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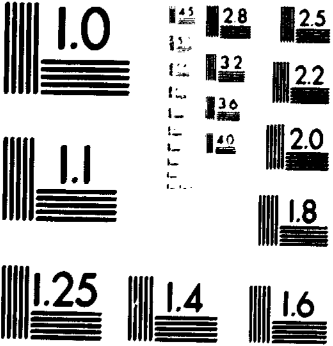

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CHANGES IN THE WORLD'S ALKALI INDUSTRY AND ITS IMPLICATIONS FOR JAMAICA.

SI/JAM/84/801

Prepared for the Government of Jamaica by the United Nations Industrial Development Organization.

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This report has not been cleared with the United Nations Industrial Development Organization which does not, therefore, necessarily share the views presented.

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Explanatory notes

All Measurements are metric.

All prices and cost are, unless otherwise specified in the text, as of February 1985.

The exchange rates used for estimating costs of equipment and commodities are as of February 1985.

The exchange rate for the Jamaican dollar was, as of February 1985, approximately US$ 1 = J$ 5.10.

INTRODUCTION

In recent years Jamaica's economy has moved from a substantial surplus of foreign currency earnings to a large deficit. Jamaica's possibilities for maintaining economic growth is dependent on whether or not this balance of payment development can be reversed.

The bauxite and alumina industry is the country's single largest foreign revenue source. Its structure as an enclave industry is such that Jamaica's options for increasing foreign currency earnings from the industry are essentially limited to substituting its imports with local products. Major imports for the alumina industry are fuel oil and caustic soda.

For this reason local production of caustic soda has been studied several times during the last decade. It has todate not been possible to demonstrate the feasibility of such a project.

In recent years improvements have been made to caustic soda processes and natural soda ash has emerged as a major source of alkali.

This study tries to answer the question as to how these changes affect Jamaica's possibilities of producing its own alkali for the alumina industry.

This study has been prepared by Lennart Königson - Industrial Economist - and Egon Boisen Schmidt - Chemical Engineer on assingment as experts to UNIDO. Both experts visited Jamaica in January/February, 1985.

The study has been co-sponsored by the Jamaica Bauxite Institute which assisted the experts with data collection in Jamaica.

CHAPTER 1

ALKALI CONSUMPTION IN JAMAICA

Background

Alkali comprising soda ash (Na_2CO_3) and caustic soda ($NaOH$) is used by Jamaica's alumina industry, by a glassbottle manufacturer as well as by soap and detergent manufacturers. Demand for caustic soda in Jamaica has fluctuated in step with the level of alumina processing for which caustic soda is used as a reactant. Other alkali users are paint manufacturers, the petroleum refinery, glass manufacturers and the textile industry. Other industries which consume substantial amounts caustic soda, i.e. the pulp and paper industry and the steel industry, do not exist in Jamaica.

Jamaican import statistics, Statistical Institute of Jamaica, give the following volumes and values for imports of caustic soda:

TABLE 1

Year	Volume (tons-dry matter)	Value (US$'000)	C.i.f. price per ton (US$)
1980	404.315	23.837	59
1981	573.628	45.395	79
1982	272.653	24.460	90
1983	247.263	14.582	59
Total	1.497.859		

For the same period the alumina industry reports that it consumed 1.000.000 tons (see following page)..

As no other significant user, but the alumina manufacturers, have been identified it is probable that imports have been overstated due to differences in measurements (50% solution in some cases being recorded as 100% solution). A closer analysis of values lends support to this assumption. In 1982, for instance, the average posted spot market price for caustic soda was US$240/ton of 100% solution. The three alumina companies reported average cost of US$173/ton whereas the average c.i.f. value recorded in the import statistics was only US$90/ton.

Soda ash is used mainly in glass manufacturing and for the production of soap and detergents. West Indies Glass would, at full capacity utilization,use 6.000 to 8.000 tons of soda ash per year whereas the soap and detergent manufacturers consume generally less than 1000 tons. Volume of imports has fluctuated considerably primarily as a consequence of variation in capacity utilization of the glassbottle plant.

TABLE 2

Year	Volume (tons)	Value (US$'000)	C.i.f. price per ton (US$)
1980	3.214	485	151
1981	4.960	835	168
1982	3.554	503	141
1983	5.634	854	151

The Alumina Industry

In the past the alumina industry used soda ash which resulted in a better water balance and consequently a somewhat lower energy consumption than caustic soda. The latter has, however, advantages in respect of transport and handling. Caustic soda is purchased by the alumina companies partly under long-terms contract with major US producers and partly on the spot market.

The three alumina companies in Jamaica, Alcoa, Alcan and Alpart, being substantial purchasers,are generally able to buy on most favourable terms. In the case of Alcoa and Alcan purchases are made through corporate pools which handle the entire requirements for the companies.

The caustic soda is shipped in 50% solution in tankers and piped to the alumina plants where it can be fed into the process with a minimum of handling costs.

In recent years caustic soda imports by the three alumina companies have been as follows:

TABLE 3

Year	Volume (tons 100% solution)	Value (US$'000)	C.i.f. price (US$/ton)
1980	290.006	36.775	127
1981	295.011	54.900	186
1982	235.085	40.770	173
1983	179.187	29.470	164
1984	126.600	19.425	152

Two factors have caused a decline in consumption during the last three years. The first and foremost is a decline in alumina production from 2.5 million tons in 1981 to around 1.6 million tons in 1984. The second is, the consumption of caustic soda per ton of alumina which has, during the same period, been reduced from approximately 120 kg to 80 kg per ton by way of improved recovery.

The alumina industry in Jamaica, under agreements between the Government and the three companies, function as an/ enclave industry. Jamaica's revenues from the alumina industry consist mainly of proceeds from sale of bauxite, salaries and wages, an alumina levy and income from sales of such proportion of alumina which corresponds to its share of ownership in the Alpart plant. In order to retain more foreign currency from the alumina industry within the country, Jamaica would need to increase its sales to the alumina industry. Apart from bauxite and energy, a major raw material is also caustic soda. Caustic soda which is produced from salt (NaCl) and to a lesser extent limestone thus constitues a possibility for Jamaica to increase its sales to the alumina industry and therefore its hard currency revenue from the industry.

Previous Studies

This is the reason why, over the last ten years, several studies have been made with respect to caustic soda production in Jamaica. In the 70's a major complex involving a refinery, caustic soda production by way of electrolysis and a PVC complex for utilizing the resulting chlorine was evaluated but found not feasible.

In the early 80's caustic soda production by way of the Solvay process was studied.

In 1984 a market study for caustic soda and by-products in the Caribbean was commissioned and at approximately the same time an improved version of the Solvay method was assessed.

CHAPTER II

ALKALI PROCESSES

General

Alumina, Al_2O_3, produced from bauxite by way of the "Bayer"-type process requires alkali which can be applied in the form of sodium hydroxide, NaOH (caustic soda) or sodium carbonate, Na_2CO_3 (soda ash).

Although today caustic soda is manufactured mainly by electrolysis of salt the possibility for using soda ash directly in the alumina process or as a raw material for making caustic soda means that a study of possible local supply of alkali to the alumina industry in Jamaica should include the different methods which could be used for alkali production.

In order to facilitate a survey of presently available alkali processes those are schematically shown in table 4 where their main features are also indicated.

A summarized description of the processes is given in the following with special emphasis on characteristics of interest for Jamaican conditions.

TABLE 4

PROCESSES FOR ALKALI PRODUCTION - SODA ASH AND CAUSTIC SODA.

Process	Raw materials	Product	Co-product(s)/use
1. "Natural soda"			
a) Ordinary mining b) Extraction mining	Trona, mineral	Soda ash	Excavation material,waste
2. "Chemical synthesis"			
a) Solvay method b) New Asahi, alt.1	Salt + Limestone	Soda ash	Calcium chloride solution/dilute/waste " " /concentrated/waste
c) New Asahi, alt.2	Salt + Limestone + Ammonia		" " /concentrated/waste + Ammonium Chloride /fertilizer
3. "Chemical synthesis"			
a) Lime causticization	Soda ash + Limestone	Caustic soda	Calcium carbonate mud/waste or recycle
b) Iron causticization	Soda ash + Iron oxide	Caustic soda	Iron oxide mud/waste or recycle
4. "Electrolysis"			
a) Diaphragm cell b) Mercury cell c) Membrane cell	Sodium chloride	Caustic soda	Chlorine

Natural Soda Processes

Mining of soda ash containing minerals (Trona) on a large scale is a recent development. The most important deposit and production site is at Green River in Wyoming where mining by extraction similar to the production of Frash-sulphur has lowered costs to such an extent that Solvay-soda in U.S.A., regardless of location, cannot compete and therefore all plants for synthetic soda ash either already have or, in a near future, will have to cease production.

As the deposits are very large no change of the above development can be expected for a very long time.

Soda Ash by Chemical Synthesis - I

The Solvay-process for making soda ash with the common and simple raw materials, salt and limestone, is not as simple as the overall chemical equation suggests:

$$CaCO_3 + 2NaCl \rightarrow Na_2CO_3 + CaCl_2.$$

The reaction occurs in a number of different steps demanding several operations in specialized apparatus as schematically shown in a flow diagram. (See Annex 1 attachment from Kirk Othmer, 1947, vol. 1, p. 394).

