3

Potash, Soda Ash, and Borates

Potash, soda ash and borates are industrial minerals. They are used primary as feedstock for other industries. They are used to make fertilizers, glass, chemicals and other materials used throughout manufacturing industries. For example, the agricultural industry relies heavily on potash and borates as fertilizers. It is the dependence of these manufacturing industries that make industrial minerals so important.

Forms of Potash

Potash is used primarily as an agricultural fertilizer because it is a source for soluble potassium. Potash denotes a variety of mined and manufactured salts, all containing the element potassium in water-soluble form. Potash can be potassium chloride [KCL, or muriate of potash (MOP)], potassium sulfate [K_2SO_4, or sulfate of potash (SOP), a manufactured product], potassium/magnesium sulfate [$K_2SO_4 \cdot MgSO_4$, or sulfate of potash magnesia (SOPM)], potassium nitrate (KNO_3 or saltpeter, a manufactured product), or mixed sodium/potassium nitrate ($NaNO_3 + KNO_3$, or Chilean saltpeter). The term potash was originally applied to potassium carbonate/potassium hydroxide crystals that were recovered in iron "pots" from leaching wood "ashes" with water.[1]

Forms of Soda Ash

Soda ash is the trade name for sodium carbonate (NA_2CO_3), a chemical refined from the mineral trona or from sodium carbonate-bearing brines (both referred to as natural soda ash) and manufactured from one of several chemical processes (referred to as synthetic soda ash). It is an essential raw material in glass, chemicals, detergents, and other important industrial products.[2]

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[1] Department of Interior, U.S. Geological Survey, *Mineral Industry Survey*, Potash, p.1, 1997
[2] Department of Interior, U.S. Geological Survey, *Mineral Industry Survey*, Soda Ash, p.1, 1997

Forms of Borates

Borates are defined by industry as compounds that contain or supply boric oxide $[B(OH)_3]$. A large number of materials contain boric oxide, but the three most common borate-containing minerals are tincal, ulexite, and colemanite. Kernite is the metamorphic phase of borax and is an important borax mineral.[3] The major products of borates include fiberglass insulation, textile or continuous-filament glass fibers, glass detergents and bleaches, enamels and frits, fertilizers, and fire retardants.

3.1 Process Overview

3.1.1 Mining Methods

Potash Mining

Conventional, solution, and cut-and-fill stope mining are methods used in extracting ore for potash.

> **Conventional Mining -** Conventional mining includes a number of steps. First, the miners travel to the extraction site. They are lowered into the ground and, then, transported to the mining face. They, then, undercut, drill, charge, and blast the ore. A continuous mining machine mines the mine seam. These machines can mine up to 882 tonnes per hour, making paths of up to 7.9 meters wide and 2.4 meter high. These machines also have the potential to be automated. Conveyor belts, next, carry the ore to underground bins where it is stored until it is hoisted up by skips at speeds of 550-1,100 meters per minute.[4]

> **Solution Mining -** When conventional underground mines become flooded and unworkable, potash can be extracted using solution mining. Water is injected as a brine or salt and water solution. It is then circulated throughout the mine workings to dissolve potash and salt from the original pillars and walls. The brine is pumped to an evaporation pond. Submersible pumps are used, each pumping about 9,000 liters per minute.[5] As the liquid cools, the potash and salt crystals settle to the bottom of the pond. The cool brine is then heated and reinjected into the mine to start dissolving potash again. The remaining potash in the ponds is removed with floating dredges and pumped to the mill.

> **Cut-and-Fill Stope Mining -** Cut-and-fill stope mining is an underground process that uses continuous mining machines to excavate the ore in a step-like manor. It uses the fresh tailings to create a new floor for further mining. This method involves transporting personnel and ore the same way as conventional mining.

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[3] U.S. Environmental Protection Agency, *Identification and Description of Mineral Processing Sectors and Waste Streams*, p. 153-163, April 1998

[4] Potash Corporation of Saskatchewan, Inc. www.porashcop.com

[5] Ibid.

Soda Ash Mining

A variety of mining methods are used in soda mining. They are:

Room-and-pillar Mining - The room-and-pillar system involves extracting the ore by carving a series of rooms 20- to 30-feet wide while leaving pillars of ore 20- to 90- feet wide and as high as the ore bed to support the mine roof. When mining reaches the end of a section of ore, called a panel, the direction of mining is generally reversed (called the "retreat") in an attempt to recover as much of the ore from the pillars as possible. Pillars are mined until the roof caves; that section of the mine is then abandoned. Generally, 50 to 60 percent of the minable ore is recovered using this system, although higher amounts are possible.

Conventional Mining - Conventional mining is a method of breaking down and removing ore in a room-and-pillar system. Conventional mining involves undercutting, drilling, shooting or blasting and loading. Undercutting is accomplished by huge chain saws protruding from the bottom of self-propelled vehicles. These saws cut a slot or *kerf* about 6 inches high and 10 feet deep, into the ore and 20 feet across the face. These machines move to the next face while the drilling machine takes its place. The ore drill is a self-propelled vehicle with a long auger attached to a movable boom. It drills holes above and as deep as the cut. One hole is required for a face area 3- to 4-feet high and 4- to 5-feet wide. The presence of rock in the ore may mandate more holes. Blasting is done with chemical explosives or compressed gas. A machine slides the ore onto a conveyor belt and dumps it into a shuttle car. The shuttle cars take the ore either to a change point, where it is transferred to a conveyor belt, mine car or directly out of the mine. Roof bolting is also an important part of the operation, as it helps maintain the structural integrity of the roof. A bolting machine drills holes in the roof and inserts anchor bolts, which firmly attach the roof to stronger overlying layers of rock through expansion shells or resin. Bolts are generally required on a 4-by-4-foot array. All these operations produce a large amount of dust. Exposed areas are rock dusted to prevent ore dust explosions. This method of mining has all but vanished, although the method is still used in certain situations where geology is favorable.

Continuous Mining - Continuous mining is also a basic variation on the room-and-pillar system. The "continuous miner" is a machine used to break down and remove ore in a room-and-pillar system. This machine combines cutting, drilling, and loading ore into one operation and requires no blasting. A large steel drum equipped with tungsten carbide steel "teeth" tears the ore from a deposit. The continuous miner also has moving arms that load ore onto a short conveyor, which leads to a nearby shuttle car. A miner drives the shuttle car to a longer conveyor, which carries the ore to the surface. Every few minutes the continuous miner is moved to a new area and miners using a roof-bolting machine secure the roof.

