17th International Mining Congress and Exhibition of Turkey-IMCET 2001,® 2001, ISBN 975-395-417-4

Salt in Turkey

M.E.Ertem
Ereğli Iron & Steel Works Inc., Kdz. Ereğli, Turkey
V.T.Engin
Dokuz Eylül University, Department of Mining Engineering, İzmir, Turkey
H.i.Ertem
Tekel Salt Industry Establishment, hmir, Turkey

ABSTRACT: NaCl salt, which is an important substance in the chemical industry and in food preparation, is produced from four main sources: lakes, seas, salt rock and underground salt water. Salt from lakes has the lowest cost and is of high quality. Turkey is surrounded by the sea in three directions, and salt production from the sea is gaining in importance, while production from salt rock is decreasing because of high production costs and other conditions. Turkey has sufficient production capacity in its seas. In this paper, the salt potential of Turkey is evaluated.

1 INTRODUCTION

Sodium chloride or common salt is the chemical compound NaCl. Salt occurs naturally İn many parts of the world as the mineral halite and as mixed evaporites in salt lakes. Seawater has a lot of salt; it contains an average of 2.6% (by weight) NaCl, or 26 metric million tons per cubic kilometer (120 million short tons per cubic mile), an inexhaustible supply. Underground salt deposits are found in both bedded sedimentary layers and domal deposits. Some salt is found on the surface as the dried-up residue of ancient seas, like the famous Bonneville Salt Flats in Utah. Salt even reaches earth from space.

Sodium chloride crystals are cubic in form. Table salt, when viewed under a magnifying glass, can be seen to consist of tiny cubes tightly bound together. The salt crystal is often used as an example of crystalline structure and many online science pages offer instruction on growing salt crystals. Salt crystals have been photographed under a microscope. Different types of crystal have different uses, such as in food (Anon., 2000).

It varies in color from colorless when pure, to white, gray or brownish, typical of rock salt (halite). Chemically, it is 60.663% elemental chlorine (CI) and 36.337% sodium (Na). The atomic weight of elemental chlorine is 35.4527 and that of sodium is 22.989768 (Anon.,2000).

Sodium chloride is sold in several different particle sizes (gradation) and forms, depending on the intended end use. Discrete crystals can be seen in rock salt used for deicing. Fine granules are typical of table salt and popcorn salt is even finer. Kosher salt, pickling salt and ice cream salt are slightly coarser. Small compressed pellets are used in water softeners and large salt blocks are used as salt licks for livestock. When viewed under strong magnification, all sodium chloride is crystalline. Very large cubic crystals, of two, three or more inches in size, can be seen in some salt mines. They are transparent and cleave into perfect cubes when struck with a hard object (Anon., 2001). The properties of salt are given in Table 1.

Table 1 Properties of salt.

Chemical Properties	
Formula	NaCl
Atomic weight - Na	22.989768 (39.337%)
Atomic weight - CI	35.4527 (60.663%) •
Eutectic composition	23.31% NaCl
Crystal form	Isometnc, cubic
Color	Clear white
Physical Properties	
Specific gravity	2 165 gr/cm
Hardness (Moh's Scale)	2.5
Critical humidity at 20 °C	75.3%
Melting point	800.8 °C
Boiling point	1,465 "C

2 SALT IN THE WORLD

2.1 *The global balance of salt*

The history of world salt production and consumption parallels the history of humankind. From primitive to modem times, every human being has had an association with salt Although not aware

of their physiological need for salt, prehistoric human beings obtained their salt primarily from the meat of the animals they hunted. These animals were often found congregating around salt springs or salt licks to satisfy their innate salt cravings. With the beginning of an agricultural society, humankind found the need to supplement vegetable and cereal diets with extra quantities of salt (Kostick, 1993).

The quest for salt became more important with the advance of civilization. Because of its solubility, surface deposits of salt were scarce, and new methods of obtaining salt were needed. This was the beginning of the world salt mining industry. The basic concepts of salt mining have changed very little since early times; only refinements in the techniques of extraction and processing have evolved (Kostick, 1993).

