The above illustrates the best quality solar sea salt. Crystal of 99.95% pure solar sea salt produced in saltworks designed by Salt Partners.

How to Produce Best Quality Solar Salt

Vladimir M Sedivy, President, Salt Partners Ltd, Switzerland.

World oceans cover the Earth since about four billion years.

Seawater absorbs carbon dioxide from the air, forming calcium carbonate, which settles and forms sedimentary rocks.

Tectonic movement brings the rocks to the surface where they are subject to weathering (the rock cycle).

Seawater evaporates and condenses as rain, which flushes the released minerals back to the sea (the water cycle).

The Global Ocean Conveyor Belt moves the cold seawater from the Arctic over the bottom of the Atlantic Ocean, around Africa to the Pacific, where it warms up and flows under the ocean surface as the Gulf Stream back to the Arctic.

These cycles maintain the salt and other minerals in the seawater at a constant concentration of about 3.5% salinity.

Seawater contains all known elements, though most of them in very small concentrations.

Seawater also contains nitrogen (about 15ppm) and phosphorus (about 0.1ppm), which, together with carbon, oxygen and hydrogen are the elements that form the deoxyribonucleic acid (DNA), the basic building block of life.

An estimated one million species live in the oceans.

Seawater supports growth of plants. Plants consist of one or more cells that absorb light (energy) and carbon dioxide. They split water by photosynthesis, producing polysaccharides and oxygen.

This function is controlled by their DNA.

Animals feed on plants. Animals consume polysaccharides and oxygen, convert them into movement (energy) and release carbon dioxide.

Also the activity of animals is controlled by their DNA.

This life cycle exists everywhere where there is water and nutrients.

Also in solar saltworks the life cycle exists. In solar saltfields, seawater flows from one pond to the next, it evaporates and becomes more and more concentrated.

However, fish living happily in 3.5% salinity cannot survive high salinity.

It becomes dehydrated by the osmotic pressure.

But other species, plants and animals, have adopted their survival strategies to higher salinities.

For example *Dunaliella salina*, a halophile micro-algae, thrive in high salinities.

Dunaliella salina serves as food to brine shrimp *Artemia salina*, which releases the non digested food residuum in form of faecal pellets to the pond bottom.

The faecal pellets contain the non-digested nitrogen and phosphorus, which gets sequestered at the bottom of the pond, overgrown by benthic mats and gypsum.

The concentrated seawater, purified of excess nutrients, is free of planktonic biota.

Biologically purified and saturated seawater flowing to the salt crystallisers contains no organics that could interfere with the process of sodium chloride crystallisation.

The salt crystals are then large, hard and transparent.

There are no impurities imbedded inside these crystals.

Such crystals can be processed with low losses to a very high purity solar salt.

The above mechanism of biological sequestration of nutrients only works if the salinity in any given pond is constant and if the change of salinity between the subsequent evaporation ponds is small.

If the concentration changes are large, the planktonic biota, flowing from one pond to the next, perish and decompose, forming mucilage, which eventually passes to the salt crystallisers.

There it disturbs the sodium chloride crystallisation, leading to formation of non upgradeable agglomerates of tiny crystals, soaked with non-removable bitterns.

As a general rule, the density difference between two subsequent ponds should be about 1°Be.

When seawater has a density of 3.5°Be and the saturated seawater flows to the crystallisers at 26°Be, then the number of ponds should be 26 – 3.5 = 22.5, i.e. at least 23, preferably 24.

The table shows an example calculation of evaporation ponds designed in line with the above general rules.

The table is valid for climatic conditions that lead to pure water evaporation of 10 mm per day from a standard Class-A evaporation pan.

It shows evaporation rates, flowrates and concentrations in a 1km² system of 24 concentration ponds.

Benthic algal mats, thriving in the system of constant seawater concentration in any pond, reduce brine losses by seepage to less than 1% of the evaporation rate.

When evaporating, calcium sulphate solutions tend to oversaturate.

Long contact time between the concentrated seawater and the gypsum crystals, growing in the high concentration ponds (pickle ponds), eliminates CaSO4 oversaturation and excess calcium in the salt.

Magnesium content in the solar salt is controlled by early draining of bitterns from the crystallisers before the harvest. Bitterns density should not exceed 28.5°Be. *AMR*