Solution Mining - When conventional underground mines become flooded and unworkable, soda ash can be extracted using solution mining. Water is injected as a brine or salt and water solution. It is then circulated throughout the mine workings to dissolve soda ash and salt from the original pillars and walls. The brine is pumped to an evaporation pond. Submersible pumps are used, each pumping about 9,000 liters per minute.[6] As the liquid cools, the soda ash and salt crystals settle to the bottom of the pond. The cool brine is then heated and reinjected into the mine to start dissolving soda ash again. The remaining soda ash in the ponds is removed with floating dredges and pumped to the mill.

Borate Mineral Mining

Borates come from several types of mines. Open pit, brine, and various in-situ mining techniques all contribute to borate production.

Surface Mining - Surface mining requires extensive blasting, as well as rock, soil, and vegetation removal, to reach load deposits. Benches are cut into the walls of the mine to provide access to progressively deeper ore, as upper-level ore is depleted. Ore is removed from the mine and transported to milling and beneficiating plants for concentrating the ore, smelting, and/or refining.

When the ore lies close to the surface, it often can be uncovered by stripping away a layer of dirt, sometimes only a few feet thick. The ore is mined from large open pits by progressive extraction along steps or benches. The benches provide access to progressively deeper ore, as upper-level ore is depleted. After the soil and overlying rock are cleared, the ore is drilled and blasted. The portion of the ore body to be removed is first drilled in a specific pattern, and the holes loaded with explosive mixtures and fragmented. Following blasting, the fractured ore is loaded by huge mechanical shovels, hydraulic excavators, or front-end loaders onto large dump trucks or railroad hopper cars. The wide holes in the ground made by the power shovels are referred to as "open pits."

Solution Mining - Borate minerals can also be extracted using solution mining. Water is injected as a brine or salt and water solution. It is then circulated throughout the mine workings to dissolve borate and salt from the original pillars and walls. The brine is pumped to an evaporation pond. Submersible pumps are used, each pumping about 9,000 liters per minute. As the liquid cools, the borate and salt crystals settle to the bottom of the pond. The cool brine is then heated and reinjected into the mine to start dissolving potash again. The remaining borate in the ponds is removed with floating dredges and pumped to the mill.

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[6] Potash Corporation of Saskatchewan, Inc. www.porashcop.com

3.1.2 Beneficiation Methods

Potash (rock)

The ore is dry-crushed by rod and ball mills to free the KCL (potassium chloride, or potash) and put into a brine similar to salt water. It is then ground into distinct particles of potash and salt, pumped into tanks, and agitated to wash the clay off the ore. After conditioning with reagents to separate the particles, it enters the flotation process in which the KCL is floated off the top of the cells. The salts then sink to the bottom and are drawn off. Potash particles are dried in natural gas fired kilns, then classified according to size by passing the particles through a screen with a specific mesh size. Fine particles of potash are compacted to a larger size for blending with other fertilizer materials. Potash dust is dissolved, pumped into a cystallizer and cooled. The potash crystals grow and separate out. Some are redissolved and recrystallized to produce a refined product with very few impurities.

Soda Ash

The monohydrate method is the primary process used to make soda ash. In the monohydrate process, trona is crushed and calcined in rotary gas-fired calciners operating at 150-300°C. Calcining removes water and carbon dioxide from the ore, leaving an impure product containing 85 percent soda ash and 15 percent insolubles. The calcinate is dissolved with hot water and sent to evaporative, multiple-effective crystallizers or mechanical vapor recompression crystallizers where sodium carbonate monohydrate crystals precipitate at 40-100° C. This is below the transition temperature of monohydrate to anhydrous soda ash. The insoluble portion of the ore containing the shale and shortite are collected by clarifiers, filtered, and washed to recover any additional alkali before they are piped as a slurry to a tailing pond or injected underground. Some companies pass the liquor through activated carbon beds prior to crystallization to remove trace organics solubilized from the oil shale so organics do not interfere with the crystal growth rate. The crystals are sent from the crystallizers to hydroclones and dewatering in centrifuges. The centrifuge cake is conveyed to steam tube dryers where the crystals are dehydrated into anhydrous soda ash at 150°C, screened, and sent to storage or shipment. The final product made by the monohydrate process is dense soda ash.[7]

Borates

Sodium borate production comes from the principle ore tincal, which is soluble in water. The ore is crushed and the tincal is dissolved in water. The resulting insolubles are then separated from the solution and the clarified liquor is fed to the crystallizers. Next, the crystals of sodium borate are separated from the weak solution, which then can be recycled back to the dissolution step. The crystals are dried and can either be sold as borax or treated further to produce other borates. One of the products prepared when the crystals are cooled is sodium borate decahydrate. If sodium borate pentahydrate is the

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[7] U.S. Environmental Protection Agency, *Identification and Description of Mineral Processing Sectors and Waste Streams*, p. 599-609. April 1998

desired product, the sodium borate decahydrate can be sent to further recrystallize. Anhydrous sodium borate can be produced by thermally dehydrating either the sodium borate decahydrate or sodium borate pentahydrate.[8]

Boric acid is produced from ore that is dissolved with sulfuric acid and used as feed in the production of boric acid. Clays, sands, and other impurities are also present in the ore. After the ore is crushed and ground, it is dissolved into an aqueous stream. Since kernite, the primary borate mineral present, is not soluble in water, sufficient sulfuric acid must be added to the dissolving unit. Next, the clay and other insolubles must be removed from the aqueous stream. Rake classifiers separate out the larger material, while settling tanks and thickeners are used to remove the finer materials. The stream is then filtered further to remove any remaining insoluble materials. After filtration, the solution is pumped to crystallizers. In the crystallizers, the solution is cooled, forming a slurry containing solid boric acid crystals and a boric acid solution. Further filtration and centrifugation separate the solid boric acid, which can be dried and packaged for sale.

