Can China emerge as a major player in the Asia-Pacific salt market?

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Until 1987, China supplied some 10% of the Japanese industrial salt annual requirement. Since 1988, Chinese salt exports to Japan became insignificant with poor salt quality frequently blamed as being one of the reasons. What is the quality of the Chinese salt today? Could the salt be upgraded or refined economically to meet the standards required by the Japanese chloralkali industry? What market segments could be accessible for the Chinese upgraded salt? What other measures would have to be taken for China to gain access to the Asia-Pacific salt market? Krebs Swiss has investigated these questions. The conclusions are discussed in this paper

Introduction

China is one of the largest solar salt producers in the world and the largest in the Asia-Pacific region. Most of the Chinese salt production is near the sea coast and therefore near the harbours. There has been an overproduction of salt in China, to the extent of millions of tons. China is much nearer to Japan than the traditional salt suppliers Australia, Mexico or Chile. China is in need of hard currency. One would think, Japan must be full of Chinese salt. And yet ...

Until 1987, some 500,000-700,000 tpa of salt used to be exported from China to Japan. As from 1988, the exports have been almost nil. Flooding of saltworks has been reported to have caused China to lose the Japanese market. Poor quality of solar salt, much below the standards set by the chloralkali industry, have been blamed for China not being able to start exporting salt to Japan again.

Recently, Krebs Swiss has been investigating whether its salt purification technology could economically improve the quality of the Chinese salt to the level that would allow its use by the Japanese chloralkali industry. Krebs Swiss examined the Chinese solar salt, the salt industry and the business environment intensively and reached the conclusion that there is a potential for the Krebs Swiss salt technology in China.

Present salt production methods in China

Approximately 50% of all Chinese salt is being produced along the coast of the Gulf of Bohai. Approximately 80% of the salt in this area is available within reasonable distance from sea harbours.

Evaporation rate in the area is approximately 1.5 metres and precipitation is approximately 0.5 metres per annum. Storms occurring occasionally in the area during the crystallization season carry most of the annual precipitation.

The area of the Gulf of Bohai consists of sediments only. Stones do not occur naturally. The only available erosion resistant building material is red brick. Accordingly, bricks are being used to build most of the erosion resistant structures in the saltworks.

Pre-concentration of seawater is being carried out in a series of rectangular ponds. Due to the seasonal character of the production, concentrated brine is available only in limited quantity and depth.

Saturated seawater is fed to rectangular crystallizing ponds with steep loose brick walls needed to protect the pond dikes from erosion by storms. The storms are so severe that they agitate the mother liquor in the crystallizing ponds, mixing it with the rain water, causing undersaturation and dissolution of the salt, thus reducing the yield significantly.

A rain protection technique has been developed in China over the past years and has found widespread utilisation. More than 50% of all crystallizing ponds have been equipped with this device and the percentage is growing *(see photo on p.xx)*.

The technique consists of a rain protection plastic foil installed in each crystallizing pond and kept rolled in a compartment alongside the pond. The foil is equipped with fixtures that fit into railings located on the brick side of the pond. Each large saltwork avails of a storm warning system that is capable of alarming the saltwork personnel within half an hour of the coming rain. On sounding the alarm, workers pull the foil over the pond, fasten it on the far side and connect the foil surface to rain water overflow gates located on the side of each pond. After the storm, the rain water is drained, the foils are rolled back into position and evaporation is resumed. The rolling of the foils is power assisted.

The procedure is manual. Labour requirement is high — the method is only effective if completed within half an hour after the alarm and the foils are rolled back quickly after the storm. A mechanized, automated system is being developed, but it is only in a trial stage at the present. The high labour requirement to operate the present rain protection system is likely to persist for the next few years.

Size of the crystallizing ponds is limited by the maximum size of the rain protection foil. Consequently, the ratio of pond dike length to the crystallization area is high. The brick walls represent

		Australia	Mexico	China	Chile	India	Others	Total
1980		3,006	3,759	711	-	-	4	7,480
1981		2,929	3,025	554	-	-	1	6,509
1982		2,878	2,873	518	-	-	-	6,269
1983		3,057	2,716	608	-	-	-	6,381
1984		3,028	2,764	666	-	-	-	6,458
1985		3,305	2,846	681	-	-	1	6,833
1986		3,188	2,729	697	-	-	-	6,614
1987		3,240	3,010	579	-	-	1	6,830
1988		3,861	3,269	-	-	-	99	7,229
1989		4,080	3,524	30	-	-	69	7,703
1990		4,189	3,583	37	80	28	3	7,920
1991		4,131	3,387	-	263	71	3	7,855
1992	1)	2,850	2,417	-	244	73	38	5,623
1993		3,661	3,192	9	395	88	-	7,344
1994		3,889	3,291	8	181	88	-	7,458
1995	2)	3,614	3,348	20	179	110	1	7,272