Economy of scale is very pronounced and plants smaller than 200.000 tpy will be built only under special circumstances. In spite of the long time, about 100 years, during which the Solvay-process has been known and has dominated soda ash production, no significant process development occurred until the so called "New Asahi-process" was launched in Japan. It has now been in full scale industrial operation for sufficiently long time to prove reliability and the advantages Asahi claims in comparison with the Solvay process. Those advantages are: more efficient use of the salt raw material, lower consumption of thermal energy and lower plant investment. The plant, being simpler, generally performs better and demands less operational work than the Solvay plants do. Whereas both Solvay and Asahi use the same basic reactions with salt, limestone and circulating ammonia, the New Asahi process offers the potential advantages of taking out the co-product calcium chloride as a more concentrated solution or to tap the circulating stream of ammonia by taking out ammonium chloride as a solid product useable as fertilizer.

Said potential advantages can, however, only be realized under conditions where there is demand for either calcium chloride or ammonium chloride. In other instances the New Asahi process will only have the merits of lower investment costs and better performance.

Caustic Soda by Chemical Synthesis - II

Before the second world war sodium hydroxide was mainly made by reacting sodium carbonate with milk of lime; so called causticization. Milk of lime was either made from new limestone (burnt and slaked) or calcium carbonate mud formed at the causticization was returned and slaked, thus avoiding the otherwise troublesome dumping of the mud.

The reactions are:

$$CaCO_3 \rightarrow CaO + CO_2$$
$$CaO + H_2O \rightarrow Ca(OH)_2$$
$$Ca(OH)_2 + Na_2CO_3 \rightarrow 2NaOH + CaCO_3$$

Although not as complicated as the Solvay-type soda ash process the causticization demands a number of operation in sequence and elaborate apparatus. (See Annex 2 attached flowsheet from Kirk Othmer, 1947, vol. 1, p 412). The process also results in a diluted (10-11%) NaOH-solution, the evaporation of which to standard grade, 50% solution, for energy reasons, must occur in multiple (3-4) unit evaporators in which crystallizing salts (sodium sulphate and others) tend to foul surfaces and have to be separated.

The chemical efficiency of causticization with lime is quite good (sodium yield ca. 98%) so development has been directed more towards lower energy consumption by using better type apparatus and in a combined soda ash-caustic soda plant by skipping the steps for isolating and drying soda ash and instead to start causticization with an intermediate soda ash product: sodium bicarbonate - sodium carbonate solution.

Attempts to obtain caustic soda solutions of higher concentration before the final evaporation to 50% have shown two possibilities: Reaction with strontium oxide or iron oxide can give solutions with min. 30-35% NaOH meaning a reduction of necessary water evaporation from about 8 ton per ton of NaOH (in form of 50% solution) to about 1 ton per ton.

Reactions with strontium are very much the same as with calcium:

$$SrCO_3 \longrightarrow SrO + CO_2$$
$$SrO + H_2O \longrightarrow Sr(OH)_2$$
$$Sr(OH)_2 + Na_2CO_3 \longrightarrow 2NaOH + SrCO_3.$$

With iron oxide the reactions follow a somewhat different sequence (the so called Loewig-process):

$$Fe_2O_3 + Na_2CO_3 \longrightarrow Na_2Fe_2O_4 + CO_2$$
$$Na_2Fe_2O_4 + H_2O \longrightarrow 2NaOH + Fe_2O_3$$

Because of the similarity of reactions the flow sheet for the strontium process will be the same as for lime whereas with iron the formation and hydrolysis of sodium ferrate gives a process shown in the flow sheet in Annex 3.

Due to high price and limited availability of strontium the strontium method has never been industrially utilized. The Loewig process has no raw material problem (useable Fe_2O_3 abundant) but purity (iron content) of the final product as well as construction of suitable equipment for the calcination and separation steps have presented difficulties.

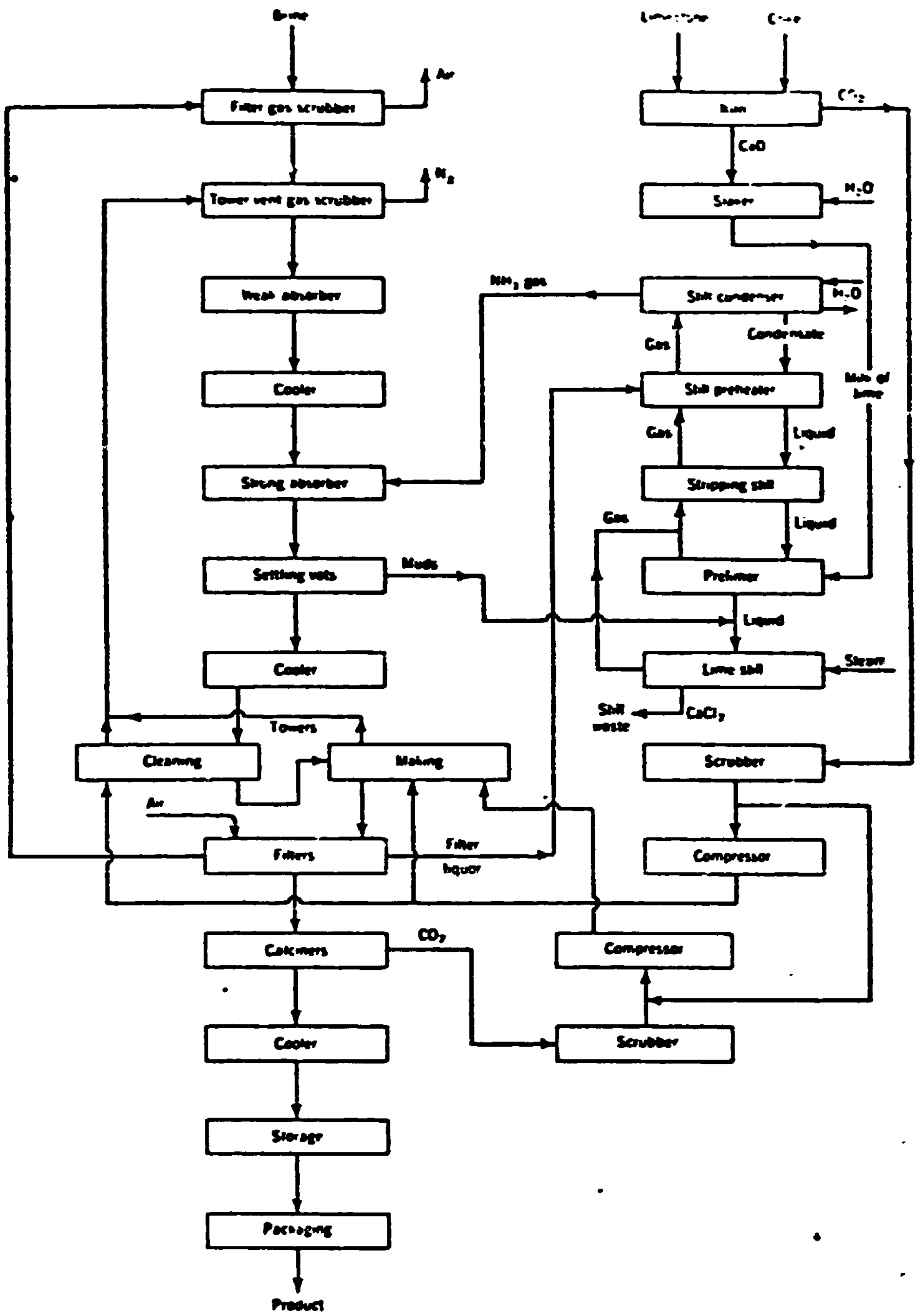
Research and development is carried out by such firms as Toyo Pulp, Japan, and Australian Pulp Manufacturers with licence to amongst others Babcock and Wilcox, U.S.A. in the Loewig method, now called DARS = Direct Alcali Recovery System. Results today suggests that, with access to low price soda ash, the DARS method could be a competitive future way to produce caustic soda.