Borate Brine Solution Mining

Carbonization is used to supersaturate the brine solution with sodium bicarbonate. The carbonated liquor is used in combination with the brine solution. After the sodium bicarbonate has precipitated out, the brine and carbonated liquor mixture is cooled to crystallize sodium borate decahydrate. The crude sodium decahydrate is filtered from the liquor, thus producing anhydrous sodium borate, which can either be packaged and sold, sent to further beneficiation, or acid digested using sulfuric acid to produce boric acid. The sodium borate decahydrated can be redissolved and hydrated and then cooled to form either sodium borate decahydrated or sodium borate pentahydrate. If the anhydrous sodium borate is reacted with sulfuric acid instead, the resulting product is boric acid.[9]

3.2 Summary of Inputs/Outputs

The following lists the inputs and outputs for potash, soda ash and borates mining and beneficiation. Figures 3-1, 3-2, and 3-3 illustrate the potash, soda ash, and borate processes with their major inputs and outputs.

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[8] U.S. Environmental Protection Agency, *Identification and Description of Mineral Processing Sectors and Waste Streams*, p. 153-163, April 1998
[9] Ibid.

Inputs

Potash
Electricity
Diesel Fuel
Natural Gas

Soda Ash
Electricity
Diesel Fuel
Carbon
Make-up Water

Borates
Electricity
Diesel Fuel
Carbon Dioxide
Natural Gas
Sulfuric Acid

Outputs

Potash
Potash
Waste Rock

Soda Ash
Soda Ash
Off-gases
Insoluables
Spent Carbon
Salt Purge
Particulates
Emissions
Filter Aid
Carbon Absorbents
Tailings

Borates
Borates
Boric Acid (H_2BO_3)
Boric Acid (B_2O_3)
Sodium Borate Decahydrate
Sodium Borate Pentahydrate
Particulates
Gangue (clay)
Spent Brine