Source: Roskill Report, "The Economics of Salt", 8th edition 1994
Roskill, private communication

Notes: 1) January to September only
2) January to November only

Table 1: Japan: Imports of salt by country of origin 1980 -1995

a high and labour intensive investment. No mortar is used to join the bricks because sand is not available locally. Therefore, the loose brick structures collapse occasionally resulting in significant, labour intensive maintenance.

Harvesting of salt is manual. It is easier when the salt layer is loose. The idea of loosening the salt by raking during the crystallization is old and has been practised not only in China, but also in India and in other countries. Raking changes the crystallization behaviour of salt. The salt crystals become large and hard.

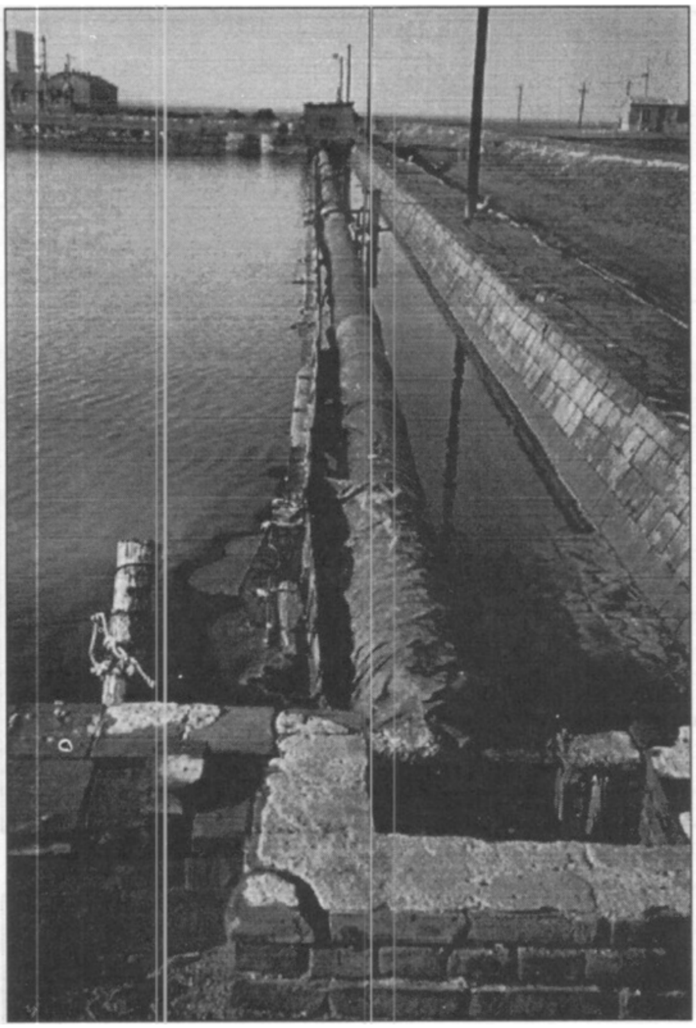
The crystallizing pond bottom consists of mud. No permanent hard salt bottom technique can be employed under the geological and climatic conditions in the area. Raking disturbs the mud at the bottom of the ponds and makes the salt crystals become dark. Dark crystals absorb more solar radiation energy and the rate of salt production is thereby increased.

In a production oriented (rather than quality oriented) economy, this effect is welcome. The overall proportion of raked compared to non-raked salt production is therefore growing. Salt raking is labour intensive. It is another element that makes high labour requirement in the Chinese solar salt industry likely to persist.

