, although these wastes are sometimes allowed to accumulate at the facility for long periods before removal.

FELDSPAR - NON-FLOTATION

This subcategory of feldspar mining and processing is characterized by completely dry operations at both the mine and the facility. Only two such facilities were found to exist in the U.S. and both were visited. Together they represent approximately 8.5 percent of total U.S. feldspar production. However, there are two important elements of difference between these two operations as follows:

All of facility 3032 production of feldspar is sold for use as an abrasive in scouring powder. At facility 3064, the high quality orthoclase (potassium aluminum silicate) is primarily sold to manufacturers of electrical porcelains and ceramics.

Process Description

Underground mining is accomplished at Facility 3032 on an intermittent, as-needed, basis using drilling and blasting techniques. A very small amount of water is used for dust control during drilling. At Facility 3064, the techniques are similar, except mining is in an open pit and is carried on for 2-3 shifts/day and 5-6 days/week depending on product demand. Hand picking is accomplished prior to truck transport of ore to the facility.

At the two facilities ore processing operations are virtually identical. They consist of crushing, ball milling, air classification, and storage prior to shipping. Product grading is a function of air classification operation. A schematic flow sheet is shown in Figure 15.

Raw Waste Loads

At Facility 3032, there are no mine wastes generated, and only a small quantity of high-silica solids emanate from the facility. The quantity of waste is unknown, and the material is used as land fill. At Facility 3064, rejects from hand picking are used as mine fill. There is very little waste at the facility.

Water Use

At the Facility 3032 mine, water is used to suppress dust while drilling. It is spilled on the ground and is readily absorbed; volume is only about 230 l/day (about 60 gpd). No water is used in facility processing at the mine. At Facility 3064, no water is used at the mine. Facility water is used at a daily rate of <1,900 l/day (500 gpd) to suppress dust in the crushers. No pre-treatment is applied to water used at either facility.

Waste water Treatment

Any waste water is spilled on the ground (Facility 3032) or is evaporated off during crushing and milling operations (Facility 3064). There is no waste water treatment at either facility.

Effluents and Disposal

There are no effluents from either mine or facility locations.

FIGURE 15.
FELDSPAR MINING AND PROCESSING
(DRY)

KYANITE

Kyanite is produced in the U.S. from 3 open pit mines, two in Virginia and one in Georgia. In this study two of these three mines were visited, one in Virginia, and one in Georgia, representing approximately 75 percent of the U.S. production of kyanite.

Process Description

Kyanite is mined in dry open quarries, using blasting to free the ore. Power shovels are used to load the ore onto trucks which then haul the ore to the processing facility. Processing consists of crushing and milling, classification and desliming, flotation to remove impurities, drying, and magnetic separation. Part of the kyanite is converted to mullite via high temperature firing at 1540°-1650°C (2800-3000°F) in a rotary kiln. A general process diagram is given in Figure 16.

Raw Waste Load

Wastes are generated in the processing of the kyanite, in classification, flotation and magnetic separation operations. These wastes consist of pyrite tailings, quartz tailings, flotation reagents, muds, sand and iron scalpings. These wastes are greater than 50 percent of the total mined material.

waste material	kg/kkg of kyanite (lb/1000 lb)
facility 3015 tailings	2,500
facility 3028 tailings	5,700

Water Use

Water is used in kyanite processing in flotation, classification, and slurry transport of ore solids. This process water amounts to:

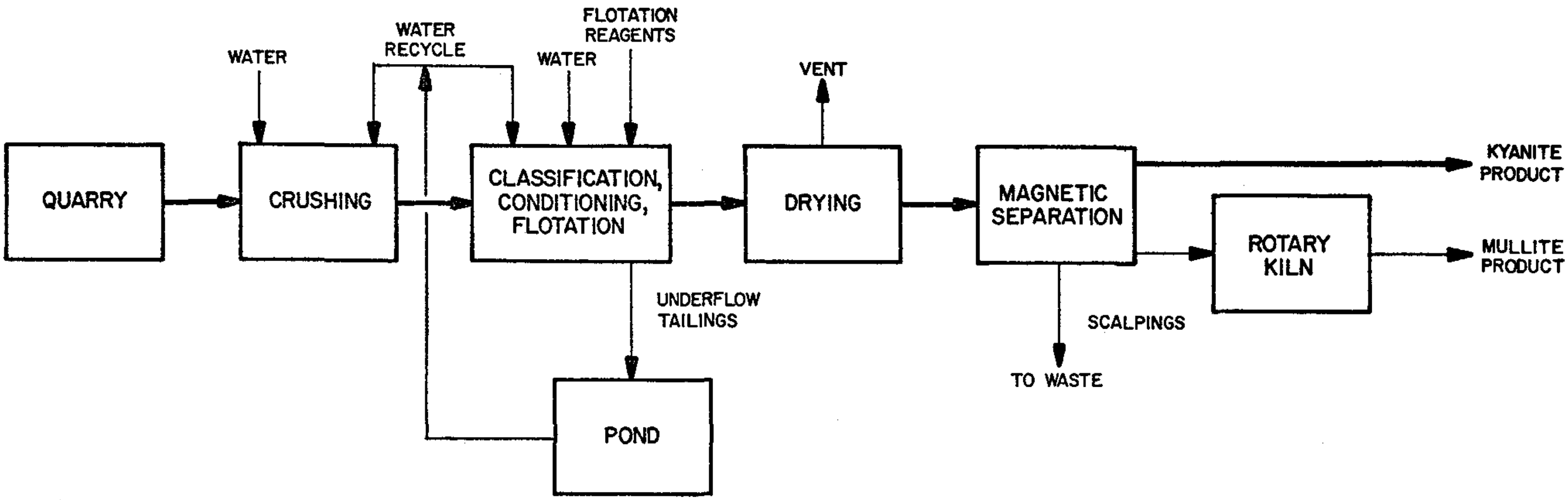


FIGURE 16.
KYANITE MINING AND PROCESSING

	l/kkg of kyanite (gal/ton)
facility 3015	29,200 (7,000)
facility 3028	87,600 (21,000)

The process water is recycled, and any losses due to evaporation and pond seepage are replaced with make-up water. Make-up water for facility 3028 is used at a rate of 4,200,000 l/day (0.288 mgd) and facility 3015 obtains make-up water from run-off draining into the settling pond and also from an artesian well.

Waste Water Treatment

Process water used in the several beneficiation steps is sent to settling ponds from which clear water is recycled to the process. There is total recycle of the process water that is not lost through evaporation and pond seepage.

Effluent and Disposal

There is no deliberate discharge of process water from facility 3015. The only time pond overflow has occurred at facility 3015 was after an unusually heavy rainfall. Facility 3028 has occasional pond overflow, usually occurring in October and November.

The solid waste generated in kyanite processing is land-disposed after removal from settling ponds. An analysis of pond water at facility 3015 showed low values for BOD_5 (2 mg/l) and oil and grease (4 mg/l). Total suspended solids were 11 mg/l and total metals 3.9 mg/l, with iron being the principal metal. No analyses were available on the occasional overflow at facility 3028.

There is only one known U.S. facility that produces magnesia from naturally occurring magnesite ore. This facility, facility 2063, mines and beneficiates magnesite ore from which caustic and dead burned magnesia are produced. The present facility consists of open pit mines, heavy media separation (HMS) and a flotation facility.

Process Description

All mining operations are accomplished by the open pit method. The deposit is chemically variable, due to the interlaid horizons of dolomite and magnesite, and megascopic identification of the ore is difficult. The company has devised a selective quality control system to obtain the various grades of ore required by the processing facilities. The pit is designed with walls inclined at 60°, with 6 m (20 ft) catch benches every 15 m (50 ft) of vertical height. The crude ore is loaded by front end loaders and shovels and then trucked to the primary crusher. The quarry is located favorably so that there is about 2 km (1.25 mi) distance to the primary crusher. About 2260 kkg/day (2500 tons/day) of ore are crushed in the mill for direct firing and beneficiation. There is about 5 percent waste at the initial crushing operation which results from a benefecation step. The remainder of the crusher product is further processed thru crushing, sizing and beneficiating operations.

The flow of material through the facility, for direct firing, follows two major circuits: (1) the dead burned magnesite circuit, and (2) the light burned magnesite circuit. In the dead burned magnesite circuit, the ore is crushed to minus 1.9 cm (3/4 in) in a cone crusher. The raw materials are dry ground in two ball mills that are in closed circuit with an air classifier. The minus 65 mesh product from the classifier is transported by air slides to the blending silos. From the silos the dry material is fed to pug mills where water and binding materials are added. From the pug mills the material is briquetted, dried, and stored in feed tanks ahead of rotary kilns. The oil or natural gas fired kilns convert the magnesite into dense magnesium clinker of various chemical constituents, depending upon the characteristics desired in the product. After leaving the kiln, the clinker is cooled by an air quenched rotary or grate type coolers, crushed to desired sizes, and stored in large storage silos for shipment.

In the light burned magnesite circuit, minus 1.9 cm (3/4 in) magnesite is fed to two Herreshoff furnaces. By controlling the amount of liberated CO_2 from the magnesite a caustic oxide is produced from these furnaces. The magnesium oxide is cooled and ground in a ball mill into a variety of grades and sizes, and is either bagged or shipped in bulk.

Magnesite is beneficiated at facility 2063 by either heavy media separation (HMS) and/or froth flotation methods. In the HMS facility, the feed is crushed to the proper size, screened, washed and drained on a vibratory screen to eliminate the fines as much as possible. The screened feed is fed to the separating cone which contains a suspension of finely ground ferro-silicon and/or magnetite in water, maintained at a predetermined specific gravity. The light fraction floats and is continuously removed by overflowing a weir. The heavy particles sink and are continuously removed by an airlift.

The float weir overflow and sink airlift discharge go to a drainage screen where 90 percent of the medium carried with the float and sink drains through the screen and is returned to the separatory cone. The "float" product passes from the drainage section of the screen to the washing section where the fines are completely removed by water sprays. The solid wastes from the wet screening operations contain -0.95 to +3.8 cm (-3/8 to +1-1/2in) material which is primarily used for the construction of settling pond contour. The fines from the spray screen operations, along with the "sink" from the separating cone, are sent into the product thickener. In the flotation facility, the feed is crushed, milled, and classified and then sent into the cyclone clarifier. Make-up water, along with the process recycled water, is introduced into the cyclone classifier. The oversize from the classifier is ground in a ball mill and recycled back to the cyclone. The cyclone product is distributed to the rougher flotation and the floated product is then routed to cleaner cells which operate in series. The flotation concentrate is then sent into the product thickener. The underflow from this thickener is filtered, dried, calcined, burned, crushed, screened and bagged for shipment.

The tailings from the flotation operation and the filtrate constitute the waste streams of these facilities and are sent into the tailings thickener for water recovery. The overflows from either thickener are recycled back to process. The underflow from the tailings thickener containing about 40 percent solids is impounded in the facility. A simplified flow diagram for this facility is given in Figure 17.

Raw Waste Loads

The raw waste from this facility consists of the underflow from the tailings thickeners and it includes about

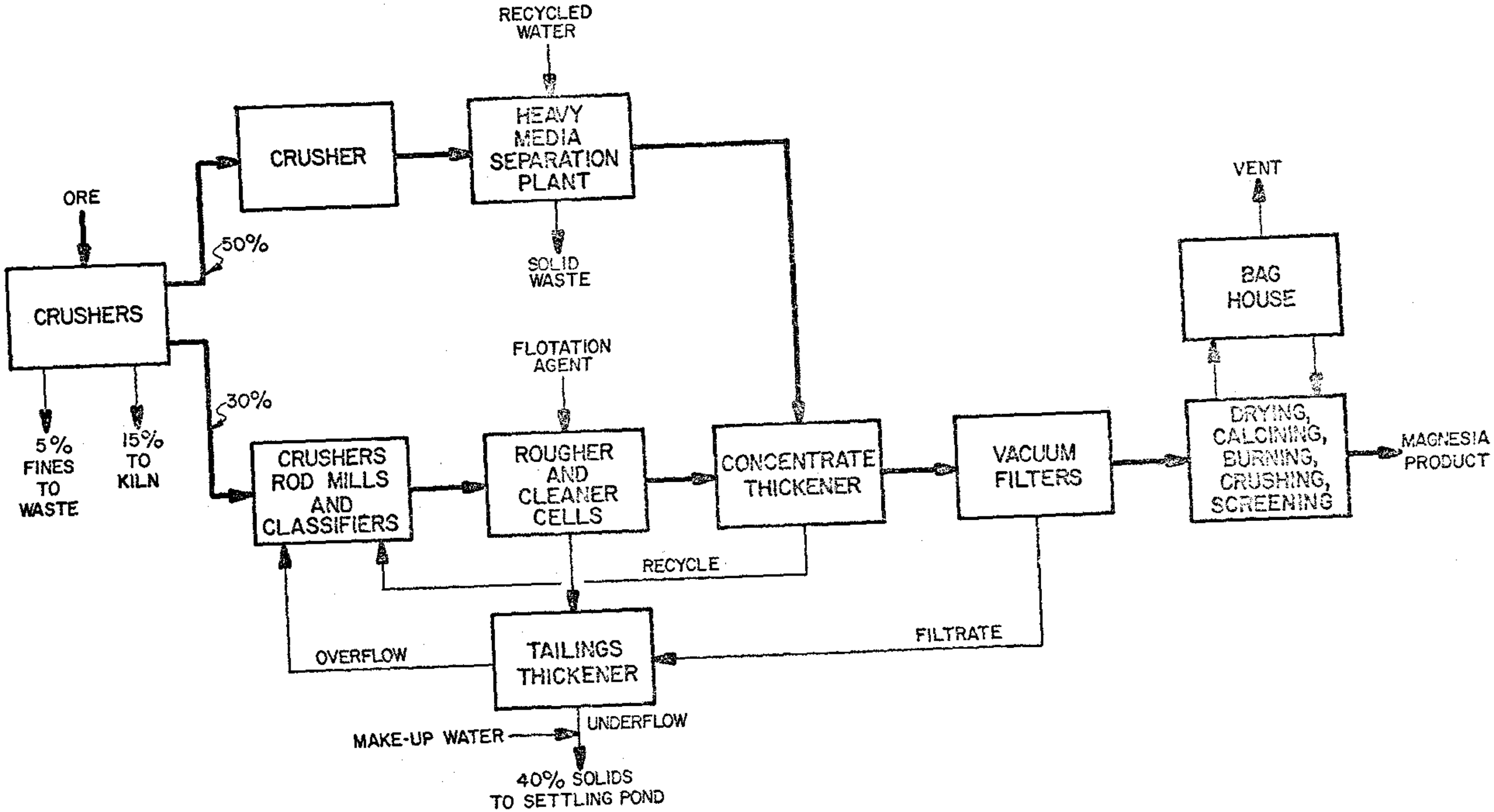


FIGURE 17.
MAGNESITE MINING AND PROCESSING

40 percent suspended solids amounting to 590,000 kg/day (1,300,000 lb/day).

Facility Water Use

This facility's fresh water system is serviced by eight wells. All wells except one are hot water wells, 50 to 70°C (121° to 160°F). The total mill intake water is 2,200,000 l/day (580,000 gal/day), 88 percent of which is cooled prior to usage. The hydraulic load of this facility is given below:

water consumption	l/day (gal/day)
process water to refine the product	163,000 (43,000)
road dust control	227,000 (60,000)
sanitary	11,360 (3,000)
tailing pond evaporation	492,000 (130,000)
tailing pond percolation	757,000 (200,000)
evaporation in water sprays, Baker coolers & cooling towers	545,000 (144,000)

No process waste waters are discharged out of the property at this facility. There is no mine water pumpout at this facility.

Waste Water Treatment

The waste stream at this facility is the underflow of the tailings thickener which contains large quantities of solid wastes. To aid the flow, make-up water is added to this waste stream and then discharged into the tailings pond. The estimated area of this pond is 15 hectares (37 acres). The estimated evaporation at this area is 21 cm/yr (54 in/yr) and the annual rainfall is 2.4 cm/yr (6 in/yr). The waste water is, therefore, lost about 40 percent by evaporation and about 60 percent by percolation. No stream discharge from the mill is visible in any of the small washes in the vicinity of the tailings pond, and also, no green vegetative patches, that would indicate the presence of near surface run-offs, were visible. The tailings pond is located at the upper end of an alluvial fan. This material is both coarse and angular and has a rapid percolation rate. This could account for the lack of run-off and the total recharge of the basin.

Effluent

As all process waters at facility 2063 are either recycled or lost by evaporation and percolation, there is no process water effluent discharge out of this property.

SHALE

Shale is a consolidated sedimentary rock composed chiefly of clay minerals, occurring in varying degrees of hardness. Shales and common clays are for the most part used by the producer in fabricating or manufacturing structural clay products (SIC 3200) so only shale mining and processing is discussed here. Less than 10 percent of total clay and shale output is sold outright. Therefore, for practical purposes, nearly all such mining is captive to ceramic or refractory manufactures. Shale is mined in open pits using rippers, scrapers, bulldozers, and front-end loaders for removal of the shale from the pit. Blasting is needed to loosen very hard shale deposits. The shale is then loaded on trucks or rail cars for transport to the facility. There, primary crushing, grinding, screening, and other operations are used in the manufacture of many different structural clay products. A general process diagram is given in Figure 18. Solid waste is generated in shale mining as overburden which is used as fill to reclaim mined-out pits. Since ceramic processing is not covered, no processing waste is accounted for.

Water Use

There is no water used in shale mining, however, due to rainfall and ground water seepage, there can be water which accumulates in the mines and must be removed. Mine pumpout is intermittent depending on rainfall frequency and geographic location. In many cases, facilities will build small earthen dams or ditches around the pit to prevent inflow of rainwater. Also shale is, in most cases, so hard that run off water will not pickup significant suspended solids. Flow rates are not generally available for mine pumpout.

Waste Water Treatment

There is no waste water treatment necessary for shale mining and processing since there is no process water used. When there is rainfall or ground water accumulation, this water is generally pumped out and discharged to abandoned pits or streams.

Effluent and Disposal

Mine pumpout is discharged without treatment. There is no other effluent.

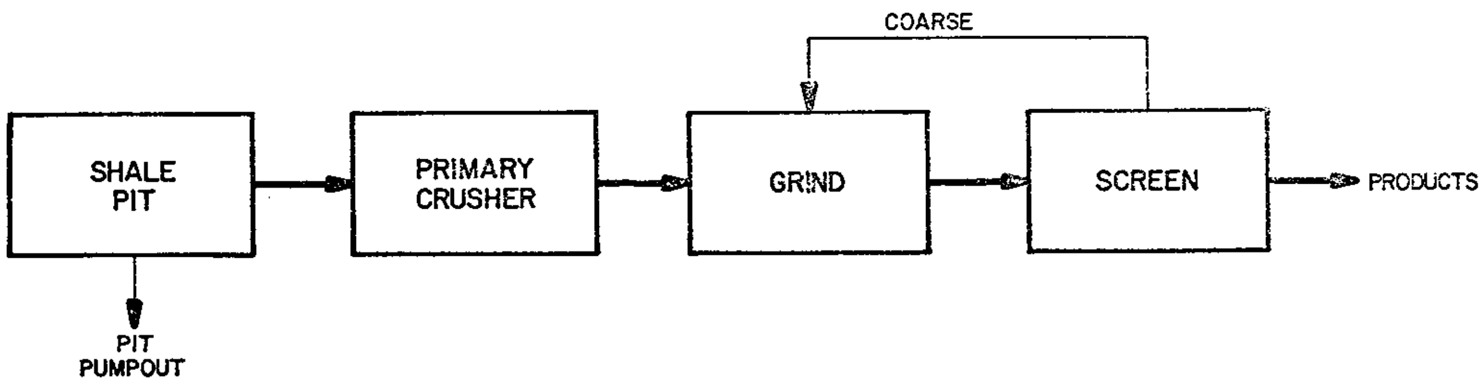


FIGURE 18.
SHALE MINING AND PROCESSING

APLITE

Aplite is found in quantity in the U.S. only in Virginia and is mined and processed by only two facilities, both of which are discussed below.

Process Description

The deposit mined by facility 3016 is relatively soft and the ore can be removed with bulldozers, scrapers, and graders, while that mined by facility 3020 requires blasting to loosen from the quarry. The ore is then loaded on trucks and hauled to the processing facility.

Facility 3016 employs a wet process consisting of wet crushing and grinding, screening, removal of mica and heavy minerals via a series of wet classifiers, dewatering and drying, magnetic separation and final storage prior to shipping.

Facility 3020 processing is dry, consisting of crushing and drying, more crushing, screening, magnetic separation and storage for shipping. However, water is used for wet scrubbing to control air pollution. A process flow diagram is given in Figure 19 depicting both processes.

Raw Waste Load

Mining waste is overburden and mine pumpout. The processing wastes are dusts and fines from air classification, iron bearing sands from magnetic separation, and tailings and heavy minerals from wet classification operations. The latter wastes obviously do not occur at the dry facility.

	Water-borne Waste Materials	kkg/year (ton/yr)	kg/kkg product (lb/1000 lb)
facility 3016 (wet)	tailings and heavy minerals and fines	136,000 (150,000)	1,000
facility 3020 (dry)	dust and fines	9,600 (10,600)	175

Other, non-waterborne wastes come from the magnetic separation step at facility 3020.

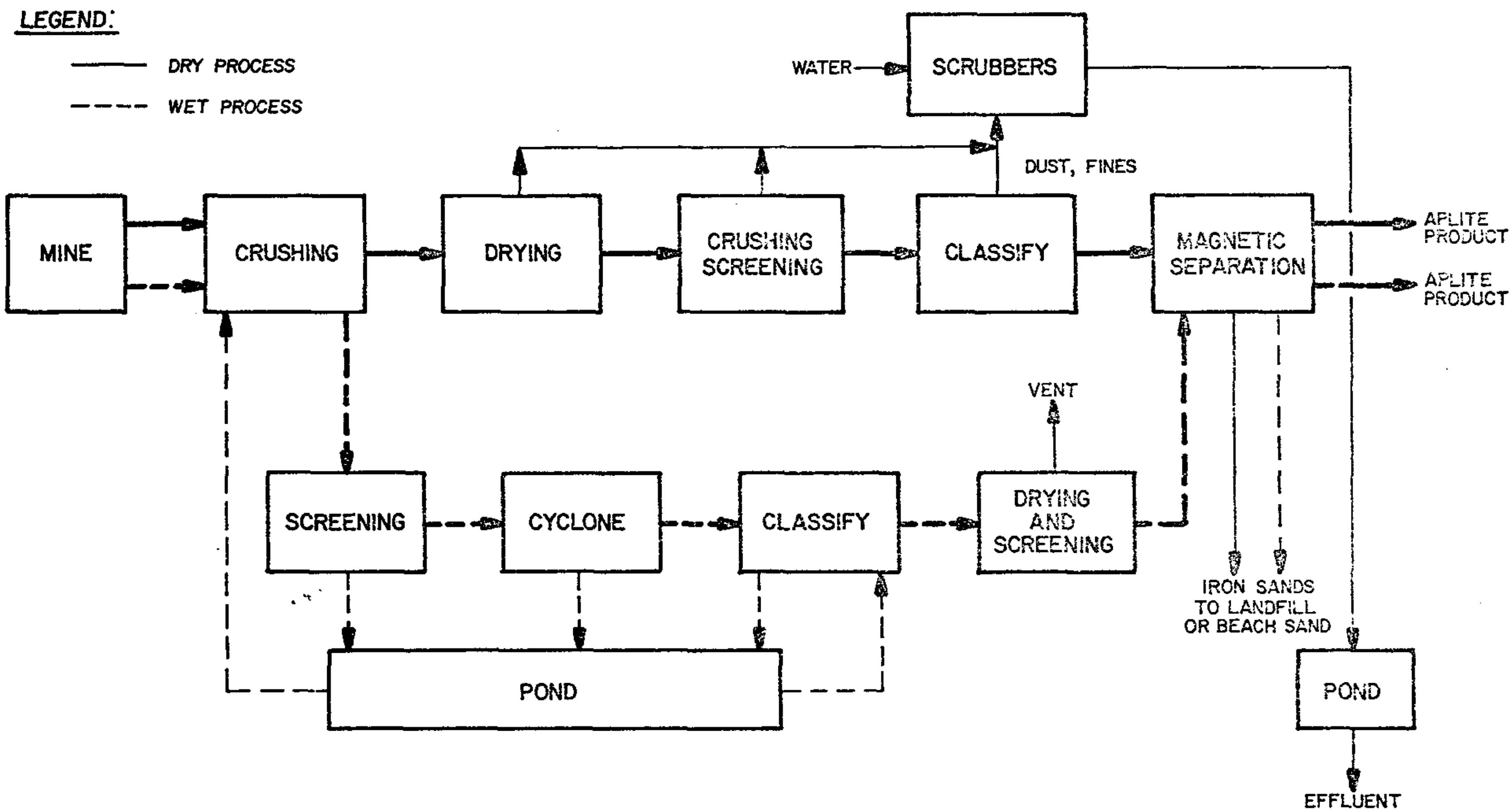


FIGURE 19.
APLITE MINING AND PROCESSING

Water Use

Water is used at facility 3020 (dry process) only for wet scrubbers which cut down on airborne dust and fines. This water totals 1,230,000 l/day (324,000 gpd) with no recycle. There is occasional mine pumpout.

Water is used at facility 3016 for crushing, screening and classifying at a rate of 38,000,000 l/day (10,000,000 gpd) which is essentially 100% recycled. Dust control requires about 1,890,000 l/day (500,000 gpd) of water which is also recycled. Any make-up water needed due to evaporation losses comes from the river. The amount was not disclosed. There is no mine pumpout at facility 3016 and any surface water which accumulates drains to a nearby river.

The facility water use in this industry can be summarized:

	l/kkg product (gal/ton)	
process use:	3016	3020
scrubber or dust control	3,600 (870)	5,900 (1,420)
crush, screen, classify	12,700 (3,040)	0
net discharge (less mine pumpout)	approx. 0	5,900 (1,420)
mine pumpout	0	not given
make-up water intake	not given	5,900 (1,420)

Waste Water Treatment

The waste water generated in these aplite operations is sent to tailings ponds where solids are allowed to settle. The scrubber water from facility 3020 is discharged after settling while the occasional mine pumpout is discharged without settling. The water from the wet process facility 3016 is essentially 100% recycled to the process. Every few years, when the pond level becomes excessive, facility 3016 discharges from the pond to a river. When this occurs, the pond is treated with alum to lower suspended solids levels in the discharge. Likewise, when suspended solids levels are excessive for recycle purposes, the pond is also treated with alum. There is no other water loss from facility 3016 except for evaporation and pond seepage.

Effluent and Disposal

Facility 3020 discharges effluent arising from wet scrubber operations to a creek after allowing settling of suspended solids in a series of ponds. Aplite clays represent a settling problem in that a portion of the clays settles out rapidly but another portion stays in suspension for a long time, imparting a milky appearance to the effluent. The occasional mine pumpout due to rainfall is discharged without treatment.

Facility 3016 recycles water from the settling ponds to the process with only infrequent discharge to a nearby river when pond levels become excessive (every 2 to 3 years). This discharge is state regulated only on suspended solids at 649 mg/l average, and 1000 mg/l for any one day. Actual settling pond water analyses have not been made.

The solid wastes generated in these processes are land-disposed, either in ponds or as land-fill, with iron bearing sands being sold as beach sand.

There are 33 known facilities in the U.S. producing talc, steatite, soapstone and pyrophyllite. Twenty-seven of these facilities use dry grinding operations, producing ground products, two utilize log washing and wet screening operations producing either crude talc or ground talc and four are wet crude ore beneficiation facilities, three using froth flotation and one heavy media separation techniques.

Process Description of Dry Grinding Operations

In a dry grinding mill, the ore is batched in ore bins and held until a representative ore sample is analyzed by the laboratory. Each batch is then assigned to a separate ore silo, and subsequently dried and crushed in a crushing circuit. The ore, containing less than 12% moisture is reclaimed from these storage silos and sent to fine dry grinding circuits in the mill. In the pebble mill (Hardinge circuit), which includes mechanical air separators in closed circuit, the ore is ground to minus 200 mesh rock powder. Part of the grades produced by this circuit are used principally by the ceramic industry; the remainder is used as feed to other grinding or classifying circuits. In a few facilities, some of this powder is introduced into the fluid energy mill to manufacture a series of minus 325 mesh products for the paint industry.

Following grinding operations, the finished grades are pumped, in dry state, to product bulk storage silos. The product is reclaimed from these silos, as needed, and either pumped to bulk hopper cars or to the bagging facility where it is packed in bags for shipment. A generalized process diagram for a dry grinding mill is given in Figure 20.

There is no water used in dry grinding facilities; therefore, there is no generation of water-borne pollutants by these facilities. Bag housed collectors are used throughout this industry for dust control. The fluid energy mills use steam. The steam generated in boilers is used in process and vented to atmosphere after being passed through a baghouse dust collector to remove dust product from the steam. The waste streams emanating from the boiler operations originate from conventional hot or cold lime softening process and/or zeolite softening operations, filter backwash, and boiler blowdown wastes which are addressed under general water guidelines in Section IX of this report.

Even though these facilities do not use water in their process, some of them do have mine water discharge from their underground mine workings.

