

SOLAR SALT PRODUCTION PROCESS

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Abstract

The 'Salt' has played an important role in the 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. Now solar salt works are playing important role in environment. Due to expansion of coastal area's cities and development of ports, Jetty, ship building yards etc the wet land, the shelter of many animals is diminishing very fast ; solar salt works are providing additional wet land where many animals / birds take shelter.

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 crystallize 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 ponds and deposits as uniform crust. The salt crust is harvested by variety of process ranging from simple hand labour to mechanical harvester. The salts which 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.

As the time advanced, uses of salt increased and the method of producing solar salt also become a very important. 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.

Now 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 crystallize 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.

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

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

- 1) Between 3 deg to 10 deg Be
- 2) Between 10 deg to 17 deg Be
- 3) Between 17 deg to 25 deg Be

First Stage-

The biological system of first stage is explained above. By gradual evaporation the seawater volume reduced to 37% when density reaches to 10 deg Be.

Second Stage-

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 to 17 deg Be the calcium sulphate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) begins to separate out in form of thin layer first it float thereafter settle down at bottom. The major portion of CaSO_4 separate out 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 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

The detail of an experiment for deep charging is given here under- Many experiments were conducted by the author to compare the result of

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:-

- 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

saturated solution we have 73.26 grams water and 26.74 grams salt. The fifth, sixth and seventh stages are for bittern and recovery of by products of salt, hence we are not discussing here.

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 of 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 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 to 30 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. 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.

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°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°Be, depth of brine 8 cm, recharged as
per requirement to maintain the column
Production: 195 MT

Observations:

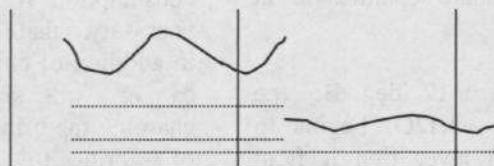
1. Temperatures of Brine

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

Temperature at the bottom of 'A' is always higher by more than an average of 2°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 of 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.

3. 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 solar heat in brine; finally this increases the rate of evaporation. The microorganisms also help to seal the sn s/seepages. Thus loss of valuable brine

4. 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 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 more washing losses. The diagrams of typical type of crystals in deep and shallow charging are given here.



1) Crystal of deep Charging, 'Cubical type'



2) Crystal of shallow charging 'Hollow type'

The conclusion based on the above details and experiments the yield of crystallizers increases by about 15%. The quality also improves.

A further study is to be carried out to analyze increase in production separately by

- Increase in temperature
- Wave actions
- 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.

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. Meter of sea brine

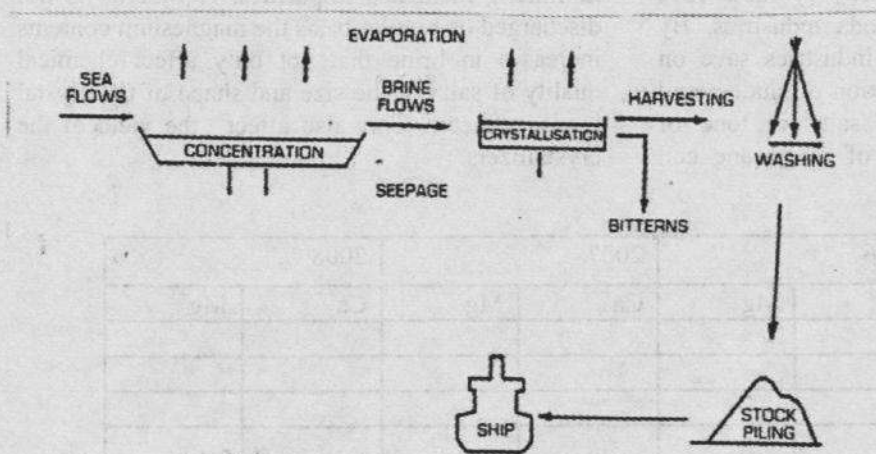
Sp.Gr.	Be	Vol. of Brine	Kg of salts or water remaining in solution					NaBr
			Caso4	Mgso4	Mgcl2	NaCL	KCl	
H2O		*Total salts Remaining M3						
1.0247	3.5	1.000	1.416	2.14	3.375	27.28	0.742	0.086
989.59		*35.039						
1.0897	12	0.2736	1.416	2.14	3.375	27.28	0.742	0.086
263.08		*35.039						
1.2100	25	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 above that

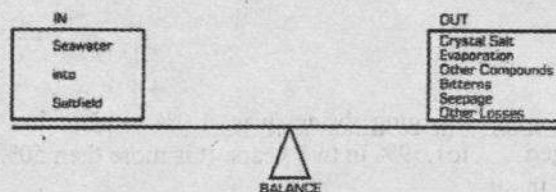
$1.416 - 0.175 = 1.241$ kg of CaSO_4 is precipitated between 12* to 25* Be
 $1.175 - 0.028 = 0.147$ kg of CaSO_4 is precipitated between 25* to 28.5* Be
 $27.28 - 7.59 = 19.69$ kg of NaCl is precipitated between 25* to 28.5* Be
 And IM3 of 3.5* be brine is reduced to 0.2736 M3 at 12* be
 IM3 of 3.5* be brine is reduced to 0.1066 M3 at 25* be
 IM3 of 3.5* be brine is reduced to 0.0394 M3 at 28.5* be

For one ton of salt precipitated –

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



Basic process features of a saltfield.



A balance between the input and the output of a saltfield.

Up grading- Freshly harvested salt, has impurities derived from sea water. 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

Quality- Proper density control of brine at different stages of ponds to crystallizers is very important for good quality salt. The charging of crystallizers with proper brine and than discharging of bitterns regularly give good quality of crystal with minimum chemicals impurities. If bitterns is not discharged on regular basis the magnesium contents increases in brine that not only affect chemical quality of salt but the size and shape of the crystal is also affected. This also affect the yield of the crystallizers.

Month	Density	2006		2007		2008	
		Ca ⁺⁺	Mg ⁺⁺	Ca ⁺⁺	Mg ⁺⁺	Ca ⁺⁺	Mg ⁺⁺
May	25 Be	0.028	1.00	0.2	1.49	0.028	1.59
December	25 Be	0.032	1.36	0.028	1.51	0.032	1.69

Above analysis report speak the increase in Mg in charging brine when bittern is not discharged regularly. During the month of May 2006 Mg in

charging brine was 1.0% which has increased to 1.59% in two years. It is more than 50%.

Conclusion-Solar Salt production process is friendly to 'Environment' & Maximum use of 'Solar Energy'

Key words- Solar Salt, Civilization, Constituent, Sulphates, Deg. Be, Concentration, Microorganisms, Algae, Crystallizers, Crystal

-----THANK YOU-----

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