Stockpiling is done manually in heaps of uniform size. The size of the stockpile is determined by the reach of a simple mobile stacking conveyor which is manufactured according to a standard design. The width of the earthen stacking dikes fits the maximum

Table 2: Composition of Chinese solar salts

	Raked 1	Raked 2	Raked 3	Raked 4	Non-raked
Calcium	0.113%	0.161%	0.153%	0.170%	0.055%
Magnesium	0.073%	0.011%	0.010%	0.027%	0.065%
Sulphate	0.34%	0.42%	0.38%	0.50%	0.22%
Insolubles	0.12%	0.09%	0.05%	0.50%	0.02%
Moisture	2.2%	-	1.6%	-	2.9%
NaCl (dry basis)	99.19%	99.31%	99.39%	98.79%	99.52%



Chinese solar salt crystallising pond with rain protection foil

width of the stockpile. A salt heap that is intended to store salt for extended period of time is manually covered by reeds. This limits the salt losses due to rain. Prior to delivery, the reed cover is removed from the stockpile — by hand.

In countries other than China, sea water evaporation and salt crystallization is a process that is being left to nature. The saltwork personnel limits its interference to pumping the brine and controlling the brine density. The only intensive work is the salt harvesting. This can be mastered by hiring seasonal labour or by employing mechanical harvesters.

Under the circumstances of solar salt production in China, with a high labour requirement throughout the production cycle, there appears to be no incentive to mechanize salt harvesting — unless an entirely new and fully mechanized salt production technique is developed that takes account of all the peculiarities of the climatic and other conditions prevailing in China.

Quality and upgradability of raked salt

Chinese raked salts from the Gulf of Bohai, from whatever saltwork they originate, are very similar to each other. The salt crystals are very large, having a diameter of 8-25mm. They are round and hard, rather dark, of brown-grey colour. The crystal structure is uniform, the crystals are monocrystals rather than crystal agglomerates.

The chemical analysis shows a high content of gypsum crystallized together with sodium chloride and ingrown inside the crystals. The relatively small crystal surface compared to the crystal volume leaves little area for surface impurities such as magnesium containing mother liquor.

Correspondingly, the magnesium content is always low, whether the analysis is done shortly after the harvest or after an extended period of time. Some saltworks use salt washing installations. However, due to the size and nature of the crystals, the chemical composition of the washed salt is only a little different from the unwashed salt.

The salt quality specification of the Japanese chloralkali industry is as follows:

Ca	0.04%
Mg	0.02%
SO_4	0.12%

On average, the calcium and sulphate content of Chinese solar salt is three to four times higher than that specified.

Krebs Swiss carried out a number of upgradability and refinability tests with Chinese solar salts from the Gulf of Bohai to determine whether they may, after suitable processing, fulfil the quality requirements of the Japanese chloralkali industry.

The graphs on the following pages show the results of the following tests:

1. Upgradability test without change of crystal size. This test illustrates how the salt quality could be improved in a washing process operating with 100% efficiency.
2. Upgradability test with selective rupturing of salt crystals to a characteristic crystal size of 6, 3 and 1.5mm to free the embedded impurities followed by purification operating with 100% efficiency and recovery of fine salt.
3. Refinability test with hydromilling of salt crystals to a characteristic crystal size of 0.8 and 0.4mm to free the embedded impurities preceded and followed by purification operating with 100% efficiency and recovery of fine salt.

The tests without change of crystal size show that the salt quality could be only marginally improved in a washing process and that the resulting salt quality would be insufficient.

The curves illustrate the processing with selective rupturing of the salt crystals. They show that a process reducing the characteristic crystal size to 1.5mm will reduce the content of Ca and SO_4 impurities to the levels that are in accordance with the Japanese chloralkali standards.