Of more than 170 nations in the world today, the Bureau collects or estimates production data from 98 different countries, which represents virtually all world output. In 1990, world salt production was 193 million tons, whereas, in 1980, world salt production was only 9 million tons. During the twentieth century, world population increased from 1.6 billion to 6 billion people. The increase in world salt production compared with population growth was significantly greater because new uses for salt were discovered that would change demand patterns.

Salt had been universally used for food flavoring and for food preservation, but it wasn't until die mid-19' century mat salt was regarded as an important raw material for die chemical industry. In the early 1860s in Belgium, the Solvay process was developed to make synthetic soda ash from salt. Later, salt became essential in the electrolytic process to make chlorine gas and sodium hydroxide. Today, salt is the largest mineral feedstock consumed by the world chemical industry (Kostick,1993).

2.2 *World Production Reserves and Reserve Base*

World resources of salt are practically unlimited. Almost every country in the world has salt deposits or solar evaporation operations of various sizes.

There are no economic substitutes or alternatives for salt. Calcium chloride and calcium magnesium acetate, hydrochloric acid and potassium chloride can be substituted for salt in deicing, certain chemical processes and food flavoring, but at a higher cost.

The world's salt reserves are large. Economic and subeconomic deposits of salt are substantial in principal salt-producing countries. The oceans comprise an inexhaustible supply of salt.

World production in 1998 and in 1999 is given in Table 2.

Table 2. World sail production

	Years (* 1000)	
	1998	1999'
United Stales	41,200	41,400
Australia	8,880	8,800
Brazil	5,500	5,700
Canada	13,300	13,400
China	30,800	31,000
France	7,000	7,100
Germany	15,700	15,200
India	9,500	9,500
Italy	3,600	3,600
Mexico	8.400	8,400
Poland	3,900	4,000
Russia	2,000	2.100
Spain	3,500	3,600
Ukraine	2,500	2,400
United Kingdom	6,600	6,600
Other Countries	23,600	37,200
World total (May be rounded)	186,000	200,000

estimated

3 SALT IN TURKEY

3.1 *Deposits*

Turkey has large salt deposits because of its geological structure. Rock salt deposits in Turkey are given in Table 3.

Although sea salt deposits in Turkey (surrounded by the sea in three directions) are unlimited, they depend on two sea salt facilities, which have a production capacity of more than 620,000 tons.

Table 3. Rock salt deposits (million tons).

Site of Facilities	City			
Sekili	Yozgat	107	359	300
Çankın	Çankırı	821	358	-
Gülşehir	Nevşehir	75	96	959
Tepesidelik	Kırşehir			20
Tuzluca	Kars			100
Kağızman	Kars			60
Oltu	Erzurum			30

Lake salt deposits can be calculated with the simple method given below.

Surface of salt lake = 1200 km^2 (production area)
Salt thickness = 8 cm (3-20 cm)
Density = 2.2 t/m^3

From this, the deposit of the salt lake is approximately:

$0.08 \times 1200.10^6 \times 2{,}2 = 210.10^6$ million tons.

However, according to research, the deposit of the lake is much larger than this.

3.2 *Production methods*

Salt production is generally carried out by one, or a combination of any of three methods.

3.2.1 *Solar evaporation*

Solar evaporation is the oldest method of salt production. It has been used since man first noticed salt crystals appearing in trapped pools of sea water. Its use is practical only in areas with warm climates in which the evaporation rate exceeds the precipitation rate, either annually or for extended periods, and ideally where there are steady prevailing winds (Calvinaco, 1990).

Solar salt production is the capturing of sea water in shallow ponds İn which the heat of the sun evaporates most of the water. The concentrated brine containing impurities is then discarded by mechanical harvesting machines. Two types of ponds are used. First is the concentrating pond. Here the salt water from the ocean or salt lake is settled and concentrated. The second is the crystallizing pond, in which the salt is actually produced.

Crystallizing ponds range from 15 to 90 acres with a foot-thick floor of salt that has been deposited over the years. During the salt-making season of four to five months, a saturated brine solution flows continuously through these ponds. There is as much salt in the water as it can hold, and, therefore, most of the pure salt crystallizes out of the solution as the water evaporates (Calvinaco, 1990).

The ponds are then completely drained. Mechanical harvesting machines gather the loose salt and carry it to piles.