Electrolysis

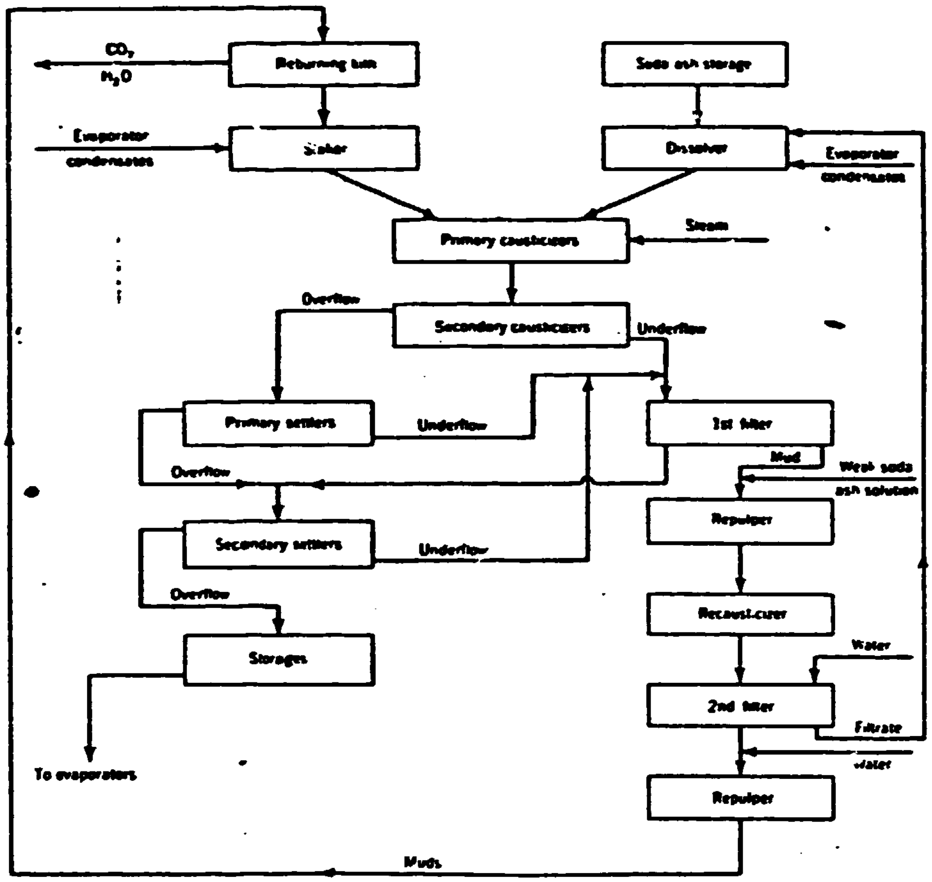
The simplest and presently most often used method for production of caustic soda is the electrolysis of sodium chloride. When the co-produced chlorine has a market the stoichiometric related production of 1 ton NaOH and 0.9 ton Cl_2 allow costs to be borne by two endproducts rather than one. This is normally not possible for other methods which is why the causticization process is only used under certain circumstances, for instance regeneration of solutions (black liquor) in the pulp and paper industry.

The different electrolytic processes in use are named after the type cell installed since this influences performance in important ways. The specific consumptions of electric energy ordinarily given per ton NaOH although the process also yields 0.9 ton Cl_2 are for: Diaphragm 2000 - 2500 kWh, Mercury over 3000 and Membrane about 2000, but as the cell solutions in the 3 cases yield NaOH-concentrations of 10-15, 50 and 30-35% respectively, the different plant energy relations, consumptions rates with Mercury set to 1.0 are: 1.05 - 1.0 - 0.8.

As furthermore diaphragm solution is less pure than that produced by other methods and since environmental aspects hamper the use of mercury a change to membrane cells has been initiated. The weakness of the elctrolytic process has been and will always be the chlorine market. In times with low chlorine consumption caustic soda becomes scarce and vice versa. In the past this has lead to very large price variations for caustic soda whereas chlorine prices have been more stable.

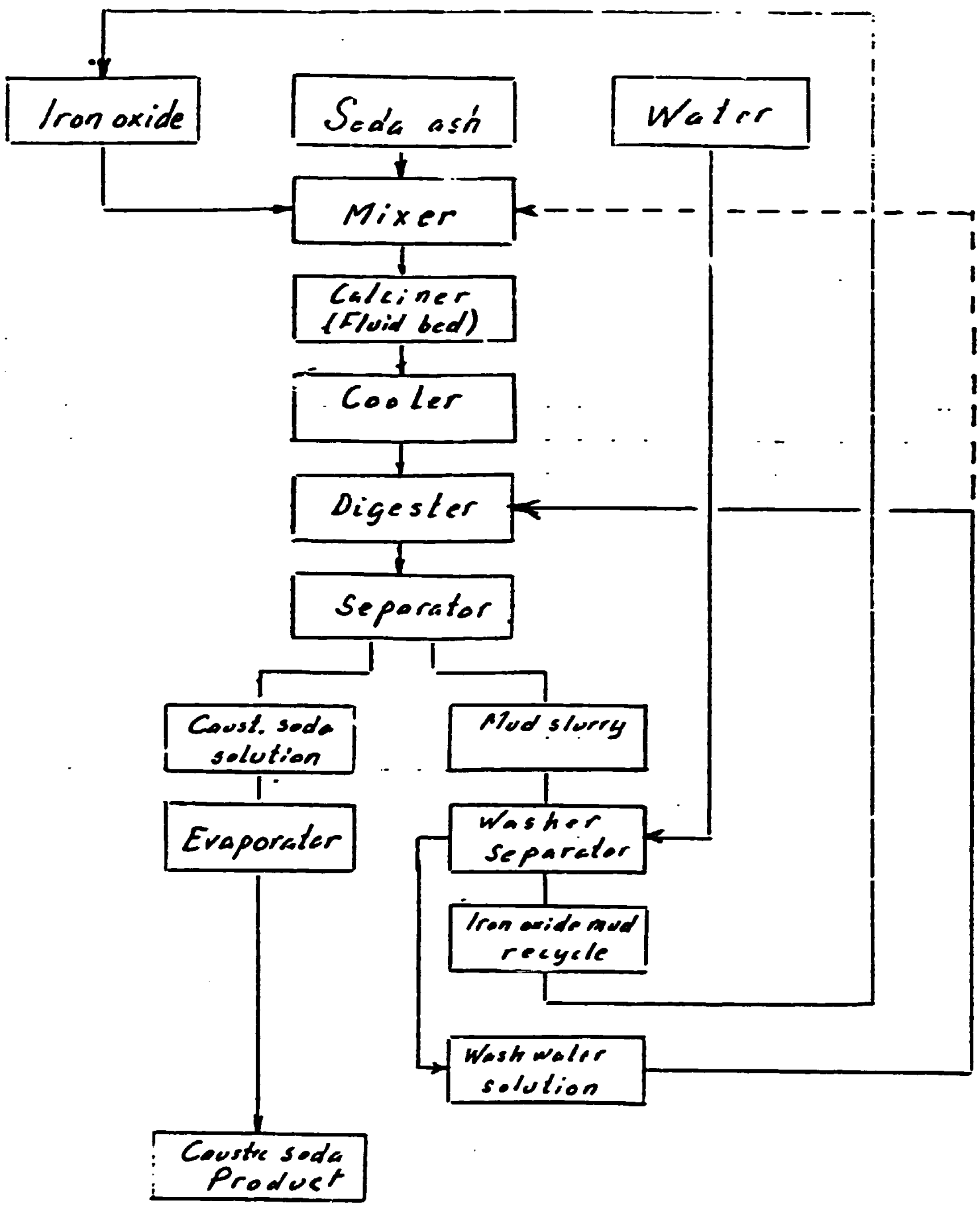


Flow diagram: Solvay process.



Continuous causticizing with double filtration.

Flow sheet: Loewig process



CHAPTER III

ALKALI USE, MARKETING AND HANDLING

The Products

The products resulting from the two principal processes for producing caustic soda are apart from the soda calcium chloride or ammonium chloride for the Solvay method calcium carbonate as a result of causticization and chlorine by way of electrolysis. In addition soda ash and sodium bicarbonate can be produced as an intermediate product in two chemical methods. Annex 1 to this chapter contains a list of the major industrial uses of the products.

Stable Industrial Feedstock

As an industrial feed-stock or raw material, caustic soda retains a principal role in those industries where it is required and there are very few substitutes which would be considered economic in their usage. At the present time most industrial users do not envisage a substitute being developed for the product in the short to medium term. The greatest possibility for substitution is in the manufacture of soaps and detergents. The market for the product will therefore essentially change in direct relationship to the productive capacity or the actual level of production performance for the consuming industries. In recent times, the demand in the alumina refining industry has fallen off due to a general decline in the production of alumina which itself directly results from the world-wide recession in the aluminium industry.

Shipment to oil refining installations have also experienced a substantial decline over the past 2-3 years due to a similar decline in the petroleum sector of many countries. The regional Caribbean demand for caustic soda in the short to medium term can be expected to be directly determined by production trends in both the alumina and petroleum sectors of the major user-countries.

Increased demand for caustic soda in the United States and Europe, particularly with regard to the requirements of the alumina and pulp/paper industries will also certainly have an impact on the regional market. Shipments to the region could as a consequence be at relatively higher prices. On the other hand, vibrant and sustained positive rates of growth i these industrial economies will serve to stimulate increased levels of demand for chlorine, an important raw material in such industries as organic chemicals and vinyl chloride. Increased chlorine production to meet high levels of industrial demand, without a commensurate increase in the demand for caustic soda, invariably serves to depress prices within the caustic soda market. This phenomenon could be to the detriment of regional suppliers who might not be as price competitive as their North Atlantic counterparts.

Increased recovery of caustic soda both in the pulp and paper and in the alumina industry could in the longer perspective change use and demand pattern. A major impetus for this change has been environmental concerns which for, for instance, the Scandinavian pulp and paper industry has led to a drastic reduction of consumption of caustic soda since close to 100% can be recovered from the black liquor.

Improved technology has also made this recovery profitable and it is probable that improved recovery would be both feasible and profitable for the alumina industry.

The Caustic Soda Market

Caustic soda is sold essentially through three types of arrangements. These are supply contracts, intra-group or corporate pools and, on the spot market. Supply contracts are usually established with major manufacturers or brokers for purposes of ensuring reliable supplies at satisfactory prices. These contracts are influenced by the outlook with regard to such factors as capacity and price and could run up to five (5) years at a time.