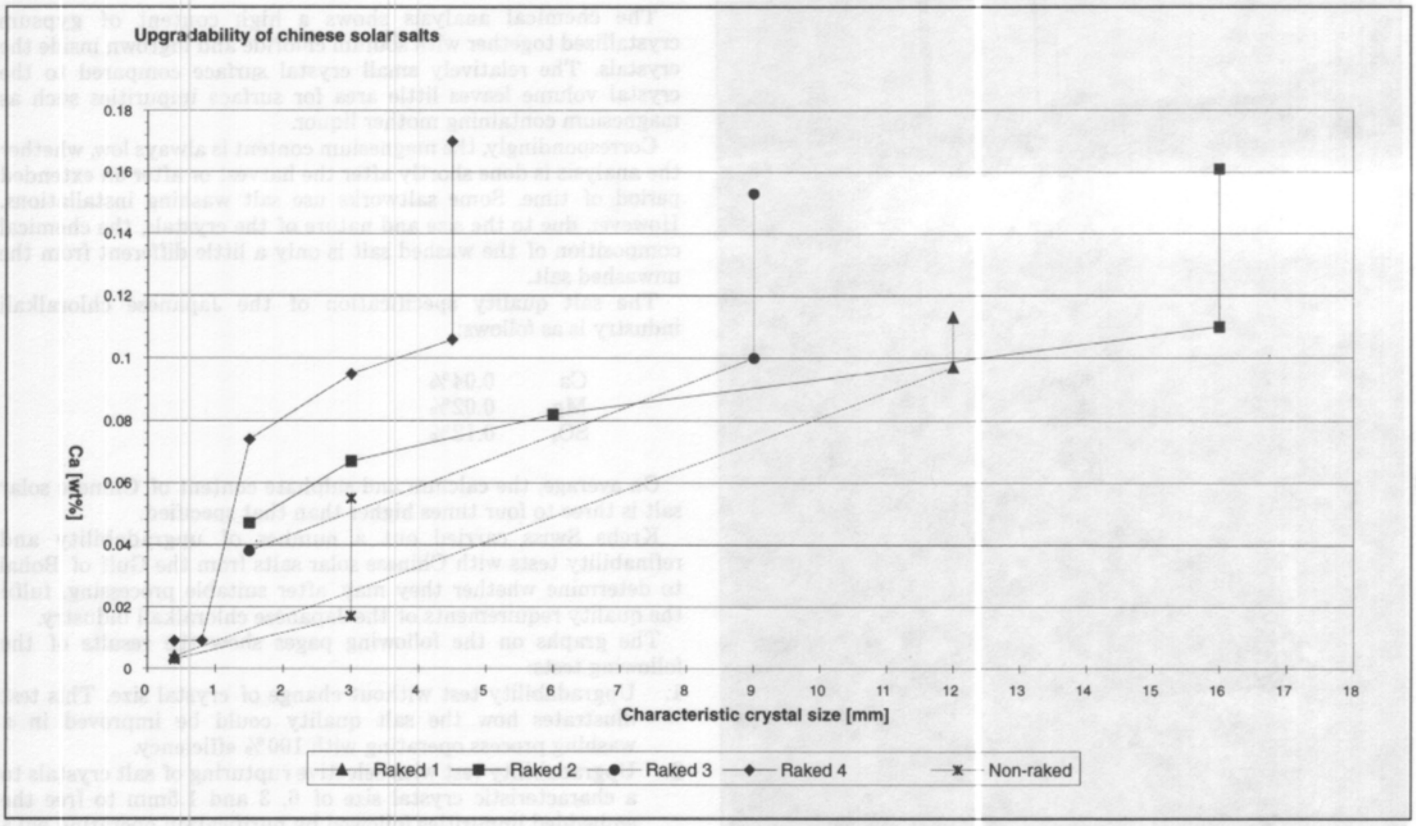
The Mg impurities in Chinese salts are much lower than required by the chloralkali industry. This is a fact that is particularly appreciated by the chlorine producers using only caustic and soda ash for brine purification.

The process with hydromilling purifies the salt to levels much higher than those specified, but its employment may not be economical for the purpose of chloralkali feedstock production.