Solar evaporation depends on certain factors.

- Large areas with small slope.
- Low salt water permeability.
- Low rainfall rate.
- High evaporation.
- Dry wind.
- Long summer season for evaporation (Calvinaco, 1990).

3.2.2 *Rock salt mining*

Salt mines are among the safest of mines and are also the most comfortable to work in. While mine temperature varies with depth, the average temperature remains about 70 degrees year-round.

Salt may appear in veins like coal. Veins are the original bedded salt deposits. Salt may also be found in domes. Salt domes are formed when earth pressures force salt up through cracks from depths as great as 9 or 12 km. These domes are roughly like plugs of an almost circular shape and are a few hundred meters to a kilometer across. Both domes and veins are mined in a similar way (Calvinaco, 1990).

Salt is mined by the room and pillar method. Salt is removed in a checkerboard pattern to leave permanent solid salt pillars for roof support. The room height may average from 3.5 meters in a bed, to 27 meters in a dome (Calvinaco, 1990).

The above-ground processing of the rock salt consists of sorting the mined salt into various marketable sizes by screening it over mechanically operated screens. When separated, each size is conveyed to its individual bulk storage bm to await packaging for shipment or to be loaded as bulk salt into railroad cars, trucks, river barges, or lake boats for *shipment to* customers (Calvinaco, 1990).

3.2.3 *Vacuum pan evaporation*

Another method of salt production used is the evaporation of salt bnne by steam heat m large commercial evaporators. This method yields a very pure salt mat is fine in texture and is principally used in those applications for which quality is of primary importance.

The first part of the operation is known as solution mining. Two wells are sunk 150 to 300 meters apart into the salt vein. Water is forced down one well under great pressure and seeks the easiest way out, namely up me other well. Once the two wells are connected, the operation beings. Water is pumped down one well. The salt below is dissolved and the resulting salt brine is forced to the surface through the other well. It then goes into huge tanks for storage (Calvinaco, 1990).

Next, the brine is pumped into vacuum pans. These are huge closed vessels about three storeys high and normally İn a series of three, four, or five, with each one in the line under greater vacuum than the preceding one (Calvinaco, 1990).

!n the vacuum pan process, steam is fed to the first pan. This causes the brine in the pan to boil. The steam from the boiling brine is then used to heat the brine in the second pan. The pressure in the second pan is lower, allowing the steam made by the

boiling in the first pan to boil the brine in the second pan.

The pressure is reduced still further in each succeeding pan. This allows the steam made by the boiling brine in the previous pan to boil the brine in the next pan. The boiling operation could be done with just one pan. Several pans in a series, however, produce more salt per pound of steam, and, thus, are more energy efficient (Calvinaco, 1990).

The heating of brine actually takes place in the middle section of the vacuum pan. Two large metal sheets act as the top and bottom of this section. The sheets are connected by hundreds of copper tubes through which the brine can flow freely between top and bottom. The pan is filled with brine to just above the top of the tubes. Steam is fed around the tubes and is hot enough to keep the brine boiling.

In most pans, the brine goes up through the tubes and down through a well in the center. There, an agitator and natural circulation keep it flowing. Vigorously boiled and agitated brine produces salt in the shape of small cubes. The salt settles continuously into the narrow bottom of the pan. Here it is pulled off as slurry - a mixture of brine and salt. The slurry goes from the vacuum pans to the filter dryer, in which heating removes the moisture and dries the salt (Calvinaco, 1990).

3.3 *Production*

In Turkey, crude salt production is made from three sources, namely, the sea, salt lakes and rock salt. The production capacity of these salt facilities and production quantities İn the East few years are given in Table 4 and Table 5.

Table 4. Salt production capacity in Turkey.

Place	Production Capacity	Rate
Kayacık	500,000	25
Kaldırım	400,000	19
Yavşan	400,000	19
Lake Total	1,300,000	63
ÇamalD	600,000	29
Ayvalık	20,000	1
Sea Total	620,000	30
Çankırı	60,000	3
Sekili	20,000	1
Tepesidelik	15,000	1
Tuzluca	20,000	1
Kağızman	12,000	1
Rock Salt Total	127.000	7
Others	21,000	1
Total	2,068,000	100

Table 5. Salt production (1998-1999).