Energy and Environmental Profile of the U.S. Mining Industry

Figure 3-1. Potash Beneficiation Flow Diagram

```
            ┌─────────────────────┐
            │  Underground Mining │
            └─────────────────────┘
                      │
                      ▼
            ┌─────────────────────┐
            │    Crushing and     │
            │      Grinding       │
            └─────────────────────┘
                      │
                      ▼
            ┌─────────────────────┐
            │   Scrubbing and     │
            │     Desliming       │
            └─────────────────────┘
                      │
                      ▼
            ┌─────────────────────┐
            │    Conditioning     │
            └─────────────────────┘
                      │
                      ▼
            ┌─────────────────────┐
            │    Heavy Media      │
            │     Flotation       │
            └─────────────────────┘
                      │
                      ▼
            ┌─────────────────────┐
            │     Debrining       │
            └─────────────────────┘
                      │
                      ▼
            ┌─────────────────────┐
            │      Drying         │
            └─────────────────────┘
                      │
                      ▼
            ┌─────────────────────┐
            │     Secondary       │
            │    Conversions      │
            └─────────────────────┘
                      │
                      ▼
            ┌─────────────────────┐
            │     Screening       │
            └─────────────────────┘
                      │
                      ▼
               ┌─────────────┐
               │    Potash   │
               └─────────────┘
```
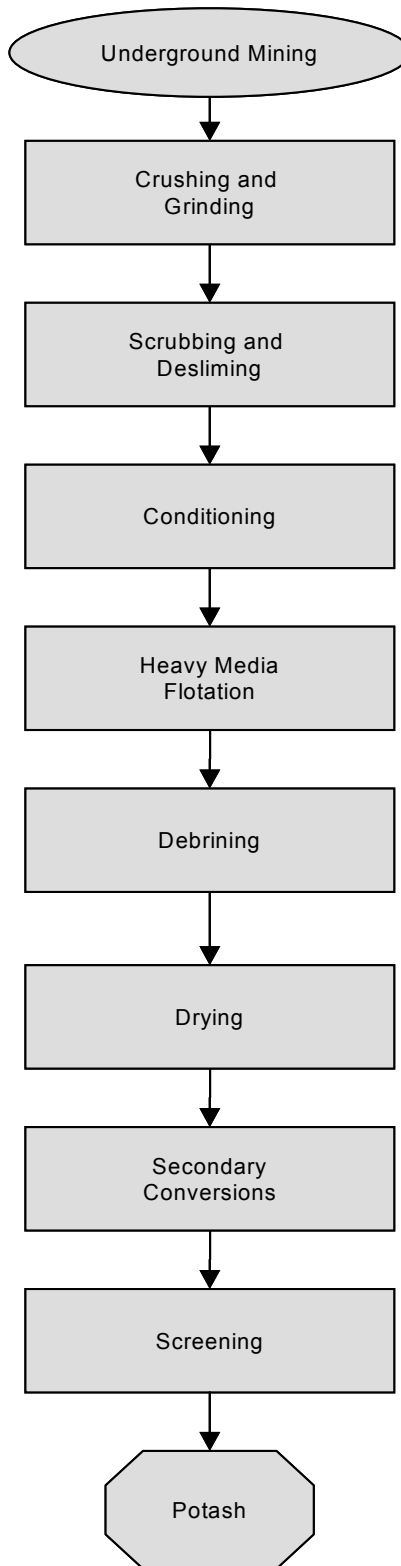
Figure 3-2. Soda Ash Monohydrate Process Flow Diagram
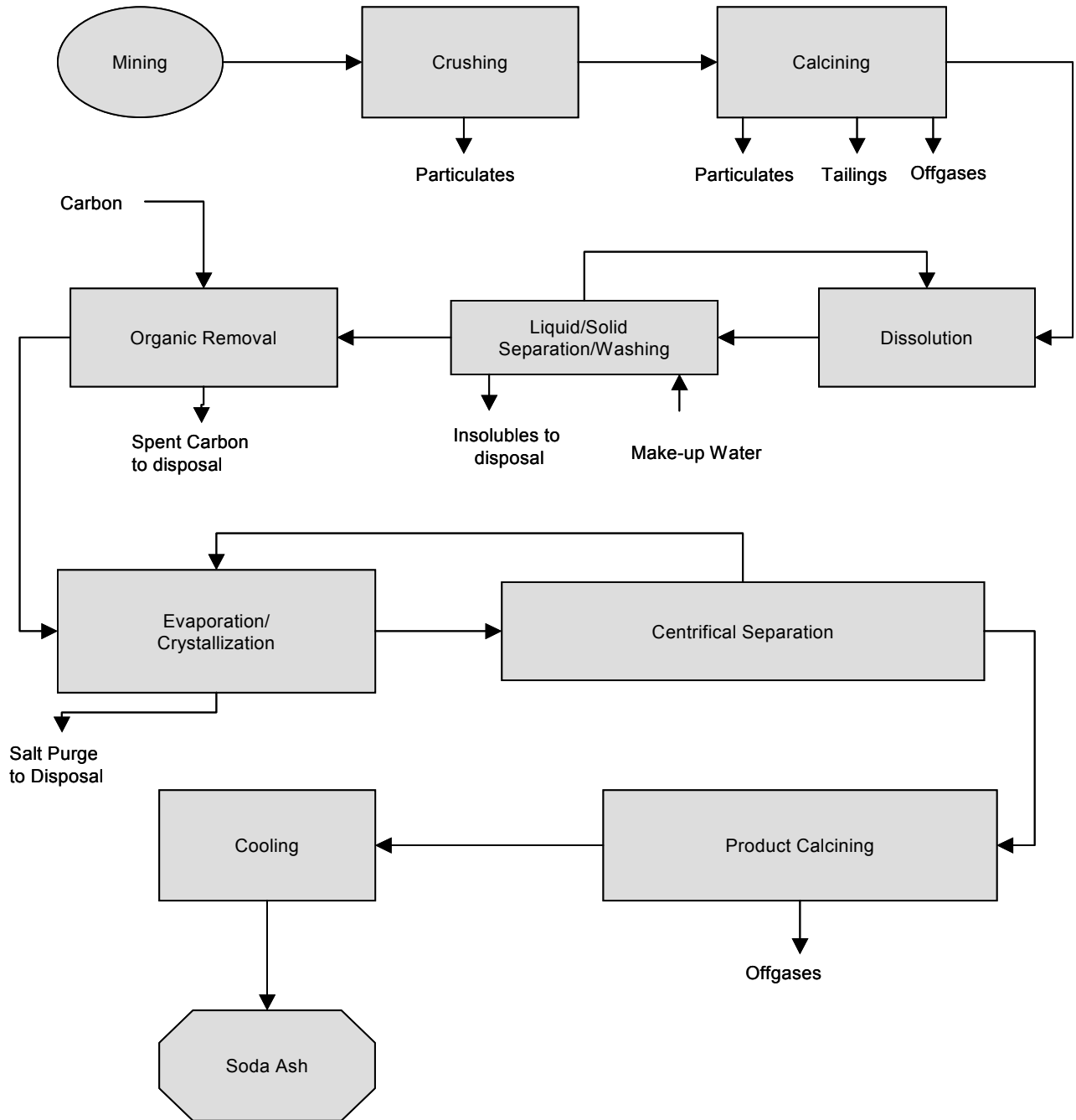
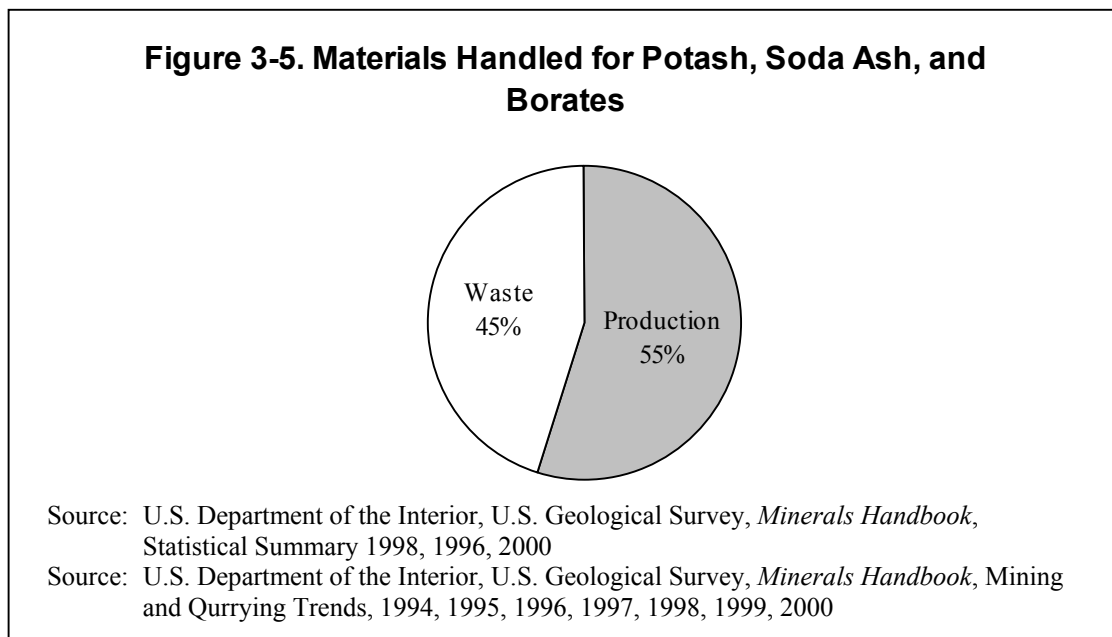**Figure 3-3. Borate Production Flow Diagram**

```
                          ┌─────────────┐
                          │   Mining    │
                          └─────────────┘
                                 │
                                 ▼
              ┌──────────────────────────────┐
   Co₂ ──────►│         Carbonation          │◄────── Brine
              └──────────────────────────────┘
                                 │
                                 ▼
              ┌──────────────────────────────┐
              │        Solid/Liquid          │──────► Sodium
              │         Separation           │        Bicarbonate
              └──────────────────────────────┘
                                 │                          H₂SO₄
                                 ▼                            │
 ┌──────────────┐   ┌──────────────────────┐              ┌──────────────┐
 │Crystallization│◄─│      Cystallizer     │──► Borax ──► │   Reaction   │
 └──────────────┘   └──────────────────────┘              └──────────────┘
        │                        │                                │
        ▼                        ▼                                ▼
 ┌──────────────┐   ┌──────────────────────┐              ┌──────────────┐
 │Sodium Sulfate│   │      Dehydration     │──►Particulates│  Boric Acid │
 └──────────────┘   └──────────────────────┘              └──────────────┘
                                 │
                                 ▼
              ┌──────────────────────────────┐
              │     Redissolution and        │──────► Gangue
              │        Cystallizaion         │──────► Spent Sodium Sulfate
              └──────────────────────────────┘
                        │              │
                        ▼              ▼
              ┌──────────────┐  ┌──────────────┐
              │Sodium Borate │  │Sodium Borate │
              │ Pentahydrate │  │ Decahydrate  │
              └──────────────┘  └──────────────┘
```

In the diagram the labels are: Mining; Carbonation (inputs CO_2 and Brine); Solid/Liquid Separation (output Sodium Bicarbonate); Cystallizer (outputs to Crystallization, Borax, Dehydration); Crystallization (output Sodium Sulfate); Reaction (input H_2SO_4, output Boric Acid); Dehydration (output Particulates); Redissolution and Cystallizaion (outputs Gangue, Spent Sodium Sulfate, Sodium Borate Pentahydrate, Sodium Borate Decahydrate).

