Salt Plants at Torrevieja (Spain) and Their Operation

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ABSTRACT

The extraction of marine salt through solar evaporation in Torrevieja and La Mata lagoons, located on the Mediterranean Coast, near Alicante is described.

The first of these lagoons -- with a surface area of about 1,400 hectares -- is used simultaneously to concentrate sea water and to crystallize salt, while the second one -- with a surface area of 700 hectares -- is employed only to concentrate sea water.

The technology of the several stages of the process followed is discussed. The stages include mining the brines, transportation, washing, piling and unpiling, milling and shipping. The chapter dealing with salt concludes with a comment on its quality, which is of the order of 99.5% NaCl, d. b., for a production which exceeds 550,000 tons per year at present.

The extraction of by-products from residual brines coming from salt production is discussed. The recovery of magnesium sulphate through the cooling of brines is described. The desulphatized brines are treated with chlorine, and bromine is obtained. Some bromine is first transformed into hydrobromic acid. Bromine is also used in the production of potassium bromate. The remainder is placed on the home market. Magnesium chloride is obtained from residual brines coming from bromine production.

The author's discussion is complemented with numerous tables which have been included with the text.

The two lagoons of Torrevieja and La Mata are situated at the southwestern end of Alicante province, about 44 km. from its capital and about 20 km. northeast of the boundary of this province and Murcia.

The Torrevieja lagoon has an area of about 1,400 hectares with a perimeter of 17 km. It is located a kilometer and a half from the village of its name, and about 1,000 meters from the Mediterranean Sea, from which it is separated by a low hill of about 10 meters in height.

The La Mata lagoon has an area of about 600 hectares, and is located 1,500 m. northeast of the above mentioned one. It has a triangular shape and its largest side faces the Torrevieja lagoon; a low hill of a kilometer in height separates this lagoon from the Sea to the east.

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The Torrevieja lagoon occupies a valley surrounded by mountains and hills. The valley is underlain by sandy alluvium below which there is a bed of red clay.

Outcrops of a Tertiary formation surround the valley on its south, west, and north sides.

This formation is composed of limestone, gypsum and clay. The dipping beds form hogbacks which make small jagged mountains around the Torrevieja valley.

The total area of the basin, so constituted, is about 130 $km.^2$, of which nearly 60 $km.^2$ are underlain by alluvial sand, 14 $km.^2$ by the brine lagoon and the remainder by the Tertiary formation.

The basin of the La Mata lagoon has little importance and has a similar geological constitution.

The map of Spain shows the location of the Torrevieja Saltworks (Fig. 1); Fig. 2 shows a detailed map of the Saltworks area, and Fig. 3 shows a geological cross section of the basin of the Torrevieja Saltworks.

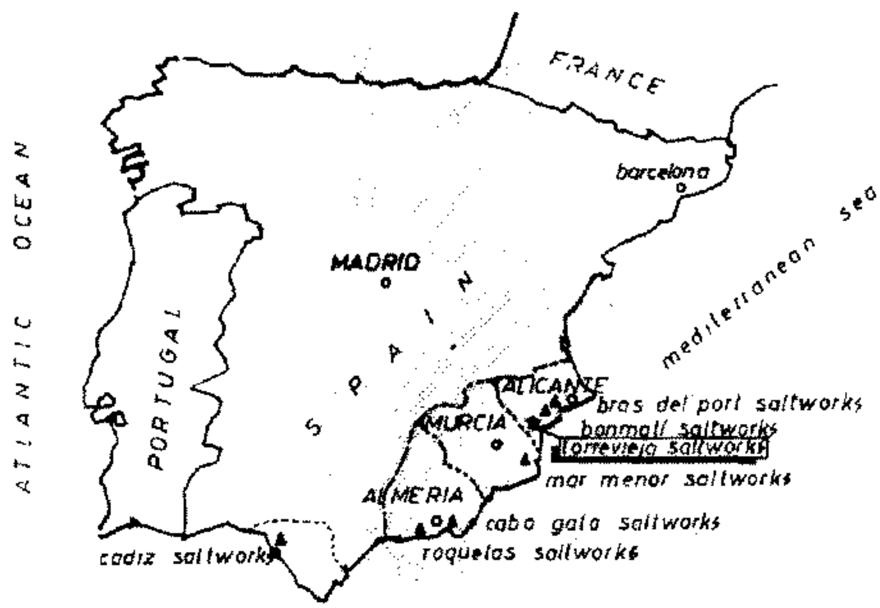

Figure 1. Torrevieja location.