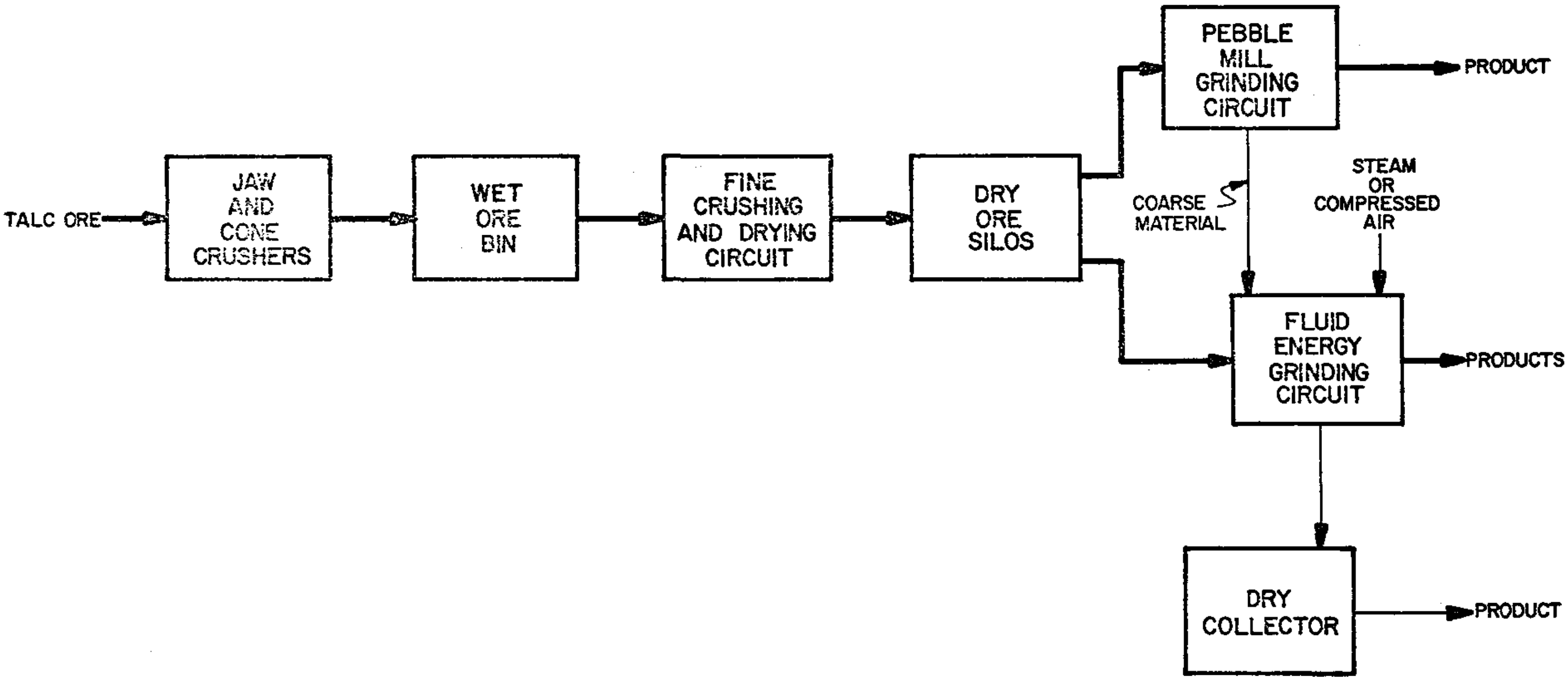


FIGURE 20.

TALC, STEATITE, SOAPSTONE AND PYROPHYLLITE MINING AND PROCESSING (DRY)

Process Description of Log Washing and Wet Screening

At log washing facility 2034 and wet screening facility 2035, the water is used to wash fines from the crushed ore. In either facility, the washed product is next screened, sorted and classified. The product from the classifier is either shipped as is or it is further processed in a dry grinding mill to various grades of finished product.

At facility 2034 wash water is sent into a hydroclone system for product recovery. The slimes from the hydroclone are then discharged into a settling pond for evaporation and drying. At facility 2035, the wash water, which carries the fines, is sent directly into a settling pond.

The wet facilities in this subcategory are operational on a six-month per year basis. During freezing weather, these facilities are shut down. Stockpiles of the wet facility products are accumulated in summer and used as source of feed in the dry grinding facility in winter. Simplified diagrams for facilities 2034 and 2035 are given in Figures 21 and 22 respectively.

Raw Waste Loads

The raw waste from facility 2034 consists of the slimes from the hydroclone operation, that of facility 2035 is the tailings emanating from the wet screening operation and the slimes from the classifiers. Neither company keeps records on the quantity of the wastes, since no water is discharged.

Facility Water Use

Both facilities are supplied by water wells on their property. Essentially all water used is process water. Facility 2034 has a water intake of 182,000 l/day (48,000 gal/day) and facility 2035 has a water intake of 363,000 l/day (96,000 gal/day).

Waste Water Treatment

The waste streams emanating from the washing operations are sent into settling ponds. The ponds are dried by evaporation and seepage. In facility 2035, when the ponds are filled with solids, they are harvested for reprocessing into saleable products.

Effluent

There is no discharge out of these properties.

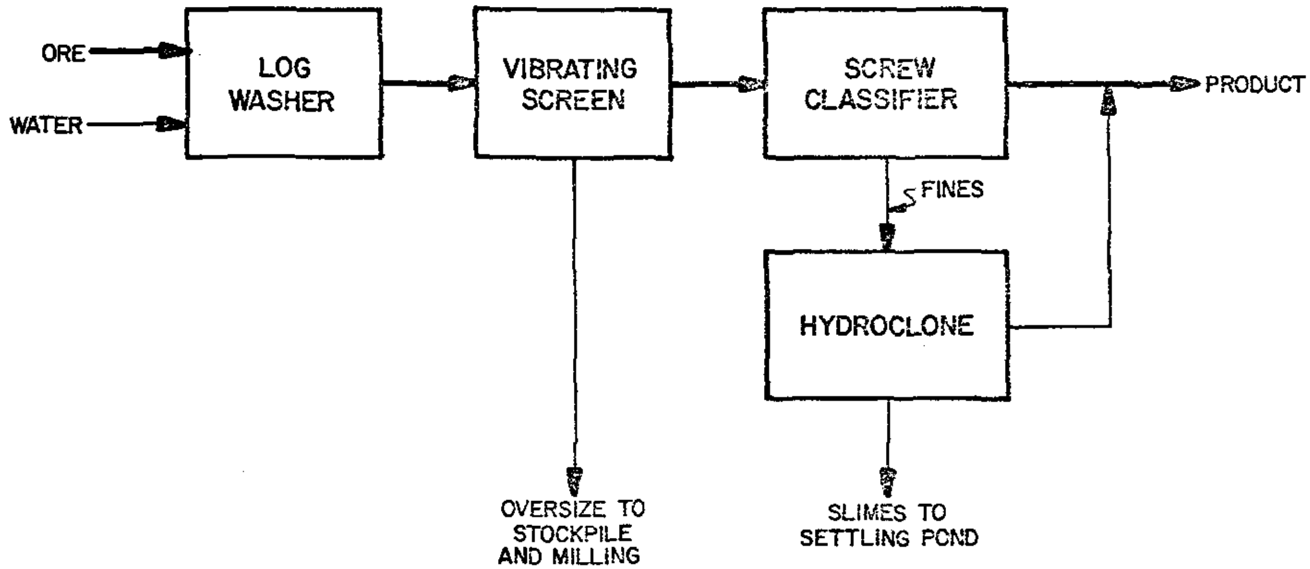


FIGURE 21.
TALC, STEATITE, SOAPSTONE AND PYROPHYLLITE MINING AND PROCESSING
(LOG WASHING PROCESS)

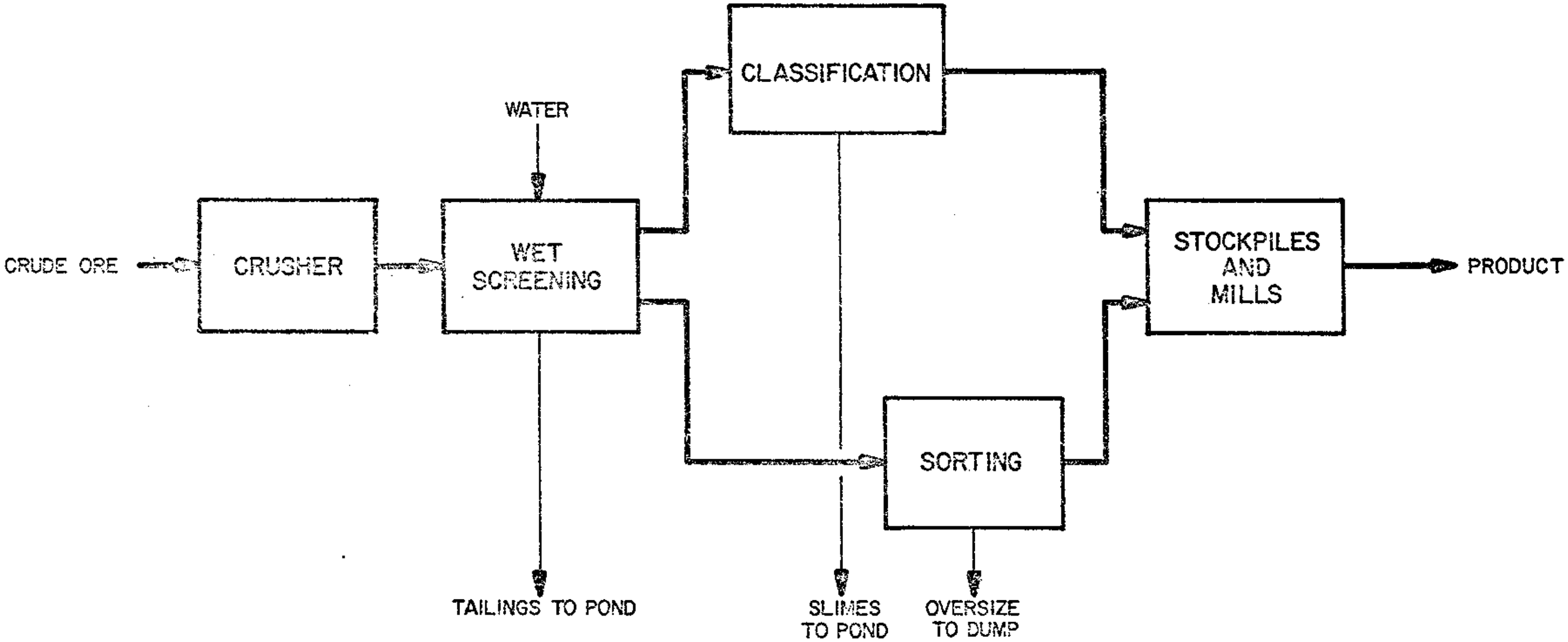


FIGURE 22.
TALC, STEATITE, SOAPSTONE AND PYROPHYLLITE MINING AND PROCESSING
(WET SCREENING PROCESS)

Mine Water Discharge

Underground mine workings intercept numerous ground water sources. The water from each underground mine is directed through ditches and culverts to sumps at each mine level. The sumps serve as sedimentation vessels and suctions for centrifugal pumps which discharge this water to upper level sumps or to the surface. In some mines, a small portion of the pump discharge is diverted for use as drill wash water and pump seal water; the remainder is discharged into a receiving waterway. The disposition and quantities of mine discharges are given as follows:

Mine#	pH	Solids mg/l	Liquid l/day (gal/day)	Disposition
2037	8.3	4, 9	1,020,000 (270,000)	Pumped to a swamp
2038	7.8	3	878,000 (232,000)	Pumped to a swamp
2039	8.1	4	1,900,000 (507,000)	Open ditch
2040	7.2-8.5	15	1,100,000 (300,000)	Settling basin than to a brook
2041	8.7	28	49,200 (13,000)	Settling basin then to a brook
2042	7.8	9	496,000 (131,000)	Settling basin then to a brook
2043	7.6	5	76,000 (20,000)	Settling basin then to a river

Mine Water Treatment

In mines 2040, 2041, 2042 and 2043, the water from each mine is directed through ditches and culverts to sumps at each mine level. The sumps serve as sedimentation vessels and suctions for centrifugal pumps which discharge this water to upper level settling basins. The overflows from these basins are discharged into a receiving stream. The remaining mines employ no surface settling basins. The water from the underground sump is directly discharged into a receiving ditch, waterway or mine without further settling.

Effluent Composition

No information was available on mines 2037 and 2038. The significant constituents, however, in the remaining mine effluents are reported to be as follows:

Waste Material Mine Number	2036	2039	2040-2043
TSS, mg/l	9	3	<20
Iron, mg/l	0.08	0.05	---
pH min-max	7.5-7.8	7.0-7.3	7.2-8.5

Process Description of Flotation and Heavy Media Separation Facilities

All four facilities in this subcategory use either flotation or heavy media separation techniques for upgrading the product. In two of the facilities (2031 and 2032) the ore is crushed, screened, classified and milled and then taken by a bucket elevator to a storage bin in the flotation section. From there it is fed to a conditioner along with well and recycled water. The conditioner feeds special processing equipment, which then sends the slurry to a pulp distributor. In facility 2031, the distributor splits the conditioner discharge over three concentrating tables from which the concentrates, the gangue material, are sent to the tailings pond. The talc middlings from the tables are then pumped to the flotation machines. However, in facility 2032, the distributor discharges directly into rougher flotation machines. A reagent is added directly into the cells and the floated product next goes to cleaning cells. The final float concentrate feeds a rake thickener which raises the solids content of the flotation product from 10 to 35 percent. The product from thickener is next filtered on a rotary vacuum filter and water from the filter flows back into the thickener. The filter cake is then dried and the finished product is sent into storage bins. The flotation tailings, along with thickener overflow, are sent to the tailings pond. A simplified flow diagram is given in Figure 23.

Facility 2033 processes ores which contain mostly clay and it employs somewhat different processing steps. In this facility, the ore is scrubbed with the addition of liquid caustic to raise the pH, so as to suspend the red clay. The scrubbed ore is next milled and sent through thickening, flotation and tabling. The product from the concentrating tables is acid treated to dissolve iron oxides and other possible impurities. Acid treated material is next passed through the product thickener, the underflow from which contains the finished product. The thickener underflow is

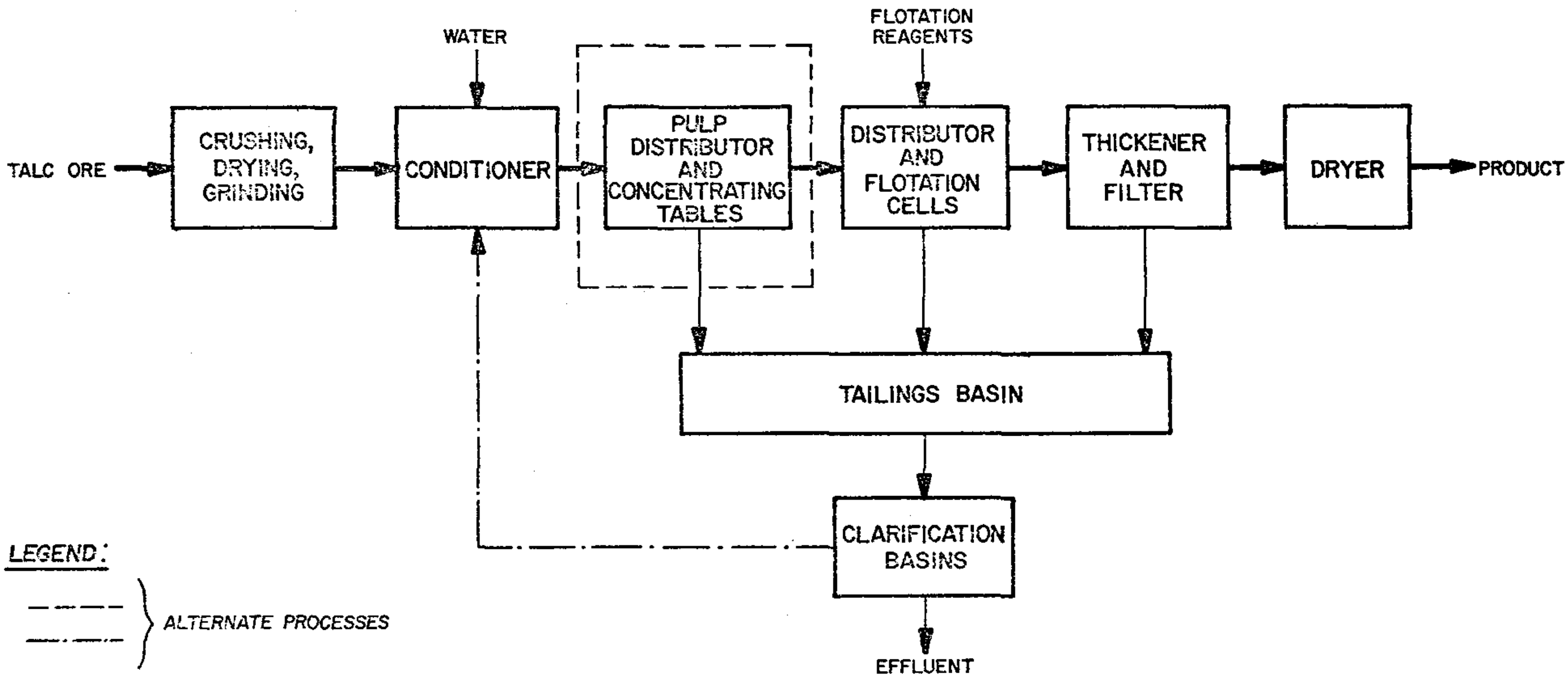


FIGURE 23.
TALC MINING AND PROCESSING
(FLOTATION PROCESS)

filtered, dried, ground and bagged. The waste streams consist of the flotation tailings, the overflow from the primary thickener and the filtrate. A generalized flow diagram is given in Figure 24.

Facility 2044 uses heavy media separation (HMS) technique for the beneficiation of a portion of their product. At this facility, the ore is crushed in a jaw crusher and sorted. The minus 2 inch material is dried before further crushing and screening operations whereas the plus 5.1 cm (2 in) fraction is crushed, screened and sized as recovered from the primary crushing stage. The minus 3 to plus 20 mesh material resulting from the final screening operation is sent to HMS facility for the rejection of high silica grains. The minus 20 mesh fraction is next separated into two sizes by air classification.

Facility 2044 uses a wet scrubber on their #1 drier for dust control. On drier #2 (product drier) a baghouse is used and the dust recovered is marketed. A simplified process flow diagram for this facility is given in Figure 25.

Raw Waste Loads

In facilities 2031 and 2032, the raw waste consists of the mill tailings emanating from the flotation step. In facility 2033, in addition to the mill tailings, the waste contains the primary thickener overflow and the filtrate from the product filtering operation. In facility 2044 the raw waste stream is the composite of the HMS tailings and the process waste stream from the scrubber. The average values given are listed as follows:

Waste Material	kg/kkg of flotation product (lb/1000 lb)			
at Facility No.	2031	2032	2033	2044
TSS	1800	1200-1750	800	26

Facility Water Use

The flotation mill at facility 2031 consumes water, on the average, 25,400 l/kkg (6,070 gal/ton) of product. This includes 200 l/kkg product of non-contact cooling water (48 gal/ton) which is used in cooling the bearings of their crushers.

Facility 2032 consumes 17,200 l/kkg (4150 gal/ton) product; 40 percent of which may be recycled back to process, after clarification. Recycled water is used in conditioners and as coolant in compressor circuits and for several other miscellaneous needs.

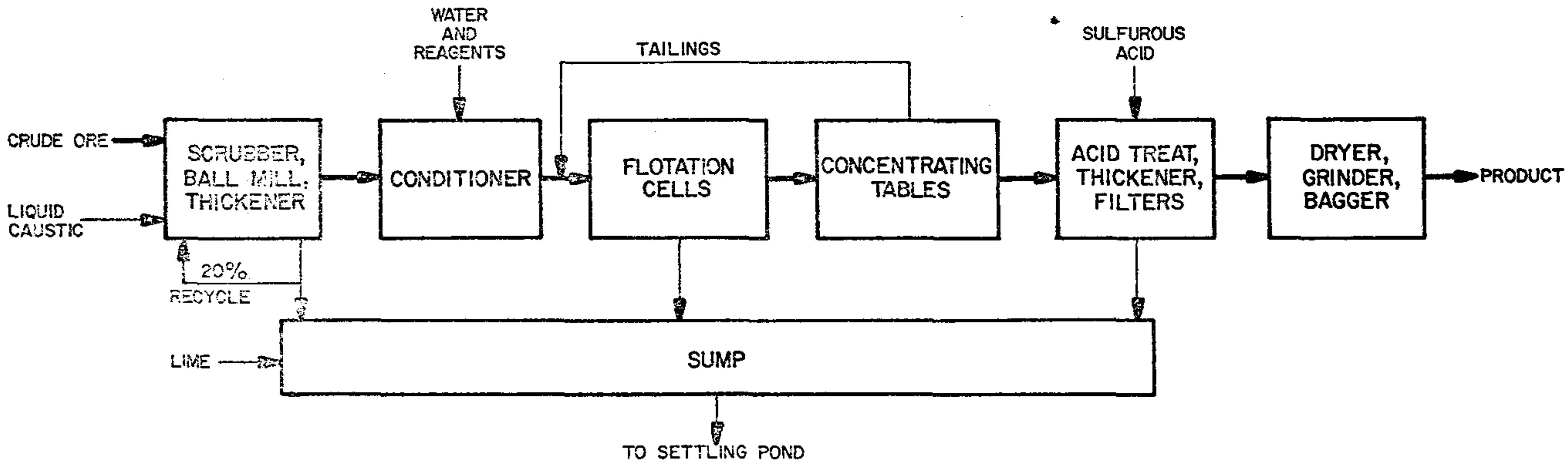


FIGURE 24.
TALC MINING AND PROCESSING (IMPURE ORE)

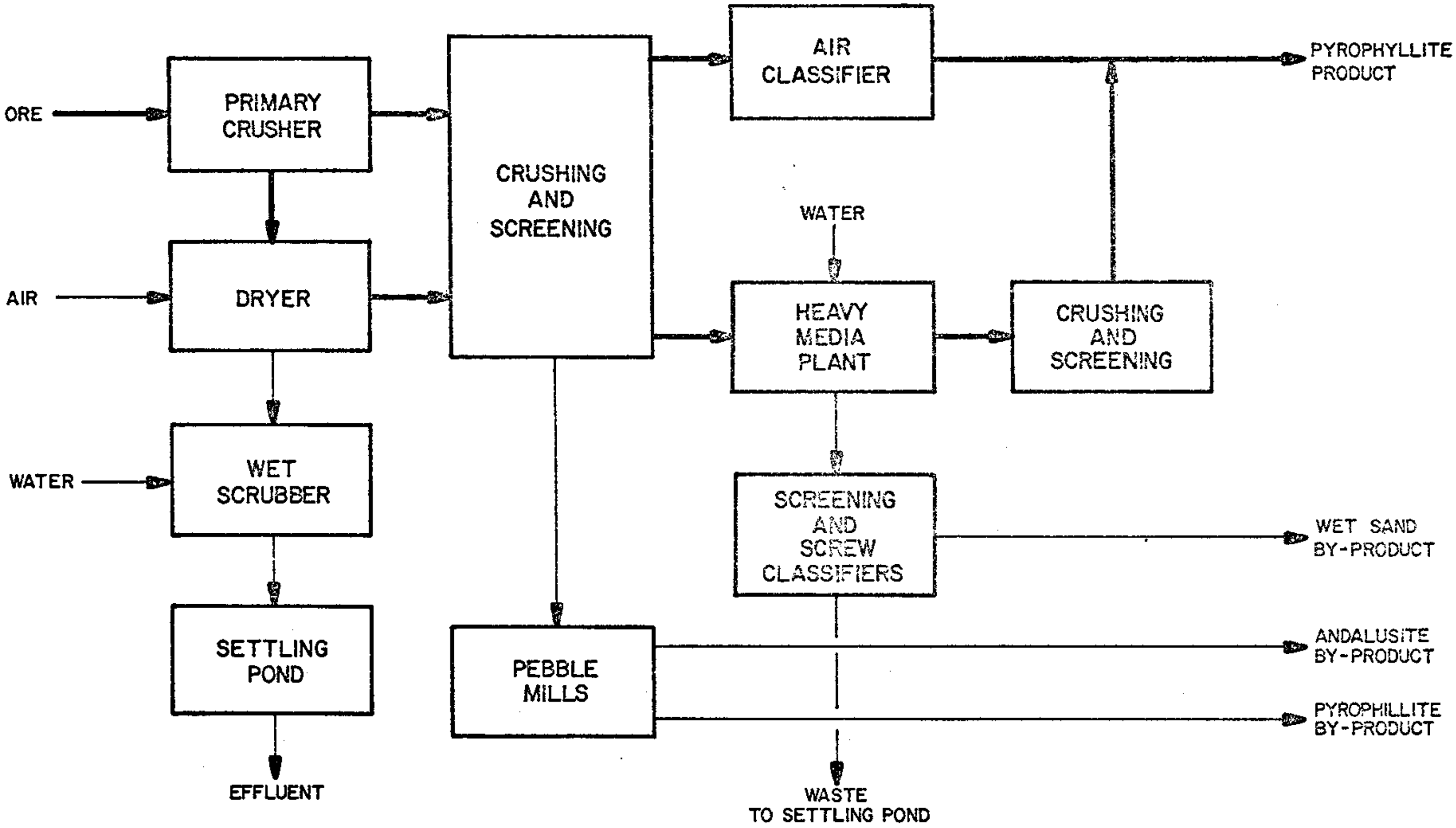


FIGURE 25.
PYROPHYLLITE MINING AND PROCESSING
(HEAVY MEDIA SEPARATION)

Facility 2033 consumes 16,800 l/kkg (4000 gal/ton) product; 20 percent of which is recycled back to process from the primary thickener operation. Facility 2044 consumes on the average l/kkg (1,305 gal/ton) total product. The hydraulic load of these facilities is summarized as follows:

Consumption at Facility No.	l/day (gal/day) 2031	2032	2033	2034
Process consumed	730,000 (192,000)	2,200,000 (583,000)	757,000 (200,000)	1,135,000 (300,000)
Non-contact cooling	37,000 (9,600)	---	54,000 (14,000)	---

Facility Waste Treatment

At facility 2031, the mill tailings are pumped into one of the three available settling ponds. The overflow from these settling ponds enters by gravity into a common clarification pond. There is no point discharge from this clarification pond. The tailings remain in the settling ponds and are dried by natural evaporation and seepage.

At facility 2032, the mill tailings are pumped uphill through 3000 feet of pipe to a pond of 34,000,000 l (9,000,000 gal) in capacity for gravity settling. The overflow from this pond is treated in a series of four settling lagoons. Approximately 40 percent of the last lagoon overflow may be sent back to the mill and the remainder is discharged to a brook near the property.

In facility 2033, the filtrate, with a pH of 3.5-4.0, the flotation tailings with a pH of 10-10.5 and the primary thickener overflow are combined, and the resulting stream, having a pH of 4.5-5.5, is sent to a small sump in the facility for treating. The effluent pH is adjusted by lime addition to a 6.5-7.5 level prior to discharge into the settling pond. The lime is added by metered pumping and the pH is controlled manually. The effluent from the treating sump is routed to one end of a "U" shaped primary settling pond and is discharged into a secondary or back-up pond. The total active pond area is about 0.8 hectare (2 acres). The clarification pond occupies about 0.3 hectare (0.75 acres). The back-up pond (clarification pond) discharges to an open ditch running into a nearby creek. The non-contact cooling water in facilities 2031 and 2033 is discharged without treatment. Facility 2044 uses a 1.6 hectare (4 acres) settling pond to treat the waste water; the overflow from this pond is discharged into the river. It has been estimated that the present settling pond will be filled within two years' time. This company has leased a new piece of property for the creation of a future pond.

Effluent Composition

As all process water at facility 2031 is impounded and lost by evaporation, there is no process water effluent out of this property. Facility 2035 a washing facility also has no discharge.

At facilities 2032, 2033, and 2044, the effluent consists of the overflow from their clarification or settling pond. The significant constituents in these streams are reported to be as follows:

Waste Material Facility Number	2032	2033	2044
pH	7.2-8.5	5.6	7.0
TSS, mg/l	<20(26)*	80 (8)**	100

*Contractor verification
**More recent data by contractor

The average amounts of TSS discharged in these effluents were calculated from the above data to be:

facility	kg/kkg product	(lb/1000 lb)
2032	<0.34	
2033	0.29	
2044	0.50	

Exemplary performance of waste water treatment was attained by facilities 2032 and 2044. Also facility 2031 is a special case in that it has no discharge by virtue of evaporation and seepage of all waste water.

NATURAL ABRASIVES

Garnet and tripoli are the major natural abrasives mined in the U.S. Other minor products, e.g. emery and special silica-stone products, are of such low volume production (2,500-3,000 kkg/yr) as to be economically insignificant and pose no significant environmental problems. They will not be considered further.

GARNET

Garnet is mined in the U.S. almost solely for use as an abrasive material. Two garnet abrasive producers, representing more than 80 percent of the total U.S. production, provided the data for this section. There are 4 facilities in the U, S. producing garnet, one of which produces it only as a by-product.

Process Description

The two garnet operations studied are in widely differing geographic locations, and so the garnet deposits differ, one being a mountain schists (3071), and the other an alluvial deposit (3037).

Facility 3071 mines by open pit methods with standard drilling and blasting equipment. The ore is trucked to a primary crushing facility and from there conveyed to the mill where additional crushing and screening occurs. The screening produces the coarse feed to the heavy-media section and a fine feed for flotation.

The heavy-media section produces a coarse tailing which is dewatered and stocked, a garnet concentrate, and a middling which is reground and sent to flotation. The garnet concentrate is then dewatered, filtered, and dried.

Facility 3037 mines shallow open pits, stripping off overburden, then using a dragline to feed the garnet-bearing earth to a trumble (heavy rotary screen). Large stones are recovered and used for road building or to refill the pits. The smaller stones are trucked to a jigging operation, also in the field, where the heavier garnet is separated from all impurities except some of the high density kyanite. The raw garnet is then trucked to the mill. There the raw garnet is dried, screened, milled, screened and packaged. Figure 26 gives the general flow diagram for these operations.