Most of the region's suppliers (manufacturers and agents) are either U.S. based, or access supplies from U.S. sources. Within CARICOM for example, about 50,0% of users import directly from overseas suppliers while the other half buy through local agents.

There are thirty-one (31) major producers of caustic soda in the United States, but about 65,0% is produced by only five (5) companies. The following table shows the distribution of production in 1982.

TABLE 1

DISTRIBUTION OF CAUSTIC SODA PRODUCTION CAPACITY - U.S.A.

Company	Percent of Industry
Dow Chemical Corporation	31.0
Pittsburgh Plate Glass Industries	10.0
Diamond - Shamrock	9.0
Hooker Corporation	8.0
Olin Corporation	7.0
Other Companies	35.0

SOURCE: Journal of the Electro-chemical Society (1982).

The larger U.S. plants, assessed in terms of rated average annual capacity, tend to dominate the market. This is primarily due to their capability to realize scale economies in production. The distribution of market share on the basis of rated capacity as at 1982 is shown in Table 2. Plants having rated capacities in excess of 121,000 metric tons per year account for 85.0% of the market for caustic soda while smaller plants, though greater in number account for the remaining 15.0%.

TABLE 2

MARKET SHARE OF U.S. CAUSTIC SODA PLANTS IN RELATION TO RATED CAPACITY.

Capacity ('000 metric tons per year)	Market Share (Percent
Above 500	69
120-500	16
42-120	6
Less than 42	9

Source: Journal of the Electro-chemical Society (1982).

Most plants within the Central American - Caribbean region supply to customers within their country or, as in the case of Pennwalt in Nicaragua, to users within the immediate geographic area - the Central America Common Market. Akzo Chemicals of Holland and ICI of the United Kingdom also represent two major European suppliers to the region.

The method of buying through corporate pools represents a system which is common to larger users, usually transnational corporations with several locations of use, such as in the case of the bauxite/alumina companies. Many of these organizations purchase in bulk on behalf of their respective subsidiaries or branches and thereby benefit from the economies accruing to such bulk purchases. The Alumina Company of Canada (ALCAN) for example, operates a pool arrangement which is administered from Montreal. Similarily, the Alumina Company of America (ALCOA) purchases in bulk on the spot market for its several operations and consigns shipments to fit in with the respective plant requirements.

The purchasing of caustic soda on the spot market at prevailing prices is also quite a normal procedure for many industrial users. This approach seeks to trade off the uncertainty of supplies with the benefits which are likely to result from lowered prices in a depressed market.

Caustic Soda Pricing

The price of caustic soda tends to be very volatile over time and therefore represents a critical variable in settling those arrangements relating to production, supply and point of purchase. The pattern of pricing which relates to purchasers from domestic and regional plants tend to be different from that which applies on the wider international market. International open market prices tend to be substantially lower than those of regional producers.

Most of the world's supply of caustic soda is produced electrolytically and, as earlier noted, has the production of chlorine as a major co-product. The respective demand patterns for those products have in the past tended to move in opposite direction. Excess supplies of chlorine invariably pose a storage and environmental problem to producers and therefore the production of caustic soda tends to move in direct relation to the demand for chlorine. Chlorine which is a gas is at times stored as ethylene dichloride (EDC) a liquid. When the demand for chlorine is low, producers of caustic soda invariably adjust their scale of operation to a point on the production possibility curve where the negative economic impact of a lowered demand (or sales) for chlorine will be minimized. The price at which caustic soda is supplied is adjusted drastically through heavy discounts and other arrangements to match the prevailing competition. At favourable prices for chlorine, excess caustic soda can be dumped in liquid form. Quoted spot prices for caustic soda delivered to the region have ranged from about US$70 to over US$300 per ton. This range demonstrates the very wide band within which pricing takes place.

Caustic Soda Handling

Caustic soda is usually shipped either in a dry state or as liquid. Shipping and other transport related charges account for a substantial proportion of the total cif price of the product to most purchasers. It is estimated that these costs could account for up to 50% of the quoted cif price. Consignments of caustic soda from U.S. suppliers to regional users are normally handled out of ports in the Gulf of Mexico. The major shippers in the industry are Concorde Lines and Samba Lines.

MAJOR INDUSTRIAL USES OF ALKALI AND CO-PRODUCTS

SODIUM HYDROXIDE (Caustic Soda):

1. Reactant in the alumina industry
2. Soap industry
3. Textile manufacture
4. Petroleum industry (refining)
5. Pulp and paper industry
6. Detergents and cleaners
7. Production of synthetic organic fibres e.g. rayon and cellophane
9. Boiler water treatment chemical (softeners)
10. Drain pipe cleaners
11. Dyes
12. Metal cleaning compounds
13. Paint and varnish removers
14. Purification of coal and coke by-products

SODA ASH

1. Glass
2. Pulp and paper
3. Soap
4. Cleaners
5. Water softeners
6. Textiles
7. Petroleum
8. Manufacture of non-ferrous metal e.g. aluminium
9. Iron and steel production
10. Pharmaceuticals

SODIUM BICARBONATE

1. Fire extingushers
2. Self raising flour
3. Neutralizing agent in leather manufacture
4. Neutralizing agent in the manufacture of synthetic fibres
5. Antacid (stomach powders)
6. High grade baking powders (different grades)

7. Pharmaceuticals - tablet manufacture
8. Detergents
9. Fruit preservatives
10. Rubber foams
11. Production of fine chemicals

CALCIUM CARBONATE AND PRECIPITATED CALCIUM CARBONATE

1. As extender/filler in plastics
2. In paper (white paper) - used as pigment and fire retardant (e.g. cigarette paper)
3. As pigment/extender in rubber
4. As pigment in paint (also used as extender)
5. In toothpaste
6. Printing ink (also typists liquid erasers)
7. As an antacid
8. In pharmaceuticals
9. In white shoe polish
10. As an extender/raw material in the pharmaceutical and fine chemicals industries.

CALCIUM CHLORIDE

1. Dust control on secondary roads (e.g. mining haul roads), unpaved streets and highway shoulders.
2. Brine production in refrigeration plants
3. Freeze proofing of coal and ore prior to shipping and in stockpiling
4. Addition to concrete mixtures
5. Brine for filling inflated tractor and other heavy mobile machinery tyres.
6. Additive to drill mud for oil exploration and production

CONSTRUCTION OR QUICKLIME

1. In glass industry as a flux
2. In alumina production (most alumina plants purchase limestone and manufacture their own quicklime).
3. Soil conditioning (treatment of heavy clays and acidic soils).
4. Calcium Carbide production
5. As flocculant in the sugar industry
6. For sewage treatment (also treatment of other industrial wastes).
7. Water purification
8. As a bleaching agent

9. Mortars and plasters
10. Asphalt paving
11. Desulphurization (SO_2 removal)
12. In lubricating greases
13. Dehydration of air, petroleum, organic solvents and alcohols
14. Production of silica bricks
15. Fruit storage
16. Dehairing hides prior to tanning
17. As a lubricant in oil well drilling muds
18. Ore flotation

CHAPTER IV

ALKALI AND CO-PRODUCTS PRODUCTION AND USE IN THE CARIBBEAN

General:

Alkali products are used by basic chemicals industries and by metals and petroleum refining plants as carriers or neutralizers.

Demand is thus centered on heavy, large scale and capital intensive industries of which there are very few in the Caribbean region. Its large number of small countries lack both domestic markets, raw materials and energy resources for this type of industry for which reason alkali consumption of any significance exists only in six of the region's countries.

Quality and availability of statistics on consumption vary substantially from country to country but a total picture which emerges from a survey of the region would suggest a present level of consumption of caustic soda slightly in excess of 500.000 tons per year of which the alumina industry would account for more than 80%.

Soda ash is the only other product with a significant use and its present consumption would appear to be in the range of 50.000 tons per year. The region's productive capacity amounts to around 100.000 tons of caustic soda and 30.000 tons of soda ash from three plants in respectively Colombia, Venezuela and Nicaragua.

Jamaica

Caustic Soda

Jamaica's major exports consist of bauxite and alumina, which makes it a captive market for caustic soda. The main export market has been the United States of America over the years, followed by the E.E.C. At present, the composition of exports is being re-adjusted in order to increase the output and sale of non-traditional goods produced in the agricultural and industrial sectors. This re-orientation of production is, however, not likely to result in increased demand for the products being studied. Caustic soda, a major raw material in the alumina industry, as well as most of the other co-products are all now imported. Calcium carbonate in its crude form is processed locally and calcium oxide (quick-lime) is produced extensively from the large deposits of limestone on the island.

The major industries identified to be potential users of the chlor-alkali products are as follows:

Paint	-	Precipitated calcium carbonate (PCC)
Detergents	-	P.C.C., Caustic soda
Bauxite/Alumina	-	Caustic soda, quicklime
Petroleum Refining	-	Soda ash, Caustic soda
Glass	-	Soda ash
Steel	-	Soda ash
Textiles	-	Soda ash, Caustic soda
Pharmaceutical Manufacturing	-	Sodium bicarbonate

Caustic soda consumption has averaged 300.000 tons per year of 100% concentration for the last 4-5 years.