Seawater Evaporation in Solar Saltfields

Pond No.	Density in	Evaporation Surface	Evaporation	Seawater Flowrate in	"All Salts" Concentration in	$CaSO_4$ in	NaCl in	"All Salts" in brine in	Seepage Brine Loss	"All Salts" in brine out	Seawater Flowrate out	"All Salts" Concentration out	Density out	Density Step
	(°Be)	(m2)	(mm/d)	(t/d)	(%)	(t/d)	(t/d)	(t/d)	(t/d)	(t/d)	(t/d)	(%)	(°Be)	(°Be)
1	3.5	272'800	6.92	7'724	3.4%	10.7	205.0	264.4	28.2	263.1	5'809	4.5%	4.6	1.1
2	4.6	162'800	6.88	5'809	4.5%	10.7	204.4	262.7	16.9	261.7	4'672	5.6%	5.7	1.1
3	5.7	108'600	6.84	4'672	5.6%	10.6	203.9	262.0	11.4	261.3	3'919	6.7%	6.8	1.1
4	6.8	80'700	6.80	3'919	6.7%	10.6	203.5	261.5	8.5	260.8	3'362	7.8%	7.9	1.2
5	7.9	57'900	6.77	3'362	7.8%	10.6	203.1	261.0	6.2	260.4	2'964	8.8%	9.0	1.0
6	9.0	52'200	6.70	2'964	8.8%	10.6	202.7	260.5	5.6	259.9	2'609	10.0%	10.1	1.1
7	10.1	41'100	6.65	2'609	10.0%	10.6	202.4	260.0	4.5	259.5	2'331	11.1%	11.2	1.1
8	11.2	32'300	6.60	2'331	11.1%	10.5	202.1	259.7	3.5	259.2	2'114	12.3%	12.3	1.1
9	12.3	26'600	6.55	2'114	12.3%	10.5	201.8	259.3	2.9	258.9	1'937	13.4%	13.4	1.1
10	13.4	26'800	6.50	1'937	13.2%	8.1	201.5	256.5	3.0	256.1	1'760	14.6%	14.5	1.1
11	14.5	19'400	6.43	1'760	14.5%	6.8	201.2	254.9	2.2	254.6	1'633	15.6%	15.4	0.9
12	15.4	14'800	6.35	1'633	15.5%	5.9	201.0	253.8	1.7	253.5	1'537	16.5%	16.2	0.8
13	16.2	14'000	6.30	1'537	16.4%	5.3	200.8	252.8	1.6	252.6	1'447	17.4%	17.1	0.9
14	17.1	11'000	6.25	1'447	17.4%	4.6	200.6	252.0	1.3	251.7	1'377	18.3%	17.9	0.8
15	17.9	9'000	6.17	1'377	18.2%	4.1	200.5	251.3	1.0	251.1	1'321	19.0%	18.6	0.7
16	18.6	9'000	6.13	1'321	19.0%	3.7	200.3	250.7	1.0	250.5	1'265	19.8%	19.4	0.8
17	19.4	11'000	6.03	1'265	19.8%	3.4	200.1	250.1	1.3	249.8	1'197	20.9%	20.3	1.0
18	20.3	10'000	5.90	1'197	20.8%	2.9	199.9	249.4	1.2	249.1	1'137	21.9%	21.2	0.9
19	21.2	8'000	5.80	1'137	21.9%	2.5	199.8	248.8	0.9	248.6	1'090	22.8%	22.0	0.8
20	22.0	7'500	5.75	1'090	22.8%	2.2	199.6	248.3	0.9	248.1	1'046	23.7%	22.8	0.8
21	22.8	7'000	5.64	1'046	23.7%	1.9	199.4	247.8	0.8	247.6	1'005	24.6%	23.7	0.8
22	23.7	6'500	5.58	1'005	24.6%	1.7	199.3	247.4	0.8	247.2	968	25.5%	24.5	0.8
23	24.5	6'000	5.46	968	25.5%	1.4	199.1	246.9	0.7	246.7	935	26.4%	25.3	0.8
24	25.3	5'000	5.35	935	26.4%	1.2	199.0	246.6	0.6	246.4	907	27.2%	26.0	0.7
C	26.0	109'530	5.02	907	27.2%	1.0	199.0	246.4	0.0	102.09	357	28.6%	28.5	2.5
B				357	28.6%	0.2	55.5	102.1						
Concentration		1'000'000				NaCl Crystallisation	143.5	(t/d)					Max.	1.2
Crystallisation		109'530				NaCl Crystallisation	52'376	(t/y)					Avg.	0.9
Total		1'109'530				Productivity	**47'206**	(t NaCl / y*km2)					Min.	0.7

"All Salts" include CaSO4, NaCl, MgSO4, MgCl2, KCl and NaBr "C" = Crystallisers "B" = Bitterns Class-A Evaporator drinking water evaporation rate = 10 mm/d

Standard and Best Quality Solar Sea Salt

		Chloralkali Standard	Best Solar Sea Salt
Calcium	(%)	< 0.04	0.009
Magnesium	(%)	< 0.02	0.003
Sulphate	(%)	< 0.12	0.028
Insolubles	(%)	< 0.002	< 0.001
NaCl	(%)	> 99.7	99.95
Ca : Mg		> 2 : 1	2.9 : 1

The author, **Vladimir M. Sedivy**, devoted some 50 years of his life to salt. He is the founder and President of Salt Partners Ltd., www.salt-partners.com, Swiss salt consultants and engineering contractors, active in the field of salt and chloralkali production and processing worldwide. In 2018, Salt Partners were entrusted by BCI Minerals to design a HYDROSAL XP® salt purification plant for their salt and potash project at Mardie, Pilbara, WA.

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Mardie Marches On

BCI Minerals is rapidly advancing its 100%-owned Mardie Salt and Potash Project, a potential Tier 1 project located on the West Pilbara coast in the centre of Australia's key salt production region.