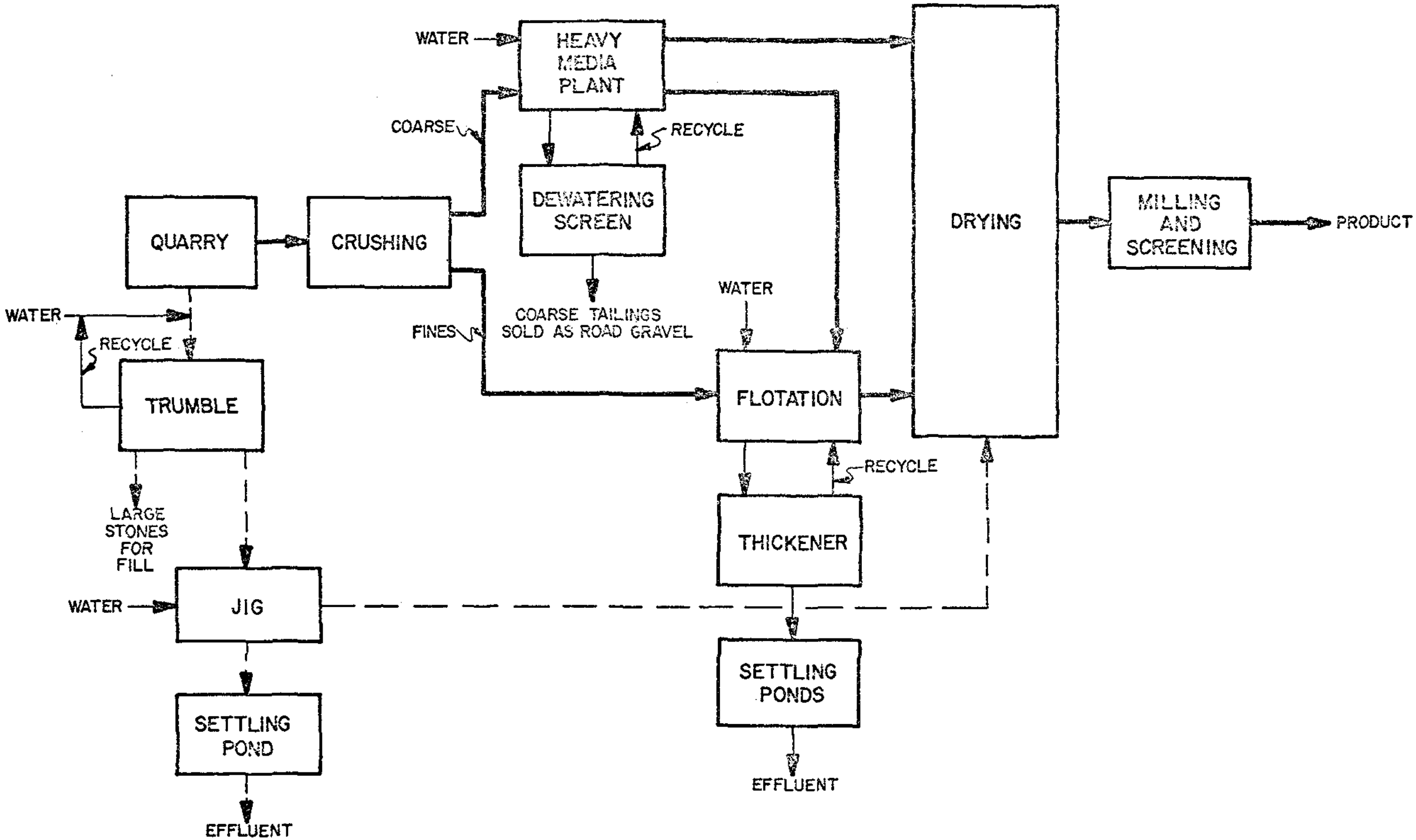


FIGURE 26.
GARNET MINING AND PROCESSING

Raw Waste Load

Solid waste is generated in garnet mining as overburden which is used for reclaiming worked-out pits. Large stones recovered from in-the-field screening operations at facility 3037 are also used to refill pits or for road building.

In the processing of the garnet ore, solid waste in the form of coarse tailings is generated from the heavy-media facility at facility 3071. These tailings are stocked and sold as road gravel. The flotation underflow at facility 3071 consisting of waste fines, flotation reagents and water is first treated to stabilize the pH and then is sent to a series of tailings ponds. In these ponds, the solids settle and are removed intermittently by a dragline and used as landfill.

The categories of raw wastes generated at these facilities are therefore:

	3037	3071
large stones and coarse tailings	yes	yes
flotation fines and reagents	no	yes
fine tailings	yes	no

Water Use

Untreated surface water is pumped to the pits at facility 3037 for initial washing and screening operations and for make-up. This pit water is recycled and none is discharged except as ground water. Surface water is also used for the jigging operation, but is discharged after passage through a settling pond. No data is available regarding the quantity of water used in these operations.

At facility 3071, water is collected from natural run-off and mine drainage into surface reservoirs, and it is used in both the heavy media facility and in flotation. This process water amounts to approximately 380-760 l/min (100-200 gpm) and is about 50 percent recycled.

Effluent flow varies seasonally from a springtime maximum of 570 l/min (150 gpm) to a minimum in summer and fall.

The summarized average water flow data given below is based on 50 percent recycle at facility 3071:

	3037	3071
	l/kkg product (gallon/ton)	
washing and screening	amount not known	none
heavy media separation and flotation	none	24,600 (5,900)
jigging	amount not known	none
discharge of wastes	jigging water only	12,300 (3,000)

Waste Water Treatment

Facility 3037 recycles untreated pit water used in screening operations, and sends water from jigging operations to a settling pond before discharging it back into the creek.

Waste water from flotation underflow at facility 3071 is first treated with caustic to stabilize the pH which was acidified from flotation reagents. Then the underflow is sent to a series of tailings ponds. The solids settle out into the ponds and the final effluent is discharged. Water from the dewatering screen is recycled to the heavy media facility.

Effluent and Disposal

Effluent arising from flotation underflow at facility 3071 is discharged. The pH is maintained at 7. The suspended solids content averaged 25 mg/l.

Effluent from jigging operations at facility 3037 is discharged after passage through a settling pond.

TRIPOLI

Tripoli encompasses a group of fine-grained, porous, silica materials which have similar properties and uses. These include tripoli, amorphous silica and rottenstone. All four producers of tripoli provided the data for this section.

Process Description

Amorphous silica (tripoli) is normally mined from underground mines using conventional room-and-pillar techniques. There is at least one open-pit mine (5688). Trucks drive into the mines where they are loaded using front-end loaders. The ore is then transported to the facility for processing. Processing consists of crushing, screening, drying, milling, classifying, storage, and packing for shipping. A general process diagram is given in Figure 27. At one facility only a special grade tripoli (a minor portion of the production, value approximately $250,000/year) is made by a unique process using wet-milling and scrubbing.

Raw Waste Load

Both facilities report no significant waste in processing. Any dust generated in screening, drying, or milling operations is gathered in cyclones and dust collectors and returned to the process as product.

Mining generates a small amount of dirt which is piled outside the mine and gravel which is used to build roads in the mining areas. The product itself is of a very pure grade so no other mining wastes are generated.

Water Use

There is no water used in mining, nor is there any ground water or rain water accumulation in the mines.

The standard process is a completely dry process.

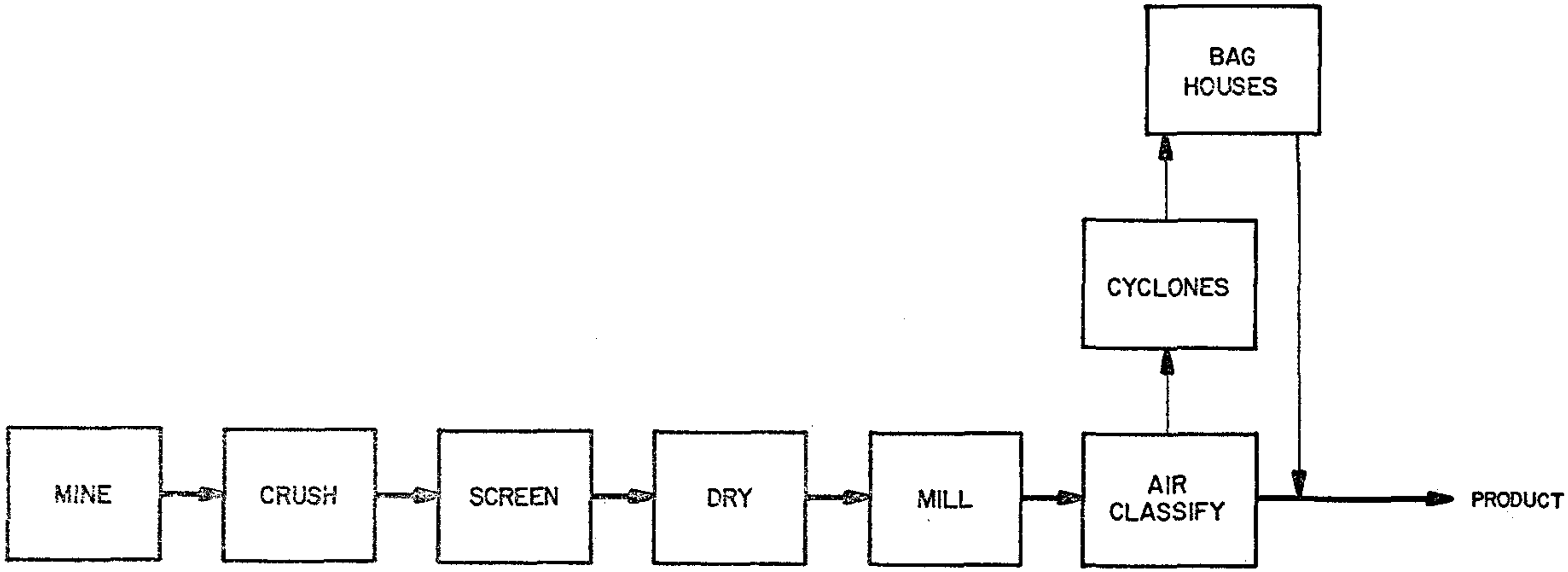


FIGURE 27.
TRIPOLI MINING AND PROCESSING
BY THE STANDARD PROCESS

DIATOMITE MINING

There are nine diatomite mining and processing facilities in the U.S. The data from three are included in this section. These three facilities produce roughly one-half of the U.S. production of this material.

Process Description

After the overburden is removed from the diatomite strata by power-driven shovels, scrapers and bulldozers, the crude diatomite is dug from the ground and loaded onto trucks. Facilities 5504 and 5505 haul the crude diatomite directly to the mills for processing. At facility 5500 the trucks carry the crude diatomite to vertical storage shafts placed in the formation at locations above a tunnel system. These shafts have gates through which the crude diatomite is fed to an electrical rail system for transportation to the primary crushers.

At facility 5500, after primary crushing, blending, and distribution, the material moves to different powder mill units. For "natural" or uncalcined powders, crude diatomite is crushed and then milled and dried simultaneously in a current of heated air. The dried powder is sent through separators to remove waste material and is further divided into coarse and fine fractions. These powders are then ready for packaging. For calcined powders, high temperature rotary kilns are continuously employed. After classifying, these powders are collected and packaged. To produce flux-calcined powders, particles are sintered together into microscopic clusters, then classified, collected and bagged.

At facilities 5504 and 5505, the ore is crushed, dried, separated and classified, collected, and stored in bins for shipping. Some of the diatomite is calcined at facility 5505 for a particular product. Diagrams for these processes are given in Figure 28.

One facility surface-quarries an oil-impregnated diatomite, which is crushed, screened, and calcined to drive off the oil. The diatomite is then cooled, ground, and packaged. In the future, the material will be heated and the oil vaporized and recovered as a petroleum product.

Raw Waste Load

Wastes from these operations consist of the oversize waste fraction from the classifiers and of fines collected in dust control equipment. The amount is estimated to be 20 percent of the mined material at facility 5500, 16-19 percent at

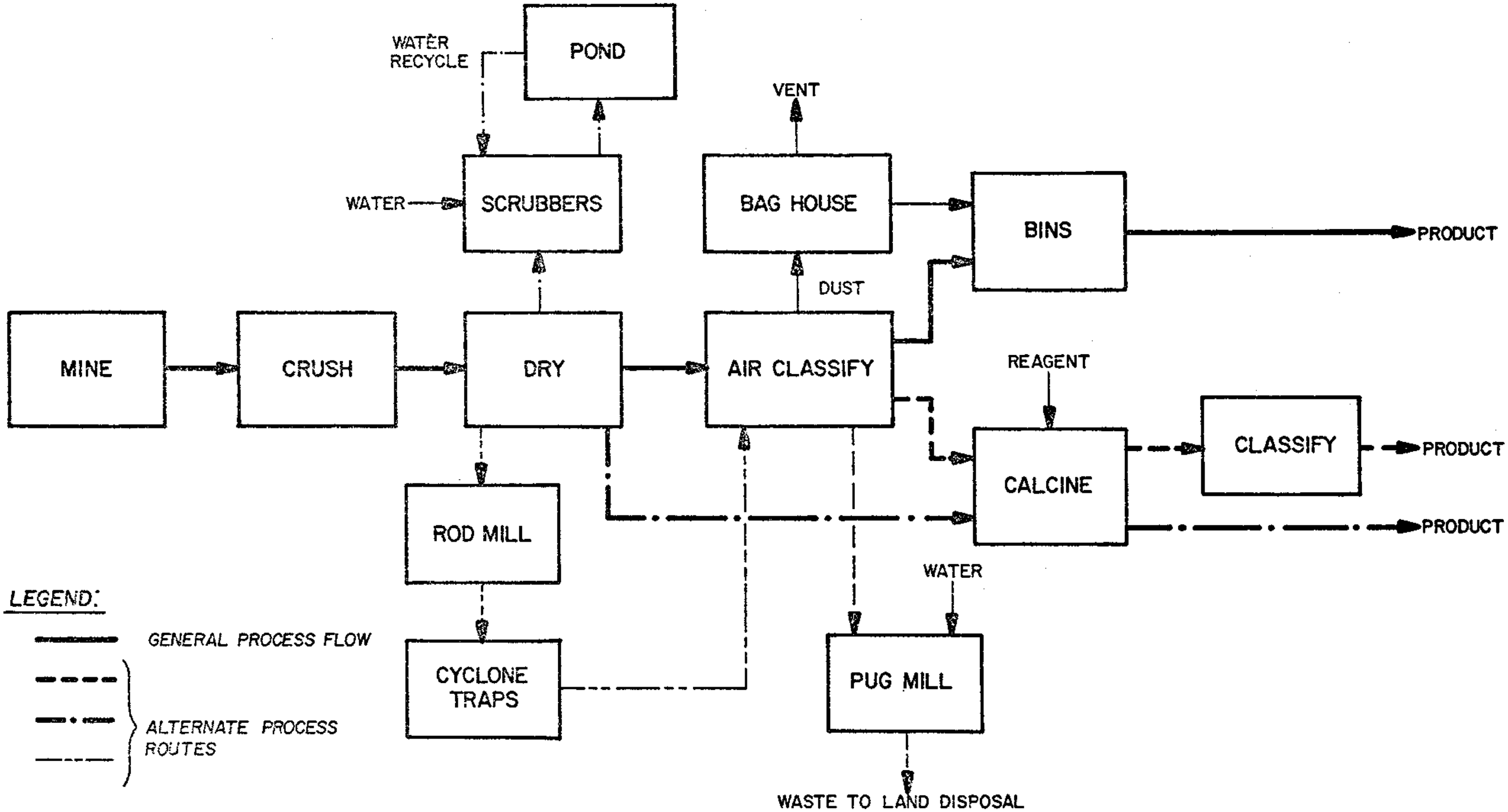


FIGURE 28.
DIATOMITE MINING AND PROCESSING

facility 5504 and 5-6 percent solids as a slurry from scrubber operations at facility 5505.

waste material	kg/kkg ore (lb/1000 lb)
Facility 5500, oversize, dust fines	200
Facility 5504, sand, rock, heavy diatoms	175
Facility 5505, dust fines (slurry)	45

Water Use

Water is used by facility 5500 in the principal process for dust collection and for preparing the waste oversize material for land disposal. In addition, a small amount of bearing cooling water is used. Water is used in the process at facility 5505 only in scrubbers used to cut down on dust fines in processing, which is recycled from settling ponds to the process. The only loss occurs through evaporation with make-up water added to the system. Water is used in the process at facility 5504 to slurry wastes to a closed pond. This water evaporates and/or percolates into the ground. As yet there is no recycle from the settling pond.

	l/kkg ore processed (gallon/ton)		
	5500	5505	5504
Intake:			
make-up water	2,800 (670)	880 (210)	3,800 (910)
Use:			
dust collection and waste disposal	2,670 (640)	8,700 (2,090)	3,800 (910)
bearing cooling	125-160 (30-38)	----	----
Consumption:			
evaporation (pond and process)	2,800 (670)	880 (210)	3,800 (910)

The much lower consumption of water at 5505 is due to the use of recycling from the settling pond to the scrubbers.

Waste Water Treatment

All waste water generated in diatomite preparation at facility 5500 is evaporated on the land. Facilities 5504 and 5505 send waste water to settling ponds with water being recycled to the process at facility 5505 and evaporated and percolated to ground water at facility 5504.

Effluent and Disposal

The only waste water at facility 5500 is land-evaporated on-site. There is no process water, cooling, or mine pumpout discharge.

At facilities 5504 and 5505, the waste water from scrubbers and waste fines slurrying is sent to settling ponds. At facility 5505, the water is decanted and recycled to the process, while facility 5504 currently impounds the water in a closed pond and the water evaporates and/or percolates into the ground. But in late 1974 a pump is being installed to enable facility 5504 to decant and recycle the water from the pond to the process. Thus, all of these diatomite operations have no discharge of any waste water.

The oversize fraction and dust fines waste is land-dumped on-site at facility 5500. The solids content of this land-disposed waste is silica (diatomite) in the amount of about 300,000 mg/l.

The waste slurries from facilities 5504 and 5505 consisting of scrubber fines and dust are land-disposed with the solids settling into ponds. The solids content of these slurries is 24,000 mg/l for facility 5505 and 146,000 mg/l for facility 5504.

GRAPHITE

There is one producer of natural graphite in the United States and data from this operation is presented in the following sections.

Process Description

The graphite ore is produced from an open pit using conventional mining methods of benching, breakage and removal. The ore is properly sized for flotation by passing through a 3-stage dry crushing and sizing system and then to a wet grinding circuit consisting of a rod mill in closed circuit with a classifier. Lime is added in the rod mill to adjust pH for optimum flotation. The classifier discharge is pumped to the flotation circuit where water additions are made and various reagents added at different points in the process flow. The graphite concentrate is floated, thickened, filtered and dried. The underflow or waste tailings from the cells are discharged as a slurry to a settling pond. The process flow diagram for the facility is shown in Figure 29.

Raw Waste Loads

There are three sources of waste associated with the facility operation. They are the tailings from the flotation circuit, (36,000 kg/kkg product low pH seepage water from the tailings pond (19,000 l/kkg product (4,500 gal/ton) under normal operating and weather conditions, and an intermittent seepage from the mine. The flotation reagents used in this process are alcohols and pine oils.

Water Use

The source of the intake water is almost totally from a lake. The exceptions are that the drinking water is taken from a well and a minimal volume for emergency or back-up for the process comes from an impoundment of an intermittent flowing creek. Some recycling of water takes place through the reuse of thickener overflow, filtrate from the filter operation and non-contact cooling water from compressors and vacuum pumps.

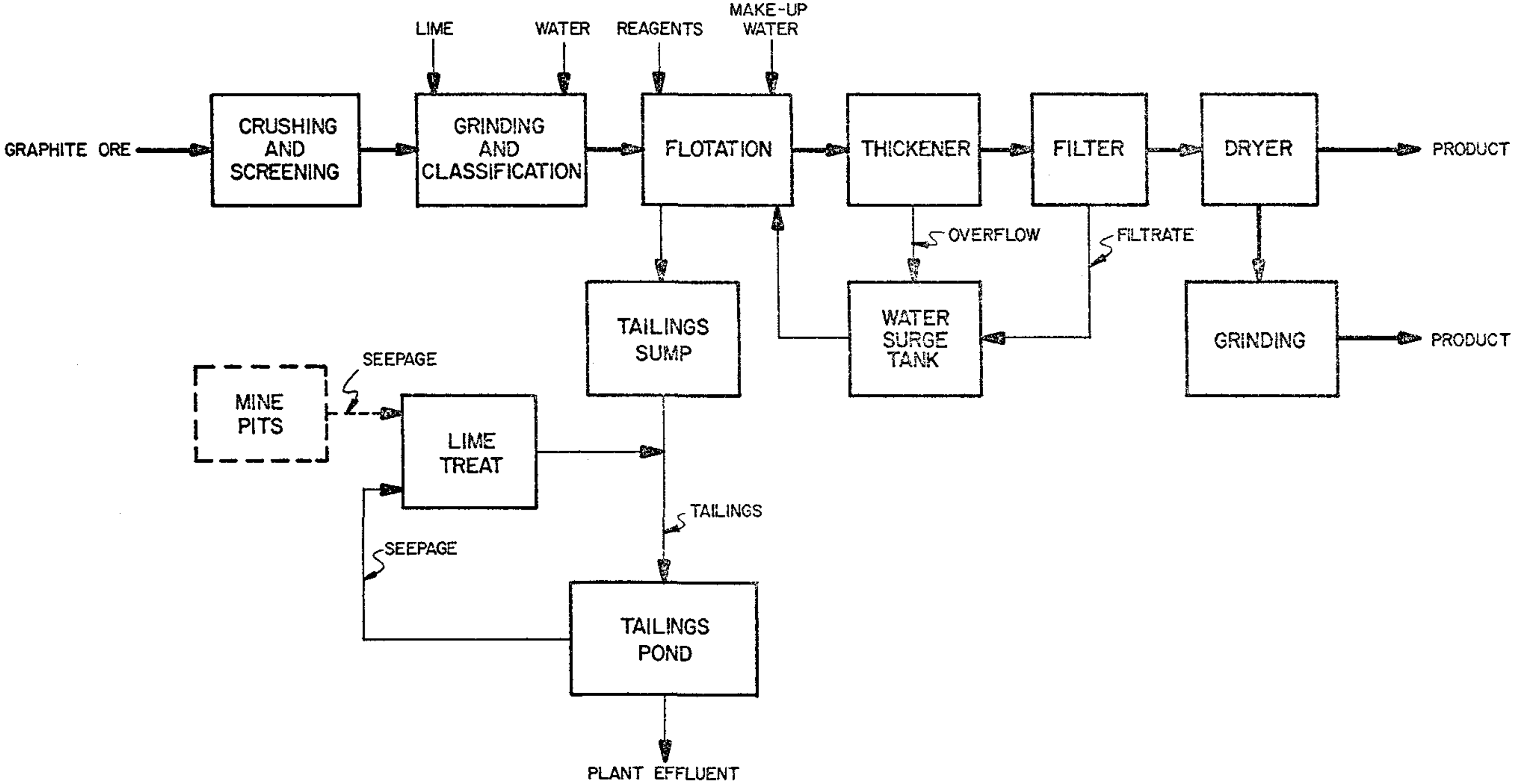


FIGURE 29.
GRAPHITE MINING AND PROCESSING

water consumption	l/metric tons of product (gal/ton)
total intake	159,000 (38,000)
process waste discharge	107,000 (26,000)
consumed (process, non-contact cooling, sanitation)	52,000 (12,000)

Waste water Treatment

The waste streams associated with the operation are flotation tailings and seepage water. The tailings slurry at about 20 percent solids and at a near neutral pH (adjustment made for optimum flotation) is discharged to a partially lined 8 hectare (20 acre) settling pond. The solids settle rapidly and the overflow is discharged. The seepage water from the tailings pond, mine and extraneous surface waters are collected through the use of an extensive network of ditches, dams and sumps. The collected waste waters are pumped to a treatment facility where lime is added to neutralize the acidity and precipitate iron. The neutralized water is pumped to the tailings pond where the iron floc is deposited. The acid condition of the pond seepage results from the extended contact of water with the tailings which dissolve some part of the contained iron pyrites.

Effluent

There is one effluent stream from this operation which is the overflow from the tailings pond. It is discharged into a stream that flows into the lake that serves as the intake water source for the facility. The effluent composition falls within the limits established by the Texas State Water Quality Board for the following parameters: flow; pH; total suspended solids; volatile solids; BOD; COD; manganese and iron. Facility measurements compared to the state limitations are:

	facility average mg/l	24 hr. maximum mg/l	State Standards monthly average
Flow l/day (gal/day)		1,160,000 (300,000)	1,820,000 (480,000)
total solids	750	1600	1380
TSS	10	20	10
Volatile Solids	1	10	0.2
Mn	0.1	0.5	-
Total Fe	0.1	2	1
BOD	9	15	10
COD	20	20	15
pH	7.3-8.5	6.8	7.5

This facility has no problem meeting this requirement because of a unique situation where the large volume of tailings entering the pond assists the settling of suspended solids more than that normally expected from a well designed pond.

JADE

The jade industry in the U.S. is very small. One facility representing 55 percent of total U.S. jade production provided the data for this section.

Process Description

The jade is mined in an open pit quarry, with rock being obtained by pneumatic drilling and wedging of large angular blocks. No explosives are used on the jade itself, only on the surrounding host rock. The rock is then trucked to the facility for processing. There the rock is sawed, sanded, polished and packaged for shipping. Of the material processed only a small amount (3 percent) is processed to gems and 47 percent is processed to floor and table tiles, grave markers, and artifacts. A general process diagram is given in Figure 30.

Raw Waste Load

Approximately 50 percent of the rock taken each year from the quarry is unusable or unavoidably wasted in processing, amounting to 29.5 ton/yr). There is no mine pumpout associated with this operation.

Water Use

Well water is used in the process for the wire saw, sanding, and polishing operations. This water use amounts to 190 l/day (50 gpd) of which none is recycled.

Waste Water Treatment

Waste waters generated from the wire saw, sanding, and polishing operations, are sent to settling tanks where the tailings settle out and the water is discharged onto the facility lawn where it evaporates and/or seeps into the ground. There is no other water treatment employed. Solid wastes in the form of tailings which collect in settling tanks are eventually land-disposed as fill.

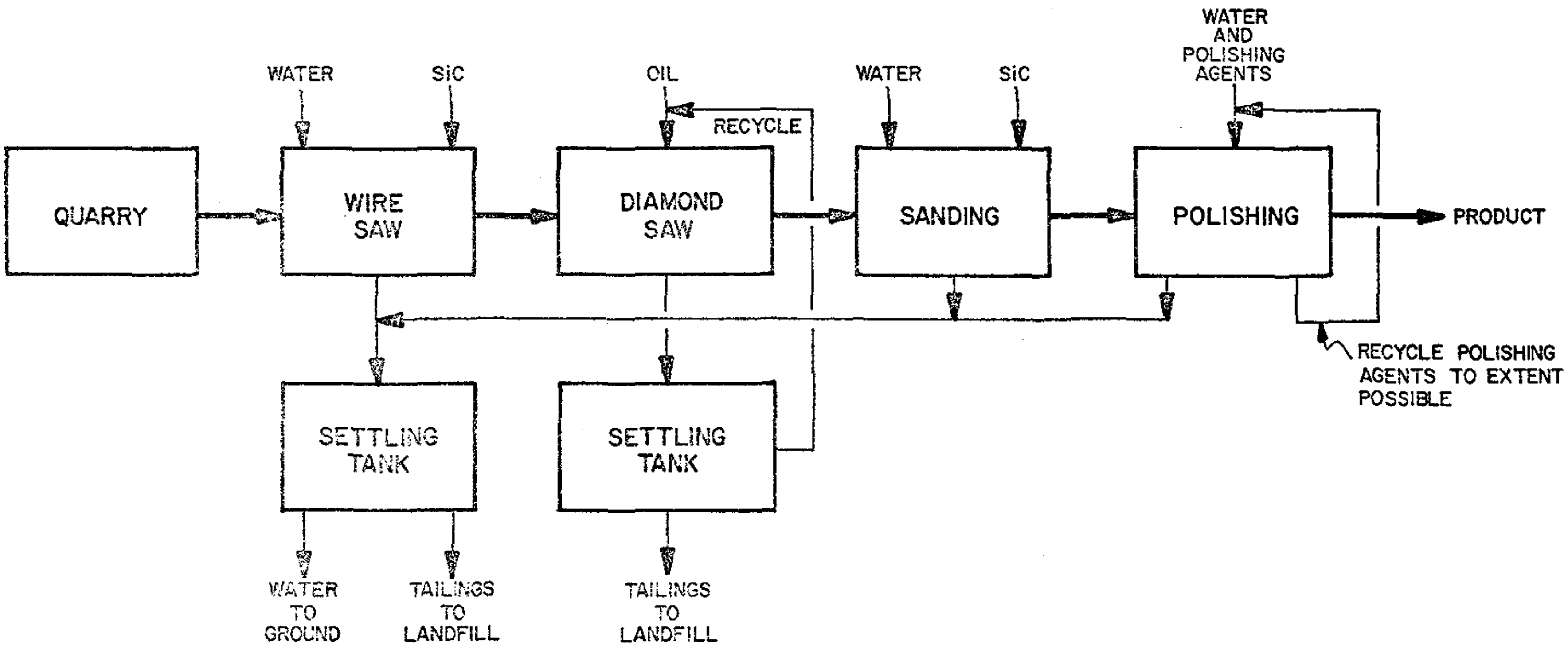


FIGURE 30.
JADE MINING AND PROCESSING

NOVACULITE

Novaculite, a generic name for large geologic formations of pure, microcrystalline silica, is mined only in Arkansas by one facility. Open quarries are mined by drilling and blasting, with a front-end loader loading trucks for transport to covered storage at the facility. Since the quarry is worked for only about 2 weeks per year, mining is contracted out. Facility processing consists essentially of crushing, drying, air classification and bagging. Normally silica will not require drying but novaculite is hydrophilic and will absorb water up to 9 parts per 100 ore. Part of the air classifier product is diverted to a batch mixer, where organics are reacted with the silica for specialty products. A general process diagram is given in Figure 31.

Raw Waste Load

Wastes generated in the mining of novaculite remain in the quarry as reclaiming fill, and processing generates only scrubber fines which are settled in a holding tank and eventually used for land-fill. There is no data available on the amount of this material. However, a new facility dust scrubber will be installed with recycle of both water and fines.