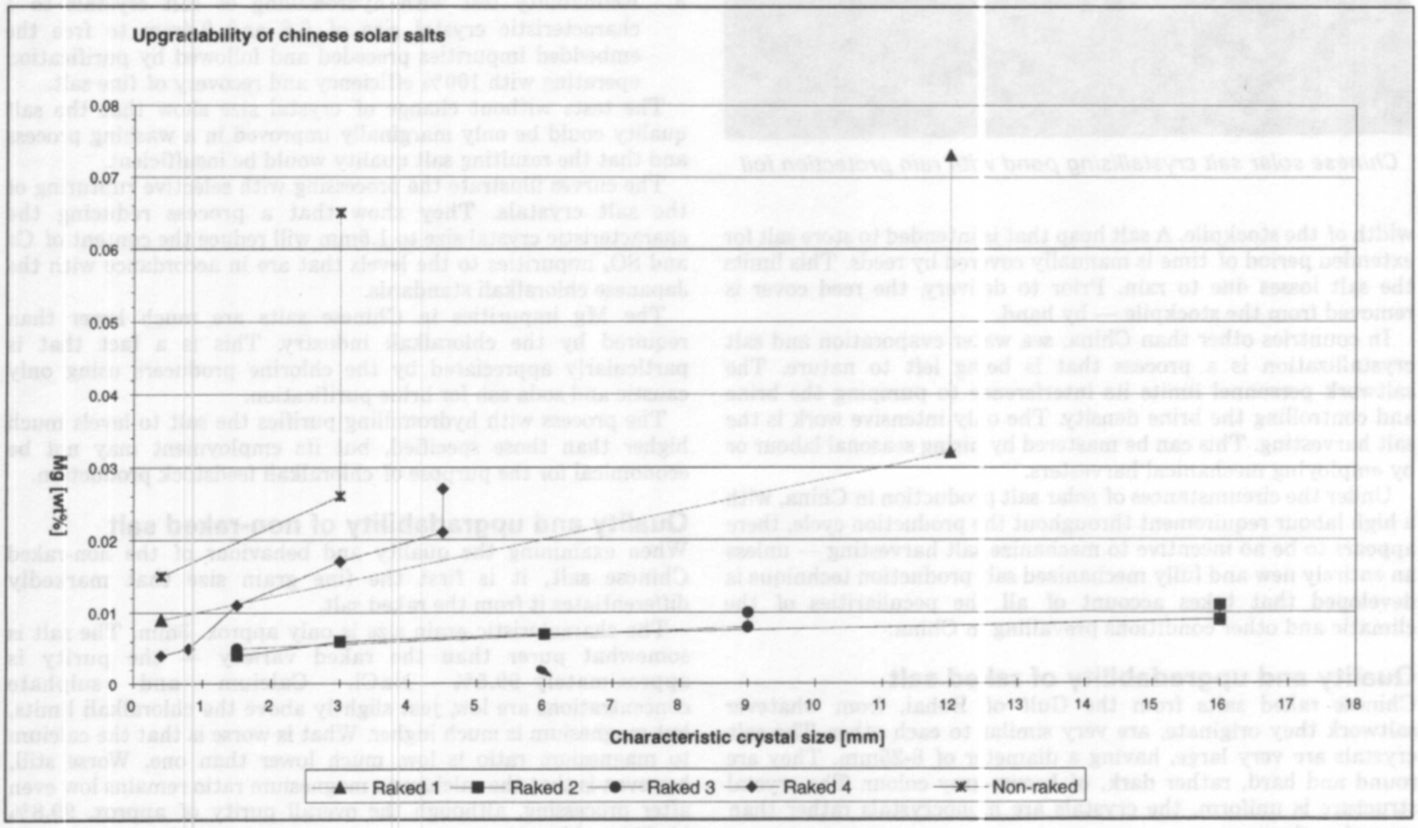
Quality and upgradability of non-raked salt

When examining the quality and behaviour of the non-raked Chinese salt, it is first the fine grain size that markedly differentiates it from the raked salt.

