SOLAR SALT PRODUCTION PROCESS

D.S. JHALA

Chairman - Dev Salt Pvt. Ltd (Salt Producer & Consultant)
President - Indian Salt Manufacturers Association, INDIA,
CAB (Salt) Member- Govt. of India
88-Panchvati, Bedi Road, Jamnagar (India) 361002
E-mails:dsjhala@bilt.com; devsalt@sancharnet.in

EXTENDED ABSTRACT

The history of Solar Salt production can be traced back to the don of human civilization. In ancient time when seawater evaporated in pits, white layer was formed and it was found tasty. The white layer was nothing but “Solar Salt”. Like this it was the beginning of civilization as well it was the beginning of solar salt production. This has a long and intriguing history. It has shaped civilizations from the very beginning, and story is a glittering, often surprising part of the history of mankind. A substance so valuable it served as currency, influences the establishment of trade routes and cities, provoked and financed wars, secured empires and inspired revolutions.

The extraction of salt from sea water consists of progressive evaporation of brine in large ponds using solar heat and natural wind. As the brine evaporates its concentration rises and constituent of salts crytallize in a set order. During the process, the sodium chloride fraction is separated from the brine over affixed concentration range in a series of flat rectangular ponds and deposits as uniform crust. The salt crust is harvested by variety of process ranging from simple hand labour to mechanical harvester. The principal salts that crystallize from concentrated brine along with sodium chloride are the chlorides and the sulphates of magnesium, calcium and potassium. The harvested salt in the form of wet crystals, washed with brine to remove insoluble matter as well as soluble impurities”. In this paper the Author has further discussed in detail the effect of deep charging as well as important data related to solar salt process based on series of experiments conducted by the author.

Keywords: Solar Salt, Civilization, Constituent, Sulphates, Immemorial, Deg. Be, Concentration, Microorganisms, Algae, Crystallizers, Crystal

INTRODUCTION

The history of Solar Salt production can be traced back to the don of human civilization. Salt is an inseparable ingredient, which sustains life on earth. In ancient time when seawater evaporated in pits, white layer was formed and found not only tasty but human being also experienced some strength after eating this white layer. The white layer was nothing but “Solar Salt”. Like this it was the beginning of civilization as well it was the beginning of solar salt production. This has a long and intriguing history. It has shaped civilizations from the very beginning, and story is a glittering, often surprising part of the history of mankind. A substance so valuable it served as currency, influences the establishment of trade routes and cities, provoked and financed wars, secured empires

and inspired revolutions. It is not known as to when salt became article of commerce, but it is certain that it one of the earliest form of commercial enterprises. As the time advanced uses of salt increased and the method producing solar salt also become a very important process. In modern times salt has about 14000 known uses from food to industry to de-icing. Presently, about 120 nations are actively engaged in salt production.

As the time has changed the in addition to Solar Salt production other process likes Vacuum salt etc. developed. The quality requirement, particularly for industry became very important. The Solar Salt production process is used world wide for producing maximum quantity of salt for industry and for edible purpose also.

Solar Salt process is environmental friendly. Salt has been manufacturing by solar evaporation from sea water from immemorial time as stated above. This process also helps to maintain wetlands, which is being diminished near big cities due to their expansion. The extraction of salt from sea water consists of progressive evaporation of brine in large ponds using solar heat and natural wind. As the brine evaporates, its concentration increases and constituent of salts crytallize in a set order. During the process, the sodium chloride fraction is separated from the brine over affixed concentration range in a series of flat rectangular ponds and deposits as uniform crust. The salt crust is harvested by variety of process ranging from simple hand labour to mechanical harvester. The other salts which crystallize from concentrated brine along with sodium chloride are the chlorides and the sulphates of magnesium, calcium and potassium, these are impurities of salt. The harvested salt in the form of wet crystals, washed with brine to remove insoluble matter as well as soluble impurities.

Process-Solar Salt process can be divided in to four parts- 1) Brine Management 2) Crystallization 3) Harvesting salt 4) Up-grading.