Water Use

No water is used in novaculite mining and the quarry is so constructed that no water accumulates. Total water usage at the facility for bearing cooling and the dust scrubber totals approximately 18,900 l/day (5,000 gpd) of city water. Of this total amount 7,300-14,500 l/day (1,900-3,800 gpd) is used for bearing cooling and an equivalent amount is used as make-up water to the dust scrubber.

Waste Water Treatment

Water from the scrubber is sent to a settling tank and clear water is recycled to the scrubber. Cooling water is discharged onto the facility lawn with no treatment.

Effluent and Disposal

Dust from the scrubber is currently land-disposed. However, with the installment of a new dust scrubber both the water and muds will be recycled to the process. Scrubber water is recycled to the process after settling out of solids in a tank. Cooling water is discharged onto the lawn at the facility and it either seeps into the ground or evaporates.

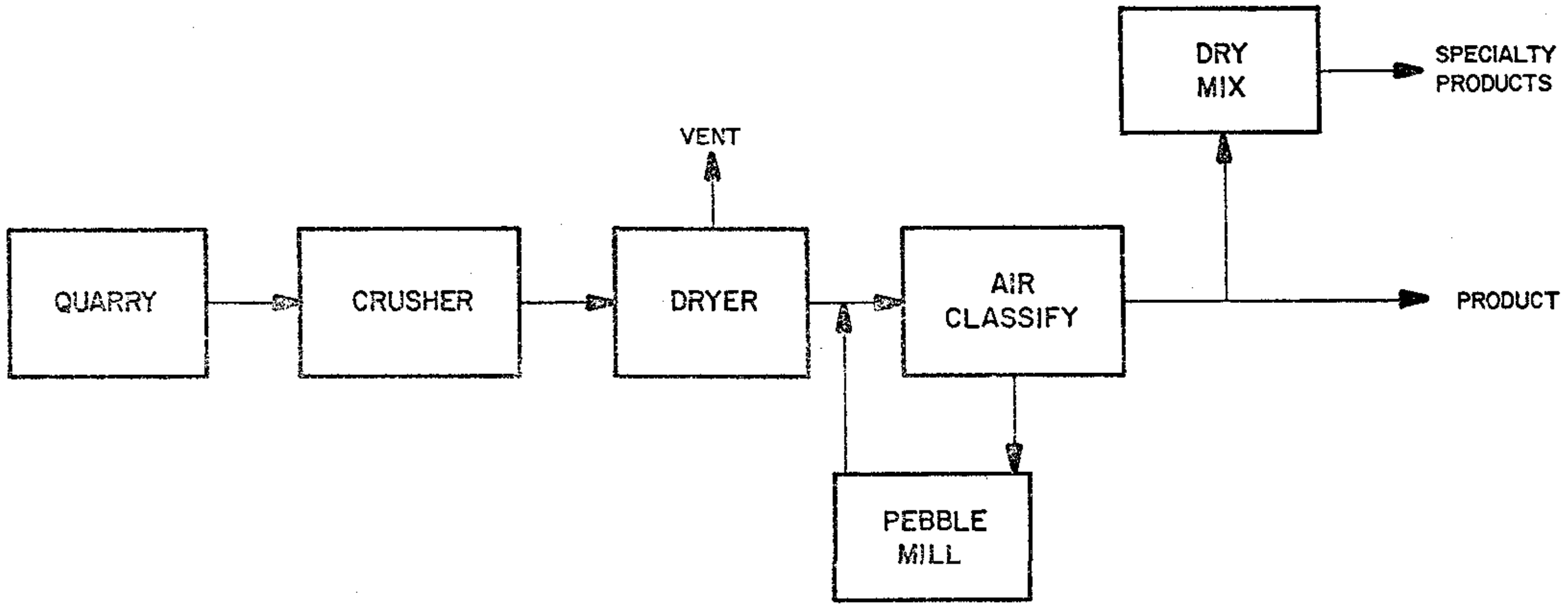


FIGURE 31.
NOVACULITE MINING AND PROCESSING

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

INTRODUCTION

The waste water constituents of pollution significance for this segment of the mineral mining and processing industry are based upon those parameters which have been identified in the untreated wastes from each subcategory of this study. The waste water constituents are further divided into those that have been selected as pollutants of significance with the rationale for their selection, and those that are not deemed significant with the rationale for their rejection.

The basis for selection of the significant pollutant parameters was:

(1) toxicity to humans, animals, fish and aquatic organisms;
(2) substances causing dissolved oxygen depletion in streams;
(3) soluble constituents that result in undesirable tastes and odors in water supplies;
(4) substances that result in eutrophication and stimulate undesirable algae growth;
(5) substances that produce unsightly conditions in receiving water; and
(6) substances that result in sludge deposits in streams.

SIGNIFICANCE AND RATIONALE FOR SELECTION OF POLLUTION PARAMETERS

Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand (BOD) is a measure of the oxygen consuming capabilities of organic matter. The BOD does not in itself cause direct harm to a water system, but it does exert an indirect effect by depressing the oxygen content of the water. Sewage and other organic effluents during their processes of decomposition exert a BOD, which can have a catastrophic effect on the ecosystem by depleting the oxygen supply. Conditions are reached frequently where all of the oxygen is used and the continuing decay process causes the production of noxious gases such as hydrogen sulfide and methane. Water with a high BOD indicates the presence of decomposing organic matter and subsequent high bacterial counts that degrade its quality and potential uses.

Dissolved oxygen (DO) is a water quality constituent that, in appropriate concentrations, is essential not only to keep organisms living but also to sustain species reproduction, vigor, and the development of populations. Organisms undergo stress at reduced DO concentrations that make them less competitive and able to sustain their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish population through delayed hatching of eggs, reduced size and vigor of embryos, production of deformities in young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxicants, reduced food efficiency and growth rate, and reduced maximum sustained swimming speed. Fish food organisms are likewise affected adversely in conditions with suppressed DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the consequences of total lack of dissolved oxygen due to a high BOD can kill all inhabitants of the affected area.

If a high BOD is present, the quality of the water is usually visually degraded by the presence of decomposing materials and algae blooms due to the uptake of degraded materials that form the foodstuffs of the algal populations. BOD was not a major contribution to pollution in this industry.

Fluorides

As the most reactive non-metal, fluorine is never found free in nature but as a constituent of fluorite or fluorspar, calcium fluoride, in sedimentary rocks and also of cryolite, sodium aluminum fluoride, in igneous rocks. Owing to their origin only in certain types of rocks and only in a few regions, fluorides in high concentrations are not a common constituent of natural surface waters, but they may occur in detrimental concentrations in ground waters.

Fluorides are used as insecticides, for disinfecting brewery apparatus, as a flux in the manufacture of steel, for preserving wood and mucilages, for the manufacture of glass and enamels, in chemical industries, for water treatment, and for other uses.

Fluorides in sufficient quantity are toxic to humans, with doses of 250 to 450 mg giving severe symptoms or causing death.

There are numerous articles describing the effects of fluoride- bearing waters on dental enamel of children; these studies lead to the generalization that water containing less than 0.9 to 1.0 mg/l of fluoride will seldom cause mottled enamel in children, and for adults, concentrations less than 3 or 4 mg/l are not likely to cause endemic cumulative fluorosis and skeletal effects. Abundant literature is also available describing the advantages of maintaining 0.8 to 1.5 mg/l of fluoride ion in drinking water to aid in the reduction of dental decay, especially among children.

Chronic fluoride poisoning of livestock has been observed in areas where water contained 10 to 15 mg/l fluoride. Concentrations of 30-50 mg/l of fluoride in the total ration of dairy cows is considered the upper safe limit. Fluoride from waters apparently does not accumulate in soft tissue to a significant degree and it is transferred to a very small extent into the milk and to a somewhat greater degree into eggs. Data for fresh water indicate that fluorides are toxic to fish at concentrations higher than 1.5 mg/l. Fluoride is found in one industry in this segment, feldspar mining by the wet process.

Iron

Iron is considered to be a highly objectional constituent in public water supplies, the permissible criterion has been set at 0.3 mg/l. Iron is found in significant quantities in graphite mining and other categories.

Manganese

Manganese in various dissolved forms may be present in significant amounts in the waste water from the mining of graphite. A permissible criterion of 0.05 mg/l has been proposed for public waters.

Oil and Grease

Oil and grease exhibit an oxygen demand. Oil emulsions may adhere to the gills of fish or coat and destroy algae or other plankton. Deposition of oil in the bottom sediments can serve to exhibit normal benthic growths, thus interrupting the aquatic food chain. Soluble and emulsified material ingested by fish may taint the flavor of the fish flesh. Water soluble components may exert toxic action on fish. Floating oil may reduce the re-aeration of the water surface and in conjunction with emulsified oil may interfere with photosynthesis. Water insoluble components damage the plumage and costs of water animals and fowls. Oil and grease in a water can result in the formation of objectionable surface slicks preventing the full aesthetic enjoyment of the water. Oil spills can damage the surface of boats and can destroy the aesthetic characteristics of beaches and shorelines.

Acidity and Alkalinity

Acidity and alkalinity are reciprocal terms. Acidity is produced by substances that yield hydrogen ions upon hydrolysis and alkalinity is produced by substances that yield hydroxyl ions. The terms "total acidity" and "total alkalinity" are often used to express the buffering capacity of a solution. Acidity in natural waters is caused by carbon dioxide, mineral acids, weakly dissociated acids, and the salts of strong acids and weak bases. Alkalinity is caused by strong bases and the salts of strong alkalies and weak acids.

The term pH is a logarithmic expression of the concentration of hydrogen ions. At a pH of 7, the hydrogen and hydroxyl ion concentrations are essentially equal and the water is neutral. Lower pH values indicate acidity while higher values indicate alkalinity. The relationship between pH and acidity and alkalinity is not necessarily linear or direct.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add such constituents to drinking water as iron, copper, zinc, cadmium and lead. The hydrogen ion concentration can affect the "taste" of the water. At a low pH water tastes "sour". The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7. This is very significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Dead fish, associated algal blooms, and foul stenches are aesthetic liabilities of any waterway. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. Metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. The availability of many nutrient substances varies with the alkalinity and acidity. Ammonia is more lethal with a higher pH.

The lacrimal fluid of the human eye has a pH of approximately 7.0 and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer. Appreciable irritation will cause severe pain.

Total Suspended Solids

Suspended solids include both organic and inorganic materials. The inorganic components include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, animal and vegetable fats, various fibers, sawdust, hair and various materials from sewers. These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. They adversely affect fisheries by covering the bottom of the stream or lake with a blanket of material that destroys the fish-food bottom fauna or the spawning ground of fish. Deposits containing organic materials may deplete bottom oxygen supplies and produce hydrogen sulfide, carbon dioxide, methane, and other noxious gases.

In raw water sources for domestic use, state and regional agencies generally specify that suspended solids in streams shall not be present in sufficient concentration to be objectionable or to interfere with normal treatment processes. Suspended solids in water may interfere with many industrial processes, and cause foaming in boilers, or encrustations on equipment exposed to water, especially as the temperature rises. Suspended solids are undesirable in water for textile industries; paper and pulp; beverages; dairy products; laundries; dyeing; photography; cooling systems, and power facilities. Suspended particles also serve as a transport mechanism for pesticides and other substances which are readily sorbed into or onto clay particles.

Solids may be suspended in water for a time, and then settle to the bed of the stream or lake. These settleable solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration and impair the photosynthetic activity of aquatic facilities.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often much more damaging to the life in water, and they retain the capacity to displease the senses. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When of an organic and therefore decomposable nature, solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a seemingly inexhaustible food source for sludgeworms and associated organisms.

Turbidity is principally a measure of the light absorbing properties of suspended solids. It is frequently used as a substitute method of quickly estimating the total suspended solids when the concentration is relatively low. Total suspended solids are the single most important pollutant parameter found in this segment of the mineral mining and processing industry.

Zinc

Occurring abundantly in rocks and ores, zinc is readily refined into a stable pure metal and is used extensively for galvanizing, in alloys, for electrical purposes, in printing plates, for dye- manufacture and for dyeing processes, and for many other industrial purposes. Zinc salts are used in paint pigments, cosmetics, pharmaceuticals, dyes, insecticides, and other products too numerous to list herein. Many of these salts (e.g., zinc chloride and zinc sulfate) are highly soluble in water; hence it is to be expected that some zinc might be found in natural waters. On the other hand, some zinc salts (zinc carbonate, zinc oxide, zinc sulfide) are insoluble in water and consequently it is to be expected that some zinc will precipitate and be removed readily in most natural waters.

In zinc mining areas, zinc has been found in waters in concentrations as high as 50 mg/l and in effluents from metal-plating works and small-arms ammunition facilities it may occur in significant concentrations. In most surface and ground waters, it is present only in trace amounts. There is some evidence that zinc ions are adsorbed strongly and permanently on silt, resulting in inactivation of the zinc.

Concentrations of zinc in excess of 5 mg/l in raw water used for drinking water supplies cause an undesirable taste which persists through conventional treatment. Zinc can have an adverse effect on man and animals at high concentrations.

In soft water, concentrations of zinc ranging from 0.1 to 1.0 mg/l have been reported to be lethal to fish. Zinc is thought to exert its toxic action by forming insoluble compounds with the mucous that covers the gills, by damage to the gill epithelium, or possibly by acting as an internal poison. The sensitivity of fish to zinc varies with species, age and condition, as well as with the physical and chemical characteristics of the water. Some acclimatization to the presence of zinc is possible. It has also been observed that the effects of zinc poisoning may not become apparent immediately, so that fish removed from zinc-contaminated to zinc-free water (after 4-6 hours of exposure to zinc) may die 48 hours later. The presence of copper in water may increase the toxicity of zinc to aquatic organisms, but the presence of calcium or hardness may decrease the relative toxicity.

Observed values for the distribution of zinc in ocean waters vary widely. The major concern with zinc compounds in marine waters is not one of acute toxicity, but rather of the long-term sub-lethal effects of the metallic compounds and complexes. From an acute toxicity point of view, invertebrate marine animals seem to be the most sensitive organisms tested. The growth of the sea urchin, for example, has been retarded by as little as 30 mu/l of zinc. Zinc sulfate has also been found to be lethal to many facilities, and it could impair agricultural uses. Zinc is found in the effluent from one process in this industry, high-grade kaolin.

SIGNIFICANCE AND RATIONAL FOR REJECTION OF POLLUTION PARAMETERS

A number of pollution parameters besides those selected were considered, but were rejected for one or several of the following reasons:

1) insufficient data on facility effluents;
2) not usually present in quantities sufficient to cause water quality degradation;
3) treatment does not "practicably" reduce the parameter; and
4) simultaneous reduction is achieved with another parameter which is limited.

Toxic Materials

Although arsenic, antimony, barium, boron, cadmium, chromium, copper, cyanide ion, mercury, nickel, lead, selenium, and tin are harmful pollutants, they were not found to be present in quantities sufficient to cause water quality degradation.

Dissolved Solids

The cations Al^{+3}, Ca^{+2}, Mg^{+2}, K^{+} and Na^{+}, the anion Cl^{-} and the radical groups CO_3^{-2}, NO_3^{-}, NO_2^{-}, phosphates, and silicates are commonly found in all natural water bodies. Process water, mine water and storm runoff will accumulate quantities of the above constituents both in the form of suspended and dissolved solids. Limiting suspended solids and dissolved solids, where they pose a problem, is a more practicable approach to limiting these specific ions.

Temperature

Temperature is one of the most important and influential water quality characteristics. Temperature determines those species that may be present; it activates the hatching of young, regulates their activity, and stimulates or suppresses their growth and development; it attracts, and may kill when the water becomes too hot or becomes chilled too suddenly. Colder water generally suppresses development. Warmer water generally accelerates activity and may be a primary cause of aquatic facility nuisances when other environmental factors are suitable.

Temperature is a prime regulator of natural processes within the water environment. It governs physiological functions in organisms and, acting directly or indirectly in combination with other water quality constituents, it affects aquatic life with each change. These effects include chemical reaction rates, enzymatic functions, molecular movements, and molecular exchanges between membranes within and between the physiological systems and the organs of an animal.

Chemical reaction rates vary with temperature and generally increase as the temperature is increased. The solubility of gases in water varies with temperature. Dissolved oxygen is decreased by the decay or decomposition of dissolved organic substances and the decay rate increases as the temperature of the water increases reaching a maximum at about 30°C (86°F). The temperature of stream water, even during summer, is below the optimum for pollution-associated bacteria. Increasing the water temperature increases the bacterial multiplication rate when the environment is favorable and the food supply is abundant.

Reproduction cycles may be changed significantly by increased temperature because this function takes place under restricted temperature ranges. Spawning may not occur at all because temperatures are too high. Thus, a fish population may exist in a heated area only by continued immigration. Disregarding the decreased reproductive potential, water temperatures need not reach lethal levels to decimate a species. Temperatures that favor competitors, predators, parasites, and disease can destroy a species at levels far below those that are lethal.

Fish food organisms are altered severely when temperatures approach or exceed 90°F. Predominant algal species change, primary production is decreased, and bottom associated organisms may be depleted or altered drastically in numbers and distribution. Increased water temperatures may cause aquatic facility nuisances when other environmental factors are favorable.

Synergistic actions of pollutants are more severe at higher water temperatures. Given amounts of domestic sewage, refinery wastes, oils, tars, insecticides, detergents, and fertilizers more rapidly deplete oxygen in water at higher temperatures, and the respective toxicities are likewise increased.

When water temperatures increase, the predominant algal species may change from diatoms to green algae, and finally at high temperatures to blue-green algae, because of species temperature preferentials. Blue-green algae can cause serious odor problems. The number and distribution of benthic organisms decreases as water temperatures increase above 90°F, which is close to the tolerance limit for the population. This could seriously affect certain fish that depend on benthic organisms as a food source.

The cost of fish being attracted to heated water in winter months may be considerable, due to fish mortalities that may result when the fish return to the cooler water.

Rising temperatures stimulate the decomposition of sludge, formation of sludge gas, multiplication of saprophytic bacteria and fungi (particularly in the presence of organic wastes), and the consumption of oxygen by putrefactive processes, thus affecting the esthetic value of a water course.

In general, marine water temperatures do not change as rapidly or range as widely as those of freshwaters. Marine and estuarine fishes, therefore, are less tolerant of temperature variation. Although this limited tolerance is greater in estuarine than in open water marine species, temperature changes are more important to those fishes in estuaries and bays than to those in open marine areas, because of the nursery and replenishment functions of the estuary that can be adversely affected by extreme temperature changes.

Excess thermal load, even in non-contact cooling water, has not been and is not expected to be a significant problem in this segment of the mineral mining and processing industry.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

INTRODUCTION

Water-borne wastes from the mining of clay, ceramic, refractory and miscellaneous minerals consist primarily of suspended solids. These are usually composed of chemically inert and very insoluble sand, clay or rock particles. Treatment technology is well developed for removing such particles from waste water and is readily applicable whenever space requirements or economics do not preclude utilization.

In a few instances dissolved substances such as fluorides, metal salts, acids, alkalies, chemical additives from ore processing and organic materials may also be involved. Where they are present, dissolved material concentrations are usually low. Treatment technology for the dissolved solids is also well-known, but may often be limited by the large volumes of waste water involved and the cost of such large scale operations.

The control and treatment of the usually simple water-borne wastes found in the mineral mining and processing industry are complicated by several factors:

(1) the large volumes of waste water involved for many of the mining operations,

(2) variable waste water amount and composition from day to day, as influenced by rainfall and other surface and underground water contributions,

(3) differences in waste water compositions arising from ore or raw material variability,

(4) geographical location: e.g., waste water can be handled differently in dry isolated locations than in industrialized wet climates.

Each of these points are discussed in the following sections.

PROBLEM POLLUTANTS

Three significant waste water problem areas have been found in these industries:

(1) High suspended solids levels in discharged waste waters caused in some cases by formation of colloidal clay suspensions which are difficult to settle. This problem is encountered in several segments of the industry;

(2) In at least one subcategory of this industry problems are encountered with water-borne fluoride wastes;

(3) In the bleaching of some clay products, zinc hydrosulfite is sometimes employed. The use of this material invariably leads to a waste water discharge containing zinc salts.

Below are given brief discussions of each of these problem areas.

The principal pollutant encountered in this segment of the minerals mining industry has been found to be suspended solids which arise from two sources:

(1) underground or surface mine pumpouts;

(2) processing washwaters and scrubber waters.

Mine water pumpout was found to be intermittent in nature and to be characterized by TSS loadings of from a few to several thousand mg/l of suspended solids prior to settling. Installation of settling areas for such waters generally has the effect reducing TSS loadings to less than 20 mg/l for most materials. It should be pointed out that mine pumpout waters from montmorillonite clay mining facilities appear to be an exception to the above statement. This type of clay forms colloidal suspensions in waste water that are very difficult to settle. These colloidal suspensions can be flocculated by addition of soluble calcium salts at concentrations of about 100 milliequivalents of calcium salt per 100 grams of suspended montmorillonite (1,2). For other clays which settle more readily, flocculation occurs generally at lower concentrations of added calcium salt. This approach apparently has yet to be tried in the industry. Other approaches mentioned in the literature, such as treatment of clays with alkyl ammonium salts (3,4) are not likely to be applicable to this situation because their use would cause worse environmental problems than those already present.

Process water discharge is encountered in several of the product subcategories. For readily settleable materials, settling lagoons were found to be effective in reducing suspended solids loadings to less than 20 mg/l in most instances. For a few of the clay materials, such as montmorillonite and fire clays, pond effluent concentrations after simple settling tend to be at least an order of magnitude higher in TSS. For one specific case with a montmorillonite facility, scrubber waste waters were found with a TSS loading of 25,000 mg/l before settling. After settling with a retention time of less than five days in a small lagoon, TSS loadings of about 2,000 mg/l were still present. Table 5 shows the settling characteristics of some of the materials treated in this volume. Application of available flocculation and clarification technology is needed in this area.

The processing of feldspar ores involves a flotation step in which hydrofluoric acid is added. This gives rise to an acidic fluoride bearing waste water stream which, prior to treatment, can contain 50 mg/l fluoride ion. At present, treatment of such waste waters has been only partially practiced. Current fluoride effluent concentrations at feldspar producing facilities range from 8 to about 40 mg/l. This is another area where improved treatment technology is needed.

In the bleaching of kaolin, solutions of zinc hydrosulfite are generally employed. This gives rise to waste waters containing 25 mg/l zinc ion prior to treatment. Technology already in use in the pigments and inorganic chemicals industries is available to reduce effluent levels to less than 25 mg/l. This will be discussed later in this section.

CONTROL PRACTICES

Control practices such as selection of raw materials, good housekeeping, minimizing leaks and spills, in-process changes, and segregation of process waste water streams are not as important in the minerals mining industry as they are in more process-oriented manufacturing operations. Raw materials are fixed by the composition of the ore available; good housekeeping and small leaks and spills have little influence on the waste loads; and it is rare that any non-contact water, such as cooling water, is involved in minerals and mining processes.

There are a number of areas, however, where control is very important. These include:

Table 5
Settling Characteristics of Some Suspended Materials

Product	Stream	Plant	Input to Pond (mg/liter)	Retention Time, Condition	Outflow (mg/liter)
Fire Clay	mine seepage, runoff, & cooling	3087	unknown	0.25 hour soda ash added	45
Montmorillonite	scrubber	3072	25,000	4.1 days, lime added	2,000
	pit pumpout	3073	unknown	variable	215
Kaolin	plant raw effluent	3024	10,300 includes sand	unknown, lime added	6
Ball Clay	scrubber	5685	unknown	1-2 months, simple settling	400
	scrubbers	5689	unknown	1 month, flocculant, 3 ponds	40
Feldspar	plant raw effluent	3026	3,800	unknown, alum added, 2 ponds	21
Talc	mine pumpout	2041, 2042, 2043, 2044	200	unknown	<20

(1) waste water containment

(2) separation and control of mine water, process water, and rain water

(3) monitoring of waste streams.

Containment

The majority of waste water treatment and control facilities in the minerals and mining industry use one or more settling ponds. Often the word "pond" is an euphemism for swamp, gully, or other low spot which will collect water. In times of heavy rainfall these "ponds" often and the settled solids may be swept out. In many other cases, the identity of the pond may be maintained during rainfall but its function as a settling pond is significantly impaired by the large amount of water flowing through it. In addition to rainfall and flooding conditions, waste containment in ponds can be troubled with seepage through the ground around and beneath the pond, escape through pot holes, faults and fissures below the water surface and physical failure of pond dams and dikes.

In most instances satisfactory pond performance can be achieved by proper design. In instances where preliminary laboratory tests indicate that insufficient land is available to achieve satisfactory suspended solids removal, alternative treatment methods can be utilized: thickeners, clarifiers, tube and lamella separators, filters, hydrocyclones, and centrifuges.

Separation and Control of Waste water

In these industries waste water may be separated into three different categories:

(1) Mine drainage water. For many mines this is the only water effluent. Usually it is low in suspended solids, but may contain dissolved minerals.

(2) Process water. This is water involved in transporting, classifying, washing, beneficiating, and separating ores and other mined materials. When present in minerals mining operations this water usually contains heavy loads of suspended solids and possibly some dissolved materials.

(3) Rain water runoff. Since minerals mining operations often involve large surface areas, the rain water that falls on the mine or mine property surface constitutes a major portion of the overall waste water load leaving the property. This runoff entrains minerals, silt, sand, clay, organic matter and other suspended solids.

The relative amounts and compositions of the above waste water streams differ from one mining category to another and the separation, control and treatment techniques differ for each.

Process water and mine drainage are normally controlled and contained by pumping or gravity flow through pipes, channels, ditches and ponds. Rain water runoff, on the other hand, is often uncontrolled and may contaminate process and mine drainage water. Rain water runoff also increases suspended solid material in rivers, streams, creeks or other surface water used for process water supply.

Control technology, as discussed in this report, includes techniques and practices employed before, during, and after the actual mining or processing operation to reduce or eliminate adverse environmental effects resulting from the discharge of mine or process facility waste water. Effective pollution-control planning can reduce pollutant contributions from active mining and processing sites and can also minimize post-operational pollution potential. Because pollution potential may not cease with closure of a mine or process facility, control measures also refer to methods practiced after an operation has terminated production of ore or concentrated product. The presence of pits, storage areas for spoil (non-ore material, or waste), tailing ponds, disturbed areas, and other results or effects of mining or processing operations necessitates integrated plans for reclamation, stabilization, and control to return the affected areas to a condition at least fully capable of supporting the uses which it was capable of supporting prior to any mining and to achieve a stability not posing any threat of water diminution, or pollution and to minimize potential hazards associated with closed operations.

Mining Techniques

Mining techniques can effectively reduce amounts of pollutants coming from a mine area by containment within the mine area or by reducing their formation. These techniques can be combined with careful reclamation planning and implementation to provide maximum at-source pollution control.

Several techniques have been implemented to reduce environmental degradation during strip-mining operations. Utilization of the box-cut technique in moderate- and shallow-slope contour mining has increased recently because more stringent environmental controls are being implemented.

A box cut is simply a contour strip mine in which a low-wall barrier is maintained. Spoil may be piled on the low wall side. This technique significantly reduces the amount of water discharged from a pit area, since that water is prevented from seeping through spoil banks. The problems of preventing slides, spoil erosion, and resulting stream sedimentation are still present, however.

Block-cut mining was developed to facilitate regrading, minimize overburden handling, and contain spoil within mining areas. In block-cut mining, contour stripping is typically accomplished by throwing spoil from the bench onto downslope areas. This downslope material can slump or rapidly erode and must be moved upslope to the mine site if contour regrading is desired. The land area affected by contour strip mining is substantially larger than the area from which the ores are extracted. When using block-cut mining, only material from the first cut is deposited in adjacent low areas. Remaining spoil is then placed in mined portions of the bench. Spoil handling is restricted to the actual pit area for all areas but the first cut, which significantly reduces the area disturbed.

Pollution-control technology in underground mining is largely restricted to at-source methods of reducing water influx into mine workings. Infiltration from strata surrounding the workings is the primary source of water, and this water reacts with air and sulfide minerals within the mines to create acid pH conditions and, thus, to increase the potential for solubilization of metals. Underground mines are, therefore, faced with problems of water handling and mine-drainage treatment. Open-pit mines, on the other hand, receive both direct rainfall and runoff contributions, as well as infiltrated water from intercepted strata.

Infiltration in underground mines generally results from rainfall recharge of a ground-water reservoir. Rock fracture zones, joints, and faults have a strong influence on ground-water flow patterns since they can collect and convey large volumes of water. These zones and faults can intersect any portion of an underground mine and permit easy access of ground water. In some mines, infiltration can result in huge volumes of water that must be handled and treated. Pumping can be a major part of the mining operation in terms of equipment and expense--particularly, in mines which do not discharge by gravity.

Water-infiltration control techniques, designed to reduce the amount of water entering the workings, are extremely important in underground mines located in or adjacent to water-bearing strata. These techniques are often employed in such mines to decrease the volume of water requiring handling and treatment, to make the mine workable, and to control energy costs associated with dewatering. The techniques include pressure grouting of fissures which are entry points for water into the mine. New polymer-based grouting materials have been developed which should improve the effectiveness of such grouting procedures. In severe cases, pilot holes can be drilled ahead of actual mining areas to determine if excessive water is likely to be encountered. When water is encountered, a small pilot hole can be easily filled by pressure grouting, and mining activity may be directed toward non-water-contributing areas in the formation. The feasibility of such control is a function of the structure of the ore body, the type of surrounding rock, and the characteristics of ground water in the area.

Decreased water volume, however, does not necessarily mean that waste water pollutant loading will also decrease. In underground mines, oxygen, in the presence of humidity, interacts with minerals on the mine walls and floor to permit pollutant formation e.g., acid mine water, while water flowing through the mine transports pollutants to the outside. If the volume of this water is decreased but the volume of pollutants remains unchanged, the resultant smaller discharge will contain increased pollutant concentrations, but approximately the same pollutant load. Rapid pumpout of the mine can, however, reduce the contact time and significantly reduce the formation of pollutants.