Figure 3-4. Boric Acid Production Flow Diagram

```
                        ┌─────────────┐
                       (   Mining     )
                        └─────────────┘
                              │
                              ▼
                    ┌───────────────────────┐
                    │ Crushing and Grinding  │
                    └───────────────────────┘
                              │
                              ▼
                    ┌───────────────────────┐
                    │         Acid           │
                    │      Digestion         │
                    └───────────────────────┘
                              │
                              ▼
                    ┌───────────────────────┐
Solid Waste ◄───────│     Clarification      │
  (clay)            └───────────────────────┘
                              │
                              ▼
                    ┌───────────────────────┐
                    │      Filtration        │
                    └───────────────────────┘
                              │
                              ▼
                    ┌───────────────────────┐
                    │    Crystallization     │
                    └───────────────────────┘
                              │
                              ▼
   Liquor                                            Solids
┌────────────┐      ┌───────────────────────┐      ┌────────────┐
│ Evaporation│◄─────│      Filtration        │─────►│    Dry     │
└────────────┘      │   and Centrifugation   │      └────────────┘
      │             └───────────────────────┘            │
      ▼                                                   ▼
┌────────────┐                                    ┌────────────┐
│  Package   │                                    │  Package   │
└────────────┘                                    └────────────┘
      │                                                   │
      ▼                                                   ▼
  Sodium Sulfate                                   Solid Boric Acid
```
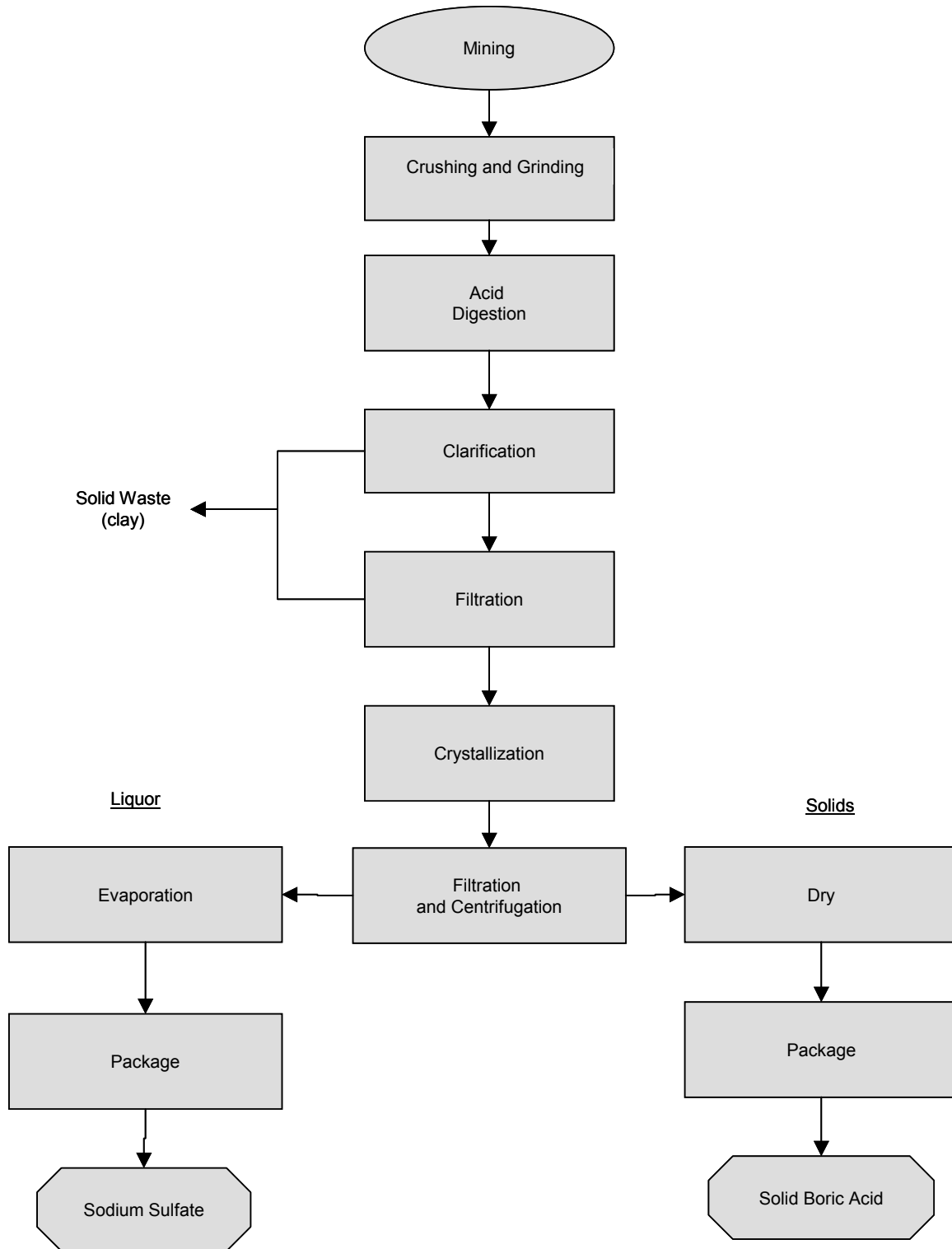
3.3 Energy Requirements

3.3.1 Materials Handled

Materials handled refer to the amount of ore and waste materials that must be handled in mining. Figure 3-4 shows the amount of mined material in relation to the amount of waste materials produced. The tonnage of materials that must be handled drives energy consumption in mining operations. For example, in 2000 the amount of materials produced was 15.3 million tons. With recovery ratios of potash at 21.5 percent and borates at 50 percent, the amount of waste produced was 11.6 million tons. This gives a total of 26.9 million tons of materials handled.