1) Brine Management

Depending on location, the initial specific gravity varies; normally it is 1.02 to 1.025 i.e. around 3.0* Be (Deg. Be). By solar evaporation it is concentrated to 1.21 i.e. little more than 25* Be. At initial stage the size of ponds are big and known as reservoir. Lots of shrimps come along with seawater. In few locations the silt also comes. The silt settles in ponds and there after clean brine flows further. It is also desirable to provide some net to stop flow of shrimps in further ponds. This will not only give more clean brine but it will allow more concentration of shrimps in first stage ponds only. The shrimps attract the birds particularly, you can see large nos. of flamingoes, pelicans, ducks and other birds. The shrimps are the best food for birds. The discharge of birds is a fertilizer for the growth of the algae, which give colour to brine, and finally it helps to increase the evaporation. This leads to more salt production. The process of seawater concentration can be divided in seven stages. Each stage represents a distinct change in the resulting liquid:-

1) Between 3 deg to 10 deg Be
2) Between 10 deg to 17 deg Be
3) Between 17 deg to 25 deg Be
4) Between 25 deg to 29 deg Be
5) Between 29 deg to 35 deg Be
6) Between 35 deg to 37 deg Be
7) Between 37 deg to 39 deg Be

<u>First Stage</u>

The biological system of first stage is explained above. By gradual evaporation the seawater volume reduced to 37% when density reaches to10 deg Be.

<u>Second Stage</u>

The original volume reduces to 20%. The liquid remain unsaturated till 17 deg Be. Some times it is noticed that a portion of Gypsum and Calcium and Magnesium Carbonate separates out at 12 deg Be.

Third Stage-
When concentration reached to17 deg Be the calcium sulphate (CaSO4 2H2O) begins to separate out in form of thin layer first it float thereafter settle down at bottom. The major portion of CaSO4 separate out at 17 deg to 25 deg Be.

Fourth Stage
Here separation of Sodium Chloride start along with other salt as impurities of sodium chloride. At this stage rate of evaporation reduces less than 50% of Sweet water. As the evaporation proceeds for every 100 grams of water evaporated from saturated solution, 36.5 grams of sodium chloride precipitate. The solubility of sodium chloride being 36.5 grams at 30 deg C in 100 grams of water, the percentage of salt present in saturated solution would be:36.5 / (100+36.5) = 26.74 % by weight. Thus for every 100 grams of saturated solution we have 73.26 grams water and 26.74 grams salt. The fifth, sixth and seventh stages are for bittern for the recovery of by products of Salt. Hence we are not discussing here.

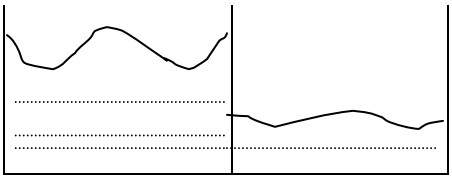
2) Crystallizers- This is a part of fourth stage only. The crystallizers are the heart of the salt works. Hence its best utilization is most important for a salt works. The crystallizers should give maximum yield, best quality salt with minimum brine consumption. It has its own importance. It is necessary that for proper control of quality, in addition of checking of sp. gravity / density the ca & mg should also be determined, before charging the brine to crystallizers. After charging of brine to crystallizers, it is necessary to continue to monitor the density and as well as Ca & Mg in Brine and in salt being precipitate. Normally specific gravity 1.21 to 1.25 (density 25.17 to 29 deg Be) maintained in crystallizers. It is also very important to maintain about 20 Cms depth in brine. In deep charging crystallizers, the formation of crystal is cubical where as in shallow charging crystals formation is hollow type. Removal of impurities in cubical crystal is easy in washing plant.
Important experiment & data- 1. Deep charging of crystallizers is the most important part of the process. '*Deep charging'* which has its own benefits to make best use of crystallizers.
The detail of an experiment for deep charging is given here under-
Many experiments were conducted by the author to compare the result of deep charging and shallow charging. The details of one of the experiment and observations are as under.
Experiment: Crystallizer 'A' charged on 9.12.96 harvested on 23.2.97
Density: 25^{o}Be, depth of brine 25cm, recharged as per requirement to maintain the column
Production: 225 MT
Experiment: Crystallizer 'B' of the same size as 'A', charged on 9.12.96, harvested on 23.2.97
Density: 25^{o}Be, depth of brine 8 cm, recharged as per requirement to maintain the column
Production: 195 MT
Observations:

1).Temperatures of Brine

Time	10am	4 pm	10 pm	4 am
A top	18^{o}C	25^{o}C	22.5^{o}C	15^{o}C
A bottom	20.5^{o}C	27^{o}C	25^{o}C	16.5^{o}C
B top	17.5^{o}C	25^{o}C	22^{o}C	13^{o}C
B bottom	18^{o}C	24.5^{o}C	23.5^{o}C	14^{o}C
Atmos temp	16.5^{o}C	25.5^{o}C	23.5^{o}C	14^{o}C

Temperature at the bottom of 'A' is always higher by more than an average of 2^{o}C (about 10%). This helps to increase the rate of evaporation due to absorption of heat. Variance in temperatures of 'A' are much less as compared to 'B'. This gives better shape of crystal, which minimize impurities in magnesium salt.