Reduction of mine discharge volume can reduce water handling costs. In cases of acid mine drainage, for example, the same amounts of neutralizing agents will be required because pollutant loads will remain unchanged. The volume of mine water to be treated, however, will be reduced significantly, together with the size of the necessary treatment and settling facilities. This cost reduction, along with cost savings which can be attributed to decreased pumping volumes (hence, smaller pumps, lower energy requirements, and smaller treatment facilities), makes use of water infiltration-control techniques highly desirable.

Water entering underground mines may pass vertically through the mine roof from rock formation above. These rock units may have well-developed joint systems (fractures along which no movement occurs), which tend to facilitate vertical flow. Roof collapses can also cause widespread fracturing in overlying rocks, as well as joint separation far above the mine roof. Opened joints may channel flow from overlying aquifers (water-bearing rocks), a flooded mine above, or even from the surface.

Fracturing of overlying strata is reduced by employing any or all of several methods: (1) Increasing pillar size; (2) Increasing support of the roof; (3) Limiting the number of mine entries and reducing mine entry widths; (4) Backfilling of the mined areas with waste material.

Surface mines are often responsible for collecting and conveying large quantities of surface water to adjacent or underlying underground mines. Ungraded surface mines often collect water in open pits when no surface discharge point is available. That water may subsequently enter the groundwater system and then percolate into an underground mine. The influx of water to underground mines from either active or abandoned surface mines can be significantly reduced through implementation of a well-designed reclamation plan.

The only actual underground mining technique developed specifically for pollution control is preplanned flooding. This technique is primarily one of mine design, in which a mine is planned from its inception for post-operation flooding or zero discharge. In drift mines and shallow slope or shaft mines, this is generally achieved by working the mine with the dip of the rock (inclination of the rock to the horizontal) and pumping out the water which collects in the shafts. Upon completion of mining activities, the mine is allowed to flood naturally, eliminating the possibility of acid formation caused by the contact between sulfide minerals and oxygen. Discharges, if any, from a flooded mine should contain a much lower pollutant concentration. A flooded mine may also be sealed.

Surface-Water Control

Pollution-control technology related to mining areas, ore-beneficiation facilites, and waste-disposal sites is generally designed for prevention of pollution of surface waters (i.e., streams, impoundments, and surface runoff). Prior planning for waste disposal is a prime control method. Disposal sites should be isolated from surface flows and impoundments to prevent or minimize pollution potential. In addition, several techniques are practiced to prevent water pollution:

(1) Construction of a clay or other type of liner beneath the planned waste disposal area to prevent infiltration of surface water (precipitation) or water contained in the waste into the ground-water system.

(2) Compaction of waste material to reduce infiltration.

(3) Maintenance of uniformly sized refuse to enhance good compaction (which may require additional crushing).

(4) Construction of a clay liner over the material to minimize infiltration. This is usually succeeded by placement of topsoil and seeding to establish a vegetative cover for erosion protection and runoff control.

(5) Excavation of diversion ditches surrounding the refuse disposal site to exclude surface runoff from the area. These ditches can also be used to collect seepage from refuse piles, with subsequent treatment, if necessary.

Surface runoff in the immediate area of beneficiation facilities presents another potential pollution problem. Runoff from haul roads, areas near conveyors, and ore storage piles is a potential source of pollutant loading to nearby surface waters. Several current industry practices to control this pollution are:

(1) Construction of ditches surrounding storage areas to divert surface runoff and collect seepage that does occur.

(2) Establishment of a vegetative cover of grasses in areas of potential sheet wash and erosion to stabilize the material, to control erosion and sedimentation, and to improve the aesthetic aspects of the area.

(3) Installation of hard surfaces on haul roads, beneath conveyors, etc., with proper slopes to direct drainage to a sump. Collected waters may be pumped to an existing treatment facility for treatment.

Another potential problem associated with construction of tailing-pond treatment systems is the use of existing valleys and natural drainage areas for impoundment of mine water or process facility process waste water. The capacity of these impoundment systems frequently is not large enough to prevent high discharge flow rates--particularly, during the late winter and early spring months. The use of ditches, flumes, pipes, trench drains, and dikes will assist in preventing runoff caused by snowmelt, rainfall, or streams from entering impoundments. Very often, this runoff flow is the only factor preventing attainment of zero discharge. Diversion of natural runoff from impoundment treatment systems, or construction of these facilities in locations which do not obstruct natural drainage, is therefore, desirable.

Ditches may be constructed upslope from the impoundment to prevent water from entering it. These ditches also convey water away and reduce the total volume of water which must be treated. This may result in decreased treatment costs, which could offset the costs of diversion.

Segregation or Combination of Mine and Process Facility Wastewaters

A widely adopted control practice in the ore mining and dressing industry is the use of mine water as a source of process water. In many areas, this is a highly desirable practice, because it serves as a water-conservation measure. Waste constituents may thus be concentrated into one waste stream for treatment. In other cases, however, this practice results in the necessity for discharge from a process facility-water impoundment system because, even with recycle of part of the process water, a net positive water balance results.

At several sites visited as part of this study, degradation of the mine water quality is caused by combining the waste-water streams for treatment at one location. A negative effect results because water with low pollutant loading serves to dilute water of higher pollutant loading. This often results in decreased water-treatment efficiency because concentrated waste streams can often be treated more effectively than dilute waste streams. The mine water in these cases may be treated by relatively simple methods; while the volume of waste water treated in the process facility impoundment system will be reduced, this water will be treated with increased efficiency.

There are also locations where the use of mine water as process water has resulted in an improvement in the ultimate effluent. Choice of the options to segregate or combine waste water treatment for mines and process facilities must be made on an individual basis, taking into account the character of the waste water to be treated (at both the mine and the process facility), the water balance in the mine/process facility system, local climate, and topography. The ability of a particular operation to meet zero or reduced effluent levels may be dependent upon this decision at each location.

Regrading

Surface mining may often require removal of large amounts of overburden to expose the ores to be exploited. Regrading involves mass movement of material following ore extraction to achieve a more desirable land configuration. Reasons for regrading strip mined land are:

(1) aesthetic improvement of land surface
(2) returning usefulness to land
(3) providing a suitable base for revegetation
(4) burying pollution-forming materials, e.g. heavy metals
(5) reducing erosion and subsequent sedimentation
(6) eliminating landsliding
(7) encouraging natural drainage
(8) eliminating ponding
(9) eliminating hazards such as high cliffs and deep pits
(10) controlling water pollution

Contour regrading is currently the required reclamation technique for many of the nations's active contour and area surface mines. This technique involves regrading a mine to approximate original land contour. It is generally one of the most favored and aesthetically pleasing regrading techniques because the land is returned to its approximate pre-mined state. This technique is also favored because nearly all spoil is placed back in the pit, eliminating oversteepened downslope spoil banks and reducing the size of erodable reclaimed area. Contour regrading facilitates deep burial of pollution-forming materials and minimizes contact time between regraded spoil and surface runoff, thereby reducing erosion and pollution formation.

However, there are also several disadvantages to contour regrading that must be considered. In area and contour stripping, there may be other forms of reclamation that provide land configurations and slopes better suited to the intended uses of the land. This can be particularly true with steepslope contour strips, where large, high walls and steep final spoil slopes limit application of contour regrading. Mining is, therefore, frequently prohibited in such areas, although there may be other regrading techniques that could be effectively utilized. In addition, where extremely thick ore bodies are mined beneath shallow overburden, there may not be sufficient spoil material remaining to return the land to the original contour.

There are several other reclamation techniques of varying effectiveness which have been utilized in both active and abandoned mines. These techniques include terrace, swale, swallow-tail, and Georgia V-ditch, several of which are quite similar in nature. In employing these techniques, the upper high-wall portion is frequently left exposed or backfilled at a steep angle, with the spoil outslope remaining somewhat steeper than the original contour. In all cases, a terrace of some form remains where the original bench was located, and there are provisions for rapidly channeling runoff from the spoil area. Such terraces may permit more effective utilization of surface-mined land in many cases.

Disposal of excess spoil material is frequently a problem where contour backfilling is not practiced. However, the same problem can also occur, although less commonly, where contour regrading is in use. Some types of overburden rock-particularly, tightly packed sandstones--substantially expand in volume when they are blasted and moved. As a result, there may be a large volume of spoil material that cannot be returned to the pit area, even when contour backfilling is employed. To solve this problem, head-of-hollow fill has been used for overburden storage. The extra overburden is placed in narrow, steep-sided hollows in compacted layers 1.2 to 2.4 meters (4 to 8 feet) thick and graded to control surface drainage.

In this regrading and spoil storage technique, natural ground is cleared of woody vegetation, and rock drains are constructed where natural drains exist, except in areas where inundation has occurred. This permits ground water and natural percolation to leave fill areas without saturating the fill, thereby reducing potential landslide and erosion problems. Normally, the face of the fill is terrace graded to minimize erosion of the steep outslope area.

This technique of fill or spoil material deposition has been limited to relatively narrow, steep-sided ravines that can be adequately filled and graded. Design considerations include the total number of acres in the watershed above a proposed head-of-hollow fill, as well as the drainage, slope stability, and prospective land use. Revegetation usually proceeds as soon as erosion and siltation protection have been completed. This technique is avoided in areas where under-drainage materials contain high concentrations of pollutants, since the resultant drainage would require treatment to meet pollution-control requirements.

Erosion Control

Although regrading is the most essential part of surface-mine reclamation, it cannot be considered a total reclamation technique. There are many other facets of surface-mine reclamation that are equally important in achieving successful reclamation. The effectivenesses of regrading and other control techniques are interdependent. Failure of any phase could severly reduce the effectiveness of an entire reclamation project.

The most important auxiliary reclamation procedures employed at regraded surface mines or refuse areas are water diversion and erosion and runoff control. Water diversion involves collection of water before it enters a mine area and conveyance of that water around the mine site, as discussed previously. This procedure decreases erosion and pollution formation. Ditches are usually excavated upslope from a mine site to collect and convey water. Flumes and pipes are used to carry water down steep slopes or across regraded areas. Riprap and dumped rock are sometimes used to reduce water velocity in the conveyance system.

Diversion and conveyance systems are designed to accommodate predicted water volumes and velocities. If the capacity of a ditch is exceeded, water erodes the sides and renders the ditch ineffective.

Water diversion is also employed as an actual part of the mining procedure. Drainways at the bases of high walls intercept and divert discharging ground water prior to its contact with pollution-forming materials. In some instances, ground water above the mine site is pumped out before it enters the mine area, where it would become polluted and require treatment. Soil erosion is significantly reduced on regraded areas by controlling the course of surface-water runoff, using interception channels constructed on the regraded surface.

Water that reaches a mine site, such as direct rainfall, can cause serious erosion, sedimentation, and pollution problems. Runoff-control techniques are available to effectively deal with this water, but these techniques may conflict with pollution-control measures. Control of chemical pollutants forming at a mine frequently involves reduction of water infiltration, while runoff controls to prevent erosion usually increase infiltration, which can subsequently increase pollutant formation.

There are a large number of techniques in use for controlling runoff, with highly variable costs and degrees of effectiveness. Mulching is sometimes used as a temporary measure which protects the runoff surface from raindrop impacts and reduces the velocity of surface runoff.

Velocity reduction is a critical facet of runoff control. This is accomplished through slope reduction by terracing or grading; revegetation; or use of flow impediments such as dikes, contour plowing, and dumped rock. Surface stabilizers have been utilized on the surface to temporarily reduce erodability of the material itself, but expense has restricted use of such materials in the past.

Revegetation

Establishment of good vegetative cover on a mine area is probably the most effective method of controlling runoff and erosion. A critical factor in mine revegetation is the quality of the soil or spoil material on the surface of a regraded mine. There are several methods by which the nature of this material has been controlled. Topsoil segregation during stripping is mandatory in many states. This permits topsoil to be replaced on a regraded surface prior to revegetation. However, in many forested, steep-sloped areas, there is little or no topsoil on the undisturbed land surface. In such areas, overburden material is segregated in a manner that will allow the most toxic materials to be placed at the base of the regraded mine, and the best spoil material is placed on the mine surface.

Vegetative cover provides effective erosion control; contributes significantly to chemical pollution control; results in aesthetic improvement; and can return land to agricultural, recreational, or silvicultural usefulness. A dense ground cover stabilizes the surface (with its root system), reduces velocity of surface runoff, helps build humus on the surface, and can virtually eliminate erosion. A soil profile begins to form, followed by a complete soil ecosystem. This soil profile acts as an oxygen barrier, reducing the amount of oxygen reaching underlying materials. This, in turn, reduces oxidation, which is a major contributing factor to pollutant formation.

The soil profile also tends to act as a sponge that retains water near the surface, as opposed to the original loose spoil (which allowed rapid infiltration). This water evaporates from the mine surface, cooling it and enhancing vegetative growth. Evaporated water also bypasses toxic materials underlying the soil, decreasing pollution production. The vegetation itself also utilizes large quantities of water in its life processes and transpires it back to the atmosphere, again reducing the amount of water reaching underlying materials.

Establishment of an adequate vegetative cover at a mine site is dependent on a number of related factors. The regraded surface of many spoils cannot support a good vegetative cover without supplemental treatment. The surface texture is often too irregular, requiring the use of raking to remove as much rock as possible and to decrease the average grain size of the remaining material. Materials toxic to plant life, usually buried during regrading, generally do not appear on or near the final graded surface. If the surface is compacted, it is usually loosened by discing, plowing, or roto-tilling prior to seeding in order to enhance plant growth.

Soil supplements are often required to establish a good vegetative cover on surface-mined lands and refuse piles, which are generally deficient in nutrients. Mine spoils are often acidic, and lime must be added to adjust the pH to the tolerance range of the species to be planted. It may be necessary to apply additional neutralizing material to revegetated areas for some time to offset continued pollutant generation.

Several potentially effective soil supplements are currently undergoing research and experimentation. Flyash is a waste product of coal-fired boilers and resembles soil with respect to certain physical and chemical properties. Flyash is often alkaline, contains some plant nutrients, and possesses moisture retaining and soil-conditioning capabilities. Its main function is that of an alkalinity source and a soil conditioner, although it must usually be augmented with lime and fertilizers. However, flyash can vary drastically in quality--particularly, with respect to pH--and may contain leachable materials capable of producing water pollution. Future research, demonstration, and monitoring of flyash supplements will probably develop the potential use of such materials.

Limestone screenings are also an effective long-term neutralizing agent for acidic spoils. Such spoils generally continue to produce acidity as oxidation continues. Use of lime for direct planting upon these surfaces is effective, but it provides only short-term alkalinity. The lime is usually consumed after several years, and the spoil may return to its acidic condition. Limestone screenings are of larger particle size and should continue to produce alkalinity on a decreasing scale for many years, after which a vegetative cover should be well-established. Use of large quantities of limestone should also add alkalinity to receiving streams. These screenings are often cheaper than lime, providing larger quantities of alkalinity for the same cost. Such applications of limestone are currently being demonstrated in several areas.

Use of digested sewage sludge as a soil supplement also has good possibilities for replacing fertilizer and simultaneously alleviating the problem of sludge disposal. Sewage sludge is currently being utilized for revegetation in strip-mined areas of Ohio. Besides supplying various nutrients, sewage sludge can reduce acidity or alkalinity and effectively increase soil absorption and moisture-retention capabilities. Digested sewage sludge can be applied in liquid or dry form and must be incorporated into the spoil surface. Liquid sludge applications require large holding ponds or tank trucks, from which sludge is pumped and sprayed over the ground, allowed to dry, and disced into the underlying material. Dry sludge application requires dryspreading machinery and must be followed by discing.

Limestone, digested sewage sludge, and flyash are all limited by their availabilities and chemical compositions. Unlike commercial fertilizers, the chemical compositions of these materials may vary greatly, depending on how and where they are produced. Therefore, a nearby supply of these supplements may be useless if it does not contain the nutrients or pH adjusters that are deficient in the area of intended application. Flyash, digested sewage sludge, and limestone screenings are all waste products of other processes and are, therefore, usually inexpensive. The major expense related to utilization of any of these wastes is the cost of transporting and applying the material to the mine area. Application may be quite costly and must be uniform to effect complete and even revegetation.

When such large amounts of certain chemical nutrients are utilized, it may also be necessary to institute controls to prevent chemical pollution of adjacent waterways. Nutrient controls may consist of preselection of vegetation to absorb certain chemicals, or of construction of berms and retention basins in which runoff can be collected and sampled, after which it can be discharged or pumped back to the spoil. The specific soil supplements and application rates employed are selected to provide the best possible conditions for the vegetative species that are to be planted.

Careful consideration should be given to species selection in surface-mine reclamation. Species are selected according to some land-use plan, based upon the degree of pollution control to be achieved and the site environment. A dense ground cover of grasses and legumes is generally planted, in addition to tree seedlings, to rapidly check erosion and siltation. Trees are frequently planted in areas of poor slope stability to help control landsliding. Intended future use of the land is an important consideration with respect to species selection. Reclaimed surface-mined lands are occasionally returned to high-use categories, such as agriculture, if the land has potential for growing crops. However, when toxic spoils are encountered, agricultural potential is greatly reduced, and only a few species will grow.

Environmental conditions--particularly, climate--are important in species selection. Usually, species are planted that are native to an area--particularly, species that have been successfully established on nearby mine areas with similar climate and spoil conditions.

Revegetation of arid and semi-arid areas involves special consideration because of the extreme difficulty of establishing vegetation. Lack of rainfall and effects of surface disturbance create hostile growth conditions. Because mining in arid regions has only recently been initiated on a large scale, there is no standard revegetation technology. Experimentation and demonstration projects exploring two general revegetation techniques--moisture retention and irrigation--are currently being conducted to solve this problem.

Moisture retention utilizes entrapment, concentration, and preservation of water within a soil structure to support vegetation. This may be obtained utilizing snow fences, mulches, pits, and other methods.

Irrigation can be achieved by pumping or by gravity, through either pipes or ditches. This technique can be extremely expensive, and acquisition of water rights may present a major problem. Use of these arid-climate revegetation techniques in conjunction with careful overburden segregation and regrading should permit return of arid mined areas to their natural states.

Exploration, Development, and Pilot-Scale Operations

Exploration activities commonly employ drilling, blasting, excavation, tunneling, and other techniques to discover, locate, or define the extent of an ore body. These activities vary from small-scale (such as a single drill hole) to large scale (such as excavation of an open pit or outcrop face). Such activities frequently contribute to the pollutant loading in waste water emanating from the site. Since available facilities (such as power sources) and ready accessibility of special equipment and supplies often are limited, sophisticated treatment is often not possible. In cases where exploration activity is being carried out, the scale of such operations is such that primary water-quality problems involve the presence of increased suspended-solid loads and potentially severe pH changes. Ponds should be provided for settling and retention of waste water, drilling fluids, or runoff from the site. Simple, accurate field tests for pH can be made, with subsequent pH adjustment by addition of lime (or other neutralizing agents).

Protection of receiving waters will thus be accomplished, with the possible additional benefits of removal of metals from solution--either in connection with solids removal or by precipitation from solution.

Development operations frequently are large-scale, compared to exploration activities, because they are intended to extend already known or currently exploited resources. Because these operations are associated with facilities and equipment already in existence, it is necessary to plan development activities to minimize pollution potential, and to use existing mine or process facility treatment and control methods and facilities. These operations should, therefore, be subject to limitations equivalent to existing operations with respect to effluent treatment and control.

Pilot-scale operations often involve small to relatively large mining and beneficiation facilities even though they may not be currently operating at full capacity or are in the process of development to full-scale. Planning of such operations should be undertaken with treatment and control of waste water in mind to ensure that effluent limitation guidelines and standards of performance for the category or subcategory will be met. Although total loadings from such operations and facilites are not at the levels expected from normal operating conditions, the compositions of wastes and the concentrations of waste water parameters are likely to be similar. Therefore, implementation of recommended treatment and control technologies must be accomplished.

Mine and Process Facility Closure

Mine Closure (Underground). Unless well-planned and well-designed abatement techniques are implemented, an underground mine can be a permanent source of water pollution.

Responsibility for the prevention of any adverse environmental impacts from the temporary or permanent closure of a deep mine should rest solely and permanently with the mine operator. This constitutes a substantial burden; therefore, it behooves the operator to make use of the best technology available for dealing with pollution problems associated with mine closure. The two techniques most frequently utilized in deep-mine pollution abatement are treatment and mine sealing. Treatment technology is well defined and is generally capable of producing acceptable mine effluent quality. If the mine operator chooses this course, he is faced with the prospect of costly permanent treatment of each mine discharge.

Mine sealing is an attractive alternative to the prospects of perpetual treatment. Mine sealing requires the mine operator to consider barrier and ceiling-support design from the perspectives of strength, mine safety, their ability to withstand high water pressure, and their utility for retarding groundwater seepage. In the case of new mines, these considerations should be included in the mine design to cover the eventual mine closure. In the case of existing mines, these considerations should be evaluated for existing mine barriers and ceiling supports, and the future mine plan should be adjusted to include these considerations if mine sealing is to be employed at mine closure.

Sealing eliminates the mine discharge and inundates the mine workings, thereby reducing or terminating the production of pollutants. However, the possibility of the failure of mine seals or outcrop barriers increases with time as the sealed mine workings gradually became inundated by ground water and the hydraulic head increases. Depending upon the rate of ground-water influx and the size of the mined area, complete inundation of a sealed mine may require several decades. Consequently, the maximum anticipated hydraulic head on the mine seals may not be realized for that length of time. In addition, seepage through, or failure of, the barrier or mine seal could occur at any time. Therefore, the mine operator should be required to permanently maintain the seals, or to provide treatment in the event of seepage or failure.

Mine Closure (Surface). The objectives of proper reclamation management of closed surface mines and associated workings are to (1) restore the affected lands to a condition at least fully capable of supporting the uses which they were capable of supporting prior to any mining, and (2) achieve a stability which does not pose any threat to public health, safety, or water pollution. With proper planning and management during mining activities, it is often possible to minimize the amount of land disturbed or excavated at any one time. In preparation for the day the operation may cease, a reclamation schedule for restoration of existing affected areas, as well as those which will be affected, should be specified. The use of a planned methodology such as this will return the workings to their premined condition at a faster rate, as well as possibly reduce the ultimate costs to the operator.

To accomplish the objectives of the desired reclamation goals, it is mandatory that the surface-mine operator regrade and revegetate the disturbed area during, or upon completion of, mining. The final regraded surface configuration is dependent upon the ultimate land use of the specific site, and control practices described in this report can be incorporated into the regrading plan to minimize erosion and sedimentation. The operator should establish a diverse and permanent vegetative cover and a plant succession at least equal in extent of cover to the natural vegetation of the area. To assure compliance with these requirements and permanence of vegetative cover, the operator should be held responsible for successful revegetation and effluent water quality for a period of five full years after the last year of augmented seeding. In areas of the country where the annual average precipitation is 64 cm (26 in.) or less, the operator's assumption of responsibility and liability should extend for a period of ten full years after the last year of augmented seeding, fertilization, irrigation, or effluent treatment.

Process Facility Closure. As with closed mines, a beneficiation facility's potential contributions to water pollution do not cease upon shutdown of the facility. Tailing ponds, waste or refuse piles, haulage areas, workings, dumps, storage areas, and processing and shipping areas often present serious problems with respect to contributions to water pollution. Among the most important are tailing ponds, waste piles, and dump areas. Failure of tailing ponds can have catastrophic consequences, with respect to both immediate safety and water quality.

To protect against catastrophic occurrences, tailing ponds should be designed to accommodate, without overflow, an abnormal storm which is observed every 25 years. Since no waste water is contributed from the processing of ores (the facility being closed), the ponds will gradually become dewatered by evaporation or by percolation into the subsurface. The structural integrity of the tailing-pond walls should be periodically examined and, if necessary, repairs made. Seeding and vegetation can assist in stabilizing the walls, prevent erosion and sedimentation, lessen the probability of structural failure, and improve the aesthetics of the area.

Refuse, waste, and tailing piles should be recontoured and revegetated to return the topography as near as possible to the condition it was in before the activity. Techniques employed in surface-mine regrading and revegetation should be utilized. Where process facilities are located adjacent to mine workings, the mines can be refilled with tailings. Care should be taken to minimize disruption of local drainage and to ensure that erosion and sedimentation will not result. Maintenance of such refuse or waste piles and tailing-disposal areas should be performed for at least five years after the last year of regrading and augmented seeding. In areas of the country where the annual average precipitation is 64 cm (26 in.) or less, the operator's assumption of responsibility should extend for a period of ten full years after the last year of augmented seeding, fertilization, irrigation, or effluent treatment.

Monitoring

Since most waste water discharges from these industries contain suspended solids as the principal pollutant, complex water analyses are not usually required. On the other hand, many of these industries today do little or no monitoring on waste water discharges. In order to obtain meaningful knowledge and control of their waste water quality, many mines and minerals processing facilities need to institute routine monitoring measurements of the few pertinent waste parameters.

SUSPENDED SOLIDS REMOVAL

The treatment technologies available for removing suspended solids from minerals and mining waste water are numerous and varied, but a relatively small number are used widely. The following shows the approximate breakdown of usage for the various techniques:

removal technique	percent of treatment facilities using technology
settling ponds (unlined)	95-97
settling ponds (lined)	<1
chemical flocculation (usually with ponds)	2-5
thickeners and clarifiers	1-2
hydrocyclones	<1
tube and lamella settlers	<1
screens	<1
filters	<1
centrifuges	<1

Settling Ponds

As shown above, the predominant treatment technique for removal of suspended solids involves one or more settling ponds. Settling ponds are versatile in that they perform several waste-oriented functions including:

(1) Solids removal. Solids settle to the bottom and the clear water overflow is much reduced in suspended solids content.

(2) Equalization and water storage capacity. The clear supernatant water layer serves as a reservoir for reuse or for controlled discharge.

(3) Solid waste storage. The settled solids are provided with long term storage.

This versatility, ease of construction and relatively low cost, explains the wide application of settling ponds as compared to other technologies. The performance of these ponds depends primarily on the settling characteristics of the solids suspended, the flow rate through the pond and the pond size. Settling ponds can be used over a wide range of suspended solids levels. Often a series of ponds is used, with the first collecting the heavy load of easily settleable material and the following ones providing final polishing to reach a desired final suspended level. As the ponds fill with settled solids they can be either dredged to remove these solids or left filled and new ponds constructed. The choice often depends on whether land for additional new ponds is available. When suspended solids levels are low and ponds large, settled solids build up so slowly that neither dredging nor pond abandonment is necessary, at least not for a period of many years.

Settling ponds used in the minerals industry run the gamut from small pits, natural depressions and swamp areas to engineered thousand acre structures with massive retaining dams and legislated construction design. The performance of these ponds varies from excellent to poor, depending on character of the suspended particles, and pond size and configuration. In general the suspended solids levels from the final pond can be reduced to 10 to 30 mg/l. Waste waters containing significant amounts of hydrophilic colloids, such as montmorillonite, are especially difficult to clarify.

Much of the poor performance exhibited by the settling ponds employed by the minerals industry is due to the lack of understating of settling techniques. This is demonstrated by the construction of ponds without prior determination of settling rate and detention time. In some cases series of ponds have been claimed to demonstrate a company's mindfullness of environmental control when in fact all the component ponds are so poorly constructed and maintained that they could be replaced by one pond with less surface area than the total of the series.

The chief problems experienced by settling ponds are rapid fill-up, insufficient retention time and the closely related short ciruciting. The first can be avoided by constructing a series of ponds as mentioned above. Frequent dredging of the first if needed will reduce the need to dredge the remaining ponds. The solution to the second involves additional pond volume or use of flocculants. The third problem, however, is almost always overlooked. Short circuiting is simply the formation of currents or water channels from pond influent to effluent whereby whole areas of the pond are not utilized. The principles of clarifier construction apply here. The object is to achieve a uniform plug flow from pond influent to effluent. This can be achieved by proper inlet-outlet construction that forces water to be uniformly distributed at those points, such as a weir. Frequent dreding or insertion of baffles will also minimize channelling. The EPA report "Waste water Treatment Studies in Aggregate and Concrete Production" (reference 25) in detail lists the procedure one should follow in designing and building settling ponds.

Clarifiers and Thickeners

An alternative method of removing suspended solids is the use of clarifiers or thickeners which are essentially tanks with internal baffles, compartments, sweeps and other directing and segregating mechanisms to provide efficient concentration and removal of suspended solids in one effluent stream and clarified liquid in the other.

Clarifiers differ from thickeners primarily in their basic purpose. Clarifiers are used when the main purpose is to produce a clear overflow with the solids content of the sludge underflow being of secondary importance. Thickeners, on the other hand, have the basic purpose of producing a high solids underflow with the character of the clarified overflow being of secondary importance. Thickeners are also usually smaller in size but more massively constructed for a given throughput. Clarifiers and thickeners have a number of distinct advantages over ponds:

(1) Less land space is required. Area-for-area these devices are much more efficient in settling capacity than ponds .

(2) Influences of rainfall are much less than for ponds. If desired the clarifiers and thickeners can even be covered.

(3) Since the external construction of clarifiers and thickeners consists of concrete or steel tanks ground seepage and rain water runoff influences do not exist.

On the other hand, clarifiers and thickeners suffer some distinct disadvantages as compared with ponds:

(1) They have more mechanical parts and maintenance.

(2) They have only limited storage capacity for either clarified water or settled solids.

(3) The internal sweeps and agitators in thickeners and clarifiers require more power and energy for operation than ponds.

Clarifiers and thickeners are usually used when sufficient land for ponds is not available or is very expensive.

Hydrocyclones

While hydrocyclones are widely used in the separation, classification and recovery operations involved in minerals processing, they are used only infrequently for waste water treatment. Even the smallest diameter units available (stream velocity and centrifugal separation forces both increase as the diameter decreases) are ineffective when particle size is less than 25-50 microns. Larger particle sizes are relatively easy to settle by means of small ponds, thickeners or clarifiers or other gravity principle settling devices. It is the smaller suspended particles that are the most difficult to remove and it is these that can not be removed by hydrocyclones but may be handled by ponds or other settling technology. Also hydrocyclones are of doubtful effectiveness when flocculating agents are used to increase settling rates.