Figure 3-5. Materials Handled for Potash, Soda Ash, and Borates

Source: U.S. Department of the Interior, U.S. Geological Survey, *Minerals Handbook*,
Statistical Summary 1998, 1996, 2000
Source: U.S. Department of the Interior, U.S. Geological Survey, *Minerals Handbook*, Mining
and Qurrying Trends, 1994, 1995, 1996, 1997, 1998, 1999, 2000

3.3.2 Energy Requirements

In the 1992, the total amount of energy consumed in potash, soda ash, and borate mining was 68.8 trillion Btu.[10] While these estimates represent total energy consumption in potash, soda ash, and borate mining, few studies have been conducted on the energy consumption associated with specific mining processes since the 1970s.

Earlier studies to estimate energy consumption in potash production found various results. The Bureau of Mines reported that for 2.17 million tons of potassium oxide produced, an estimated 6 million Btu per short ton of potassium oxide (K_2O) was needed. The Fertilizer Institute surveyed the energy consumption of four North American muriate of potash producers in 1979. This survey found that the average energy consumption was 2.2 million Btu per short ton of product, equivalent to about 4.2 million Btu per short ton

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[10] U.S. Department of Commerce, Bureau of Census, Census of Mineral Industries, Subject Series, *Fuels and Electricity Consumed*, 1992

of K_2O, a reduction of 30 percent since 1973. This was comprised of about 1 million Btu of natural gas, 1 million Btu of electricity, and 1,000 Btu per short ton of K_2O.[11]

Estimated energy consumption in soda ash indicated that 15.8 million Btu were required to produce 1 ton of synthetic soda ash, whereas the energy requirement to produce the same quantity from trona was 7.2 million Btu. The domestic soda ash industry has reduced its energy requirements significantly since 1973 by replacing gas-fired dryers with steam-tube units, triple-effect evaporators with mechanical vapor recompression units and converting to coal exclusively as a fuel source or coal combined with other fuel sources. As a result of these energy-saving measures, energy requirements have been reduced from 4.5 to 12 million Btu per ton of synthetic soda ash produced. An estimated one-half of the energy consumed in natural soda ash refining goes to triple-effect evaporators, one-third is for calcining and the remainder is for drying.[12]

About 4.5 million Btu are required to produce 1 ton of natural sodium sulfate.[13] Technical improvements, such as the installation of mechanical vapor recompression crystallizers, have reduced the overall energy requirement to slightly less than 3 million Btu per ton of sulfate produced.

Major energy sources include coal and purchased electric energy. Table 3-1 shows the type and quantity of fuels consumed during potash, soda ash and borate mining as reported by the U.S. Census of Mineral Industries.

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[11] U.S. Department of Interior, Bureau of Mines, *Mineral Facts and Problems*, p. 617-633, 1985
[12] U.S. Department of Interior, Bureau of Mines, *Mineral Facts and Problems*, p. 617-633, 1985
[13] U.S. Department of Interior, Bureau of Mines, *Mineral Facts and Problems*, p. 617-633, 1985

Table 3-1. Potash, Soda Ash and Borates Production and Energy Consumed by Type [a]				
	Units	**1987**	**1992**	**1997**
Potash, Soda Ash, and Borates Production	Million tons	-	13.4	15.8
Energy Consumption				
Coal	Million tons	1.7	1.3	1.7
Fuel oil [b]	Thousand bbl.	443.8	190.3	Withheld
Gas	Billion Cubic Feet	30.5	27.8	25.2
Gasoline	Thousand bbl.	Withheld	33.3	7.1
Electricity Purchased	Million kWh	1,100	1,600	1,300
Electricity Generated Less Sold	Million kWh	789.2	Withheld	Withheld

a   Potash, Soda Ash and Borate Mineral is SIC Code 1474 (1997 NAICS Code 212392)
b   Summation of distillate and residual fuel oil
Sources: U.S. Department of Commerce, Economics and Statistics Administration, Bureau of the Census, Census of
    Mineral Industries, *Industry Series*, Potash, Soda Ash and Borate Minerals.

Due to a lack of current information on the energy requirements of mining and beneficiation, *the SHERPA Mine Cost Estimating Model* along with the *Mine and Mill Equipment Cost, An Estimators Guide* from Western Mine Engineering, Inc. were used to estimate the energy requirements of mining and beneficiation potash in an underground cut and fill mine.

The model was used to estimate the energy requirements of a hypothetical underground cut-and-fill potash mine. The results are shown in Table 3-2. This hypothetical mine operates over a 20-year lifetime with a 56,172,480-ton output at the end of its life. The mine runs 365 days a year with two 8.00 hour shifts per day, which gives it a daily production rate of 7,695 tons per day. The deposit characteristics are a bedded deposit with an average dip of 25 degrees. It has an average maximum horizontal of 26 feet and a minimum of 26 feet. The average maximum vertical is 8 feet with a vertical distance to the surface of 2,296 feet.

The single hoist, which is run on electricity, is the most energy-intensive piece of equipment used in the mine. Alone, it accounts for 16 percent of the total energy consumed per ton. This is followed by the continuous miners, also run on electricity. The

Table 3-2. Energy Requirements for a 7,695 ton/day Underground Potash Mine					
		Energy Consumption			
Equipment (number of units)	Daily hours/ unit	Single Unit (Btu/ton)	All Units (Btu/hour)	All Units (Btu/day)	All Units (Btu/ton)
Service Trucks [b] (23)	16.00	706	7,810,000	125,000,000	16,200
Continuous Miner [a] (2)	16.00	4,140	3,980,000	63,700,000	8,280
Drain Pumps [c] (8)	16.00	918	3,530,000	56,500,000	7,350
Hoist [a] (1)	16.00	7,240	3,480,000	55,700,000	7,240
Compressor [a] (3)	0.72	955	30,600,000	22,000,000	2,860
Conveyor [a] (2)	16.00	910	875,000	14,000,000	1,820
Main Fan [a] (1)	16.00	459	221,000	3,530,000	459
Backfill Pumps [a] (2)	16.00	91	87,800	1,400,000	182
Water Pumps [a] (2)	16.00	23	22,300	357,000	46
Total			50,600,000	342,000,000	44,500