Purchasers are mainly the three alumina companies Alcan, Alcoa and Alpart and suppliers are US producers such as Dow Chemicals, LCP Chemicals & Plastics, Olin and Diamond Shamrock.

Other Alkali Products

Jamaica consumes less than 10.000 tons per year of soda ash all of which is imported. With the major consumer being the local glass manufacturer which has suffered from sluggish demand for several years there is little scope for increased use of soda ash.

Sodium bicarbonate is imported in amounts of less than 1.000 tons per year for the detergent, pharmaceutical and food industries. The detergent and pharmaceutical industries along with the paint industry is also a major consumer of calcium carbonate, both in natural and precipitated form. Natural calcium carbonate is produced locally whereas precipitated calcium carbonate is imported, however, in very small quantities of generally less than 1000 tons per year.

Calcium chloride which would be a primary co-product of caustic soda in the New Asahi process finds very limited use in Jamaica and elsewhere.

It is used mainly for purposes of dust control on gravel and dirt roads, as brine in refrigeration plants and in solution as shock-absorbing filler in some very heavy duty tires. In recent years use of calcium chloride as additive to drill mud for oil exploration has increased.

Colombîa

With a growing industrial sector, Colombia represents a potential market for alkali products. The size and potential of the market are, however, dependent on the domestic capacity to produce the products, many of which are presently manufactured in the country.

The major industrial consumers of chlor-alkali products in Colombia are:

Coal	- Sodium hydroxide Sodium bicarbonate
Glass	- Sodium carbonate
Paper	- Calcium carbonate incl. PCC Caustic soda
Leather tanning	- Caustic soda

Caustic soda is produced by Colombiana de Alcalis with an annual capacity of approx. 25.000 tons and a monopoly on imports of all alkali products required over and above its own production. With the Alcalis plant being old imports, which have fluctuated substantially in the past, would likely increase in the future.

Alcalis also produces soda ash used primarily by the textile industry in amounts of about 30.000 tons per year and the age of the plant may lead to a gradual decline of capacity and increased import.

Consumption of other alkali products is insignificant. Of interest is, however, that Colombia has the largest production capacity for salt (sodium chloride) in the Caribbean but that its utilization has been hampered by inadequate port facilities.

The Dominican Republic

The Dominican Republic although one of the most populous countries in the Caribbean, does not have the major industries which consume caustic soda and other alkali products. A small oil refinery and the detergent and food processing industries are the main consumers, all of which import caustic primarily from the U.S. Volumes have averaged between 15.000 and 20.000 tons during recent years.

Soda ash imports have been much lower, generally less 1.000 tons per year and imports of other alkalis are insignificant.

Guyana

Guyana was a major source of alumina prior to the closing of the refining plant in 1982 and although plans for a re-opening exist the sluggish world market demand for aluminium has todate prevented the realization of such plans.

Other uses are for the sugar industry and for textiles.

The level of imports of caustic soda, primarily from the U.S., was prior to the closing of the alumina plant between 25.000 and 35.000 tons per year with substantial variations from year to year.

Venezuela

With a population of 15 million and a wealth of natural resources Venezuela has a substantial potential for expanding its basic industries which makes it likely to develop into an important user of chlor-alkali products.

The main present users of alkali products are:

Plastics	-	Precipitated calcium
Pharmaceuticals	-	- " -
Pulp and paper	-	Precipitated calcium carbonate Caustic soda Sodium carbonate
Alumina	-	Caustic soda
Petro chemicals	-	- " - Sodium carbonate

Caustic soda is produced in Venezuela but not in adequate quantities for supplying the local market.

Petroquimica de Venezuela produces about 35.000 tons per year primarily for the alumina refining plant, Inter-Alumina.

Estimated future demand and supply for caustic soda in Venezuela is approximately as follows:

Users	metric tons
Inter-Alumina	150.000
Other industries	45.000
Total	195.000
Sources	
Local production	35.000
Import	160.000

This is borne out by import statistics which show that imports have risen from approx. 60.000 tons in 1980 to around 140.000 tons in 1983, largely on account of commissioning of a new alumina plant. A further increase in this plants capacity utilization along with the implementation of other basic industries such as pulp and paper could further increase demand for caustic soda.

Soda ash consumption has fluctuated erratically in recent years and a sustainable level would seem to be in the order of 10.000 tons per year.

Suriname

Suriname's alumina industry is virtually the only alkali user in the country. The entire consumption is imported primarily from the US and the level of imports have averaged around 100.000 tons per year up until 1982 after which it is believed to have fallen in step with reduced alumina production.

Neither soda ash nor alkali co-products are consumed to any significant extent in Suriname.

Nicaragua

Nicaragua's industrial production has fluctuated drastically in recent years as a consequence of internal strife and political changes. Its caustic soda plant is reported to have a name plate capacity of approximately 40.000 tons per year but its exports to other countries in the region is reported to have been negligible in recent years.

Other Caribbean Countries

Other countries in the area generally lack the type of industries which use alkali products and their annual consumption of for instance caustic soda and soda ash is generally in the range of a few thousand tons or less.

The limestone based products such as calcium carbonate, precipitated calcium carbonate and quicklime are often locally produced on a small scale.

Calcium chloride consumption is not of any consequence in any of the countries in respect.

Ammonium chloride as a fertilizer is generally not used in the area which is dominated by sulphate based fertilizers.

CHAPTER V

JAMAICAN ALUMINA INDUSTRY

Caustic Soda versus Soda Ash

Alumina production and caustic soda consumption have shown the following pattern for the last 5 years:

TABLE 5

Year	Alumina production ton	Caustic soda consumption ton	Soda/alumina ton/ton	Caustic soda Price US$/ton	Caustic soda Total US$/year
1980	2.455.870	290.006	0.118	126,81	36.800.000
1981	2.556.057	295.011	0.115	186,11	54.900.000
1982	1.757.811	235.085	0.102	173,42	40.800.000
1983	1.850.847	179.187	0.097	164,45	29.500.000
1984	1.590.000	127.600	0.08	153,4	19.400.000

(Source: Jamaica Bauxite Institute)

The tendency towards lower consumption of caustic soda per ton produced alumina is, according to Alcan and Alcoa, expected to continue down to 0.06-0.08 ton of caustic soda per ton of alumina with a minimum of about 0.05 considered possible in the future. This is on account of the bauxite in Jamaica being of an easily treated trihydrate type (in contrast to for instance Australian bauxite demanding up to and over 0.3 ton/ton). This is also the reason why treatment with soda ash instead of caustic soda is possible with unchanged yield (in Australia lower yield with soda ash).

This flexibility in choice of raw material (soda ash or caustic soda) is at present of limited interest for the Jamaican alumina industry, since the entire supply system (transportation, storage, handling, use) cannot be readapted to soda ash without substantial investments, which would not be profitable at present price relationship between caustic soda and soda ash.

The bauxite refining process, although it requires water, aims at producing a dry material - Al_2O_3. Water is added essentially for removing, by way of a slurry, waste material - mainly ironoxide. In order to produce the dry aluminium trioxide,evaporation of water is required. A process using a 50% caustic soda solution is provided with water both directly, for the washing, and indirectly through the caustic soda. If alkali were to be added in the form of soda ash, which is a solid anhydrous material, the result would be better control over the water balance in the process, resulting in reduced need for evaporation of water. The use of soda ash instead of caustic soda would reduce the need for evaporation by approximately 0,1 ton water per ton of alumina produced, which in terms of energy would correspond to approximately 80.000 kcal.

Since evaporation is costly in terms of energy, an obvious question would be why this cost could not be avoided by importing a caustic soda in higher concentration. The reason is twofold. Firstly, caustic soda in higher concentrations than 50% crystalizes at normal room-temperatures which means that all installations for its transport, pumping and piping would need to be heated and insulated. Secondly, caustic soda is not produced in higher concentrations than 50%. The electrolytic mercury cell process yields this concentration whereas all other process yields a lower concentration so the cost of production of a higher concentrate would have to include cost of evaporation.

The reasons why the alumina industry in Jamaica, which shifted from soda ash to caustic soda at a time when energy costs were low, has not reverted to soda ash, are essentially three.

The first is the price of the alkali. Caustic soda on a dry substance basis contains 33% more active sodiumoxide (Na_2O) and this in combination with the price relationship which has existed between caustic soda and soda ash, would not have made the latter significatly less costly.

The second is that of handling. With pumping and piping in several cases in Jamaica directly from the port to the plant, handling of a solution becomes less complicated than handling of a very dusty bulk material.

Thirdly, alumina processing is highly complex, highly sensitive to changes in chemical balances and highly capital intensive. The risk of production disruptions etc. has not been justified by the relatively small savings which could possibly accrue by shifting from caustic soda to soda ash.

An assessment of the various alternatives which exist for Jamaica in terms of supplying its alumina industry with alkali should, however, include a review of those three factors and as a consequence the issue of reverting back to soda ash.

Future Demand

Jamaica's alumina industry has, in recent years, reduced its consumption of caustic soda due to lower production of alumina and due to improved recovery techniques.

The future level of alumina production in Jamaica will depend on world demand for aluminium and on Jamaica's competitiveness as a producer.