Hydrocyclones are used as scalping units to recover small sand or other mineral particles in the 25 to 200 micron range, particularly if the recovered material can be sold as product. In this regard hydrocyclones may be considered as converting part of the waste load to useful product as well as providing the first step of waste water treatment. Where land availability is a problem a bank of hydrocyclones may serve in place of a primary settling pond.

Tube and Lamella Settlers

Tube and lamella settlers require less land area than clarifiers and thickeners. These compact units, which increase gravity settling efficiency by means of closely packed inclined tubes and plates, can be used for either scalping or waste water polishing operations depending on throughput and design.

Centrifuges

Centrifuges are not widely used for minerals mining waste water treatment. Present industrial-type centrifuges are relatively expensive and not particularly suited for this purpose. Future use of centrifuges will depend on regulations, land space availability and the development of specialized units suitable for minerals mining operations.

Flocculation

Flocculating agents increase the efficiency of settling facilities and they are of two general types: ionic and polymeric. The ionic types such as alum, ferrous sulfate and ferric chloride function by neutralizing the repelling double layer ionic charges around the suspended particles and thereby allowing the particles to attract each other and agglomerate. Polymeric types function by forming physical bridges from one particle to another and thereby agglomerating the particles. Flocculating agents are most commonly used after the larger, more readily settled, particles (and loads) have been removed by a settling pond, hydrocyclone or other such scalping treatment. Agglomeration, or flocculation, can then be achieved with less reagent and less settling load on the polishing pond or clarifier.

Flocculation agents can be used with minor modifications and additions to existing treatment systems, but the costs for the flocculating chemicals are often significant. Ionic types are used in 10 to 100 mg/l concentrations in the waste water while the higher priced polymeric types are effective in the 2 to 20 mg/l concentrations. Flocculants have been used by several segments within the minerals industry with varying degrees of success. The use of flocculants particularly for the hard to settle solids is more of an art than a science, since it is frequently necessary to try several flocculants at varying concentrations.

Screens

Screens are widely used in minerals and mining processing operations for separations, classifications and beneficiations. They are similar to hydrocyclones in that they are restricted to removing the larger (<50-100 micron) particle size suspended solids of the waste water, which can then often be sold as useful product. Screens are not practical for removing the smaller suspended particles.

Filtration

Filtration is accomplished by passing the waste water stream through solids-retaining screens, cloths, or particulates such as sand, gravel, coal or diatomaceous earth using gravity, pressure or vacuum as the driving force. Filtration is versatile in that it can be used to remove a wide range of suspended particle sizes. The large volumes of many waste water streams found in minerals mining operations require large filters. The cost of these units and their relative complexity, compared to settling ponds, has restricted their use to a few industry segments committed to complex waste water treatment.

DISSOLVED MATERIAL TREATMENTS

Dissolved materials are a problem only in scattered instances in the industries covered herein. Treatments for dissolved materials are based on either modifying or removing the undesired materials. Modification techniques include chemical treatments such as neutralization and oxidation-reduction reactions. Acids, alkaline materials, sulfides and other toxic or hazardous materials are examples of dissolved materials modified in this way. Most removal of dissolved solids is accomplished by chemical precipitation. Techniques such as ion exchange, carbon adsorption, reverse osmosis and evaporation are rarely used in the minerals mining industry. Chemical treatments for abatement of water-borne wastes are common. Included in this overall category are neutralization, pH control, oxidation-reduction reactions, coagulations, and precipitations.

Neutralization

Some of the waste waters of this study, often including mine drainage water, are either acidic or alkaline. Before disposal to surface water or other medium excess acidity or alkalinity needs to be controlled to the range of pH 6 to 9. The most common method is to treat acidic streams with alkaline materials such as limestone, lime, soda ash, or sodium hydroxide. Alkaline streams are treated with acids such as sulfuric. Whenever possible, advantage is taken of the availability of acidic waste streams to neutralize basic waste streams and vice versa. Neutralization often produces suspended solids which must be removed prior to waste water disposal.

pH Control

The control of pH may be equivalent to neutralization if the control point is at or close to pH 7. Sometimes chemical addition to waste streams is designed to maintain a pH level on either the acidic or basic side for purposes of controlling solubility. Examples of pH control being used for precipitating undesired pollutants are:

(1) $Fe^{+3} + 3OH^- = Fe(OH)_3$

(2) $Mn^{+2} + 2OH^- = Mn(OH)_2 = MnO_2 + 2H^+ + 4e^-$

(3) $Zn^{+2} + 2OH^- = Zn(OH)_2$

(4) $Pb^{+2} + 2(OH)^- = Pb(OH)2$

(5) $Cu + 2OH^- = Cu(OH)_2$.

Reaction (1) is used for removal of iron contaminants. Reaction (2) is used for removing manganese from manganese-containing water-borne wastes. Reactions (3), (4), and (5) are used on waste water containing copper, lead, and zinc salts.

Oxidation-Reduction Reactions

The modification or destruction of many hazardous wastes is accomplished by chemical oxidation or reduction reactions. Hexavalent chromium is reduced to the less hazardous trivalent form with sulfur dioxide or bisulfites. Sulfides, with large COD values, can be oxidized with air to relatively innocuous sulfates. These examples and many others are basic to the modification of inorganic chemical water-borne wastes to make them less troublesome. In general waste materials requiring oxidation-reduction treatments are not encountered in these industries.

Precipitations

The reaction of two soluble chemicals to produce insoluble or precipitated products is the basis for removing many undesired water-borne wastes. The use of this technique varies from lime treatments to precipitate sulfates, fluorides, hydroxides and carbonates to sodium sulfide precipitations of copper, lead and other toxic heavy metals. Precipitation reactions are particularly responsible for heavy suspended solids loads. These suspended solids are removed by settling ponds, clarifiers and thickeners, filters, and centrifuges.

The following are examples of precipitation reactions used for waste water treatment:

(1) $SO_4^{=} + Ca(OH)_2 = CaSO_4 + 2OH^-$

(2) $2F^- + Ca(OH)_2 = CaF_2 + 2OH^-$

(3) $Zn^{++} + Na_2CO_3 = ZnCO_3 + Na^+$

SUMMARY OF TREATMENT TECHNOLOGY APPLICATIONS, LIMITATIONS AND RELIABILITY

Table 6 summarizes comments on the various treatment technologies as they are utilized for the minerals and mining industry. Estimates of the efficiency with which the treatments remove suspended or dissolved solids from waste water, given in Table 6 need to be interpreted in the following context. These values will obviously not be valid for all circumstances, concentrations or materials, but they should provide a general guideline for treatment performance capabilities. Several comments may be made concerning the values:

(1) At high concentrations and optimum conditions, all treatments can achieve 99 percent or better removal of the desired material;

(2) At low concentrations, the removal efficiency drops off.

(3) Minimum concentration ranges achievable will not hold in every case. For example, pond settling of some suspended solids might not achieve less than the 100 mg/l level. This is not typical, however, since many such pond settling treatments can achieve 10 to 20 mg/l without difficulty. Failure to achieve the minimum concentration levels listed usually means that either the wrong treatment methods have been selected or that an additional treatment step is necessary (such as a second pond or filtration).

PRETREATMENT TECHNOLOGY

Mineral mining operations are usually conducted in relatively isolated regions where there is no access to publicly-owned activated sludge or trickling filter waste water treatment facilities. In areas where publicly-owned facilities could be used, pretreatment would often be required to reduce the heavy suspended solids load. In the relatively few instances where dissolved materials are serious, pH control and some reduction of hazardous constituents such as fluorides and heavy metals would be

Table 6. Summary of Technology, Applications, Limitations & Reliability

Waste Water Constituents	Treatment Process	Application	Percent Solids Removal	Expected Concentration (mg/l)	Minimum Concentration Achievable (mg/l)	Availability of Equipment	Lead Time (months)	Space or Land Needed	Maintenance Required	Sensitivity to Shock Loads	Effects of Shutdown and Startup	Energy Requirements
Suspended Solids	(1) Pond Settling	Used for all concentrations	60-99	5-200	5-30	none needed	1-12	large 1-500 acres small 0.05-1.0 acres	small	small	small	small
	(2) Clarifier Thickeners	Used for all concentrations	60-99	5-1000	5-30	readily available	3-24	<1 acre	nominal	sensitive	nominal	nominal
	(3) Hydro-cyclones	Removal of larger particle sizes	50-99	—	—	ready available	3-12	approx. 10' x 10'	small	sensitive	small	small
	(4) Tube and Lamella Settlers	Removal of smaller particle sizes	90-99	—	—	readily available	3-12	approx. 10' x 10'	small	sensitive	nominal	small
	(5) Screens	Removal of larger particle sizes	50-99	—	—	ready available	3-12	approx. 10' x 10'	nominal	small	small	small
	(6) Rotary Vacuum Filters	Mainly for sludges and other high suspended solids streams	90-99	5-1000	5-30	readily available	3-12	approx. 10' x 10'	nominal	sensitive	nominal	nominal
	(7) Solid Bowl Centrifuge	Mainly for sludges and other high suspended solids streams	60-99	—	—	readily available	3-12	approx. 10' x 10'	nominal	sensitive	small	nominal
	(8) Leaf and Pressure Filters	Used over wide concentration range	90-99	10-100	5-30	readily available	3-6	approx. 10' x 10'	small	sensitive	small	small
	(9) Cartridge and Candle Filters	Mainly for polishing filtrations of suspended solids	50-99	2-10	2-10	readily available	1-3	approx. 10' x 10'	small	sensitive	small	small
	(10) Sand and Mixed Media Filters	Mainly for polishing filtrations of suspended solids	50-99	2-50	2-10	readily available	3-6	approx. 10' x 10'	small	sensitive	small	small
Dissolved Solids	(1) Neutralization and pH Control	General	99	NA	NA	readily available	3-12	small 20' x 20' or less	minor	nominal	small	small
	(2) Precipitation	Broadly used to remove solubles	50-99	0-20	0-10	readily available	3-6	small 20' x 20'	minor	sensitive	small	small

required. Lime treatment will usually be sufficient for reductions of both categories.

NON-WATER QUALITY ENVIRONMENTAL ASPECTS, INCLUDING ENERGY REQUIREMENTS

The effects of these treatment and control technologies on air pollution, noise pollution, and radiation are usually small and not of any significance. Large amounts of solid waste in the form of both solids and sludges are formed as a result of all suspended solids operations as well as chemical treatments for neutralization, and precipitations. Easy-to-handle, relatively dry solids are usually left in settling ponds or dredged out periodically and dumped onto the land. Since mineral mining properties are usually large, space for such dumping is often available. Sludges and difficultly settled solids are most often left in the settling pond, but may in some instances be landfilled.

For those waste materials considered to be non-hazardous where land disposal is the choice for disposal, practices similar to proper sanitary landfill technology may be followed. The principles set forth in the EPA's Land Disposal of Solid Wastes Guidelines (CFR Title 40, Chapter 1; Part 241) may be used as guidance for acceptable land disposal techniques.

For those waste materials considered to be hazardous, disposal will require special precautions. In order to ensure long-term protection of public health and the environment, special preparation and pretreatment may be required prior to disposal. If land disposal is to be practiced, these sites must not allow movement of pollutants such as fluoride and radium-226 to either ground or surface water. Sites should be selected that have natural soil and geological conditions to prevent such contamination or, if such conditions do not exist, artificial means (e.g., liners) must be provided to ensure long-term protection of the environment from hazardous materials. Where appropriate, the location of solid hazardous materials disposal sites should be permanently recorded in the appropriate office of the legal jurisdiction in which the site is located. In summary, the solid wastes and sludges from the mineral mining industry waste water treatments are very large in quantity, but the industry, having sufficient space and earth-moving capabilities, manages it with greater ease than could most other industries.

For the best practicable control technology currently available the added annual energy requirements are estimated at 1.6×10^8 kcal. This would increase the present energy use for pollution control in this industry by less than one percent.

SECTION VIII

COST, ENERGY, WASTE REDUCTION BENEFITS AND NON-WATER ASPECTS OF TREATMENT AND CONTROL TECHNOLOGIES

SUMMARY

The clay, ceramic, refractory and miscellaneous minerals segment of the mineral mining and processing industry is characterized by individuality of facilities. Unlike manufacturing operations, where raw materials for the process may be selected and controlled as to purity and uniformity, mining and minerals processing operations are themselves largely controlled by the purity and uniformity of the ores or raw materials involved. Operations have to be located, at or near the mineral deposits. This lack of control over raw material quality and location, coupled with the fact that both mines and ore beneficiation processes may have waste water effluents, leads to several basic treatment costing differences from those for manufacturing operations:

(1) In order to achieve reasonable homogeneity, industries have to be segregated into subcategories such as wet mines, dry mines, dry processes and one or more wet processes.

(2) Solid waste loads vary widely depending on ore composition.

(3) Types of water-borne waste vary with ore and process. Processes are modified according to ore composition.

(4) Treatment costs often vary widely depending on character of pollutants involved. The most widespread example is particle size and composition variation of suspended solids. Deposits with large particle sized wastes have high settling rates while small or colloidal suspended particles are slow and difficult to settle, requiring large ponds, thickeners, flocculating treatments, other devices for removing suspended solids in many cases.

In general, facility size and age have little influence on the type of waste effluent. The amounts and costs for their treatment and disposal are readily scaled from facility size and are not greatly affected by facility age.

Geographical location is important. Mines and processing facilities located in dry western areas rarely require major waste water treatment or have subsequent disposal problems.

Terrain and land availability are also significant factors affecting treatment technology and costs. Lack of sufficient flat space for settling ponds often forces utilization of mechanical thickeners, clarifiers, or settlers. On the other hand, advantage is often taken of valleys, hills, swamps, gullies and other natural configurations to provide low cost pond and solid waste disposal facilities.

In view of the large number of mines and beneficiation facilities and the significant variables listed above, costs have been developed for representative mines and processing facilities rather than specific exemplary facilities that may have advantageous geographical, terrain or ore composition.

A summary of cost and energy information for the present level of waste water treatment technology for this segment is given in Table 7. Present capital investment for waste water treatment in the clay, ceramic, refractory and miscellaneous minerals segment is estimated at $7,500,000.

COST REFERENCES AND RATIONALE

Cost information contained in this report was assembled directly from industry, from waste treatment and disposal contractors, engineering firms, equipment suppliers, government sources, and published literature. Whenever possible, costs are taken from actual installations, engineering estimates for projected facilities as supplied by contributing companies, or from waste treatment and disposal contractors quoted prices. In the absence of such information, cost estimates have been developed insofar as possible from facility-supplied costs for similar waste treatments and disposal for other facilities or industries.

Interest Costs and Equity Financing Charges

Capital investment estimates for this study have been based on 10 percent cost of capital, representing a composite number for interest paid or return on investment required.

Time Basis for Costs

All cost estimates are based on August 1972 prices and when necessary have been adjusted to this basis using the chemical engineering facility cost index.

TABLE 7

CAPITAL INVESTMENTS AND ENERGY CONSUMPTION OF PRESENT WASTEWATER TREATMENT FACILITIES

Subcategory	Capital Spent Dollars	Present Energy Use - Kcal x 10^6	Total Annual Costs -$/kkg Produced
Bentonite		No Waste Water	
Fire Clay		No Waste Water	
Attapulgite) Montmorillonite)	$ 330,000	180	0.22
Kaolin (dry process)		No Waste Water	
Kaolin (wet process)	2,670,000	6,875	0.29
Ball Clay	335,000	825	0.26
Feldspar (dry process)		No Waste Water	
Feldspar (flotation)	1,000,000	4,950	1.65
Kyanite	375,000	830	2.83
Magnesite	300,000	small	0.19
Shale		No Waste Water	
Aplite	695,000	2,230	0.69
Talc minerals (dry)		No Waste Water	
Talc minerals (wet washing)	335,000	1,670	1.09
Talc minerals (heavy media flotation)	450,000	2,500	1.09
Abrasives, Garnet	370,000	1,250	5.88
Abrasives, Tripoli		No Waste Water (except one scrubber)	
Diatomite	500,000	small	0.27
Graphite	<100,000	small	$20-25
Jade	1,000	negligible	negligible
Novaculite	negligible	negligible	negligible
TOTAL	7,500,000	21,300	---

Useful Service Life

The useful service life of treatment and disposal equipment varies depending on the nature of the equipment and process involved, its usage pattern, maintenance care and numerous other factors. Individual companies may apply service lives based on their actual experience for internal amortization. Internal Revenue Service provides guidelines for tax purposes which are intended to approximate average experience. Based on discussions with industry and condensed IRS guideline information, the following useful service life values have been used:

(1)	General process equipment	10 years
(2)	Ponds, lined and unlined	20 years
(3)	Trucks, bulldozers, loaders and other such materials handling and transporting equipment.	5 years

Depreciation

The economic value of treatment and disposal equipment and facilities decreases over its service life. At the end of the useful life, it is usually assumed that the salvage or recovery value becomes zero. For IRS tax purposes or internal depreciation provisions, straight line, or accelerated write-off schedules may be used. Straight line depreciation was used solely in this report.

Capital Costs

Capital costs are defined as all front-end out-of-pocket expenditures for providing treatment/disposal facilities. These costs include costs for research and development necessary to establish the process, land costs when applicable, equipment, construction and installation, buildings, services, engineering, special start-up costs and contractor profits and contingencies.

Annual Capital Costs

Most if not all of the capital costs are accrued during the year or two prior to actual use of the facility. This present worth sum can be converted to equivalent uniform annual disbursements by utilizing the Capital Recovery Factor Method:

Uniform Annual Disbursement = $P \frac{i\ (1+i)^{n}}{(1+i)^{n} - 1}$

Where P = present value (capital expenditure), i = interest rate, %/100, n = useful life in years

The capital recovery factor equation above may be rewritten as:

Uniform Annual Disbursement = P(CR - i% - n)

Where (CR - i% - n) is the Capital Recovery Factor for i% interest taken over "n" years useful life.

Land Costs

Land-destined solid wastes require removal of land from other economic use. The amount of land so tied up will depend on the treatment/disposal method employed and the amount of wastes involved. Although land is non-depreciable according to IRS regulations, there are numerous instances where the market value of the land for land-destined wastes has been significantly reduced permanently, or actually becomes unsuitable for future use due to the nature of the stored waste. The general criteria applied to costing land are as follows:

(1) If land requirements for on-site treatment/disposal are not significant, no cost allowance is applied.
(2) Where on-site land requirements are significant and the storage or disposal of wastes does not affect the ultimate market value of the land, cost estimates include only interest on invested money.
(3) For significant on-site land requirements where the ultimate market value and/or availability of the land has been seriously reduced, cost estimates include both capital depreciation and interest on invested money.
(4) Off-site treatment/disposal land requirements and costs are not considered directly. It is assumed that land costs are included in the overall contractor's fees along with its other expenses and profit.
(5) In view of the extreme variability of land costs, adjustments have been made for individual industry situations. In general, isolated, plentiful land has been costed at $2,470/hectare ($1,000/acre).

Operating Expenses

Annual costs of operating the treatment/disposal facilities include labor, supervision, materials, maintenance, taxes, insurance and power and energy. Operating costs combined with annualized capital costs give the total costs for treatment and disposal operations. No interest cost was included for operating (working) capital. Since working capital might be assumed to be one sixth to one third of annual operating costs (excluding depreciation), about 1-2 percent of total operating costs might be involved. This is considered to be well within the accuracy of the estimates.

Rationale for Representative Facilities

All facility costs are estimated for representative facilities rather than for any actual facility. Representative facilities are defined to have a size and age agreed upon by a substantial fraction of the manufacturers in the subcategory producing the given mineral, or, in the absence of such a consensus, the arithmetic average of production size and age for all facilities. Location is selected to represent the industry as closely as possibly. For instance, if all facilities are in northeastern U.S., typical location is noted as "northeastern states". If locations are widely scattered around the U.S., typical location would be not specified geographically. If two facilities exist, one on the west coast and one on the east cost, typical location would be "1 east coast - 1 west coast". It should be noted that the unit costs to treat and dispose of hazardous wastes at any given facility may be considerably higher or lower than the representative facility because of individual circumstances.

Definition of Levels of Treatment and Control

Costs are developed for various types and levels of technology:

Minimum (or basic level) is that level of technology which is equalled or exceeded by most or all of the involved facilities. Usually money for this treatment level has already been spent (in the case of capital investment) or is being spent (in the case of operating and overall costs).

B,C,D,E---Levels are successively greater degrees of treatment with respect to critical pollutant parameters. Two or more alternative treatments are developed when applicable.

Rationale for Pollutant Considerations

(1) All non-contact cooling water is exempted from treatment (and treatment costs) provided that it is not contaminated by process water and no harmful pollutants are introduced.

(2) Water treatment, cooling tower and boiler blowdown discharges are not treated provided they are not contaminated by process water and contain no harmful pollutants.
(3) Removal of dissolved solids, other than harmful pollutants, is not included because of high cost factors.
(4) Mine drainage treatments and costs are considered separately from process water treatment and costs. Mine drainage costs are estimated for all mineral categories for which such costs are a significant factor.
(5) All solid waste disposal costs are included as part of the cost development.

Cost Variances

The effects of age, location, and size on costs for treatment and control have been considered and are detailed in subsequent sections for each specific subcategory.

INDUSTRY STATISTICS

Following are summarized the estimated 1972 selling prices for the individual minerals covered in this report. These values were taken from minerals industry yearbooks and Bureau of Census publications.

	$/kkg	lb/ton
Bentonite	11.70	10.60
Fire Clay	9.00	8.15
Fuller's Earth	25.50	23.00
Kaolin	28.40	25.75
Ball Clay	17.65	16.00
Feldspar	22-28	24-31
Kyanite	70.50	64.00
Magnesite	165	150
Shale & Misc. Clay	1.76	1.60
Aplite	not known	
Talc Minerals	34	31
Abrasives, Garnet	114	103
Abrasives, Tripoli	10	9
Diatomite	72	65
Graphite	withheld	
Jade	22,000 after cutting	20,000
Novaculite	66	60

INDIVIDUAL WASTE WATER TREATMENT COSTS

BENTONITE

There is no waste water from the processing of bentonite. Therefore, there is no treatment cost involved.

FIRE CLAY

The only waste water from mining and processing of fire clay is mine water discharge. Treatment costs for settling suspended solids in mine water are estimated at \$0.01-0.05/kkg of produced fire clay. Since there is no process water discharge in the production of fire clay, there are no costs for process waste water treatment.

FULLER'S EARTH

Fuller's earth was divided into two subcategories - attapulgite and montmorillonite. Suspended solids in attapulgite mine drainage and process water generally settle rapidly. Suspended solids in montmorillonite mine drainage and process water are more difficult to settle.

Estimates of treatment costs for mine water, including use of flocculating agents to settle montmorillonite wastes, range from \$0.17 to \$0.28/kkg of montmorillonite produced, see Table 10.

Process and air scrubber waste water treatment costs are summarized in Tables 8 and 9.

Cost Variance

Age
In the montmorillonite subcategory, there are three facilities ranging in age from 3 to 18 years. Age is not a significant factor in cost variance.

There are four facilities representing the attapulgite subcategory ranging in age from 20 to 90 years. Age is not a significant factor in cost variance.

Location
All the facilities in the montmorillonite subcategory are located in Georgia and, thus, location is not a significant factor in cost variance.

The attapulgite facilities are located in Georgia and Florida, in close proximity and therefore, location is not a significant factor in cost variance.

TABLE 8

COST FOR A REPRESENTATIVE PLANT

(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY Attapulgite (Process Water Only)

PLANT SIZE 200,000 METRIC TONS PER YEAR OF Attapulgite

PLANT AGE 60 YEARS PLANT LOCATION Georgia-North Florida Region

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS:						
TOTAL		71,000	77,000	95,000		
ANNUAL CAPITAL RECOVERY		8,400	9,300	11,100		
OPERATING AND MAINTENANCE COSTS:						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		37,400	39,800	39,100		
ANNUAL ENERGY AND POWER		200	200	300		
TOTAL ANNUAL COSTS		46,000	49,300	50,500		
COST/METRIC TON Attapulgite		0.21	0.22	0.23		
WASTE LOAD PARAMETERS (kg/metric ton of ______)	RAW WASTE LOAD					
TSS		0.01-0.02	0.01	0		
pH		6-9	6-9	-		

LEVEL DESCRIPTION:

A — pond settling

B — A plus flocculating agents

C — B plus recycle to process

TABLE 9

COST FOR A REPRESENTATIVE PLANT

(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY Montmorillonite (Process Water Only)

PLANT SIZE 182,000 METRIC TONS PER YEAR OF Montmorillonite

PLANT AGE 10 YEARS PLANT LOCATION Georgia

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS:						
TOTAL		60,000	65,000	80,000		
ANNUAL CAPITAL RECOVERY		7,000	7,900	9,400		
OPERATING AND MAINTENANCE COSTS:						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		30,900	32,900	32,300		
ANNUAL ENERGY AND POWER		200	200	300		
TOTAL ANNUAL COSTS		38,100	41,000	43,000		
COST/METRIC TON Montomorillonite		0.21	0.22	0.24		
WASTE LOAD PARAMETERS (kg/metric ton of montmorillonite)	RAW WASTE LOAD					
TSS		0.3	0.05	0		
pH		6-9	6-9	-		

LEVEL DESCRIPTION:

A — pond settling of scrubber water
B — A plus flocculating agents
C — B plus recycle to process

TABLE 10

COST FOR A REPRESENTATIVE PLANT

(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY Montmorillonite (Mine Water Only)

PLANT SIZE 182,000 METRIC TONS PER YEAR OF Montmorillonite

PLANT AGE 10 YEARS PLANT LOCATION Georgia

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS:						
TOTAL		0	60,000	62,000		
ANNUAL CAPITAL RECOVERY		0	15,800	16,300		
OPERATING AND MAINTENANCE COSTS:						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		0	12,300	32,300		
ANNUAL ENERGY AND POWER		0	3,000	3,000		
TOTAL ANNUAL COSTS		0	32,300	51,800		
COST/METRIC TON Montmorillonite		0	0.17	0.28		
WASTE LOAD PARAMETERS (kg/metric ton of ______)	RAW WASTE LOAD					
TSS, mg/liter		200—5,000	200—2,000	<50		

LEVEL DESCRIPTION:

A — no treatment

B — pond settling

C — B plus flocculating agents

Size

The facilities in the montmorillonite subcategory range from 13,600 to 207,000 kg/yr (15,000-228,000 ton/yr). The representative facility is 182,000 kkg/yr (200,000 ton/yr).

The attapulgite facilities range from 21,800 kkg/yr (24,000 ton/yr) and 227,000 kkg/yr (250,000 ton/yr). The representative facility is 200,000 kkg/yr (220,000 ton/yr).

In both these subcategories the cost variance with size is estimated to be a 0.9 exponential function for capital and its related annual costs, and directly proportional for operating costs other than taxes, insurance and capital recovery.

Cost Basis for Table 8.

Capital Costs

- Pond cost, $/hectare ($/acre): 24,700 (10,000)
- Mine pumpout settling pond area, hectares (acres):0.1 (0.25)
- Process Settling pond area, hectares (acres):2 (5)
- Pumps and pipes: $10,000

Operating and Maintenance Costs

- Energy unit cost: $0.01/kwh
- Labor rate assumed: $10,000/yr

Cost Basis for Table 9.

Capital Costs

- Pond cost, $/hectare ($/acre):24,700 (10,000)
- Mine pumpout settling pond hectares (acres):0.1 (0.25)
- Process settling pond area, hectares (acres):2 (5)
- Pumps and pipes: $10,000

Operating and Maintenance Costs

- Treatment chemicals
    - Flocculating agent: $1.50/kg ($0.70/lb)
- Energy unit cost: $0.01/kwh
- Labor rate assumed: $10,000/yr

KAOLIN AND BALL CLAY

Kaolin and ball clay mining and processing operations differ widely as to their waste water effluents. All treatments involve settling ponds for their basic technology. Dry mines need no treatment or treatment expenditures. Wet mines (from rain water and ground seepage) use settling ponds to reduce suspended solids. These settling ponds are small and cost an estimated $0.01-$0.06/kkg of clay product.

Processing facilities may be either wet or dry. Dry facilities have no treatment or treatment costs. Wet processing facilities have process waste water from two primary sources: scrubber water from air pollution facilities, and process water that may contain zinc compound from a product bleaching operation.

Scrubber and process water need to be treated to reduce suspended solids and zinc compounds. Costs for reduction are summarized in Tables 11 and 12 for wet process kaolin and ball clay, respectively.

Cost Variance

Age
The kaolin wet process subcategory consists of two facilities having ages of 29 and 37 years. Age is not a cost variance factor.

The ball clay subcategory has a range of facility ages from 15 to 56 years. Age has not been found to be a significant factor on costs.

Location
The wet process kaolin operations are only located in Georgia, hence not a variance.

Ball clay operations are located in the Kentucky-Tennessee rural areas and hence location is not a significant cost variance factor.

Size
The two wet process kaolin facilities are 300,000 and 600,000 kkg/yr (330,000 and 650,000 ton/yr) size. The representative facility is 450,000 kkg/yr (500,000 ton/yr). Capital costs over this size range are estimated to be a 0.9 exponential function of size, and operating costs other than taxes, insurance, and capital recovery are estimated to be proportional to size.

TABLE 11

COST FOR A REPRESENTATIVE PLANT

(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY Wet Process Kaolin

PLANT SIZE 450,000 METRIC TONS PER YEAR OF Kaolin

PLANT AGE 30 YEARS PLANT LOCATION Georgia-South Carolina

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS:						
TOTAL		447,000	463,000	487,000		
ANNUAL CAPITAL RECOVERY		49,200	51,800	55,600		
OPERATING AND MAINTENANCE COSTS:						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		85,000	112,000	90,000		
ANNUAL ENERGY AND POWER		5,000	5,000	5,000		
TOTAL ANNUAL COSTS		139,200	168,800	152,200		
COST/METRIC TON of Kaolin		0.31	0.38	0.34		
WASTE LOAD PARAMETERS (kg/metric ton of Kaolin)	RAW WASTE LOAD					
TSS	35-100	0.02-0.2	<0.1	0		
Dissolved zinc	0.4	0.001	0.001	0		
pH		6-9	6-9	--		

LEVEL DESCRIPTION:

A — pond settling with lime treatment

B — A plus flocculating agents

C — pond settling and recycle to process (This should be satisfactory for cases where only cooling water and scrubber water are present. Process water will build up dissolved solids, requiring a purge.)