a   Calculated at $0.049 per kWH: average for Rocky Mountain Region, 1999
b   Calculated at $0.535 per gallon: average prices for sales to end-users in U.S. Petroleum Administration for Defense District No. IV, 1999
Note: Mine operates during a 20-year lifetime with a 56,172,480-ton output at the end of its life. Mine runs 364 days a year with one shift per day of 8.00 hours, which gives it a daily production rate of 7,695 tons per day. Assumes deposit characteristics are a bedded deposit with an average dip of 25 degrees. Assumes average maximum horizontal of 26 feet and a minimum of 26 feet. Assumes maximum vertical is 8 feet with a vertical distance to the surface of 2,296 feet.
Source: BCS, Incorporated estimates (June, 2000) using the Western Mining Engineering, Inc. *SHERPA Mine Cost Software* and *Mine and Mill Cost, An Estimators Guide*
Conversations with Industry Experts

new continuous miners combined are similarly energy-intensive and account for 19 percent of the total energy consumed per ton. Also, a number of pumps are needed in the mine. Pumps needed include drain, water and backfill pumps. These pumps operating on electric energy, account for 17 percent of the total energy required in the mine. As with the mining industry in general, transportation energy account for a major portion of total energy consumption in the industry. The service trucks require 16,200 Btu/ton or 36 percent.

Estimated energy consumption in potash beneficiation is shown in Table 3-3. The rod mill operating on electric energy requires the most energy in beneficiation and is the most energy-intensive piece of equipment. This is partially due to the inefficiency of the rods striking the ore. Every time a rod strikes the casing of the mill instead of ore, energy is

Table 3-3. Energy Requirements for Potash Beneficiation					
Equipment (number of units)	Daily hours/ unit	Energy Consumption			
		Single Unit (Btu/ton)	All Units (Btu/hour)	All Units (Btu/day)	All Units (Btu/ton)
Rod Mill [a] (1)	16.00	41,300	19,900,000	318,000,000	41,300
Crusher [a] (1)	16.00	224	108,000	1,730,000	224
Flotation [a] (20)	16.00	138	1,320,000	21,200,000	2,750
Dryer [a] (1)	16.00	91	43,900	702,000	91
Screens [a] (1)	16.00	46	22,300	357,000	46
Compactor [a] (1)	16.00	23	11,100	178,000	23
Total			21,400,000	342,000,000	44,400

a   Calculated at $0.049 per kWH: average for Rocky Mountain Region, 1999
b   Calculated at $0.535 per gallon: average prices for sales to end-users in U.S. Petroleum Administration for
    Defense District No. IV, 1999
Note: Mine operates during a 20-year lifetime with a 56,172,480-ton output at the end of its life.
        Mine runs 364 days a year with two 8.00 shifts per day, which gives it a daily production rate
        of 7,695 tons per day. Assumes deposit characteristics are a bedded deposit with an average
        dip of 25 degrees. Assumes average maximum horizontal of 26 feet and a minimum of 26 feet.
        Assumes maximum vertical is 8 feet with a vertical distance to the surface of 2,296 feet.
Source: BCS, Incorporated estimates (June, 2000) using the Western Mining Engineering, Inc. *SHERPA Mine
        Cost Software* and *Mine and Mill Cost, An Estimators Guide*
        Conversations with Industry Experts

wasted. A rod mill requires 93 percent of the total energy consumed per ton. All crushing and grinding steps include the rod mill with the crusher. These steps account for 94 percent of the total energy consumed per ton. The crusher also operates on electric energy. The energy required by mining accounts for 50 percent of the total energy required. The combined energy requirements for mining and beneficiation of potash are 88,900 Btu per ton.

3.4 Emissions

Potash

In potash recovery, electrostatic dust precipitators are used to minimize dust emissions to the environment.

Soda Ash (monohydrate process)

Emissions from both soda ash processes are reported in Table 3-4.

Particulates from crushing and calcination are generated. The calciner offgases contain carbon dioxide. Airborne particulate emissions from crushing is about 1.5 kg per kkg of product. From calcination, emissions are about 95 kg per kkg or product. The particulates from crushing and conveying are collected in bags and recycled to the ore bin, which feeds the calciners. Residual emissions from the bag collectors are 0.015 kg per kkg of product. Particulates from the calciner consist of raw sodium carbonate dust. These particulates are passed through dry cyclones and electrostatic precipitators in series. The overall removal efficiency is 99.5 percent, resulting in residual particulates of 0.28 kg per kkg of product. Collected particulate is periodically recycled to the calciner.

Airborne emissions from product drying, cooling and packaging are generated from the monohydrate process. These wastes are controlled by the use of baghouses and wet scrubbers, with the recovered materials being recycled to the process. Emissions from the sodium carbonate dryer are generated at about 2 kg per kkg of product. After bag dust collection, the residual emission is 0.005 kg per kkg of product. Product screening, storing, and packaging generates 1.4 kg of emissions per kkg of product. After bag dust collection, residual emission is 0.005 kg per kkg of product.

Soda Ash (sesquicarbonate process)

Trona particulates generated from crushing, drying and calcination are about 99.5 Kg per kkg. About 1.5 kg per kkg of trona particulates are generated from crushing. Drying operations generate about 3 kg per kkg of particulates. Approximately 95 kg per kkg of particulate are produced by calcination. Wet scrubbers and dry bag collectors control particulate emissions from drying and packaging, respectively. Emissions after control average 0.02 kg per kkg from the driers and 0.02 kg per kkg from the product packaging operations. Solids recovered from the dry bag collectors are recycled to product storage. Emissions from ore calcination are also collected and recycled.