The aluminium industry is generally regarded as a mature industry offering limited possibilities for growth. The largest single market segment for aluminium is that of packaging, cans and foils, where different plastic materials are making strong inroads. The same applies for many components for machinery, vehicles and airplanes. Development of reinforced plastics and of conductive plastic materials can be expected to continue to the point where those materials can match the strength per unit of weight of aluminium at competitive prices.

The prospects for the industry are thus little or no growth in which case Jamaica's cost competiveness will determine the extent to which its alumina industry will utilize capacity.

Jamaica's advantages are principally the quality and easy accessibility of its bauxite. Mining costs in Jamaica are low in comparison to those of the main competitors Australia, Brazil and Venezuela, which has vast untapped deposits.

The other advantage is that of proximity to major smelters in Canada and the US. The difference in shipping cost for Jamaican and, for instance, Australian alumina is substantial and will remain so.

Jamaica's main disadvantage is that of energy cost. Alumina processing is (between 0,35 to 0,4 ton of oil per ton of alumina) energy intensive and aluminium smelting is even more so. The aluminium companies have therefore tended to concentrate production to countries which combine large bauxite deposits with lowcost energy. Energy production for Jamaica's alumina plants is today entirely based on imported oil and as such considerably more costly than would be the case with coal-fired steamboilers. A changeover to the latter would entail substantial investments which are difficult to justify for aluminium companies facing stagnant demand and weak prices.

It is therefore not unlikely that Jamaica's alumina industry will continue to operate at a level well below full capacity utilization. From 1981 to 83 production has fallen to around 1.7 to 1.8 million tons per year. This represents close to a 30% decline as compared to production in 1980. The production figures for 1984 are only indicative but they suggest a further slight reduction in capacity utilization to approx. 1.6 million tons per year. Further cutbacks cannot be excluded. The fact that production was reduced at a point in time when the US economy experienced an unprecedented high rate growth doesn't augur well for the industries' capability to compete with comparable materials. It would therefore seem prudent to expect further reductions in capacity utilization and a future level of consumption of caustic soda which is lower than that recorded for 1984.

At a level of alumina production of 1.5 million tons and a caustic soda consumption rate of 6%, annual caustic soda consumption would be 90.000 tons on a dry substance basis. It is, however, doubtful if the alumina plants can reduce both production and caustic soda consumption to this extent so a caustic soda consumption level of 100.000 tons per year might be more realistic.

Options

The options for Jamaica, were it to supply its alumina industry with alkali and thus create a domestic value added, would essentially be the following three process alternatives.

A. Production of synthetic soda ash with or without causticization to caustic soda.

B. Import of natural soda ash and causticization to caustic soda.

C. Production of electrolytic caustic soda.

A fourth alternative exists but this would not yield any value added for Jamaica. This would be import of natural soda to be fed directly into the alumina refining process.

Synthetic Soda Ash

For option A there are, in the case of synthetic soda ash production, two alternatives namely the "Solvay" method and the "New Asahi" [1] method, the latter being essentially a refinement of the former. For the causticization there are also two alternatives, causticization with lime or with ironoxide, both of which can be combined with either the Solvay or the New Asahi process. As those two causticization methods are applicable also for option B (import and causticization of natural soda ash) they are dealt with separately.

The New Asahi process is a refinement of the soda ash Solvay process necessitated by among other things the oil crisis. The classic Solvay process uses only 70% of its principal raw material salt or sodiumchloride. By recycling the raw material the New Asahi process achieves a 98% utilization of the salt and as a consequence sharply reduces energy consumption per unit of soda ash. Improvements have also been made with respect to other aspects of the process which has resulted in lower investment cost, lower labor cost and reduced volumes of waste. The waste is less diluted (by a factor of 2.5). Calcium chloride can be recovered with substantially less evaporation which reduces both energy consumption and investment cost for evaporators.

1) There exists a third process "Asahi Dual" which was a forerunner to the New Asahi process and which yields as a co-product ammonium chloride.

The following table presents, in summarized form, a comparison between main cost parameters for respectively the Solvay and the New Asahi process.

TABLE 6

Cost Parameters per ton of Soda Ash

Item	Unit	Solvay	New Asahi
Salt	Ton	1.6	1.2
Limestone	Ton	1.3	1.1
Electricity 1)	kWh	250	270
Boiler fuel	Ton coal	0.43	0.21
Kiln fuel 2)	Ton anthracite	0.09	0.09
Water (process)	Ton	8	4
Water (cooling)	Ton	140	125
Labor rate 3)	Pers/1000 TPY	1.2	0.9
Liquid waste	Ton	10	4
Solid waste	Ton	0.3	0.2

(Paper at Fifth Industrial Minerals Int'l Congress, 1982 by Roger Aitala, Isonex Inc., Houston, Texas)

1) Total power consumption with electric powered compressors.

2) Carbondioxide is recovered which necessitates anthracite, coke or oil as fuel.

3) Based on 150.000 TPY plant size.

The New Asahi process has been installed in several plants in Japan and has been evaluated by the Quebec Government for 400.000 TPY project at Becancour.

Since the process has been in operation for the better part of 10 years, there is no reason to doubt that it would function well and that the above comparison is realistic. The fact that proponents of the process expect plant investment to be only 80% of that of a similar size Solvay plant adds to the advantages of the New Asahi process.

Causticization

There are, as mentioned above, two methods for causticizing soda ash into caustic soda.

One uses limestone [1] in the chemical reactions described above in Chapter 2. The other is the so called Loewig process which uses ironoxide (see Chapter II). The difference between the two is that the Loewig process yields a higher concentrated caustic soda solution and thus reduces the cost of evaporation. With lime causticization a concentration of 10-11% can be achieved whereas the Loewig process would yield a concentration of up to 35%.

Australian and Japanese companies have initiated research and development into the Loewig process in an effort to enhance soda recovery in the pulp and paper industry. The resulting process called "Direct Alkali Recovery System" (D.A.R.S.) has been tested in a pilot plant but not yet in full scale.

The following table compares expected parameters for the two processes with the assumption that both limestone and ironoxide are available at cost of mining which is the case in Jamaica.

1) Strontium can be used instead of limestone but this process has no practical applicability.

TABLE 7

Cost parameters per ton of Caustic Soda in 50% solution.

Item	Unit	Caustlcization	D.A.R.S.
Soda ash	Ton	1.36	1.36
Lime 1)	Ton	0.10	-
Ironoxide 1)	Ton	-	0.16
Electricity	kWh	40	40
Boiler fuel	Ton coal	0.10	0.03
Kiln fuel	Ton coal	0.20	0.20
Water	Ton	8	2
Labor rate	Pers/1000 TPY	0.2	0.3
Waste	Ton	0.10	0.16

1) Both limestone and ironoxide are recirculated in the process with losses estimated at 10% of active substance.

The major difference is that of reduced evaporation for the D.A.R.S. process which is reflected in a lower consumption of boiler fuel. This also affects the plant cost which for a plant producing 100.000 tons of caustic soda has been estimated at US$ 22 million for the D.A.R.S. process and around US$ 30 million for the lime process. It needs, however, to be emphasized and stressed that the D.A.R.S. process cannot yet be considered to constitute proven technology and the cost data given above may not be borne out in a full scale operation.

Caustic Soda by Electrolysis

There are as mentioned above three electrolytical processes using salt for the production of caustic soda and chlorine. They are

- the traditional mercury cell process,
- the diaphragm cell method, and
- the membrane cell method

As the membrane cell method has a lower overall energy consumption, and yields higher purity with less environmental implications and at a lower investment cost, it has become the preferred process to which an increasing number of producers are converting. A membrane cell process typically costs 15 to 25% less and consumes 20 to 35% less energy than more traditional mercury and diaphragm cell plants. It should also be noted that the industry expects further improvements in membrane cell technology. Energy consumption as low as 1.600 kWh/ton of caustic soda and a concentration of 40% has been claimed by membrane cell manufacturers. New bilaminar membranes, operating at increased current densities ($4kA/m^2$ as compared to $3kA/m^2$) promise further reductions in investment cost.

At present cost parameters for caustic soda production in a membrane cell plant would be as follows:

TABLE 8

Cost parameters per ton of Caustic Soda in 50' solution

Item	Unit	Electrolytic-membrane cell
Salt	Ton	1.50
Brine purification	Ton	0.1
Power-electrolysis	kWh	2000
Power plant	kWh	400
Boiler fuel	Ton coal	0.03
Membranes	piece	1 change/2 years
Water	Ton	0.1
Labor	Pers/ton	0.6

In addition to large quantities of caustic soda the process yields hydrogen and chlorine.

Comparison of Options

The above analysis suggests that the three best options for producing caustic soda would be, firstly, through the New Asahi process coupled with D.A.R.S. causticization, secondly, from imported natural soda ash causticized in the D.A.R.S. process and thirdly, by electrolysis using the membrane cell technology. Production cost parameters for those three options would compare as follows:

TABLE 9

Comparison of Cost Parameters per ton of Caustic Soda in 50% solution.