TABLE 12

COST FOR A REPRESENTATIVE PLANT

(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY Ball Clay

PLANT SIZE 75,000 METRIC TONS PER YEAR OF Ball Clay

PLANT AGE 30 YEARS PLANT LOCATION Kentucky-Tennessee Region

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS:						
TOTAL		89,000	92,000	97,000		
ANNUAL CAPITAL RECOVERY		9,800	10,300	11,100		
OPERATING AND MAINTENANCE COSTS:						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		14,000	19,000	15,000		
ANNUAL ENERGY AND POWER		800	800	1,100		
TOTAL ANNUAL COSTS		24,600	30,100	27,200		
COST/METRIC TON of Ball Clay		0.33	0.40	0.36		
WASTE LOAD PARAMETERS (kg/metric ton of ball clay)	RAW WASTE LOAD					
TSS		0.4-2.0	0.2	0		
pH		6-9	6-9	-		

LEVEL DESCRIPTION:

A — pond settling
B — A plus flocculating agent
C — closed cycle operation (satisfactory only for scrubbers and cooling water)

The ball clay facilities range from 3,000 to 113,000 kkg/yr (3,300 to 125,000 ton/yr). The representative facility is 68,000 kkg/yr (75,000 ton/yr). Capital cost and operating cost variance factors for size are the same as for wet process kaolin above.

Cost Basis for Table 11

Capital Costs
- Pond cost, $/hectare ($/acre):12,350 (5,000)
- Settling pond area, hectares (acres):20 (50)
- Pumps and pipes: $25,000
- Chemical metering equipment: $10,000

Operating and Maintenance Costs
- Pond dredging: $20,000/yr
- Treatment chemicals
  - Lime: $22/kkg ($20/ton)
  - Flocculating agent: $2.2/kg ($1/lb)
- Energy unit cost: $0.01/kwh
- Maintenance: $10,000-11,000/yr

Cost Basis for Table 12

Capital Costs
- Land cost, $/hectare ($/acre): 12,350 (5,000)
- Settling pond area, hectares (acres): 20 (50)
- Pumps and pipes: $25,000
- Chemical metering equipment: $10,000

Operating and Maintenance Costs
- Pond dredging: $20,000/yr
- Treatment chemicals
  - Lime: $22/kkg ($20/ton)
  - Flocculating agent: $2.2/kg ($1/lb)
- Maintenance: $10,000-11,000/yr

Feldspar may be produced as the sole product, as the main product with by-product sand and mica, or as a co-product of processes for producing mica. Co-product production processes will be discussed under mica. Dry processes (in western U.S.) where feldspar is the sole product have no water effluent and no waste water treatment costs. Therefore, the only subcategory involving major treatment and cost is wet beneficiation of feldspar ore.

After initial scalpings with screens, hydrocyclones or other such devices to remove the large particle sizes, the smaller particle sizes are removed by (1) settling ponds or (2) mechanical thickeners, clarifiers and filters. Often the method selected depends on the amount and type of land available for treatment facilities. Where sufficient flat land is available ponds are usually preferred. Unfortunately, most of the industry is located in hill country and flat land is not available. Therefore, thickeners and filters are often used. Waste water from the feldspar beneficiation involves as primary pollutants suspended solids and fluorides. There is also a solid waste disposal problem for ore components such as mud, clays and some types of sand, some of which have to be landfilled. Fluoride pollutants come from the hydrofluoric acid flotation reagent.

Treatment and cost options are developed in Table 13 for both suspended solids and fluoride reductions. Successive treatments for reducing suspended solids and fluorides are shown.

Reduction of fluoride ion level to less than 10 mg/l can be accomplished through segregation and separate treatment of fluoride-containing streams. This approach is already planned by at least one producer, and is a good example of in-process modification to reduce pollutant levels. A modest reduction of fluoride of less than 50 percent is presently achieved at only one facility with alum treatment that has been installed for the purpose of flocculating suspended solids.

Cost Variance

Age

The feldspar wet process subcategory consists of 6 facilities ranging in age from 3 to 26 years. Age is not a significant cost variance factor because of similar raw waste loads.

Location

TABLE 13

COST FOR A REPRESENTATIVE PLANT

(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY Feldspar, Wet Process

PLANT SIZE 90,900 METRIC TONS PER YEAR OF Feldspar

PLANT AGE 10 YEARS PLANT LOCATION Eastern U.S.

		LEVEL A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS:						
TOTAL		115,000	260,000	375,000	185,000	415,000
ANNUAL CAPITAL RECOVERY		18,700	42,100	60,800	30,100	70,800
OPERATING AND MAINTENANCE COSTS:						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		107,500	132,500	157,500	118,500	156,500
ANNUAL ENERGY AND POWER		2,000	2,000	2,000	4,000	6,000
TOTAL ANNUAL COSTS		128,200	176,600	220,300	152,600	233,300
COST/METRIC TON Feldspar		1.41	1.95	2.42	1.68	2.56
WASTE LOAD PARAMETERS (kg/metric ton of ore)	RAW WASTE LOAD					
Suspended Solids	260-530	0.6	0.3	0.3	0.3-3	0.1-0.3
Fluoride	0.22-0.25	0.2	0.1	0.03	0.2	0.03
pH	--	6-9	6-9	6-9	6-9	6-9

LEVEL DESCRIPTION:

A — settling pond for suspended solids removal, no fluoride treatment.

B — larger settling ponds plus internal recycle of some fluoride-containing water plus flocculation agents.

C — B plus segregation and separate lime treatment of fluoride water.

D — present treatment by thickeners and filters plus lime treatment for fluoride.

E — D plus segregation and separate lime treatment of fluoride water plus improved suspended solids treatment by clarifier installation.

The feldspar wet processing operations are located in southeastern and northeastern states in rural areas. Location has not been found to be a significant cost variance factor.

Size
The feldspar wet processing operations range in size from 45,700 to 154,000 kkg/yr (50,400-170,000 ton/yr). The representative facility is 90,900 kkg/yr (100,000 ton/yr). The range of capital costs for treatment is $36,800 to $250,000, and the range of annual operating costs is $18,400 to $165,000 as reported by the feldspar wet process producers.

The variance of cost with size is estimated to be for
capital: exponent of 0.9 for treatments based on ponds, exponent of 0.7 for treatments based on thickeners.

Operating costs other than taxes, insurance and capital recovery are approximately proportional to size.

Cost Basis for Table 13

Capital Costs
- Pond cost, $/hectare ($/acre): 30,600 (12,500)
- Settling pond area, hectares (acres): 0.4-0.8 (1-2)
- Thickeners, filters, clarifiers: 0-$50,000
- Solids handling equipment: $40,000-50,000
- Chemical metering equipment: 0-$50,000

Operating and Maintenance Costs
- Other solid waste disposal costs: 0-$0.5/ton
- Treatment chemicals: $10,000-25,000/yr
- Energy unit cost: $0.01/kwh
- Monitoring: 0-$15,000/yr

KYANITE

Kyanite is produced at three locations. Two of the three facilities have complete recycle of process water after passing through settling ponds. A summary of treatment technology costs is given in Table 14. Approximately two-thirds of the cost comes from solid wastes removal from the settling pond and land disposal. Depending on solid waste load, costs could vary from approximately $1 to $4 per metric ton of product.

Cost Variance

Age

The three facilities of this subcategory range in age between 10 and 30 years. There is no significant treatment cost variance due to this range.

Location

These facilities are in two southeastern states in rural locations, not a significant cost variance factor.

Size

The sizes range from 16,000 to 45,000 kkg/yr (18,000 to 50,000 ton/yr). The costs given are meant to be representative over this size range on a unit production basis, that is, costs are roughly proportional to size.

Cost Basis for Kyanite Category

Capital Costs

- Pond cost, $/hectare ($/acre): 12,300 (5,000)
- Settling pond area, hectares (acres): 10 (25)
- Pipes: $28,000
- Pumps: $4,400

Operating and Maintenance Costs

- Pond dredging and solids waste hauling: $82,500/yr
- Pond: $14,600/yr
- Pipes: $3,300/yr
- Energy unit cost: $0.01/kwh
- Pumps: $1,200/yr
- Labor: $3,000/yr
- Maintenance: $16,900/yr

TABLE 14

COST FOR A REPRESENTATIVE PLANT

(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY Kyanite

PLANT SIZE 45,000 METRIC TONS PER YEAR OF Kyanite

PLANT AGE 15 YEARS PLANT LOCATION Southeastern U.S.

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS:						
TOTAL		80,000	157,400			
ANNUAL CAPITAL RECOVERY		9,700	19,100			
OPERATING AND MAINTENANCE COSTS:						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		75,000	108,100			
ANNUAL ENERGY AND POWER		1,000	1,400			
TOTAL ANNUAL COSTS		85,700	128,600			
COST/METRIC TON of Kyanite		1.90	2.83			
WASTE LOAD PARAMETERS (kg/metric ton of ____)	RAW WASTE LOAD					
Tailings	5500					
TSS		3	0			
pH		6-9	-			

LEVEL DESCRIPTION:

A — pond settling

B — A plus recycle

Note: Most of the above cost at A level (65-70%) is the cost of removal and disposal of solids from ponds.

MAGNESITE

There is only one known U.S. facility that produces magnesia from naturally occurring magnesite ore. This facility is located in a dry western climate and has no discharge to surface water by virtue of a combination evaporation-percolation pond. Capital costs for this treatment are $300,000 with operation/maintenance costs of $15,000/yr plus annual capital investment costs of $35,220.

SHALE AND COMMON CLAY

No water is used in either mining or processing of shale and common clay. The only water involved is occasional mine drainage from rain or ground water. In most cases runoff does not pick up significant suspended solids. Any needed treatment costs would be expected to fall in the range of $0.01 to $0.05/kkg shale produced.

Cost Variance

Age
Shale facilities range from 8 to 80 years in age. This is not a significant variance factor for the costs to treat mine water since the eqiupment is similar.

Location
Shale facilities having significant mine water are located through the eastern half of the U.S. The volume of mine water is the only significant cost factor influenced by location.

Size
Shale facilities range from 700 to 250,000 kkg/yr (770 to 270,000 ton/yr). Size is not a cost variance factor, since the mine pumpout is unrelated to production rate.

APLITE

Aplite is dry mined produced at two facilities in the U.S.

One facility with a dry process uses wet scrubbers the discharge from which is ponded to remove suspended solids and then discharged. Waste water treatment costs were calculated to be $0.48/kkg product. The second processing facility uses a wet classification process and a significantly higher water usage per ton of product than the first facility. Except for a pond pumpout every one to two years, this facility is on complete recycle. The total treatment costs per kkg of product is $0.78. The estimated costs to bring the "dry process" facility to a condition of total recycle of its scrubber water are:

capital: $9,000
annual capital recovery: $1,470
annual operating and maintenance, excluding power and energy: $630
annual power and energy: $1,300
total annual cost: $3,400

Cost Variance

Age
Aplite is produced by two facilities which are 17 and 41 years old. Age has not been found to be a significant cost variance factor.

Location
Both aplite facilities are located in Virginia and, therefore, location is not a significant cost variance factor.

Size
The aplite facilities are 54,400 kkg/yr (60,000 ton/yr) and 136,000 kkg/yr (150,000 ton/yr). The costs per unit production are applicable for only the facilities specified.

Cost Basis for Aplite Category

Capital Costs
Pond cost, $/hectare ($/acre): 12,300-24,500 (5,000-10,000)
Settling pond area, hectares (acres): 5.5-32 (14-80)
Recycle equipment: $9,000

Operating and Maintenance Costs
Treatment chemical costs: $3,500/yr
Energy unit cost: $0.01/kwh
Recycle O & M cost: $1,900/yr
Maintenance: $4,500-16,500/yr

Suspended solids are the only major pollutant involved in the waste water from this category. In some wet processing operations pH control through addition of acid and alkalies is practiced. Neutralization of the final waste water may be needed to bring the pH into the 6-9 range. Both mines and processing facilities may be either wet or dry. Dry operations have no treatment costs.

Mine Water

Rain water and ground water seepage often make it necessary to pumpout mine water. The only treatment normally needed for this water is settling ponds for suspended solids. Ponds are usually small, one acre or less. Costs for this treatment are in the range of $0.01 to 200 kkg talc produced, the large figure representing small mines.

Wet Processes

Wet processes are conducted in both the eastern and western U.S.

Eastern Operations

Waste water from wet processes comes from process operations and/or scrubber water. The usual method of treating the effluent is to adjust pH by addition of lime, followed by pond settling.

Treatment options, costs and resultant effluent quality are summarized in Table 15. Facilities not requiring lime treatment would have somewhat lower costs than those given.

Western Operations

Wet process facilities in the western part of the U.S. are mostly located in arid regions and can achieve no discharge through evaporation. Costs for these evaporation pond systems were estimated to be the same cost as Level B of Table 15. The required evaporation pond size in this case is similar to that needed for good settling pond performance.

Cost Variance

Age
Facilities in the talc minerals group range from 2 to 70 years of age. However, the heavy media separation and flotation subcategory with a discharge consists of only

TABLE 15

COST FOR A REPRESENTATIVE PLANT

(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY Talc Minerals, Ore Mining, Heavy Media and Flotation

PLANT SIZE 45,000 METRIC TONS PER YEAR OF talc minerals

PLANT AGE 25 YEARS PLANT LOCATION Eastern U.S.

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS:						
TOTAL		100,000	150,000			
ANNUAL CAPITAL RECOVERY		11,700	17,600			
OPERATING AND MAINTENANCE COSTS:						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		27,000	34,000			
ANNUAL ENERGY AND POWER		2,000	3,000			
TOTAL ANNUAL COSTS		40,700	54,600			
COST/METRIC TON of products		0.89	1.09			
WASTE LOAD PARAMETERS (kg/metric ton of products)	RAW WASTE LOAD					
TSS	800 to 1800	0.3-1.3	0.3			
pH		6-9	6-9			

LEVEL DESCRIPTION:

A — lime treatment and pond settling

B — A plus additional pond settling

three facilities of 10 to 30 years of age. This is not a significant treatment cost variance factor.

Location
The heavy media separation and flotation subcategory facilities are located in rural areas of the eastern U.S. This location spread is a minor cost variance factor.

Size
Talc minerals facilities range in size from 12,000 to 300,000 kkg/yr (13,000 to 330,000 ton/yr). The heavy media separation and flotation subcategory facilities range from 12,000 to 236,000 kkg/yr (13,000 to 260,000 ton/yr). The representative facility size selected is 45,000 kkg/yr (50,000 ton/yr). Over this range of sizes, capital costs variance can be estimated by an exponent of 0.8 to size, and operating costs other than capital recovery, taxes and insurance are approximately proportional to size.

Cost Basis for Table 15.

Capital Costs
- Land cost, $/hectare ($/acre): 24,500 (10,000)
- Mine pumpout, settling pond area, hectares (acres):
  up to 0.4 (up to 1)
- Process settling pond area, hectares (acres): 2 (5)
- Pumps and pipes: $15,000
- Chemical treatment equipment: $35,000

Operating and Maintenance Costs
- Treatment chemicals
  - Lime: $22/kkg ($20/ton)
- Energy cost: $1,000-2,000/yr
- Maintenance: $5,000/yr
- Labor: $3,000-10,000/yr

GARNET

There are three garnet producers in the U.S., two in Idaho and one in New York State. Two basic types of processing are used: (1) wet washing and classifying of the ore, and (2) heavy media and froth flotation. Washing and classifying facilities have already incurred estimated waste water treatment costs of $0.16 per metric ton of garnet produced. Heavy media and flotation process waste water treatment estimated costs already incurred are significantly higher, $5 to $10/kkg of product.

The quantity and quality of discharge at the Idaho facilities are not known by the manufacturer. Sampling was precluded by seasonal halting of operations. The hydraulic load per ton of product at the Idaho operations is believed to be higher than at the New York operation studied. The costs to reduce the amount of suspended solids in these discharges to that of the New York operation are estimated to be:

capital: $100,000
annual operating costs: $30,000

Cost Variance

Age
There are three garnet producers ranging in age from 40 to 50 years. Age has not been found to be a significant cost variance factor.

Location
Two of the garnet producers are located in Idaho and one in New York State. The regional deposits differ widely making different ore processes necessary. Due to this difference in processes, there is no representative facility in this subcategory. Treatment costs must be calculated on an individual basis.

Size
The garnet producers range in size from 5,100 kkg/yr to an estimated 86,200 kkg/yr (5,600 ton/yr to an estimated 95,000 ton/yr). The differences in size are so great that there is no representative facility for this subcategory. Due to process and size differences, treatment costs must be calculated on an individual basis.

TRIPOLI

There are several tripoli producers in the United States. The production is dry both at the facilities and the mines. One small facility has installed a wet scrubber.

Cost Variance

There is only one facility in this subcategory that has any process waste water. This is only from a special process producing 10 percent of that facility's production. Therefore, there are no cost variances due to age, location or size.

DIATOMITE

Diatomite is mined and processed in the western U.S. Both mining and processing are practically dry operations. Evaporation ponds are used for waste disposal in all cases. The selected technology of partial recycle and chemical treatment is practiced at the better facilities. All facilities are currently employing settling and neutralization.

GRAPHITE

There is only one producer of natural graphite in the United States. For this mine and processing facility, mine drainage, settling pond seepage and process water are treated for suspended solids, iron removal and pH level. The pH level and iron precipitation are controlled by lime addition. The precipitated iron and other suspended solids are removed in the settling pond and the treated waste water discharged. Present treatment costs are approximately $20-25/kkg graphite produced.

JADE

The jade industry is very small and involves very little waste water. One facility representing 55 percent of the total U.S. production has only 190 l/day (50 gpd) of waste water. Suspended solids are settled in a small tank followed by discharge to the company lawn. Treatment costs are considered negligible.

NOVACULITE

There is only one novaculite producer in the United States. Processing is a dry operation resulting in no discharge. A dust scrubber is utilized and the water is recycled after passing through a settling tank. Both present treatment costs and proposed recycle costs are negligible.

SECTION IX

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

INTRODUCTION

The effluent limitations which must be achieved by July 1, 1977, are based on the degree of effluent reduction attainable through the application of the best practicable control technology currently available. For the mining of clay, ceramic, refractory, and miscellaneous materials, this level of technology was based on the average of the best existing performance by facilities of various sizes, ages, and processes within each of the industry's subcategories. In Section IV, this segment of the minerals mining and processing industry was divided into 17 major categories based on similarities of process. Several of these major categories have been further subcategorized and, for reasons explained in Section IV, each subcategory will be treated separately for the recommendation of effluent limitations guidelines and standards of performance.

Best practicable control technology currently available emphasizes treatment facilities at the end of a manufacturing process but also includes the control technology within the process itself when it is considered to be normal practice within an industry. Examples of waste management techniques which were considered normal practice within these industries are:

a) manufacturing process controls;
b) recycle and alternative uses of water; and
c) recovery and/or resue of some waste water constitutents.

Consideration was also given to:

a) the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application;
b) the size and age of equipment and facilities involved;
c) the process employed;
d) the engineering aspects of the application of various types of control techniques;
e) process changes; and
f) non-water quality environmental impact (including energy requirements).

The following is a discussion of the best practicable control technology currently available for each of the chemical subcategories, and the proposed limitations on the pollutants in their effluents.

GENERAL WATER GUIDELINES

Process Water

Process water is defined as any water contacting the ore, processing chemicals, intermediate products, by-products or products of a process including contact cooling water. All process water effluents are limited to the pH range of 6.0 to 9.0 unless otherwise specified.

Process generated waste water is defined as any water which in the mineral processing operations such as crushing, washing and beneficiation, comes into direct contact with any raw material, intermediate product, by-product or product used in or resulting from the process.

Where sufficient data was available a statistical analysis of the data was performed to determine a monthly and a daily maximum. In most subcategories, where there is an allowable discharge, an achievable monthly maximum was determined from the data available.

A detailed analysis of the ratio of daily TSS to monthly TSS maximum at a 99 percent level of confidence for large phosphate slime ponds indicate that a TSS ratio of 2.0 is representative of a large settling pond treatment system, and this ratio was used where there was insufficient data to predict a daily maximum directly.

A ratio of 2.0 was also used for parameters other than TSS. It is judged that this is an adequate ratio since the treatment systems for F, Zn and Fe for instance, have controllable variables, such as pH and amount of lime addition. This is in contrast to a pond treating only TSS which has few if any operator controllable variables.

Cooling Water

In the minerals mining and processing industry, cooling and process waters are sometimes mixed prior to treatment and discharge. In other situtations, cooling water is discharged separately. Based on the application of best practicable technology currently available, the recommendations for the discharge of such cooling water are as follows.

An allowed discharge of all non-contact cooling waters provided that the following conditions are met:

(a) Thermal pollution be in accordance with EPA standards. Excessive thermal rise in once through non-contact cooling water in the mineral mining industry has not been a significant problem.

(b) All non-contact cooling waters should be monitored to detect leaks of pollutants from the process. Provisions should be made for treatment to the standards established for process waste water discharges prior to release in the event of such leaks.

(c) No untreated process waters be added to the cooling waters prior to discharge.

The above non-contact cooling water recommendations should be considered as interim, since this type of water plus blowdowns from water treatment, boilers and cooling towers will be regulated by EPA as a separate category.

Mine Drainage

Mine drainage is any water drained, pumped or siphoned from a mine.

Storm Water Runoff

Untreated overflow may be discharged from process waste water or mine drainage impoundments without limitation if the impoundments are designed, constructed and operated to contain all process generated waste water or mine drainage and surface runoff into the impoundments resulting from a 10 year 24 hour precipitation event as established by the National Climatic Center, National Oceanic and Atmospheric Administration for the locality in which such impoundments are located. To preclude unfavorable water balance conditions resulting from precipitation and runoff in connection with tailing impoundments, diversion ditching should be constructed to prevent natural drainage or runoff from mingling with process waste water or mine drainage.

PROCESS WASTE WATER GUIDELINES AND LIMITATIONS

BENTONITE

There is no control technology needed for the processing of bentonite, because no water is used in the process. Hence best practicable control technology currently available is no discharge of process generated waste water pollutants.

From the data in Section V the following limits for mine drainage and process contaminated runoff are achievable.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	35 mg/l

FIRE CLAY

The best practicable control technology currently available is no discharge of process generated waste water pollutants since no process water is used.

From the data in Section V the following limits for mine drainage and process contaminated runoff are achievable.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	35 mg/l

FULLER'S EARTH - ATTAPULGITE

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is: no discharge of process generated waste water pollutants. This condition is currently met by four facilities.

From the data in Section V the following limits for mine drainage and process contaminated runoff are achievable.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	35 mg/l

Best practicable control technology currently available for the mining and processing of Fuller's Earth (attapulgite) is no discharge of process waste water. This is currently achieved by four facilities. To implement this technology at facilities not already using the recommended control techniques would require use of dry air pollution control equipment and reuse of waste fines or recycle of fines slurry and scrubber water after settling and pH adjustment.

FULLER'S EARTH - MONTMORILLONITE

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

Best practicable control technology currently available for the mining and processing of Fuller's Earth-Montmorillonite is recycle of all process scrubber water. To implement this technology at facilities not already using the recommended control techniques would require the installation of pumps and associated recycle equipment. Two of the three facilities studied presently use the recommended technology.

KAOLIN - DRY PROCESSING

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants. This is feasible since no process waste water is used.

From the data in Section V the following limits for mine drainage and process contaminated runoff are achievable.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	35 mg/l

KAOLIN MINING - WET PROCESSING

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is:

	Effluent Limitation	
Effluent Characteristic	Monthly Average	Daily Maximum
TSS, mg/l	45	90
Turbidity, JTU or FTU	50	100
Zinc, mg/l	0.25	0.50

The above limitations were based on the performance attainable by the two facilities (3024 and 3025), see Section V. In addition other Georgia kaolin producers have claimed that these limits are achievable.

From the data in Section V the following limits apply to mine drainage from mines not pumping the ore as a slurry to the processing facility and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	35 mg/l

From the data in Section V the following limits apply to mine dewatering from mines pumping the ore as a slurry to the processing facility.

	Effluent Limitation	
Effluent Characteristic	Monthly Average	Daily Maximum
TSS, mg/l	45	90
Turbidity, JTU or FTU	50	100

The use of clay dispersants in the slurry necessitates the use of flocculants and clarification in larger ponds than would be needed if the ore were transported by dry means.

Best practicable control technology currently available for the wet mining and processing of kaolin for high grade product is lime treatment to precipitate zinc followed by pond settling to reduce suspended solids. To implement this technology at facilities not already using the recommended control techniques would require the installation of lime treatment facilities and settling ponds.

The recommended technologies are presently being used by at least 4 facilities.

BALL CLAY - WET PROCESSING

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is:

	Effluent Limitation kg/kkg (lb/1000 lb) of Product	
Effluent Characteristic	Monthly Average	Daily Maximum
TSS	0.17	0.34

The above limitations were based on the performance demonstrated at facility 5689 which employs wet scrubbers for dust collection. Other facilities have no wet scrubbers and hence no process waste water.

From the data in Section V the following limits for mine drainage and process contaminated runoff are achievable.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	35 mg/l

Best practicable control technology currently available for the mining and processing of ball clay is either the use of dry bag collection techniques for dust control or, where wet scrubbers are employed, the use of settling ponds to reduce suspended solids in the effluent. To implement this technology at facilities not already using the recommended control techniques would require either the installation of dry bag collectors or settling ponds. All of the facilities contacted use either one or the other of the recommended technologies.

BALL CLAY-DRY PROCESSING

Where ball clay is processed without the use of wet scrubbers for air emissions control there is no need to discharge process waste water since it is either evaporated or goes to the product. Hence, best practicable control technology currently available is no discharge of process generated waste water pollutants.

From the data in Section V the following limits for mine drainage and process contaminated runoff are achievable.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	35 mg/l

FELDSPAR - FLOTATION

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is:

	Effluent Limitation kg/kkg (lb/1000 lb) of ore processed	
Effluent Characteristic	Monthly Average	Daily Maximum

TSS	0.60	1.2
Fluoride	0.175	0.35

The above limitations were based on the performance achieved by three exemplary facilities for TSS (3026, 3054 and 3067) and one of these three (3026) for fluoride reduction. The fluoride can be achieved by treatment with lime of the HF flotation process waste water only to 40 mg/l. This waste stream can then be combined with the remaining 75 percent of the non-HF contaminated water.

From the data in Section V the following limits for mine drainage are achievable.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	35 mg/l

Best practicable control technology currently available for the mining and processing of feldspar by the wet process is to recycle part of the process waste water for washing purposes, then neutralize and settle the remaining waste water to reduce the suspended solids. In addition, fluoride reduction can be accomplished by chemical treatment of waste water from the flotation circuit and/or partial recycle of the fluoride containing portion of the flotation circuit. To implement this technology at facilities not already using the recommended control techniques would require installation of piping and pumps for recycle of water and installation of neutralization, chemical treatment and settling equipment or ponds. The selected technology of partial recycle and chemical treatment is practiced at the better facilities. All facilities are currently employing settling and neutralization.

FELDSPAR-NON-FLOTATION

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants. This technology for the processing of feldspar by the dry process is natural evaporation of dust control water used in the process. This is the only water used in the process.

From the data in Section V the following limits for mine drainage and process contaminated runoff are achievable.

Effluent Characteristic	Effluent Limitation Daily Maximum

TSS	35 mg/l

KYANITE

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

From the data in Section V the following limits for mine drainage and process contaminated runoff are achievable.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	35 mg/l

Best practicable control technology currently available for the mining and processing of kyanite by the standard process is recycle of process water from settling ponds. To implement this technology at facilities not already using the recommended control techniques would require installation of suitable impoundments and recycle where required.

One of the three facilities in this production subcategory is currently employing the recommended technologies.

MAGNESITE

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

Best practicable control technology currently available for the manufacture of magnesia (MgO) from naturally occurring magnesite is either impoundment or recycle of process waste water. There is one facility in the U.S. and this facility currently uses the recommended technology.

SHALE AND COMMON CLAY

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants, since no water is used.

From the data in Section V the following limits for mine drainage and process contaminated runoff are achievable.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	35 mg/l

APLITE

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants. From the data in Section V the following limits for mine drainage and process contaminated runoff are achievable.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	35 mg/l

Best practicable control technology currently available for the mining and processing of aplite is ponding of process waste water to settle solids and recycle of water. To implement this technology at facilities not already using the recommended control techniques would require installation of water recycle equipment.

TALC, STEATITE, SOAPSTONE AND PYROPHYLLITE, DRY PROCESS

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants because no process water is used.

TALC, STEATITE, SOAPSTONE AND PYROPHYLLITE, WASHING PROCESS

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

Best practicable control technology currently available for the mining of talc minerals by the ore mining and washing processes is total impoundment or recycle of process waste water. All facilities in this production subcategory currently employ the recommended control technology.

TALC, STEATITE, SOAPSTONE AND PYROPHYLLITE, HEAVY MEDIA AND FLOTATION

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is:

Effluent Characteristic	Effluent Limitation kg/kkg (lb/1000 lb) of product Monthly Average	Daily Maximum
TSS	0.5	1.0

The above limitations were based on the performance achievable by three facilities (2032, 2033 and 2044) and a fourth facility (2031) achieving no discharge of process waste water.

Best practicable control technology currently available for the processing of talc minerals by heavy media process is pH adjustment of the flotation tailings, gravity settling and clarification. To implement this technology at facilities not already using the recommended control techniques would require the installation of pH monitoring and adjustment equipment and the installation of settling and/or clarification ponds. All facilities in this subcategory are presently using the recommended technologies.