Both lagoons are formed as a consequence of the subsidence of two areas. This circumstance together with the high permeability of the low hills which separate the brine lagoons from the Sea allows the salt water to pass to the lagoons. The intense action of the sun has caused evaporation and crystallization of beds of salt which the winter rains dissolve again sometimes. Other times large floods cover it with mud or slime of variable thickness, over which occurs a new crystallization of salt.

Having shown in brief the geological basis of the Saltworks, we shall center the present article on the extraordinary work performed since the beginning of the last decade. The industrial plants at Torrevieja have required investments which exceeded one hundred thirty-five million pesetas (2.25 million dollars).

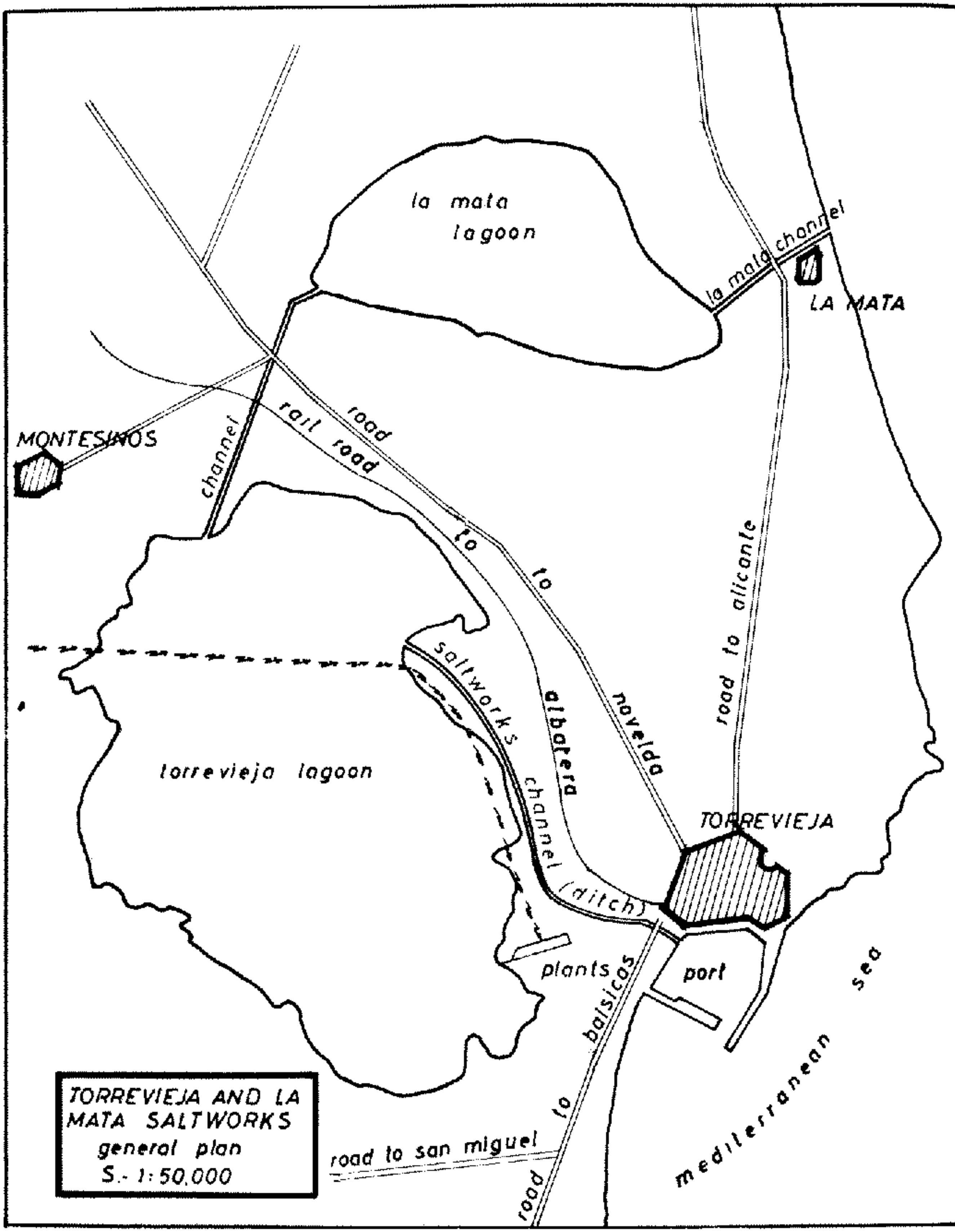

Figure 2. Torrevieja and La Mata Saltworks.

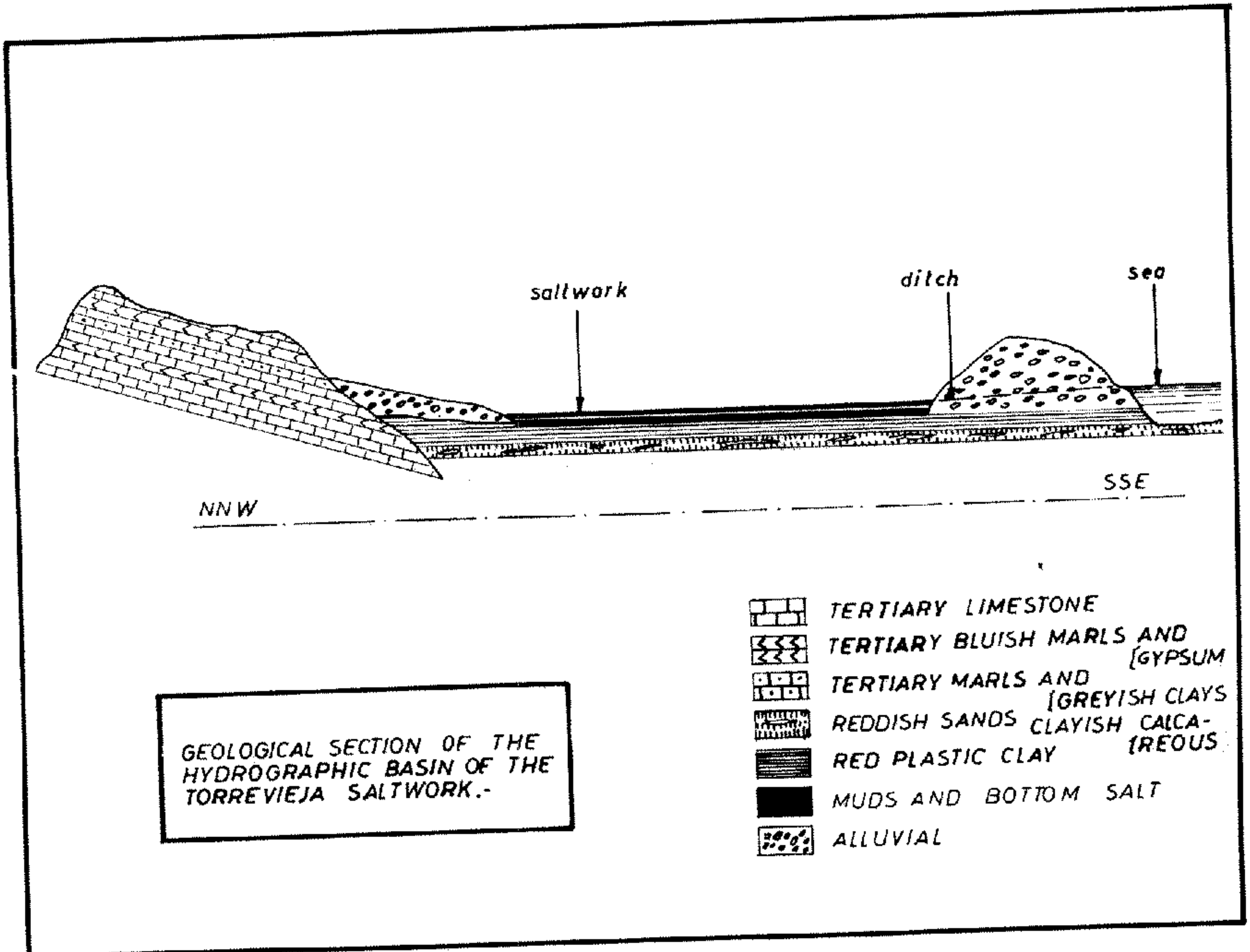

Figure 3. Geological section of the hydrographic basin of the Torrevieja Saltworks.