Table 3-4. Emissions from Soda Ash	
Emission	**Quantity**
Airborne Particulates	1.5 kg per kkg of product
Calcination Particulates	95 kg per kkg or product
Residual Particulates	0.015 kg per kkg of product
Airborne Emissions	2kg per kkg of product
Calciner Offgases	415 kg of carbon dioxide per kkg of soda ash
Particulate Emissions from Dryers	3 kg per kkg
Crushing ore Particulates	1.5 kg per kkg

Source: U.S. Environmental Protection Agency, Office of Solid Waste, *Identification and Description of Mineral Processing Sectors and Waste Streams.*

Calciner offgases are about 170 kg of water vapor and 415 k of carbon dioxide per kkg of soda ash generated by calcination of the sodium bicarbonate intermediate. These offgases are cooled to recover water for other on-site uses and for use in product purification. After water removal, the carbon dioxide is recycled to the initial process calcination step. Carbon dioxide is emitted as a result of the production process. During production, natural sources of sodium carbonate are heated and transformed into a crude ash that

Table 3-5. Carbon Dioxide Emissions from Soda Ash Manufacture and Consumption	
Year	Million Metric Tons of Carbon Equivalent
1990	1.1
1991	1.1
1992	1.1
1993	1.1
1994	1.1
1995	1.2
1996	1.2
1997	1.2
1998	1.2

Source: U.S. Environmental Protection Agency, Office of Policy Planning and Evaluation, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1998.*

Table 3-6. Emissions from Borate Minerals	
Emission	Quantity
Particulate Emissions	14 kg per kkg of product

Source: U.S. Environmental Protection Agency, Office of Solid Waste, *Identification and Description of Mineral Processing Sectors and Waste Streams.*

requires further refining. Carbon dioxide is generated as a by-product of this reaction and is eventually emitted into the atmosphere. Carbon dioxide emissions from 1990 to 1997 are shown in Table 3-5.

Borate Brines

Emissions from borates are shown is Table 3-6. Particulate generated from drying operations are collected in dry bags and recycled. In 1980, the wastes were generated at approximately 14 kg per kkg of product.

3.5 Effluents

Soda Ash (monohydrate process)

Effluents from both soda ash processes are shown in Table 3-7. Ore insolubles are about 110 to 150 kg per kkg of ore insolubles generated. These insolubles are transported to evaporation ponds for disposal. Filter aid and carbon absorbent ranges from about 0.5 to 2 kg per kkg of product. Spent carbon absorbent and spent filter aids are sent to on-site evaporation

Table 3-7. Effluents from Soda Ash and Borate Minerals	
Effluent	Quantity
Ore Insolubles	110 to 150 kg per kkg
Filter Aid and Carbon Absorbent	0.5 to 2 kg per kkg of product
Scrubber water	-
Spent Carbon and Filter Wastes	0.5 to 2 kg per kkg per product
Suspended Particulate Matter	2 kg of suspend particulates
Spent Brine	16,000 kg per kkg of product

Source: U.S. Environmental Protection Agency, Office of Solid Waste, *Identification and Description of Mineral Processing Sectors and Waste Streams.*

ponds for disposal. Scrubber water is recycled to the process for recovery of additional product.

Soda Ash (sesquicarbonate process)

Scrubber water is generated from air pollution control devices. This is recycled to recover additional product.

Spent carbon and filter wastes from carbon absorption and filtration range from 0.5 to 2 kg per kkg per product. Waste filter aids and carbon absorbents are washed to the evaporation ponds for final disposal. Solid wastes from initial ore are slurried to tailing ponds to settle out suspended materials and then to the final disposal ponds, which serve as evaporation ponds where there is no discharge. Suspended particulate matter is generated by the use of wet scrubbers for air pollution control, resulting in wastewater containing 2 kg of suspended particulates.

Spent brine from the initial carbonation and filtration steps contains about 16,000 kg per kkg of product of unrecovered sodium carbonate and other raw brine constituents. The spent brine contains about 65 percent water, 16 percent sodium chloride, and 19 percent of other constituents including sodium sulfate, borax, and potassium chloride. This waste stream is combined with other waterborne waste streams and returned to the brine source.

Borates

Process wastewater from washing contains dissolved borax and other salts that may be sent to lined evaporation ponds.[14]

3.6 By-products and Solid Waste

Soda Ash Extraction and Beneficiation

Extraction and beneficiation wastes include overburden, tailings, and spent dissolution wastes. The trona ore dissolution wastes are sent to tailings ponds. Waste tailings are injected underground.

Soda Ash (monohydrate process)

Table 3-8 shows by-products with quantities from soda ash production. Tailings generated from the calcining process are discharged to the tailings tank. The tailings tank also receives fly ash and bottom ash generated from

Table 3-8. By-products from Soda Ash	
By-product	**Quantity**
Ore insolubles	110 to 150 kg per kkg of ore are generated
Filter aid and carbon absorbent waste	0.5 to 2 kg per kkg of product

Source: U.S. Environmental Protection Agency, Office of Solid Waste, *Identification and Description of Mineral Processing Sectors and Waste Streams.*

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[14] U.S. Environmental Protection Agency, *Identification and Description of Mineral Processing Sectors and Waste Streams*, p. 153-163, April 1998

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using coal to fire the kiln and the steam boiler. This waste is treated in a thickening tank by adding anionic and cationic flocculants to the tailings to increase the solids content from approximately 10 to 50 pecent solids. The waste is then disposed of in one of two waste management units, (1) the tailing pond, or (2) the mine void. The mine void is located in an old mineshaft. Tailings are gravity fed into the mine when the holding tanks full. Tailing supernatant that accumulates in the mine is collected in a sump and periodically pumped and disposed of in the tailing pond.

Purge liquor from calcining is often sold as a sulfur neutralizer or dust suppressant. Mother liquor is a possible waste stream from centrifugation. This waste stream is recycled.[15]

Soda Ash (sesquicarbonate process)

As in the monohydrate, purge liquor from calcining can be generated. Again, it is often sold as a sulfur neutralizer or dust suppressant. Mother liquor is a possible by-product from centrifugation and is recycled.[16]

Borates

Gangue solids are generated from the initial dissolution step during the production of sodium borate decahydrate. In 1980, these wastes were reported as generally inert insolubles, although they contained 0.08 percent natural arsenic mineral realgar. The solid wastes from ore residues and evaporation wastes were sent to on-site lined evaporation ponds.[17]

The brine extraction process generates waste brine and spent solvents. The plant extract or crud generated during the recovery of borates form brines containing arsenic and halogens and is ignitable.[18]

Spent sodium sulfate is produced by crystallization. Waste liquor and underflow mud that remains after the boric acid is filtered off contains arsenic. This waste is recycled.[19]

3.7 Hazardous Waste

There are no RCRA-listed hazardous wastes associated with potash, soda ash, and borate production.

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[15] U.S. Environmental Protection Agency, *Identification and Description of Mineral Processing Sectors and Waste Streams*, p. 599-609. April 1998
[16] Ibid.
[17] Ibid.
[18] Ibid.
[19] Ibid.