2).Wave action



Wave action in Deep charging Wave action in Shallow charging

Deep charged crystallizers get much more wave actions as compared to shallow charged. This artificially increases the surface area, which again helps to increase the evaporation. The surface area increases by about 15% depending on wind velocity, direction and size of the crystallizers. The above figures show wave action in deep and shallow charged crystallizers.

Crystal

The shape of the crystal is very important of quality of salt in deep charging the crystals are solid, heavier and do not retain mother liquor after harvesting impurities are drained out very fast and at the time of washing also magnesium salts can be washed out very fast.
Whereas in shallow charging it is just the opposite. Crystal is of hollow type, which retains mother liquor after harvesting, and it dries up inside the crystal. At the time of washing it takes longer time to remove impurities, which results in washing losses. The diagrams of typical type of crystals in deep and shallow charging are given here.

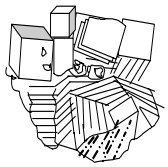


Figure 1: Crystal of deep Charging, 'Cubical type'

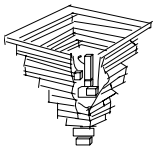


Figure 2: Crystal of shallow charging 'Hollow type'

Microorganisms

The biological system of salt works particularly of crystallizers is very important. In crystallizers it is most concentrated brine having maximum value as all cost is already incurred hence its losses by leakage of seepages is definitely erosion of salt works profit. The biological system helps to develop more algae in salt works, which in final stages in crystallizers becomes of deep red color. Higher column of brine helps in growth of microorganisms. The higher column also gives more dark color shade to brine. This helps to absorb more heat in brine; finally this increases the rate of evaporation. The microorganisms also help to seal the small leakages/seepages. Thus loss of valuable brine decreases. I

Result-In above experiment of deep charging average yield increases by 15% however further experiment is to be carried out to analyze increase in production separately by-

a) Increase in temperature
b) Wave actions
c) Micro organisms

Such study will help to improve the yield of the salt works. Lot of work is required to be done in this field.

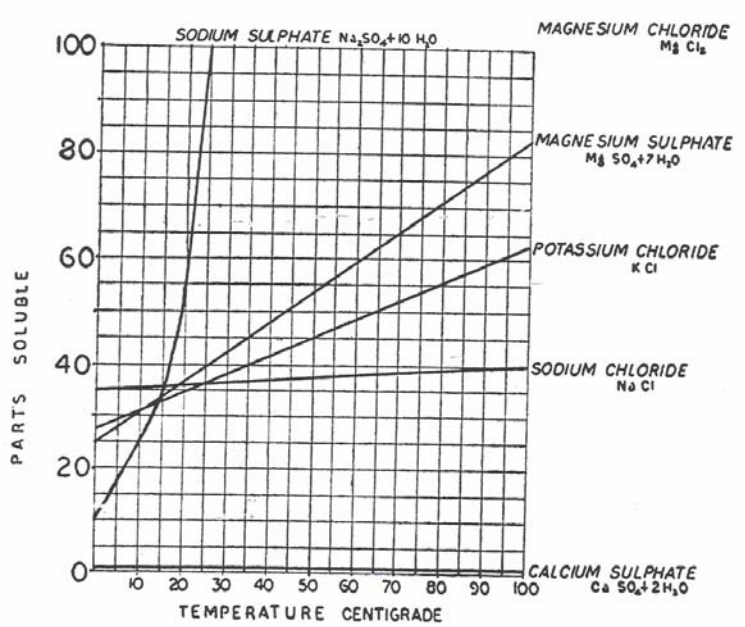


Figure 3: DIAGRAM OF SOLUBILITY IN 100 PARTS OF WATER

Few important data are given here under, for Solar Salt Works production process-

Table-1 : Weights of constituents remaining in solution on progressive evaporation of sea brine starting from one Cu. M. of sea brine