Type of Production	1998	1999
ÇamaKı (Sea)	430,513	557,262
Ayvalık (Sea)	8,340	9,843
Sea Total	438,853	567,105
Kaldırım	458,196	483,728
Kayacık	597,055	404,145
Yavşan	562,750	490,564
Lake Total	1,618,001	1,378,437
Rock Total	93,931	89,377
Others	18,846	19,458
Total	2,196,631	2,169,631

3.4 *Sales*

The 1999 reported distribution of salt by major end use was, chemicals, ice control, distributors, general industrial, agricultural and food, and exports. The selling quantities from 1995 to 1999 are given in Table 6, and exported salt İs given in Table 7.

Table 6. Salt sales.

Years	Sales (Tons)
1995	1,619,000
1996	1,825,000
1997	1,999,000
1998	1,916,000
1999	1,850,000

Table 7. Salt exports of Turkey (1995-1999).

Years	Quantity (Tons)	Value (USD)
1995	3,418	21,000
1996	3,568	35,680
1997	13,021	156,240
1998	12,737	101,8%
1999	11,564	92,512

Although the quantity of exported salt is not sufficient, there has been progress in recent years. Turkey has exported salt to the Turkish Republic of Northern Cyprus, Bulgaria and Azerbaijan.

Salt sales according to production area for 1999 are given in Figure 1.

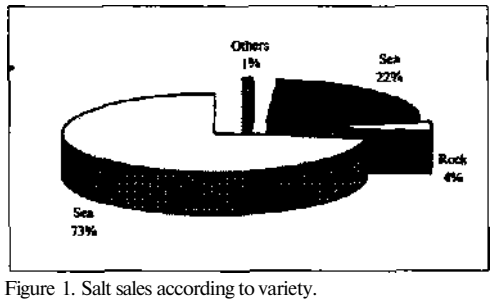

Figure 1. Salt sales according to variety.

3.5 *Consumption*

Chemical: the greatest quantity of salt used in the chemical industry is by the chloralkali sector. Traditionally, the chloralkali sector included salt consumed for chlorine, coproduct sodium hydroxide, and synthetic soda ash. Chlorine and caustic soda are considered to be the first generation of products made from salt. These two chemicals are further used to manufacture other materials, which are considered to be the second generation of products from salt.

Food processing: every person uses some quantity of salt in their food. Salt is used in meat packing, canning and the dairy industry.

General industrial: the industrial uses of salt are diverse. They include, in descending order, oil and gas exploration, other industrial, textiles and dyeing, metal processing, pulp and paper, tanning and leather treatment, and rubber manufacture.

Agricultural industry: since prehistoric times, humankind has noticed that animals satisfy their hunger for salt by locating salt springs, salt licks, or playa lake salt crusts (Kostick, 1998).

Water treatment: commercial and residential water-softening units use salt to remove the ions causing hardness (Kostick, 1998).

Ice control and road stabilization: the second largest use of salt is for highway deicing. The developer of the Celsius temperature scale discovered that salt mixed with ice {at temperatures below the freezing point of water) creates a solution with a lower freezing point than water by itself (Kostick, 1998).

3.6 *Quality of Salt*

In obtaining high quality in sea salt production, the important thing is the cutting process and not letting other minerals down. However, for lake salt and rock salt, the salt naturally comes into existence itself. For this reason, İn these kinds of salt, people have little chance of determining the quality. Thus, the quality of lake and rock salt is better than sea salt and other types. The qualities of salt produced in Turkey are given in Table 8.

Table 8. Sail qualities.