Figure 4 shows the variety of the products obtained at Torrevieja.

The process begins with the obtention of salt, the fundamental product of the saltwork plant, which is developed in the following stages:

a. preparation of the lagoon and crystallization of salt,

b. harvesting and transportation,

c. washing,

d. heaping up,

e. unpiling,

f. grinding and milling,

g. shipping.

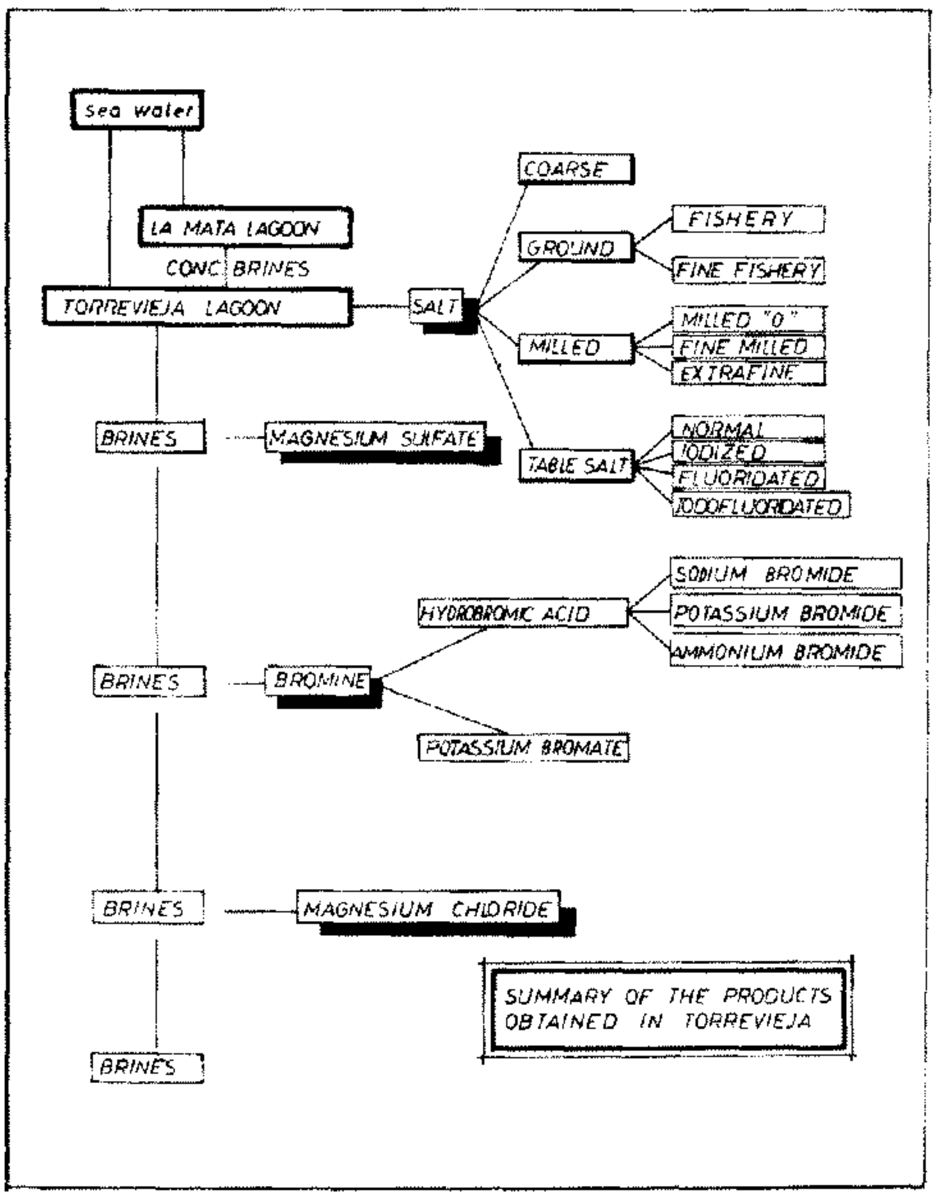

Figure 4. Summary of the products obtained in Torrevieja.