	Unit	New Asahi +D.A.R.S.	Trona +D.A.R.S.	Electrolysis membrane cell
Salt	Ton	1.63	-	1.50
Limestone	Ton	1.50	-	-
Soda ash	Ton	-	1.36	-
Ironoxide	Ton	0.16	0.16	-
Brine pur. chemicals	Ton	-	-	0.1
Electricity	kWh	400	40	2.300
Boiler fuel	Ton coal	0.32	0.03	0.03
Kiln fuel	Ton coal	0.20	0.20	-
Kiln fuel	Ton anthracite	0.12	-	-
Process water	Ton	7.5	2	0.1
Labor rate	Pers/1000 TPY	1.2	0.3	0.6
Membranes	piece	-	-	1 change/2 years

The three principal alternatives differ substantially in terms of operating costs and investments which is analysed in detail in the following chapter.

CHAPTER VI

FINANCIAL ANALYSIS OF CAUSTIC SODA PRODUCTION ALTERNATIVES

General

In the following analysis production parameter values determined in Chapter V for the three process alternatives are transformed into costs for a project presumed to be operating in Jamaica at the present time.

For several raw materials there are at present limited or no imports on which to base cost. Salt, for instance, is at present imported in small quantities at cost of US$ 20/ton. With a large operation justifying specialized shipping arrangements it is probable that this cost could be halved.

For soda ash it has been assumed that a large long-term buyer could purchase the soda ash at a slight discount compared to present price level f.o.b. Wyoming which is US$ 70 to 75/ton. Freight Wyoming Jamaica has estimated to cost US$ 45 per ton.

Coal is at present not imported in substantial volumes. The cost estimate of US$ 45/ton c.i.f. is commensurate with cost assumption made in a recent coal conversion study for Jamaica. Indications in January/February 1985 were that a slight reduction on this price might be possible for a large buyer with a long-terms contract.

Electric power has been assumed to be supplied by Jamaica's electric utilities at cost which in turn should equal approximately USc 5/kWh. It should be noted, however, that Jamaica's electric power capacity is at present virtually fully utilized and that, for instance, an electrolytic plant would require a substantial increase of Jamaica's electric power production, presumably with a coalfired plant.

The following table summarizes the production cost assumptions.

TABLE 10

Costs - basis deliveries Jamaica -85.

Salt	US$ 10/ton	(imported from Colombia $4 + $6 freight)
Lime	3/ton	(locally available - mining cost)
Soda ash	110/ton	(imported trona $65 + $45 freight)
Ironoxide	3/ton	(locally available - mining cost)
Brine chemicals	150/ton	(average price misc. salts and acids)
Electricity	0.05/kWh	
Boiler fuel coal	45/ton	(imported from Colombia)
Kiln fuel anthracite	120/ton	(imported from US)
Kiln fuel coal	45/ton	(imported from Colombia)
Process water	0.05/ton	(available on site)
Labor (incl. benefits)	7.500/year	(average salaries and wages)

The two tables (9 & 10) in combination would yield the following comparative cost data for the respective process alternatives. Below are also noted the respective estimated plant costs (within battery limits) which are further commented on in the ensuing text.

TABLE 11

	New Asahi + D.A.R.S.	Trona +D.A.R.S.	Electrolytic membrane cell
Salt	US$ 16.30	-	15.00
Limestone	4.50	-	-
Soda ash	-	149.60	-
Ironoxide	0.50	0.50	
Brine chemicals	-	-	15.00
Electricity	16.00	1.60	120.00
Boiler fuel coal	14.40	1.35	1.35
Kiln fuel coal	9.00	9.00	-
Kiln fuel anthracite	14.40	-	-
Process water	0.40	0.10	-
Labor rate/ton	9.00	2.25	4.50
Membranes	-	-	3.00
Total	84.50	164.40	158.85

Plant Cost Estimates

The following are the plant cost estimates considered realistic enough for the purposes of this comparative analysis.

Estimated 100.000 TPY caustic soda plant cost (battery limits) (US$'000.000)	New Asahi +D.A.R.S.	Trona +D.A.R.S.	Electrolytic membrane cell
	120	25	90

The plant cost estimates are based on cost assessment which date back some three to four years. Those have been corrected for inflation and adjusted for exchange rate variations during this period. The resulting plant costs have been checked with manufacturers and chemical engineering firms to ensure that they fall within a range which industry sources consider reasonable.

The cost estimates are inclusive of auxillary equipment within battery limits, freight and erection as well as of interest during construction, pre-operating and start-up costs but exclusive of plant external costs such as roads, railroads, port handling equipment, water and waste treatment plants, quarries etc.

The investments in material handling and transport facilities would likely be similar for all three alternatives since the volume of raw material is similar but for limestone in the case of the New Asahi process. Limestone being available at any number of locations in Jamaica would, however, not require transport and handling investments of any significance.

A contemplated site for a possible caustic soda production unit is an area in Clarendon, near Mitchell Town, which is served by roads as well as by railroad and which borders a substantial and high grade limestone deposit. It is also close to a stream which has adequate water for process purposes.

Given this location external costs for a 100.000 TPY caustic soda production unit could likely be limited to US$ 5 million.

Value of Co-products

The chemical synthesis (New Asahi and Solvay) yields, apart from soda ash, calcium chloride which as noted in Chapter III has very limited application and no marketable value in Jamaica. A chemical synthesis using the New Asahi process would for each ton of soda ash produce 0.3 tons of solid calcium chloride. The product would, however, come in the form of a solution with approximately 10% concentration of calcium chloride.

The New Asahi process, however, offers the possibility of converting part of the calcium chloride to ammonium chloride by recovering ammonia in the process through distillation. The investment would be increased with an ammonia unit and ammonia would have to be fed into the process in the same amount as it is removed in the form of ammonium chloride.

Jamaica which annually imports some 60.000 tons of ammonium sulphate could likely substitute part of the imported ammonium sulphate with chloride but the implication would be a corresponding increase in imports of ammonia since it is not produced in Jamaica. Neither sulphate nor chloride has any important fertilizing benefits. With chloride the opposite could be the case for crops and soils sensitive to salinity. The fertilizing ingredient is the ammonia and it is the amount of ammonia contained in the fertilizer which determines its value. It is therefore unlikely that local production of ammonium chloride as fertilizer would produce any value added for a Jamaican caustic soda plant.

The question would then arise as to whether or not disposal of calcium chloride would pose any environmental hazards.

Given the low concentration of the calcium chloride solution which can be lowered further by mixing the solution with outgoing cooling water and given the fact that the recipient, the ocean, contains chloride it is difficult to envision any environmental hazards provided the emission is made in an area where the sea water is not stagnant.

Causticization whether with lime or with ironoxide need not have any waste or co-products since lime or ironoxide can be recirculated in the form of calcium carbonate or ironoxide (see Chapter II). If energy consumption versus mining cost should favor continuous use of dry limestone or ironoxide the resulting waste should not need to pose any danger to the environment.

For the electrolytical process the co-product is hydrogen and chlorine, of which the chlorine for environmental reasons, cannot be disposed of as waste. It would either need to be converted into hydrochloric acid and be neutralized with lime to calcium chloride with both measures entailing additional costs. Chlorine, being highly toxic gas, is very costly to transport. As the demand for chlorine in Jamaica is neglible the only possibility for disposing of the chlorine would be to sell it to petrochemical industries in the US or the southern Caribbean region.

The efforts which have been made todate to structure projects on the basis of long ocean transports of chlorine have, however, not proved successful. A recent project in Iceland aiming at utilizing locally available brine and lowcost energy for production of caustic soda and chlorine, where the latter would be exported to Europe, was not found feasible mainly on account of costs associated with handling and shipping of chlorine.

Conclusion

The conclusion is therefore that none of the co-products of the three alternative processes for producing caustic soda in Jamaica would have any marketable value but rather increase costs on account of their disposal. In the case of the electrolytic process such costs would be of such a magnitude as to rule out the process as an alternative which is consistent with conventional wisdom of the industry. The analysis of the electrolytic process in this report nevertheless fills a purpose in that it is indicative of the cost levels at which other producers using membrane cells can supply caustic soda.

A comparison of total costs for the three alternatives would thus give the following result (ignoring possible costs of waste disposal):

TABLE 12

Item	New Asahi +D.A.R.S.	Trona +D.A.R.S.	Electrolytic membrane cell
		(US$'000.000)	
Operating cost	8.45	16.44	15.88
General overheads	0.50	0.25	0.40
Repair and maint.	2.16	0.45	1.60
Depreciation	7.53	1.83	5.73
Interest	9.00	1.90	6.80
Total cost	27.64	20.87	30.41
Total cost/ton NaOH	US$276.40	208.70	304.10
Selling price/ton (incl. profit)	348.40	223.70	358.10

Operating costs have been taken from Table 11 above. General overheads covering management, expatriate technical support and other overhead costs have assumed to bear a relationship with the number of laborers of the respective plants.

The repair and maintenance cost has been assumed to be 3% of the cost of equipment which in turn should correspond to approximately 60% of plant cost. Depreciation has been based on an assumed economic lifespan of 15 years for 90% of plant cost. The cost of interest must be based on assumptions with respect to both debt/equity ratio and interest rate. The level of interest cost given above corresponds to any of the following combinations of assumption; 15% with a debt/equity ratio of 50/50, 12.5% with a ratio of 60/40 and 10% with a ratio of 75/25. The above total cost estimate is therefore exclusive of any return on the equity investment in a plant which at a rate of 15%, on the basis of interest at 12.5% and a debt equity ratio of 60/40 would give the selling price shown in the bottom line of the preceding table.