Analyze	Kayacık	Kaldırım	Yavşan	Çamaltı	Çankırı
Humidity	5.4950	16710	1.1320	8.1212	0.1710
Melting material m water	0 0780	0.1100	0.2840	0.2998	0.2040
$CaS0_4$	0.6807	0.4766	0.6870	0.8848	12610
$CaCl_2$	-	-	-	-	0 0205
K_2S0_4	0.2467	0.4629	0.4371	-	-
MgSO«	0.0430	0.3481	0.0348	0.2794	-
MgClî	-	-	-	0 2553	-
NaCl (Humid)	93.2566	96.7314	97.2314	89.9595	98.1435
NaCl (Dry)	98.7516	98.4024	98.3634	98.0807	98.3145

3.7 *Costs*

The average production quantity per worker was 520 tons in 1995, 774 tons in 1996, 899 tons in 1997, 785 tons in 1998, and 774 tons in 1999. Labor costs make up a large part of overall costs. Hence, modernization studies and the use of artificial intelligence in the salt industry have been growing in importance. The relation between production quantity and number of workers is given in Figure 2. As shown in this figure, in spite of reductions in the number of workers, production quantity has increased since 1995.

The production costs are given in Table 9; as shown in the table, the most expensive salt category is others, followed by rock salt and sea salt.

The price is determined by the general management, which is known as TEKEL, three times a year. The crude salt sale price was set at: 3700 TL/kg ($10.58/ton) for the first part of the year, 4000 TL/kg ($9.89/ton) for the second part of the year, 4500 TL/kg ($10.48/ton) for the third part of the year, and 6000 TL/kg ($11.76 /ton) for the last part of die year (Anon., 1999).

Table 9. Production costs QJSD/ton).

Type Of Crude Salt	1997	1998	1999
Sea salt *	8.78	10.54	996
Lakesalt	4.33	5.10	6 28
Rock salt	19.93	20.27	28.21
Others	62 83	60.86	64.39
Average	6.37	7.35	8.80

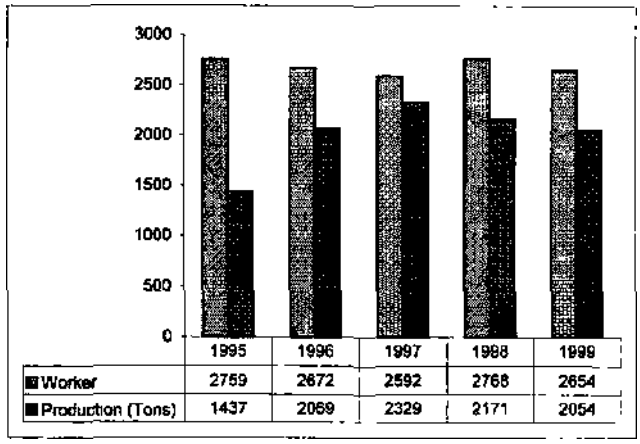

Figure 2 Relationship between worker and production

4 DEVELOPMENTS IN SALT INDUSTRY

TEKEL has been investing in a number of projects recently to achieve this goal. Some of the recent investments are given in Table 10.

Table 10 Important investments by Tekel

Name of Project	Place
• Investment of Çama İt ı Salt Washing Facilities and Improvement of Production Ponds	Izmir
• Kaldırım Saltworks Dockage System (Completed)	Şerefi i kochi sar-Ankara
• Construction of dykes for Lake Saltworks Production Ponds (Yavşan - Kayacık) (completed)	Cıhanbeylı-Konya Şeref] i koçh i sar-Ankara

Salt washing facilities are among the most important investments. The salt washing facilities are designed to work as two production lines, each producing 50 tons per hour washed salt from the seawater. The raw salt carried by conveyors and trucks from the stock area is transferred into a bunker. It is then transferred from the bunker through a crusher/grinder to a pickling brine mixing tank where calcium sulfate and salt crystals are separated from each other. All of the magnesium sulfate dissolves in water. From here they are transferred respectively to the first washing tank, hydraulic cyclone and the second washing tank, and calcium sulfates and thin solid materials left in the salt crystals are separated from the salt. Salt crystals in the washing tanks move down by gravity, water and thin solid materials are carried by water move up and poured from overflow wessel.

In the process before stacking, washed salt is dried with centrifugal extractor. During this process clean water sprayed into the centrifugal extractor removes the main solution including soluble materials in it from the salt.

There are two important reasons to found washing facilities in Çamaltı Saltwork.

First reason is that chlorine is the main input material in Petkim Chlorine and Alcohol Facilities, which purchases nearly the half of raw material production of saline and it is obtained here. So Petkim needs washed salt having required conditions.