TALC, STEATITE, SOAPSTONE, PYROPHYYLLITE, MINE DRAINAGE AND PROCESS CONTAMINATED RUNOFF

Based upon information contained in Section V, a determination has been made that the degree of effluent attainble through the application of the best practicable control technology currently available is:

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

The above limitations are based on the effluent quality from 7 mines.

GARNET

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent attainable through the application of the best practicable control technology currently available is:

Effluent Characteristic	Effluent Limitation kg/kkg (lb/1000 lb) product Monthly Average	Daily Maximum
TSS	0.4	0.8

The above limitations were based on an estimated average process waste water discharge of 12,500 l/kkg (3,000 gal/ton) product and an estimated TSS level of 30 mg/l. In the two facilities studied, mine water is used as process water.

From the data in Section V the following limits for mine drainage and process contaminated runoff are achievable.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	35 mg/l

Best practicable control technology currently available for the mining and processing of garnet is pH adjustment, where necessary, and settling of suspended solids. To implement this technology at facilities not already using the recommended control techniques would require the installation of pH adjustment equipment, where necessary, and construction of settling ponds. The two facilities accounting for over 80 percent of the U.S. production are presently using the recommended technologies.

TRIPOLI

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants from dry processes, since no process waste water is used.

From the data in Section V the following limits for mine drainage and process contaminated runoff are achievable.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	35 mg/l

DIATOMITE

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

From the data in Section V the following limits for mine drainage and process contaminated runoff are achievable.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	35 mg/l

Best practicable control technology currently available for the mining and processing of diatomite by the standard process is use of evaporation ponds and/or recycle of process water. To implement this technology at facilities not already using the recommended control techniques would require the construction of impoundments and/or recycling equipment. Three facilities (5504, 5505 and 5500) of this subcategory representing approximately half the U.S. production utilize this recommended technology.

GRAPHITE

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is:

Effluent Characteristic	Effluent Limitation mg/l Monthly Average	Daily Maximum
TSS	10	20
Total Iron	1	2

The above average limitations were based on the performance achievable by the single facility in this subcategory. Both process waste water and mine drainage are included. Concentration was used because of the variable flow of mine seepage.

Best practicable control technology currently available for the mining and processing of graphite is neutralization of mine seepage and pond settling. There is only one facility in the U.S., and this facility currently uses the recommended technology.

JADE

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

From the data in Section V the following limits for mine drainage and process contaminated runoff are achievable.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	35 mg/l

Best practicable control technology currently available for the mining and processing of jade is settling and evaporation of the small volume of waste water. To implement this technology at facilities not already using the recommended control techniques would require installation of a settling tank and appropriate evaporation facilities. The only major U.S. jade production facility presently employs these techniques.

NOVACULITE

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

From the data in Section V the following limits for mine drainage and process contaminated runoff are achievable.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	35 mg/l

Best practicable control technology currently available for the mining and processing of novaculite by the quarrying process is total recycle of process scrubber water. There is only one facility in the U.S. It is presently using this technology.

SECTION X

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

INTRODUCTION

The effluent limitations which must be achieved by July 1, 1983 are based on the degree of effluent reduction attainable through the application of the best available technology economically achievable. For the mining clay, ceramic, refractory and miscellaneous minerals industry, this level of technology was based on the very best control and treatment technology employed by a specific point source within each of the industry's subcategories, or where it is readily transferable from one industry process to another. In Section IV, this segment of the mineral mining and processing industry was divided into 17 major categories based on similarities of process. Several of those major categories have been further subcategorized and, for reasons explained in Section IV, each subcategory will be treated separately for the recommendation of effluent limitations guidelines and standards of performance.

The following factors were taken into consideration in determining the best available technology economically achievable:

(1) the age of equipment and facilities involved;
(2) the process employed;
(3) the engineering aspects of the application of various types of control techniques;
(4) process changes;
(5) cost of achieving the effluent reduction resulting from application of BATEA; and
(6) non-water quality environmental impact (including energy requirements).

In contrast to the best practicable technology currently available, best available technology economically achievable assesses the availability in all cases of in-process controls as well as control or additional treatment techniques employed at the end of a production process. In-process control options available which were considered in establishing these control and treatment technologies include the following:

(1) alternative water uses

(2) water conservation
(3) waste stream segregation
(4) water reuse
(5) cascading water uses
(6) by-product recovery
(7) reuse of waste water constituents
(8) waste treatment
(9) good housekeeping
(10) preventive maintenance
(11) quality control (raw material, product, effluent)
(12) monitoring and alarm systems.

Those facility processes and control technologies which at the pilot facility, semi-works, or other level, have demonstrated both technological performances and economic viability at a level sufficient to reasonably justify investing in such facilities were also considered in assessing the best available technology economically achievable. Although economic factors are considered in this development, the costs for this level of control are intended to be for the top-of-the-line of current technology subject to limitations imposed by economic and engineering feasibility. However, this technology may necessitate some industrially sponsored development work prior to its application.

Based upon the information contained in Sections III through IX of this report, the following determinations were made on the degree of effluent reduction attainable with the application of the best available control technology economically achievable in the various subcategories of the inorganic chemical industry.

GENERAL WATER GUIDELINES

Storm Water Runoff

Untreated overflow may be discharged from process waste water or mine drainage impoundments without limitation if the impoundments are designed, constructed and operated to contain all process generated waste water or mine drainage and surface runoff into the impoundments resulting from a 25 year 24 hour precipitation event as established by the National Climatic Center, National Oceanic and Atmospheric Administration for the locality in which such impoundments are located. To preclude unfavorable water balance conditions resulting from precipitation and runoff in connection with tailing impoundments, diversion ditching should be constructed to prevent natural drainage or runoff from mingling with process waste water or mine drainage.

PROCESS WASTEWATER GUIDELINES AND LIMITATIONS

NO DISCHARGE GROUP

The following industry subcategories are required to achieve no discharge of process generated waste water pollutants to navigable waters based on best practicable control technology currently available:

- bentonite
- fire clay
- fuller's earth (montmorillonite and attapulgite)
- kaolin (general purpose grade)
- ball clay (dry process)
- feldspar (non-flotation)
- kyanite
- magnesite
- shale
- aplite
- talc group (dry process)
- talc group (washing process)
- tripoli
- diatomite
- jade
- novaculite

Best available technology economically achievable is also no discharge of process waste water pollutants for these subcategories.

KAOLIN - WET PROCESSING

Based upon the information contained in Sections III through IX, a determination has been made that the degree of effluent reduction attainable through the application of the best available technology economically achievable is the same as for the best practicable control technology currently available.

Best available technology economically achievable for the mining and processing of ball clay is the use of dry bag collectors where possible or recycle of wet scrubber where wet scrubbers are used. To implement this technology at facilities not already using the recommended control techniques would require the installation of settling ponds or equipment and flocculation plus piping and pumps for recycle of scrubber water where used. Settling of suspended solids and recycle of scrubber water is currently practiced in other portions of this industry.

FELDSPAR - - FLOTATION

Based upon the information contained in Sections III through IX, a determination has been made that the degree of effluent reduction attainable through the application of the best available technology economically achievable is:

Effluent Characteristic	Effluent Limitation kg/kkg (lb/1000 lb) ore processed Monthly Average	Daily Maximum
TSS	0.6	1.2
Fluoride	0.13	0.26

The above limitation for fluoride is based on an improvement in exemplary facility performance by lime treatment to reduce fluorides to 30 mg/l in the HF contaminated segregated waste water. The limitation on suspended solids for best practicable control technology currently available is deemed also to represent best available technology economically achievable.

Best available technology economically achievable for the mining and processing of feldspar by the wet process is to recycle part of the process waste water for washing purposes, neutralization to pH 9 with lime to reduce soluble fluoride and settling to remove suspended solids. To implement this technology at facilities not already using the recommended control techniques would require installation of piping and pumps for recycle of water, lime feeding and neutralization equipment and settling equipment or ponds. The selected technology of partial recycle is currently practiced at two facilities. Three facilities are currently using lime treatment to adjust pH and can readily adopt this technology to reduce soluble fluoride. All facilities are using settling equipment or ponds.

TALC MINERALS GROUP, HEAVY MEDIA AND FLOTATION

Based upon the information contained in Sections III through IX, a determination has been made that the degree of effluent reduction attainable through the application of the best available technology economically achievable is:

Effluent Characteristic	Effluent Limitation kg/kkg (lb/1000 lb) of product Monthly Average	Daily Maximum
TSS	0.3	0.6

The above limitations were based on performance of one facility (2032) plus one facility achieving no discharge of process water (2031).

Best available technology economically achievable for the mining and processing of talc minerals by the ore mining, heavy media and/or flotation process is the same as for best practicable control technology currently available plus additional settling or in one case, conversion from wet scrubbing to a dry collection method to control air pollution. To implement this technology at facilities not already using the recommended control techniques would require installation of additional ponds or installation of dry dust collectors. Two of the four facilities in this subcategory are presently achieving this level of effluent reduction using the recommended treatment technologies.

GARNET

Based upon the information contained in Sections III through IX, a determination has been made that the degree of effluent reduction attainable through the application of the best available technology economically achievable is:

Effluent Characteristic	Effluent Limitation kg/kkg (lb/1000 lb) product	
	Monthly Average	Daily Maximum
TSS	0.25	0.5

The above limitations were based on an estimated average process waste water discharge of 12,500 l/kkg (3,000 gal/ton) and an estimated TSS level of 20 mg/l.

Best available technology economically achievable for the mining and processing of garnet is pH adjustment to achieve pH 6 to 9, settling of suspended solids, and sand bed filtration where necessary. To implement this technology at facilities not already using the recommended control techniques would require the installation of pH neutralization equipment, settling ponds, and sand bed filter equipment.

Two facilities accounting for over 80 percent of the U.S. production presently use a portion of the recommended technologies and technology exists for further removal of suspended solids.

GRAPHITE

Based upon the information contained in Sections III through IX, a determination has been made that the degree of effluent reduction attainable through the application of the best available technology economically achievable is the same as that recommended for best practicable control technology currently available because no proven technology option exists to reduce the pollutants further.

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS AND PRETREATMENT STANDARDS

INTRODUCTION

This level of technology is to be achieved by new sources. The term "new source" is defined in the Act to mean "any source, the construction of which is commenced after the publication of proposed regulations prescribing a standard of performance". This technology is evaluated by adding to the consideration underlying the identification of best available technology economically achievable, a determination of what higher levels of pollution control are available through the use of improved production processes and/or treatment techniques. Thus, in addition to considering the best in-facility and end-of-process control technology, new source performance standards are how the level of effluent may be reduced by changing the production process itself. Alternative processes, operating methods or other alternatives were considered. However, the end result of the analysis identifies effluent standards which reflect levels of control achievable through the use of improved production processes (as well as control technology), rather than prescribing a particular type of process or technology which must be employed.

The following factors were considered with respect to production processes which were analyzed in assessing the best demonstrated control technology currently available for new sources:

a) the type of process employed and process changes;
b) operating methods;
c) batch as opposed to continuous operations;
d) use of alternative raw materials and mixes of raw materials;
e) use of dry rather than wet processes (including substitution of recoverable solvents from water); and
f) recovery of pollutants as by-products.

In addition to the effluent limitations covering discharges directly into waterways, the constituents of the effluent discharge from a facility within the industrial category which would interfere with, pass through, or otherwise be incompatible with a well designed and operated publicly owned activated sludge or trickling filter waste water treatment facility were identified. A determination was made of whether the introduction of such pollutants into the treatment facility should be completely prohibited.

GENERAL WATER GUIDELINES

The process water, cooling water and blowdown guidelines for new sources are identical to those based on best available technology economically achievable.

PROCESS WATER GUIDELINES

Based upon the information contained in Sections III through X of this report, the following determinations were made on the degree of effluent reduction attainable with the application of new source standards for the various subcategories of the clay, ceramic, refractory, and miscellaneous minerals segment of the mineral mining and processing industry.

Storm Water Runoff

Untreated overflow may be discharged from process waste water or mine drainage impoundments without limitation if the impoundments are designed, constructed and operated to contain all process generated waste water or mine drainage and surface runoff into the impoundments resulting from a 25 year 24 hour precipitation event as established by the National Climatic Center, National Oceanic and Atmospheric Administration for the locality in which such impoundments are located. To preclude unfavorable water balance conditions resulting from precipitation and runoff in connection with tailing impoundments, diversion ditching should be constructed to prevent natural drainage or runoff from mingling with process waste water or mine drainage.

The following industry subcategories were required to achieve no discharge of process generated waste water pollutants to navigable waters based on best available technology economically achievable:

- bentonite
- fire clay
- fuller's earth (montmorillonite and attapulgite)
- kaolin (dry process)
- ball clay
- feldspar (non-flotation)
- kyanite
- magnesite
- shale
- aplite
- talc group (dry process)
- talc group (ore mining and washing process)

tripoli
diatomite
jade
novaculite

The same limitations guidelines are recommended as new source performance standards.

The following industry subcategories are required to achieve specific effluent limitations as given in the following paragraphs.

KAOLIN (WET PROCESS)

Same as best available technology economically achievable.

FELDSPAR (FLOTATION)

Same as best available technology economically achievable.

TALC GROUP (HEAVY MEDIA AND FLOATION PROCESS)

Same as best available technology economically achievable

GARNET

Same as best available technology economically achievable

GRAPHITE

Same as best available technology economically achievable

PRETREATMENT STANDARDS

Recommended pretreatment guidelines for discharge of facility waste water into public treatment works conform in general with EPA Pretreatment Standards for Municipal Sewer Works as published in the July 19, 1973 Federal Register and "Title 40 - Protection of the Environment, Chapter 1 - Environmental Protection Agency, Subchapter D - Water Programs - Part 128 - Pretreatment Standards" a subsequent EPA publication. The following definitions conform to these publications:

Compatible Pollutant

The term "compatible pollutant" means biochemical oxygen demand, suspended solids, pH and fecal coliform bacteria, plus additional pollutants identified in the NPDES permit if the publicly owned treatment works was designed to treat such pollutants, and, in fact, does remove such pollutants to a substantial degree. Examples of such additional pollutants may include:

- chemical oxygen demand
- total organic carbon
- phosphorus and phosphorus compounds
- nitrogen and nitrogen compounds
- fats, oils, and greases of animal or vegetable origin except as defined below in Prohibited Wastes.

Incompatible Pollutant

The term "incompatible pollutant" means any pollutant which is not a compatible pollutant as defined above.

Joint Treatment Works

Publicly owned treatment works for both non-industrial and industrial waste water.

Major Contributing Industry

A major contributing industry is an industrial user of the publicly owned treatment works if it: has a flow of 50,000 gallons or more per average work day; has a flow greater than five percent of the flow carried by the municipal system receiving the waste; has in its waste, a toxic pollutant in toxic amounts as defined in standards issued under Section 307(a) of the Act; or is found by the permit issuance authority, in connection with the issuance of an NPDES permit to the publicly owned treatment works receiving the waste, to have significant impact, either singly or in combination with other contributing industries, on that treatment works or upon the quality of effluent from that treatment works.

Pretreatment

Treatment of waste waters from sources before introduction into the joint treatment works.

Prohibited Wastes

No waste introduced into a publicly owned treatment works shall interfere with the operation or performance of the works. Specifically, the following wastes shall not be introduced into the publicly owned treatment works:

a. Wastes which create a fire or explosion hazard in the publicly owned treatment works;

b. Wastes which will cause corrosive structural damage to treatment works, but in no case wastes with a pH lower than 5.0, unless the works are designed to accommodate such wastes;

c. Solid or viscous wastes in amounts which would cause obstruction to the flow in sewers, or other interference with the proper operation of the publicly owned treatment works, and

d. Wastes at a flow rate and/or pollutant discharge rate which is excessive over relatively short time periods so that there is a treatment process upset and subsequent loss of treatment efficiency.

Recommended Pretreatment Guidelines for Existing Sources

In accordance with the preceding Pretreatment Standards for Municipal Sewer Works, the following are recommended for Pretreatment Guidelines for the waste water effluents:

a. No pretreatment required for removal of compatible pollutants - biochemical oxygen demand, suspended solids (unless hazardous) pH and fecal coliform bacteria. The principal pollutant in the mineral industry is suspended solids.

b. Suspended solids containing hazardous pollutants such as heavy metals, cyanides and chromates should be restricted to those quantities recommended for the best practicable control technology currently available for existing sources and new source performance standards for new sources.

c. Pollutants such as chemical oxygen demand, total organic carbon, phosphorus and phosphorus compounds, nitrogen and nitrogen compounds and fats, oils and greases need not be removed provided the publicly owned treatment works was designed to treat such pollutants and will accept them. Otherwise levels should be at or below the best practicable control technology currently available for existing sources and new source performance standards for new sources.

d. Limitation on dissolved solids is not recommended except in cases of water quality violations.

SECTION XII

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Gypsum Association
Indiana Limestone Institute
Louisiana Fish and Wildlife Commission
Louisiana Water Pollution Control Board
Marble Institute of America
National Clay Pipe Institute
National Crushed Stone Association
National Industrial Sand Association
National Limestone Institute
National Sand and Gravel Association

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SECTION XIII

REFERENCES

1. Agnello, L., "Kaolin", Industrial and Engineering Chemistry, Vol. 52, No. 5, May 1960, pp. 370-376.

2. "American Ceramic Society Bulletin," Vol. 53, No. 1, January 1974, Columbus, Ohio.

3. Bates, R. L., Geology of the Industrial Rocks and Minerals, Dover Publications, Inc., New York, 1969.

4. Boruff, C.S., "Removal of Fluorides from Drinking Waters," Industrial and Engineering Chemistry, Vol. 26, No. 1, January 1934, pp. 69-71.

5. Brown, W.E., U.S. Patent 2,761,835, September 1956.

6. Brown, W.E., and Gracobine, C.R., U.S. Patent 2,761,841, September 1956.

7. "Census of Minerals Industries", 1972, Bureau of the Census, U.S. Department of Commerce, U.S. Government Printing Office, Washington, D.C. MIC72(P)-14A-1 through MIC72(P)-14E-4.

8. "Commodity Data Summaries, 1974, Appendix I To Mining and Minerals Policy," Bureau of Mines, U.S., Department of the Interior, U.S. Government Printing Office, Washington, D.C.

9. "Dictionary of Mining, Mineral, and Related Terms," Bureau of Mines, U.S. Department of the Interior, U.S. Government Printing Office, Washington, D.C., 1968.

10. "Engineering and Mining Journal," McGraw-Hill, October 1974. 1974.

11. Haden, W., Jr., and Schwint, I., "Attapulgite, Its Properties and Applications," Industrial and Engineering Chemistry, Vol. 59, No. 9, September 1967, pp. 57-69.

12. Maier, F.J., "Defluoridation of Municipal Water Supplies," Journal AWWA, August 1953, pp. 879-888.

13. McNeal, W., and Nielsen, G., "International Directory of Mining and Mineral Processing Operations," E/MJ, McGraw-Hill, 1973-1974.

14. "Minerals Yearbook, Metals, Minerals, and Fuels, Vol. 1," U.S. Department of the Interior, U.S. Government Printing Office, Washington, D.C., 1971, 1972.

15. "Mining Engineering, Publication of the Society of Mining Engineers of AIME, Annual Review for 1973;" Vol. 25, No. 1, January 1973; Vol. 26, No. 3, March 1974 through Vol. 26, No. 8, August 1974.

16. "Modern Mineral Processing Flowsheets," Denver Equipment Company, 2nd Ed., Denver, Colorado

17. Patton, T.C., "Silica, Microcrystalline," Pigment Handbook Vol. 1, J. Wiley and Sons, Inc., 1973, pp. 157-159.

18. Popper, H., Modern Engineering Cost Techniques, McGraw-Hill, New York, 1970.

19. "Product Directory of the Refractories Industry in the U.S.," The Refractories Institute, Pittsburgh, Pa. 1972.

20. Slabaugh, W.H., and Culbertsen, J.L., J. Phys. Chem., 55, 744, 1951.

21. State Directories of the Mineral Mining Industry from 36 of 50 States.

22. Trauffer, W.E., "New Vermont Talc Facility Makes High-Grade Flotation Product for Special Uses," Pit and Quarry, December 1964, pp. 72-74, 101.

23. Williams, F.J., Nezmayko, M., and Weintsitt, D.J., $J. Phys. Chem., 57, 8, 1953.

24. "Standard Industrial Classification Manual", Executive Office of the President, Office of Management and Budget, U. S. Government Printing Office, 1972.

SECTION XIV

GLOSSARY

Aeration - the introduction of air into the pulp in a flotation cell in order to form air bubbles.

Aquifer - an underground stratum that yields water.

Baghouse - chamber in which exit gases are filtered through membranes (bags) which arrest solids.

Bench - a ledge, which, in open pit mines and quarries, forms a single level of operation above which mineral or waste materials are excavated from a contiguous bank or bench face.

Berm - a horizontal shelf built for the purpose of strengthening and increasing the stability of a slope or to catch or arrest slope slough material; berm is sometimes used as a synonym for bench.

Blunge - to mix thoroughly.

Burden - valueless material overlying the ore.

Cell, cleaner - secondary cells for the retreatment of the concentrate from primary cells.

Cell, rougher - flotation cells in which the bulk of the gangue is removed from the ore.

Clarifier - a centrifuge, settling tank, or other device, for separating suspended solid matter from a liquid.

Classifier, air - an appliance for approximately sizing crushed minerals or ores employing currents of air.

Classifier, rake - a mechanical classifier utilizing reciprocal rakes on an inclined plane to separate coarse from fine material contained in a water pulp.

Classifier, spiral - a classifier for separating fine-size solids from coarser solids in a wet pulp consisting of an interrupted-flight screw conveyor, operating in an inclined trough.

Collector - a heteropolar compound chosen for its ability to adsorb selectively in froth flotation and render the adsorbing surface relatively hydrophobic.

Conditioner - an apparatus in which the surfaces of the mineral species present in a pulp are treated with appropriate chemicals to influence their reaction during aeration.

Crusher, cone - a machine for reducing the size of materials by means of a truncated cone revolving on its vertical axis within an outer chamber, the anular space between the outer chamber and cone being tapered.

Crusher, gyratory - a primary crusher consisting of a vertical spindle, the foot of which is mounted in an eccentric bearing within a conical shell. The top carries a conical crushing head revolving eccentrically in a conical maw.

Crusher, jaw - a primary crusher designed to reduce the size of materials by impact or crushing between a fixed plate and an oscillating plate or between two oscillating plates, forming a tapered jaw.

Crusher, roll - a reduction crusher consisting of a heavy frame on which two rolls are mounted; the rolls are driven so that they rotate toward one another. Rock is fed in from above and nipped between the moving rolls, crushed, and discharged below.

Depressant - a chemical which causes substances to sink through a froth, in froth flotation.

Dispersant - a substance (as a polyphosphate) for promoting the formation and stabilization of a dispersion of one substance in another.

Dragline - a type of excavating equipment which employs a rope-hung bucket to dig up and collect the material.

Dredge, bucket - a two-pontooned dredge from which are suspended buckets which excavate material at the bottom of the pond and deposit it in concentrating devices on the dredge decks.

Dredge, suction - a centrifugal pump mounted on a barge.

Drill, churn - a drilling rig utilizing a blunt-edged chisel bit suspended from a cable for putting down vertical holes in exploration and quarry blasting.

Drill, diamond - a drilling machine with a rotating, hollow, diamond-studded bit that cuts a circular channel around a core which when recovered provides a columnar sample of the rock penetrated.

Drill, rotary - various types of drill machines that rotate a rigid, tubular string of rods to which is attached a bit for cutting rock to produce boreholes.

Dryer, flash - an appliance in which the moist material is fed into a column of upward-flowing hot gases with moisture removal being virtually instantaneous.

Dryer, fluidized bed - a cool dryer which depends on a mass of particles being fluidized by passing a stream of hot air through it. As a result of the fluidization, intense turbulence is created in the mass including a rapid drying action.

Dryer, rotary - a dryer in the shape of an inclined rotating tube used to dry loose material as it rolls through.

Electrostatic separator - a vessel fitted with positively and negatively charged conductors used for extracting dust from flue gas or for separating mineral dust from gangues.

Filter, pressure - a machine utilizing pressure to increase the removal rate of solids from tailings.

Filter, vacuum - a filter in which the air beneath the filtering material is exhausted to hasten the process.

Flocculant - an agent that induces or promotes gathering of suspended particles into aggregations.

Flotation - the method of mineral separation in which a froth created in water by a variety of reagents floats some finely crushed minerals, whereas other minerals sink.

Frother - substances used in flotation to make air bubbles sufficiently permanent, principally by reducing surface tension.

Grizzly - a device for the coarse screening or scalping of bulk materials.

Hydraulic Mining - mining by washing sand and dirt away with water which leaves the desired mineral.

Hydrocyclone - a cyclone separator in which a spray of water is used.

Hydroclassifier - a machine which uses an upward current of water to remove fine particles from coarser material.

Humphrey spiral - a concentrating device which exploits differential densities of mixed sands by a combination of sluicing and centrifugal action. The ore pulp gravitates down through a stationary spiral trough with five turns. Heavy particles stay on the inside and the lightest ones climb to the outside.

Jumbo - a drill carriage on which several drills are mounted.

Kiln, rotary - a kiln in the form of a long cylinder, usually inclined, and slowly rotated about its axis; the kiln is fired by a burner set axially at its lower end.

Kiln, tunnel - a long tunnel-shaped furnace through which ware is generally moved on cars, passing progressively through zones in which the temperature is maintained for preheating, firing and cooling.

Launder - a chute or trough for conveying powdered ore, or for carrying water to or from the crushing apparatus.

Log washer - a slightly slanting trough in which revolves a thick shaft or log, carring blades obliquely set to the axis. Ore is fed in at the lower end, water at the upper. The blades slowly convey the lumps of ore upward against the current, while any adhering clay is gradually disintegrated and floated out the lower end.

Magnetic separator - a device used to separate magnetic from less magnetic or nonmagnetic materials.

Mill, ball - a rotating horizontal cylinder in which non-metallic materials are ground using various types of grinding media such as quartz pebbles, porcelain balls, etc.

Mill, buhr - a stone disk mill, with an upper horizontal disk rotating above a fixed lower one.

Mill, chaser - a cylindrical steel tank lined with wooden rollers revolving 15-30 times a minute.

Mill, hammer - an impact mill consisting of a rotor, fitted with movable hammers, that is revolved rapidly in a vertical plane within a closely fitting steel casing.

Mill, pebble - horizontally mounted cylindrical mill, charged with flints or selected lumps of ore or rock.

Mill, rod - a mill for fine grinding, somewhat similar to a ball mill, but employing long steel rods instead of balls to effect the grinding.

Mill, roller - a fine grinding mill having vertical rollers running in a circular enclosure with a stone or iron base.

Neutralization - making neutral or inert, as by the addition of an alkali or an acid solution.

Outcrop - the part of a rock formation that appears at the surface of the ground or deposits that are so near to the surface as to be found easily by digging.

Overburden - material of any nature, consolidated or unconsolidated, that overlies a deposit of useful materials, ores, etc.

Permeability - capacity for transmitting a fluid.

Raise - an inclined opening driven upward from a level to connect with the level above or to explore the ground for a limited distance above one level.

Reserve - known ore bodies that may be worked at some future time.

Ripper - a tractor accessory used to loosen compacted soils and soft rocks for scraper loading.

Room and Pillar - a system of mining in which the distinguishing feature is the winning of 50 percent or more of the ore in the first working. The ore is mined in rooms separated by narrow ribs (pillars); the ore in the pillars is won by subsequent working in which the roof is caved in successive blocks.

Scraper - a tractor-driven surface vehicle the bottom of which is fitted with a cutting blade which when lowered is dragged through the soil.

Scrubber, dust - special apparatus used to remove dust from air by washing.

Scrubber, ore - device in which coarse and sticky ore is washed free of adherent material, or mildly disintegrated.

Shuttle-car - a vehicle which transports raw materials from loading machines in trackless areas of a mine to the main transportation system.

Skip - a guided steel hoppit used in vertical or inclined shafts for hoisting mineral.

SIC - standard industrial classification, see reference 24.

Sink-float - processes that separate particles of different sizes or composition on the basis of specific gravity.

Stacker - a conveyor adapted to piling or stacking bulk materials or objects.

Slimes - extremely fine particles derived from ore, associated rock, clay or altered rock.

Sluice - to cause water to flow at high velocities for wastage, for purposes of excavation, ejecting debris, etc.

Slurry - pulp not thick enough to consolidate as a sludge but sufficiently dewatered to flow viscously.

Stope - an excavation from which ore has been excavated in a series of steps.

Stripping ratio - the unit amount of spoil that must be removed to gain access to a similar unit amount of ore or mineral material.

Sump - any excavation in a mine for the collection of water for pumping.

Table, air - a vibrating, porous table using air currents to effect gravity concentration of sands.

Table, wet - a concentration process whereby a separation of minerals is effected by flowing a pulp across a riffled plane surface inclined slightly from the horizontal, differentially shaken in the direction of the long axis and washed with an even flow of water at right angles to the direction of motion.

Thickener - an apparatus for reducing the proportion of water in a pulp.

TSS - Total suspended solids.

Waste - the barren rock in a mine or the part of the ore deposit that is too low in grade to be of economic value at the time.

Weir - an obstruction placed across a stream for the purpose of channeling the water through a notch or an opening in the weir itself.

Wire saw - a saw consisting of one- and three-strand wire cables, running over pulleys as a belt. When fed by a slurry of sand and water and held against rock by tension, it cuts a narrow channel by abrasion.

TABLE 16

METRIC UNITS

CONVERSION TABLE

Multiply (English Units) by To obtain (Metric units)

ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram - calories
British Thermal Unit/ pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	F°	0.555 (°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	killowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
tons (short)	t	0.907	kkg	metric tons (1000 kilograms)
yard	y	0.9144	m	meters

*Actual conversion, not a multiplier

* U.S. GOVERNMENT PRINTING OFFICE : 1975—592-189/6054