Preparation of the Lagoon and Crystallization of Salt

The industrial cycle starts in January with alimentation of sea water in order to dissolve the salt of the previous cycle which has not been harvested, and to yield sodium chloride which will be the salt of the new crop.

The average composition of the brines of the lagoon at the beginning of the admission of sea water is shown in Table 1.

The crystallization of salt starts in April, in accordance with the climatologic conditions, at which time the brines have the composition shown in the table. The harvest starts when the thickness of the salt exceeds 50 mm.

TABLE 1

COMPOSITION OF BRINES OF THE TORREVIEJA LAGOON

(average in the last 8 years)

	In the month of January of each year	At the beginning of the salt crystallization
$Mg(OH)_2$	0'23 gr./1.	0'19 gr./1.
$MgCO_3$	0'37 gr./1.	0'31 gr./1.
$CaSO_4$	0'24 gr./1.	0'24 gr./1.
$MgSO_4$	46'85 gr./1.	40'94 gr./1.
$MgBr_2$	1'60 gr./1.	1'42 gr./1.
$MgCl_2$	74'35 gr./1.	61'85 gr./1.
K Cl	14'87 gr./1.	13'31 gr./1.
Na Cl	180'45 gr./1.	207'05 gr./1.
Specific gravity	26'2 º Bé	26'2 º Bé

Independently, the La Mata lagoon feeds brines of medium concentration to the Torrevieja lagoon.

The Torrevieja and La Mata lagoons work in series and are connected by a channel. In order to obtain the maximum contribution of the latter, taking into account the productivity obtained in Torrevieja, the concentration of its brine is reduced, in order to cause the greatest possible evaporation of water.

The surfaces of both lagoons are roughly in the proportion of 2:1. In La Mata the concentration ranges from 12º to 15º Be while it ranges from 23º to 30º Be in Torrevieja. If one takes into account the respective coefficients and assumes an annual evaporation of fresh water of 3 meters, the water evaporated in each lagoon is the same, amounting to a total of about 20 millions of cubic meters.

As each cubic meter of sea water contains about 29 kilos of NaCl, it is evident that the present average production of about 550,000 tons per year is almost twice the 300,000 tons per year obtained in the best years, when only the Torrevieja lagoon was worked.

Table 2 shows the development of salt production in Torrevieja from 1926 to 1964.

Hereafter we describe the harvest of the salt, its treatment, and at the same time the several machines and plants employed. These procedures are the result of mechanization and investments dating from the early years of the last decade.

TABLE 2

SALT PRODUCTION AT TORREVIEJA

Year	Metric tons/year
1926/1930	346.956 (average)
1931/1935	269.524 (average)
1936/1940	140.565 (average)
1941/1945	135.720 (average)
1946/1950	201.687 (average)
1951/1955	329.744 (average)
1956/1960	363.963 (average)
1961	452.267
1962	475.502
1963	521.383
1964	596.922

Harvesting and Transportation

When the thickness of the salt surpasses 50 mm. the harvest begins with digging machines, termed "volvedoras." Three of these machines are used and another is kept as a spare. They consist of scraper blades and a system of moving shutters which transport the salt to a belt conveyor set up on a chassis located on two large floating boxes and pulled by a caterpillar which rests on the bottom of the lagoon.

This bottom is formed by a bed of hardened salt, with variable thickness over which lies a thin bed of mud. Salt is deposited over this mud in each season's cycle.

The salt is transported in barges of small draft tied together. The maximum depth of the lagoon during the harvesting season is about 700 mm. The capacity of each barge is about 3.5 tons, and each series of ten double barges is pulled by a tugboat, forming what in saline terminology is called a "RACHE" of which there are 14 in operation.