The analysis thus suggests that the most competitive alternative, given the fact that there is no market in Jamaica for chlorine, is to import and causticize natural soda.

CHAPTER VII

THE CAUSTIC SODA MARKET

General

The world market for caustic soda has changed in step with the market for chlorine as most caustic soda is produced by way of electrolysis. Price statistics suggest that manufacturers have tended to maintain a relatively stable price for chlorine whereas cost increases and decreases caused primarily by variations in capacity utilization have resulted in dramatic changes in caustic soda prices.

Soda ash prices have not followed the changes in caustic soda prices since the major soda ash consumer - the glass industry - cannot convert to using caustic soda. Conversion is theoretically possible for the pulp and paper industry and for the alumina industry but caustic soda constitute only a very small part of these industries' raw material costs for which reason it is generally not worth their while to convert.

The following table shows how list prices for alkali and chlorine have varied during the period 1979 to 1984:

TABLE 13

f.o.b. US$/ton dry substance

	1979	1980	1981	1982	1983	1984
Caustic soda (in 50% solution)	140	160	220	275	230	240
Chlorine	135	145	145	145	145	195
Sub-total	275	305	365	420	375	435
Natural Soda Ash (f.o.b. Wyoming)	61	75-86	86	92	84	84

(Source: Chemical Engineering News)

The industry works with a set of list prices which are adjusted as demand changes. Since there is a natural tendency to try to maintain a high price level for longer than market conditions warrant, list prices tend to overstate the true cost of alkali. This is particularly true for caustic soda and soda ash where manufacturers instead of lowering prices in the face of declining demand, grant buyers so called Temporary Voluntary Allowances which is synonymous with discount. The level of discounting being 20% or more is not unusual and in instances it has reached 50%.

The following are some actual average import c.i.f. prices for caustic soda for the Caribbean for part of the same period. Those prices are on c.i.f. basis as opposed to list prices which are f.o.b.

TABLE 14

US$/ton dry substance

	1980	1981	1982	1983
US List Prices f.o.b.	140	160	220	275
Jamaica c.i.f.	127	186	173	164
Venezuela c.i.f.	175	237	172	126
Dom. Republic c.i.f.	202	222	258	138
Costa Rica c.i.f.	-	-	203	218
Guyana c.i.f.	102	-	-	-

Freight cost Gulf Port - Venezuela US$ 18/ton
" " " " - Jamaica US$ 10/ton.

The above list prices therefore overstate cost to consumers since the market during the -80s has been generally weak. After a good 1981 prices weakened substantially in 1982 when capacity utilization sank to 60% or less for many US producers of electrolytic soda. Normal capacity utilization is in the range of 80 to 95%. For natural soda ash, which had experienced two good years, production fell by 6% in 1982. 1983 witnessed a short recovery primarily due to increased demand of polyvinyl chloride and therefore for chlorine. Prices for caustic soda climbed to a peak of US$ 240/ton. As part of the recovery was due to plant shutdowns, estimated at 5% of capacity for each of 1982 and 1983 the rally could not be sustained. For soda ash the recovery was primarily due to increased export of natural US soda ash of which, for instance, China was a major buyer. As the US dollar climbed, these sales abated and growing demand for housing and cars (using glass) did not suffice. F.o.b. prices reached US$ 80 per ton in mid-84, after which they started to decline. Towards the end of 1984 spot market prices for caustic soda had fallen an unprecedented 50 to 60% whereas soda ash prices declined by close to 20%. The beginning of

1985 saw a further slide to a f.o.b. Gulf port price of US$ 80/ton of caustic soda.

The mechanics at work emerged already during the mid-70s with a shift in the chlorine use pattern to greater dominance by derivatives. At the same time chlorine/caustic soda capacity increased substantially. Towards the -70s consumers started to turn away from many products using chlorine. Chlorine's use by pulp and paper industries is being affected by a reduced demand for bleached paper and by plastics making inroads in the packaging market. Caustic soda's waning fortune is also a result of build-up of capacity at a point in time when aluminium, paper, steel and oil refining industries had to curtail production. This was exacerbated by increasing environmental concern leading to increased recovery and a switch to less harmful unfinished caustic liquor straight from the electrolytic cells. This caustic doesn't go through the further processing to remove chloride ion and evaporate water and although it isn't reported in official production data trade in unfinished caustic liquor has grown substantially in recent years.

Soda ash has fared less badly than chlorine and caustic soda but not by far fulfilled the lofty expectations of the late -70s. These expectations led to a rapid build-up of capacity to approximately 10 million tons per year. To the vast reserves of brine in Wyoming and Utah have since been added new brine reserves in Turkey and South Africa which may be developed to compete for the export market which has todate been the exclusive domain of US producers. The US capacity has todate not been used to more than about 75% and utilization during the rest of the -80s may not exceed this figure.

The Future

The chlor-alkali industry has acquired many of the characteristics of mature if not overly mature industries such as steel, shipping etc. Short market and price rallies are interspersed by long depressions in which many producers are struggling to cover variable costs. The industry shake-out is, however, well under way with plant scrappings at an increasing rate in the US which accounts for some 30% of world production. The US caustic soda capacity at 16 million tons in 1981 had dropped to barely 14 million tons in 1984 and the country's last Solvay plant (Allied Chemical at Syracuse) along with several older electrolytical mercury cell plants are expected to be closed for good.

All plants in Japan and approximately 1/3 of US electrolytical plants have changed to membrane cells but this in itself will not revive the market. It may, however, hasten the pace of plant scrapping and thus result in a balance in the not too distant future.

The chlorine growth in demand during the -80s is generally expected to be stagnant to sluggish and in the range 1 to 3% per year. Caustic soda is expected to do marginally better with a growth ranging between 2 and 4% per year. This difference in market growth would gradually result in better caustic soda prices but the large potential supply of natural soda would maintain caustic soda prices below a level where it would pay to causticize natural soda ash. The pulp and paper industry's role in the market may in the future be more pronounced than it has been todate. Pulp and paper mills are substantial producers of both chlorine and soda for their own use. Chlorine is used for bleaching and caustic soda for sulphate pulp which in turn is used for kraft paper production. Heavy demand for bleached paper would mean higher consumption of chlorine and therefore a surplus of caustic whereas reduced demand for bleached paper leaves the pulp and paper mills with a chlorine surplus or makes them buyers of soda. The pulp and paper industry accounts for some 10 to 20% of the world's production of caustic soda.

The export trade of caustic soda is expected to be influenced by the substantial new capacity, 300.000 tons per year, coming on stream in Saudi Arabia. It is expected that Saudi caustic soda will replace part of the Japanese, European and US exports to Australia's alumina industry which have been at a total level of 900.000 tons per year in recent years.

With traditional mining methods present producers need to sell natural soda at US$ 55 to 60 per ton in order to cover costs. New technology, related to so called Frash mining of sulphur, has, however, been introduced by FMC in Wyoming and may also be applied by that company in Turkey. This method would result in a cost reduction, the exact size of which has not been disclosed.

If one, however, assumes that natural soda can be profitably produced at US$ 60 per ton, that cost of transport to the East and Gulf coast is US$ 40 per ton and that causticization would cost US$ 60-80 per ton of caustic, an upper limit on the price of caustic soda would be approximately US$ 210 per ton.

Conclusion

A likely future scenario for the caustic soda market is, firstly, that the presently very low price level will improve during 1985 but that the price will tend to stay below US$ 150 until such time as the export market has absorbed the added Saudi Arabian capacity. This may require a period of several years after which prices would tend to approach the maximum allowed by natural soda conversion costs i.e. around US$ 210 per ton f.o.b. US Gulf and East Coast ports.

CHAPTER VIII

CONCLUSION

The Process

Jamaica should consider only two options in terms of process; one being the so called "New Asahi" chemical synthesis of sodium chloride (salt), the other being causticization of natural soda. The problems and costs associated with disposing of hydrochloric acid would preclude the electrolytic process.

Of the two processes the causticization whether with limestone or with ironoxide, gives lower cost of production as well as lower investment and therefore risk exposure than does the chemical synthesis.

The Present and Future Market

With caustic soda prices at about US$ 100 per ton the most economical process - causticization-would not cover more than 2/3 of its principal raw material cost. Caustic soda prices are expected to stay below US$ 150 per ton for the near future and there are no reasons to expect prices to move up to a level adequate for a causticization project in Jamaica until the end of the -80s.

Competitive Advantage

With the most economical process being causticization based on imported natural soda, Jamaica would have no competitive advantage over producers employing the same process in the US.

The likelihood is instead that such causticization plants, were they to be built in the US, would be at a competitive disadvantage compared to modern membrane cell electrolytical plants.

The conclusion is thus that Jamaica has no competitive advantage for caustic soda production and that it is highly unlikely to have it in the future.

Consequences of Process Development

Most of the world's caustic soda is produced by way of electrolysis. The improvements of the chemical process which have been achieved in the New Asahi process are not significant enough to make synthetic soda competitive with electrolytic soda.

On the contrary, improvements in the elctrolytic process have and will likely increase the competitive advantage of electrolytic soda. The implication is that caustic soda will continue to be traded as a by-product to chlorine, the pricing of which can be highly erratic. In such a situation a plant for synthetic soda - having caustic soda as its only saleable product - will always be at a competitive disadvantage.

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