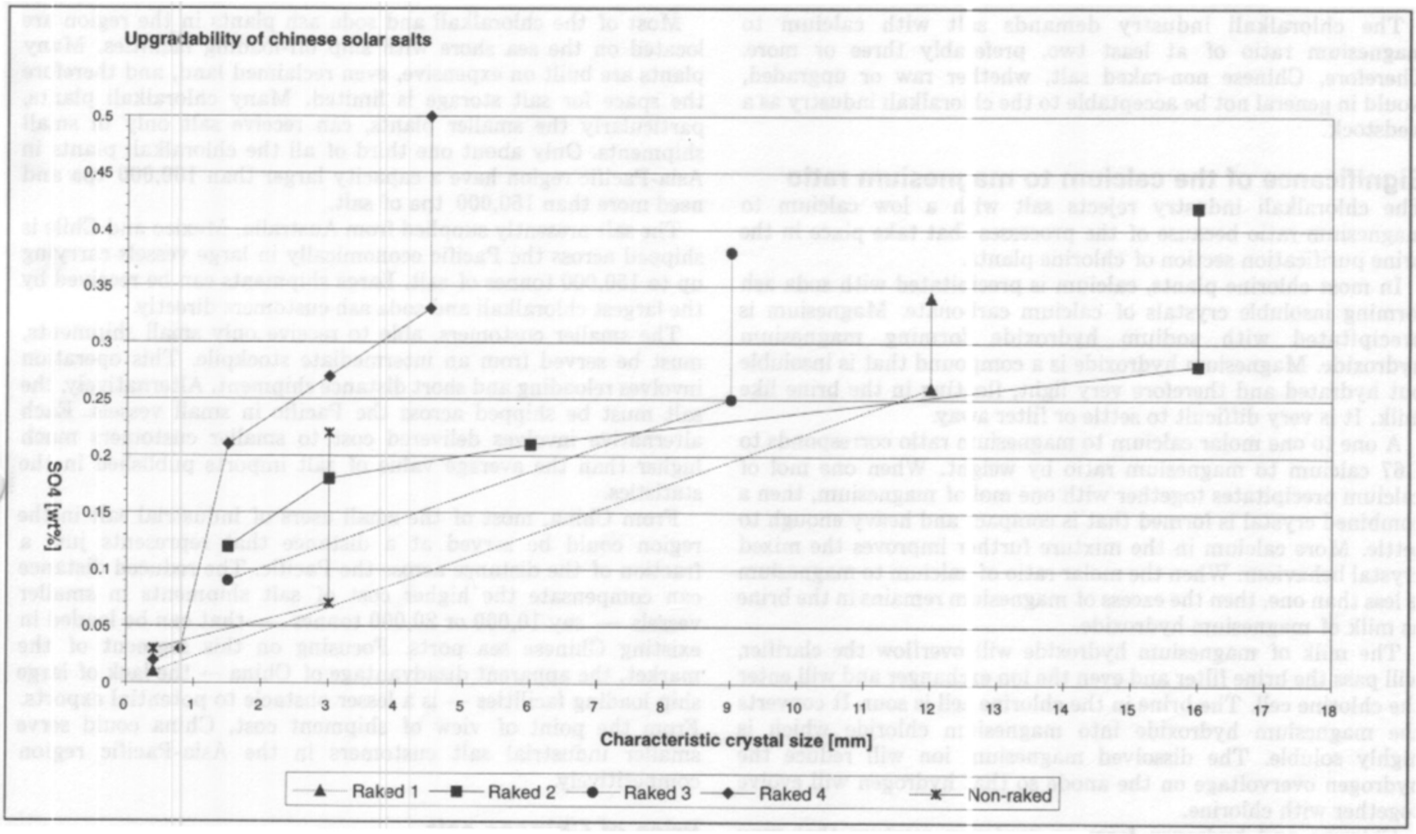
The characteristic grain size is only approx. 3mm. The salt is somewhat purer than the raked variety — the purity is approximately 99.5% NaCl. Calcium and sulphate concentrations are low, just slightly above the chloralkali limits, but magnesium is much higher. What is worse is that the calcium to magnesium ratio is low, much lower than one. Worse still, however, is that the calcium to magnesium ratio remains low even after processing, although the overall purity of approx. 99.8% NaCl is achievable.