Washing

The salt taken from the lagoon contains as impurities calcium and magnesium salts and mud which cause serious difficulties in its utilization. Therefore, the salt must be washed in order to decrease the quantity of calcium and magnesium salts.

The calcium sulphate precipitates in very fine form when the sea water or the brines from La Mata are admitted to the lagoon and mix with the brines there. It is relatively easy to separate the calcium sulphate by washing this precipitate from the crystals of salt, to which it becomes attached, thus recovering the halite crystals.

The magnesium salts are precipitated with the salt, especially when the concentration of the brines is high. By washing the salt mixture with sea water or a very dilute brine it is possible to remove the magnesium salts.

It is evident that in the washing of the salt there are two steps required, which can be performed together or separately.

In the first step the salt is mixed with a strong batter which contains concentrated mother liquors. Thus, salt is not dissolved, but mud, other mechanical impurities, and almost all the calcium sulphate is removed.

In the other step, dilute mother liquor is sprinkled over the salt. The magnesium salts are partly dissolved and removed. The second step can be carried out simultaneously, using the dilute mother liquors of the first step.

Further, to remove the remaining magnesium salts, it is convenient to sprinkle the salt with fresh water, which removes the other impurities which can impregnate it.

The more dilute the brine is, the more it cleans the salt. However, the loss by dissolution will be greater, and low yields are obtained from washed salt.

By increasing the batter of the salt and arranging the washing plant in such a manner that it is well drained before the final sprinkling, losses can be reduced to a minimum.

The washing plant includes two twin conveyors, with a unit capacity of 300 tons/hour. Each of them form a double channel in which turn two screw conveyors. These take the salt thrown in a hopper placed at their head and roll it towards the end of the conveyors. There the salt falls into a bin at the foot of a double elevator with perforated buckets which takes the salt and lifts it up. The perforated buckets allow the greatest part of the brine to drain.

Each elevator pours the salt on a train formed by three draining conveyors with scrapers which remove the washing brine which impregnates it. At the beginning of the conveyor fresh water is sprinkled on the salt which completes its cleaning, and it arrives at the end of the train completely drained and clean.

The drainboards carry the salt into hoppers feeding belt conveyors which carry the salt up to the heap.

Heaping Up and Unpiling

The salt coming from the washing plant is elevated, by an inclined belt conveyor, up to another belt conveyor which distributes it to the center of a large heaping space with a shape of a semicircle of 176 m. average radius. The heap of salt can reach a height of about 8 meters in the center and 18 m. at the sides.

The salt is heaped by scrapers with 3.50 cubic meters of capacity. The scrapers are pulled up by ropes rolled in hoists located at the foot of movable towers. There are three towers which contain hoists operated by 200 H. P. electric motors. The hoists are operated from a cabin placed in the top of each tower.

To unpile the salt, the position of one or more scrapers is inverted. The salt is carried towards the center of the heap, where there is a hopper which collects it and feeds it to a belt which carries the salt to a 150 meter horizontal conveyor. This conveyor carries it to another, with a length of 40 m. which is inclined and feeds the milling and loading equipment.

Milling and Shipping

These plants include six silos for the loading of a railway which goes to the port. Above each silo are two screens which catch the extra-coarse salt called Kurkutch.

Connected to the feeding belt there is a transport system of conveying belts which feed four crushing mills where two smaller sizes called Fishery and Fine Fishery are produced. Further, a battery of horizontal stone mills produces even finer sizes.

The bagging and loading equipment is located close to the milling installation. Four bagging machines with automatic weighing scales, machines for sewing jute and esparto bags, and welding machines for plastic bags are used in the bagging operation. Machines for transporting and handling the bags and for loading them into lorries and train wagons are nearby.

For shipping by rail a railway was built which begins at the loading wharf, alongside the bagging installation.

Ships are loaded in the harbour in a special dock called Salt Quay which can handle vessels with a draft of up to 9.5 meters.

The quay has a general storage area which can hold 20,000 tons of salt. The loading facilities include four mechanical sets which can take the salt either from the bulk stock or directly from the train.

The loading rate for vessels taking coarse salt in bulk easily reaches 3,000 tons every eight hour period of work. Each loading set uses a trimming machine placed at the end of a pouring telescopic tube which sprays the salt into each hold.