Sp.Gr	^{0}Be	Vol.of Brine Remaining M^3	Kg of salts or water remaining in solution							
			$CaSO_4$	$MgSO_4$	$MgCl_2$	NaCl	KCl	NaBr	H_2O	Total salts
1.0247	3.5	1.000	1.416	2.14	3.375	27.28	0.742	0.086	989.59	35.039
1.0897	12	0.2736	1.416	2.14	3.375	27.28	0.742	0.086	263.08	35.039
1.2100	25	0.1066	0.175	2.14	3.375	28.28	0.742	0.086	95.09	33.798
1.245	28.5	0.0394	0.028	2.14	3.375	7.59	0.742	0.086	35.10	13.961

It can be noted from table-1 that :

1.416 – 0.175 = 1.241 kg of $Caso_4$ is precipitated between 12^0 to 25^0 Be (^{0}Be)
1.175 – 0.028 = 0.147 kg of $CaSo_4$ is precipitated between 25^0 to 28.5^0 Be
27.28 – 7.59 = 19.69 kg of NaCl is precipitated between 25^0 to 28.5^0 Be
And IM3 of 3.5^0 Be brine is reduced to 0.2736 M^3 at 12^0 Be
IM3 of 3.5^0 Be brine is reduced to 0.1066 M^3 at 25^0 Be
IM3 of 3.5^0 be brine is reduced to 0.0394 M^3 at 28.5^0 Be

The above statement can figuratively be represented in Figs. 1 & 2.
It can be noted from the figure -2 that for one ton of salt precipitated –

The requirement of sea brine	3.5^0 Be is 50.8 M^3
The requirement of brine	25^0 Be is 5.4 M^3
And remaining bitten	28.5^0 Be is 2.0 M^3
With evaporation of 45.5 M3 between	3.5^0 and 25^0 Be
With evaporation of 3.4 M3 between	25^0 and 28.5^0 Be