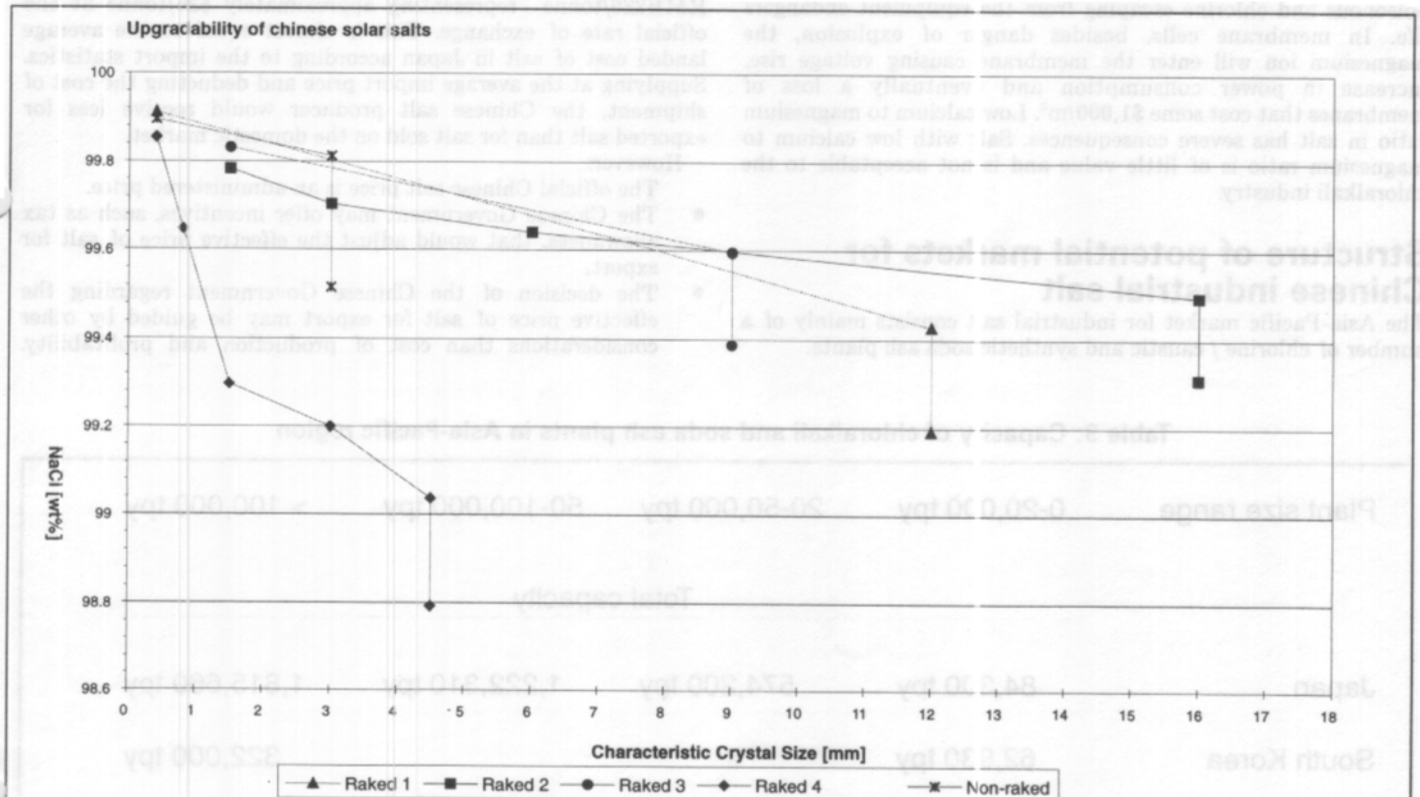
Graph 1: Calcium



Graph 2: Magnesium



Graph 3: Sulphate



Graph 4: NaCl content

The chloralkali industry demands salt with calcium to magnesium ratio of at least two, preferably three or more. Therefore, Chinese non-raked salt, whether raw or upgraded, would in general not be acceptable to the chloralkali industry as a feedstock.

Significance of the calcium to magnesium ratio

The chloralkali industry rejects salt with a low calcium to magnesium ratio because of the processes that take place in the brine purification section of chlorine plants.

In most chlorine plants, calcium is precipitated with soda ash forming insoluble crystals of calcium carbonate. Magnesium is precipitated with sodium hydroxide forming magnesium hydroxide. Magnesium hydroxide is a compound that is insoluble but hydrated and therefore very light, floating in the brine like milk. It is very difficult to settle or filter away.

A one to one molar calcium to magnesium ratio corresponds to 1.67 calcium to magnesium ratio by weight. When one mol of calcium precipitates together with one mol of magnesium, then a combined crystal is formed that is compact and heavy enough to settle. More calcium in the mixture further improves the mixed crystal behaviour. When the molar ratio of calcium to magnesium is less than one, then the excess of magnesium remains in the brine as milk of magnesium hydroxide.

The milk of magnesium hydroxide will overflow the clarifier, will pass the brine filter and even the ion exchanger and will enter the chlorine cell. The brine in the chlorine cell is sour. It converts the magnesium hydroxide into magnesium chloride which is highly soluble. The dissolved magnesium ion will reduce the hydrogen overvoltage on the anode so that hydrogen will evolve together with chlorine.

Chlorine and hydrogen form an explosive mixture that may explode in the cell or in the downstream units. Chlorine is highly poisonous and chlorine escaping from the equipment endangers life. In membrane cells, besides danger of explosion, the magnesium ion will enter the membrane causing voltage rise, increase in power consumption and eventually a loss of membranes that cost some $1,000/m^2$. Low calcium to magnesium ratio in salt has severe consequences. Salt with low calcium to magnesium ratio is of little value and is not acceptable to the chloralkali industry.

Structure of potential markets for Chinese industrial salt

The Asia-Pacific market for industrial salt consists mainly of a number of chlorine / caustic and synthetic soda ash plants.