Quality of the Salt

We think it is worth completing this paper concerning the salt production with a short commentary on its quality.

After arriving from the washing plant, the salt shows a magnesium content expressed as MgO of about 0.35%. During the storage period in the heap a natural process of draining takes place. Consequently, its quality is improved by a reduction of half of the MgO contents. Table 3 shows the average composition of the salt shipped in the last few years.

As the chloro-alkaline industry is one of the main consumers of salt, we try to give it salt with a low magnesium content. In the last few years an average of from 0.11 to 0.14% of magnesium oxide was present in salt sold to this industry.

The salt must be carefully analyzed in accordance with the uses to which it is destined. We will set forth the problem which the salt-fish industry of northern Europe, particularly Iceland, has had to face. A yellow-brown discoloration occurred in codfish after the fish had been cured ten or twenty days with salt containing traces of copper. The discoloration is due to a chemical reaction of the Maillard type, catalyzed by copper and inhibited, as it seems, by the presence of magnesium salts. Therefore, salt with a copper content of lower than 0.1 p.p.m. must be used to

TABLE 3

AVERAGE COMPOSITION OF THE SALT LOADED AT TORREVIEJA

Year	1960	1961	1962	1963	1964
$Ca\ SO_4$	0'159	0'177	0'166	0'171	0'214
$Mg\ SO_4$	0'204	0'225	0'189	0'215	0'191
$Mg\ Cl_2$	0'257	0'262	0'282	0'322	0'327
Na Cl	96'844	97'006	96'368	96'239	96'396
Moisture	2'467	2'265	2'884	2'989	2'830
Water insolubles	0'022	0'024	0'023	0'025	0'030
	99'953	99'959	99'912	99'961	99'988
% Na Cl, dry/basis	99'3	99'5	99'3	99'2	99'2

NOTE: The chemical analysis is performed according to the method shown in reference no. 2.

salt codfish. The presence of copper in salt is not surprising taking into account its existence in sea water. The data we possess is not sufficient to determine the distribution of copper in the oceans and seas. We know that it is not uniformly distributed and that its concentration depends on the depth and also on the season in which the sample is taken.

In order to be able to systematically and continuously verify "in situ" the variation of the contents in copper of the salt in the various saltworks of our companies we have used a method based on the catalitic action of the copper over the oxidation of 2.3-dimercapto-propanol. This method has an advantage over the spectrophotometric method used until now (reference 1) because it does not require any special instruments. Further, it is possible to determine precisely traces of copper within the normal means of any laboratory.

DRY AND PACKED SALT

Its fabrication is based on scientific methods already known and its technological development occurs in accordance with the following process:

Washing and Draining

The salt coming from the heap, is washed thoroughly with fresh sea water and simultaneously drained in a centrifuge.

Pre-Drying

This operation takes place after the drying and before the grinding of the salt. The centrifuged coarse salt enters the venturi trompe of a drying plant through a disintegrator, which breaks up the salt lumps formed in the centrifuge and in the union hopper. Lumps would obstruct the pneumatic circuit.

A powerful ventilator sucks in hot air coming from a generator annexed to it. The mixture of salt and air is impelled by the ventilator through the length of drying set where a temperature of 90°C is obtained. A cyclone separates the dry salt from the saturated air.

The salt from the pre-drying operation passes through a rotative valve placed at the bottom of the separating cyclone and the air which has been used for the drying is expelled to the outside.

The salt, after this first drying, is sent to be ground to the granulometric composition suitable to the use for which it is intended.

Drying

The drying installation has a biconic pneumatic drying set equipped with a recycling design system.

The salt coming from the cylinder mill is introduced into the drying set through a rotative valve. In the driers an air stream carries the particles upward.

Taking into account the shape of the drying rooms, the small particles advance at greater speeds so that the drying speed is inversely proportional to the weight of the particles.

The drying operation takes place in two drying chambers, heated to 200°C., placed in a series. Each chamber is formed of two cones which are joined at their bases.

At the outlet of the drying chambers there is a separating cyclone where dry salt is separated from the air, a part of which is recycled. Still smaller grains are recovered in another separator. The salt is now sterilized.