Firstly the yearly-required quantity of salt (220-250 thousand ton washed salt) will be supplied by Tekel, construction of which has been completed and yearly production capacity is 300 thousand ton/year.

The second important point is that raw salt produced in all EU countries is taken to the stock areas after being passed through washing facilities. This application is realized also in other countries than EU ones like Egypt and Jordan in which production of salt is high. By founding salt washing facilities in İzmir Çamaltı Saltwork, Tekel will be the first one who realizes this in the industry in Turkey.

There is a need for washed salt in our developing economy of Turkey and the important part of our industry establishments are growing every year. This need increases continuously especially in leather, textile, paint and oil chemical industries.

This facility has also the capacity to satisfy these needs.

By using the latest developments in the world sea salt production and washing technologies in Çamaltı Salt Washing Facilities,

- The production can be realized with less cost,

- The more quality washed salt can be obtained,
- Modern technologies can be used,
- The environment İs not polluted,

The salt with %99,5 purity, which does not include heavy metals and which İs required by chemical and oil chemical industries, can be produced. (Tekel, 1999)

5 CONCLUSIONS

Turkey has potential to become one of the world's leaders in salt production and export by increasing the quality and efficiency of die salt production.

Turkey produces approximately 2 million tons of salt, which counts for only 1% of the total world salt production. Turkey exports almost 12000 tons of salt a year.

Salt has strategical importance in industry and the chemical sector. Turkey is surrounded by the sea in three directions, and has large deposits in Salt Lake, so salt production becomes important in evaluating these large sources.

Modernization studies are being carried out and efforts to increase capacity are being made by Tekel in order to produce better quality and cheaper salt. With a view to more efficient salt production, some suggestions are given below.

- To increase exports, all commercial and political possibilities should be explored.
- More production areas for sea salt production should be examined and evaluated.
- Produced crude salt should be sent to processing facilities directly wimout stocking so as to decrease salt losses due to weather and ground conditions.
- Environmental pollution surrounding salt lakes should be stopped immediately for the production of clearer and better quality salt.
- Costs in other salt production plants and rock salt mines should be decreased by modernization or by decreasing the number of workers; otherwise, these place should be closed until salt prices cover salt costs,
- Turkey has no potash deposits and the annual demand for potash, which is 90,000 tons, is satisfied by imports from other countries. However, in many countries, dissolved potash is extracted from lake and sea water. Potash production directly from lakes or from the processing of bitterns remaining after solar salt production is very common. After the increase of the annual production capacity to 1,000,000 tons at the Çamaltı sea salt plant, which is the largest plant İn Turkey, approximately 30,000 tons of potash, 170,000 tons of magnesium, 100,000 tons of NaïS04 and 3,760 tons of Br2 will be extracted from remaining bitterns.

REFERENCES

.... (...). Halite. http ://ww w.desertu sa.com/mag99/jan/papr/geo_hat i te. h tm l

....(...). Halite. hnp://www.minerals.net/mineral/halides/halite/halite.html

.... (...). Salt. Epicurious food dictionary. http://www. epicuri ous. co m/ru n/fooddict ionary/browse?ent r y_id=10033

.... (...). The mineral halite. http://mineral.galleries.com/minerals/hatides/halite/haiite.ht ml

.... (...). What is salt? http;//www.saltinstitute.org/15.html. Salt Institute

.... (1999). Annual Report of 1999. Tekel Salt Establishment.

Calvonico, J.H. (1990). Economic life of improvements associated with salt production. Appraisal Journal. Vol. 58 Issue 1. p44. 7p.

Kostick, D.S. (1993). The material flow of salt. Bureau of mines information circular.

Kostick, D.S. 1998. Salt, http://www.usgs.gov

Mordogan, H. Ertem, M.E. ErbİI, Ö. Yamık, A. 1997. Opportunities in recycling wastes of CamaJti saltpan. 2nd Industrial Minerals Symposium: 216-224.

Uz, B.. (1999). Endüstriyel mineraller envanteri-kaya tuzu, Yurt Madenciliğini Geliştirme Vakfı

Yalçın, E. Ertem. M.E. 1997. The place of sea salt İn Turkey's salt potential. 2nd Industrial Minerals Symposium: 208-216.