Most of the chloralkali and soda ash plants in the region are located on the sea shore with ship off-loading facilities. Many plants are built on expensive, even reclaimed land, and therefore the space for salt storage is limited. Many chloralkali plants, particularly the smaller plants, can receive salt only in small shipments. Only about one third of all the chloralkali plants in Asia-Pacific region have a capacity larger than 100,000 tpa and need more than 150,000 tpa of salt.

The salt presently supplied from Australia, Mexico and Chile is shipped across the Pacific economically in large vessels carrying up to 150,000 tonnes of salt. Large shipments can be received by the largest chloralkali and soda ash customers directly.

The smaller customers, able to receive only small shipments, must be served from an intermediate stockpile. This operation involves reloading and short distance shipment. Alternatively, the salt must be shipped across the Pacific in small vessels. Each alternative involves delivered cost to smaller customers much higher than the average value of salt imports published in the statistics.

From China, most of the small users of industrial salt in the region could be served at a distance that represents just a fraction of the distance across the Pacific. The reduced distance can compensate the higher cost of salt shipments in smaller vessels — say 10,000 or 20,000 tonnes — that can be loaded in existing Chinese sea ports. Focusing on this segment of the market, the apparent disadvantage of China — the lack of large ship loading facilities – is a lesser obstacle to potential exports. From the point of view of shipment cost, China could serve smaller industrial salt customers in the Asia-Pacific region competitively.

Price of Chinese salt

The official price of salt in China today is said to be RMB226/tonne representing approximately $26/tonne at the official rate of exchange. This is almost equal to the average landed cost of salt in Japan according to the import statistics. Supplying at the average import price and deducting the cost of shipment, the Chinese salt producer would receive less for exported salt than for salt sold on the domestic market.

However:

The official Chinese salt price is an administered price.

- The Chinese Government may offer incentives, such as tax allowances, that would adjust the effective price of salt for export.
- The decision of the Chinese Government regarding the effective price of salt for export may be guided by other considerations than cost of production and profitability.

Table 3: Capacity of chloralkali and soda ash plants in Asia-Pacific region

Plant size range	0-20,000 tpy	20-50,000 tpy	50-100,000 tpy	> 100,000 tpy
	Total capacity			
Japan	84,300 tpy	574,200 tpy	1,222,310 tpy	1,815,660 tpy
South Korea	62,930 tpy			322,000 tpy
Indonesia	15,670 tpy		100,000 tpy	

	Australia	Mexico	Chile
Japan	4,000,000 tpy	3,500,000 tpy	200,000
South Korea	1,000,000 tpy		
Taiwan	1,000,000 tpy	occasionally	
Philippines	100,000 tpy		
Indonesia	400,000 tpy		
Malaysia	100,000 tpy		

Table 4: Salt trade in Asia-Pacific region, countries and quantities

	Australia	Mexico	Chile	China
Japan	5,000 km	10,000 km	17,000 km	2,000 km

Table 5: Salt trade in Asia-Pacific region, distances

Desire to widen the flow of foreign currency into the country is likely to play an important role.

- Export prices as low as $17/tonne have been reported, however, not for salt of Japanese chloralkali standard.
- The landed cost of salt to the small chloralkali producers in the Asia-Pacific region is higher than the reported value of imports to Japan of $26-30/tonne. The Chinese salt could be supplied to this market segment at a competitive price.

Conclusions

Quality and price will ultimately decide whether China can become a major supplier of industrial salt to the Asia-Pacific region. It appears that quality and pricing levels, both attractive to the small chloralkali customers and to the Chinese salt producers, are possible, provided that:

1. The Chinese salt industry will produce salt of better quality, similar to that presently supplied from Australia, Mexico or Chile. Advanced and proven technology to purify the presently produced Chinese raw salt to the required level economically is available from Krebs Swiss.
2. The Chinese Government will offer incentives to export salt at price levels that allow profitable production and return on investment in the purification technology.
3. Business partnerships between the Chinese salt suppliers and the trading companies that have access to the market segment of smaller chloralkali producers in the Asia-Pacific region will be formed.
4. The potential for export of Chinese salt could be extended beyond the limits given by the effectiveness of government measures and the size of the market segment of small chloralkali plants only by producing salt of better quality at lower cost. This may be achieved with the use of advanced technology such as salt crystallization in open ponds with forced evaporation utilizing waste heat from power generation plants. This technology that produces salt of top quality, independent of climatic conditions and at a fraction of conventional solar salt production cost, is also available from Krebs Swiss.