The saturated and clean air is expelled to the outside through an extractor.

The dry salt is extracted from the separating cyclone through a rotative valve and enters a pneumatic conveyor.

The smallest grains recovered in the second separating cyclone are expelled through another rotative valve placed in the lower part of the cyclone.

Pneumatic Conveyor

Its purpose is to convey the dry salt coming from the drying set to the packing plant. Further, it gradually cools the salt by maintaining its isolation from the outside, both to avoid the absorption of the moisture of the ambient atmosphere and to ensure the total absence of pathogenic germs which it could acquire.

The dry salt is introduced into the circuit with the help of a venturi trompe. Taking into account the 70 m. of tubing and the hygroscopicity of the salt, there is a decrease of the stress of the air stream which serves as a transporting agent. It is reheated slightly with the addition of hot air.

The separation of the air and salt is made through the separating-cyclones. After the salt leaves the cyclone it is screened and an anticaking agent is added.

The anticaking agents usually employed are magnesium carbonate and/or tricalcium phosphate in variable quantities, in accordance with the composition of the salt, but always in amounts of less than 2%.

Packing

In the packing plant the salt comes to an automatic packing machine which also prepares the plastic bags.

Also in this packing equipment the salt is kept completely isolated from the outside, so that it cannot be contaminated.

The packing plant is completed with a machine which prints Kraft paper and packs ten bags of one kilo or 20 bags of one half kilo.

The four types of salt obtained are:

Normal table salt,
Iodized salt,
Fluoridated salt, and
Iodo-fluoridated salt.

The iodized salt is used in the treatment of goiter prophilaxis in the regions where the sanitary authorities recommend it.

The fluoridated salt is produced for its use in the prophylaxis of dental caries. It has been verified that in the region where dental caries prevail, its incidence can be reduced by increasing the contents of the fluorine in the drinking water, or by fluoridation of the salt (reference 4).

OBTENTION OF BY-PRODUCTS

Production of Magnesium Sulphate

The mother liquor coming from the production of common salt is concentrated by solar evaporation until it reaches a density of 34/35° Be. After this, it is sent to the magnesium sulphate plant where it is cooled down to about 5°C., and crystallized with the addition of water.

The sulphate slurry is sent to a conic feed filter tank and to a vacuum filter.

Production of Bromine and Bromides

The desulfated brines containing about three-fourths of a gram of magnesium bromide per liter are acidulated with chamber sulphuric acid, in order to reduce the consumption of chlorine and avoid the hydrolisis of bromine. After going through an interchanger of heat where they circulate in countercurrent with the debrominated brines they enter a set of Kubierschky towers where the oxidation of bromide ion to elemental bromine through treatment with chlorine takes place.

The bromine obtained is refined in order to eliminate the excess of chlorine. The excess bromine is sent back through the Kubierschky towers. The product obtained has the following average composition (determined following the process as per reference 3):

Bromine, minimum	98.5%
Chlorine, maximum	1.0%
Iodine	Negative
Organic matter	Traces
Water	Saturated (0.04% approximately)
Fixed residue	Traces

a part of which is intended for another purification cycle, in order to obtain a product technically pure.

It is not possible to establish an equivalence between the production of salt, magnesium sulphate and bromine, because for the production of salt we try to obtain the maximum possible production allowed in accordance with the climatologic conditions in each season, whereas, the production of magnesium sulphate and bromine is fixed according to the foreseen demands of the consumption. The total use of the magnesium salts and bromine contained in the mother liquors has never been reached.

A part of the bromine obtained is placed in the home market and packed in glass flasks, with a net content in each bottle of 3.0/3.5 kilos. The balance is destined to be transformed into inorganic bromides and bromates.

The alkaline bromides are obtained by the neutralization of hydrobromic acid with the respective hydroxides.

The most important bromate produced is potassium bromate which is obtained by oxidation of solutions of potassium bromide with chlorine.

The production of crystallized magnesium chloride, consists of the concentration of the mother liquor from the bromine production, after having eliminated their acidity and the excess of chlorine.

Our description of the operation of the salt plant is concluded, but our continuing task is to look for new improvements in both our commercial and industrial methods.

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