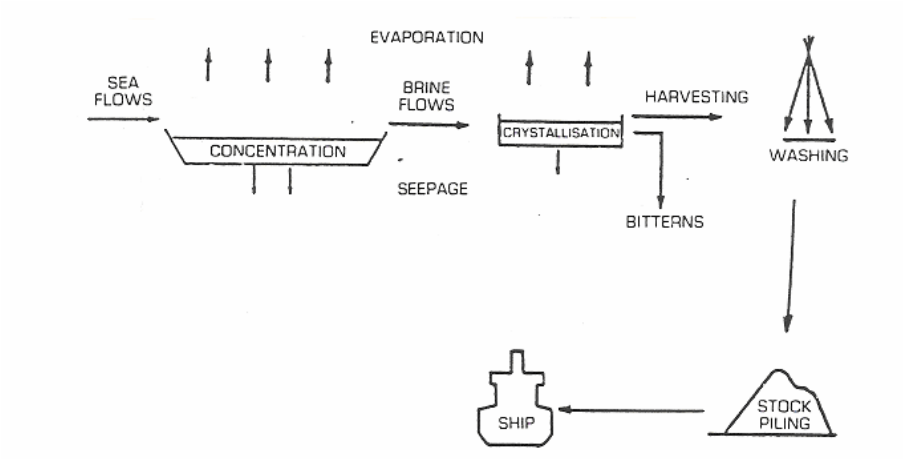


Figure 4: Basic Process Features Of Solar Salt Works

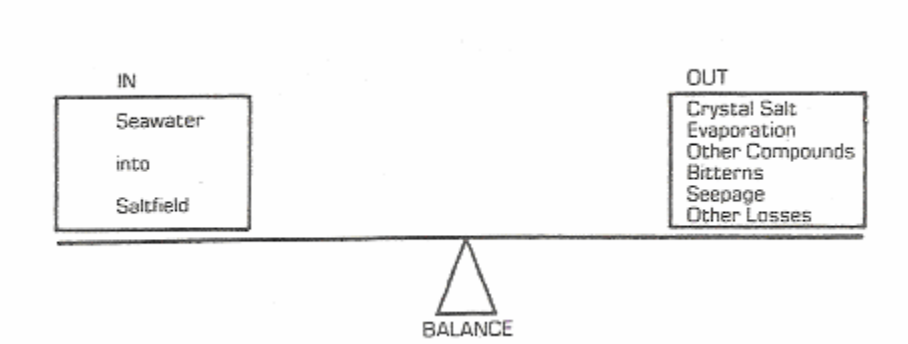


Figure 5: A balance between the input and the output of a salt works

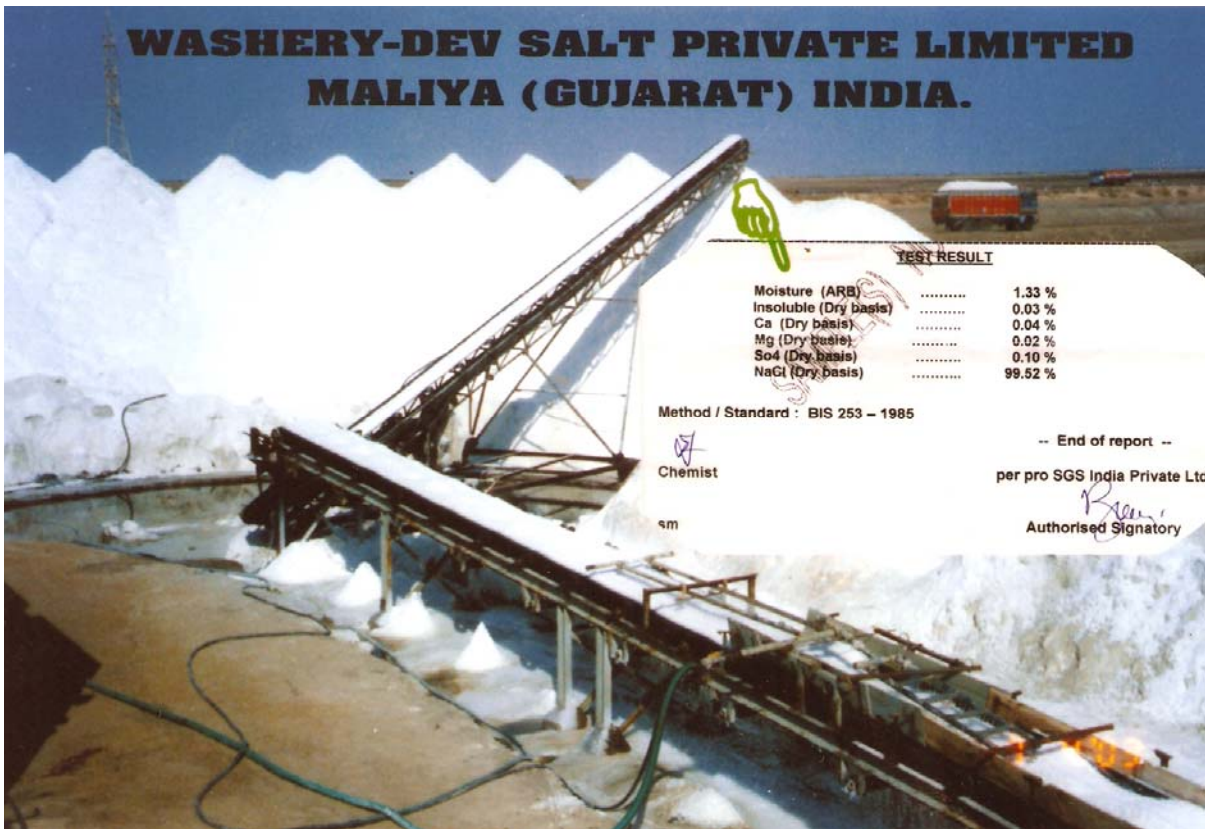


Figure 6

3.Harvesting- The first salt crust of about 30cms thickness used as permanent bed there after Subsequent salt crust of the thickness 10cms to 30cms are harvested and sent to washing plant.

4.Up grading- Freshly harvested salt, has impurities derived from seawater. By washing with brine these impurities are removed partly by about 70% before supplying to Caustic Soda industries. By using washed salt the caustic industries save on chemicals, minimize the generation of sludge, and also reduce consumption of salt per tone of caustic soda reduces, the life of membrane cell increases, the power consumption also goes down.

CONCLUSION-

Process of Solar Salt Production is friendly to Environment

REFERENCES-

1. Jadav M.H. *Papers-CSMCRI (India) Quaterly Publications.*
2. BOB Report for Salt Dept., Govt. of India.
3. Jhala D.S. Deep Charging of Solar Crytallizers *8th World Salt Symposium, in The Hauge during May, 2000* V.2 page 1293-94
4. Aggrawal S.C Publication The Salt Industry in India *1976 edition*
5. Dampier Salt Publication First Edition August 1990*Technical Aspects of Solar Salt*
6. Neelkantan P.R. Basic Calculations for the Lay out of A Salt Works, International Sympo. *International Salt Symposium CSMCRI Bhavnagar India;* March 1982, page 9-11