Mardie aims to produce 4.4Mtpa of high-purity salt (>99.5% NaCl) and 120ktpa of sulphate of potash (SOP) (>52% K2O) via solar evaporation of seawater.

Using the inexhaustible seawater resource that WA is blessed with, and a production process driven mainly by natural solar and wind energy, Mardie is a sustainable opportunity to supply the salt and potash growth markets in Asia over many decades.

There is potential to optimise and expand the project beyond currently planned production levels.

With a Final Investment Decision targeted in Q2 2021 and construction start by mid-2021, first salt sales can be achieved by mid-2024 and first SOP sales by mid-2025.

BCI Minerals managing director Alwyn Vorster said the expansive seawater resource was an important parameter established by the 2020 Definitive Feasibility Study.

“We are working to a 60-year mine life but it’s arguably a 100-year mine life or longer because it is different from inland SOP projects that pump water from ancient aquifers underground,” he said.

“The economic results from the DFS include a pre-tax NPV of more than $1b.

“Importantly for most investors who look at this type of project, it has an annual Earnings Before Interest, Taxes, Depreciation and Amortisation (EBITDA) of nearly $200m, which for an annuity for the next 100 years, is quite significant.

“We were really pleased with the result of the DFS and really the confirmation that Mardie has the potential to be a globally significant Tier 1 salt and potash fertiliser project.”

The project has received major project status from the Federal Government following a six-month process with the Departments of Resources and Industry.

It is the first large scale solar evaporation salt project to be undertaken in Australia in two decades.

“It is important to reflect on the fact that there hasn’t been a project of this nature constructed for more than 20 years in Australia,” Mr Forster said.

“Mardie is a relative novelty in the Australian industry so the Department of Industry looked at it from that perspective and measured it in terms of what benefits it can bring to the community.”

The project ticked the boxes on six major criteria, including the economic benefits to WA and Australia through taxes and royalties as well as the creation of 500 new construction jobs.

From a regional development point of view, KPMG produced a study showing the project would contribute a Gross Regional Product of more than $2b to the Pilbara region over 60 years.

The project would also be powered by renewables, deriving 99 % of its energy from natural solar and wind energy.
It would also provide new infrastructure such as a new port facility.

Sunrise over the Mardie Project camp.

A diagram of the Mardie SOP plant.

“We will also be the first Australian salt project where we are planning to do a secondary processing for the salt waste, which will be converted into the SOP fertiliser on site,” Mr Vorster said.

The projects include salt purification technology provided by Salt Partners.

The WA-based BCI Minerals successfully completed a $48m capital raise which enabled early construction work on Mardie to start last December.

BCI has awarded around $90m in contracts to WA companies for the project, including the initial earthworks contract to WBHO Infrastructure, and Karratha-based company Engenium as the project management contractor (PMC).

Initially, the contracts will be funded by BCI's cash balance and royalties from Iron Valley, an iron ore mine located in the Central Pilbara region operated by Mineral Resources Ltd. BCI’s EBITDA from Iron Valley for FY20 was $23m.

WBHO Infrastructure is the Australian subsidiary of international civil construction expert WBHO Construction. The contract provides for the initial construction of a large-scale trial pond, scheduled to commence in April, as well as the construction of evaporation ponds one and two.

BCI estimates the total earthworks volume within this scope to be 800,000m3 over $24km^2$.

AThproject management contractor (PMC) for Mardie.

The PMC role, slated to be an important contract in the overall execution of the project, will see Engenium manage the construction program through the provision of people and systems as an extension of the BCI team.

Engenium will be engaged on a staged basis to support BCI in achieving construction-ready status ahead of main construction commencing in the second quarter of this year.

The company has also awarded several other smaller contracts this calendar year, covering the accomodation village's expansion, minor earthworks, site surveys, communications, water supply, fuel storage and supply, and the fit-out of the Karratha office.

With the above works underway, BCI has engaged Pilbara contractors to fit-out the Karratha office, as well as local indigenous companies to carry out aboriginal heritage surveys and minor earthworks.

"The award of the initial earthworks contract, in particular, represents a key milestone in BCI's progress toward main construction and demonstrates board confidence in Mardie's development pathway," he said.

"These contracts will be initially funded from BCI's healthy cash balance and strong Iron Valley royalty income.

“The DFS shows the project has a $780m capital cost, so if we assume two thirds of that comes from debt and one third from equity, we are talking about $250m that needs to be raised by April or May next year for final construction to start.”

The plan is for BCI to obtain all required funding and approvals allowing full project construction to commence by this month or shortly after.

“It is a three-year construction program and that is the nature of a solar evaporation project,” Mr Vorster said.

“It is a three-year period from filling the first pond to putting the first salt on ship, so it is a long natured project, and that is why we’re focusing on a certain type of shareholder who is patient and prepared to wait.

“Investors will get decades-long annuities but they will need to understand it takes a while to get into production.”

The company’s major shareholder Wroxby, which currently has a voting power of about 29%, has committed to taking up its full pro rata entitlement of approximately $14m.

“The Iron Valley royalties is valuable at the moment for BCI for doing all the studies and the initial de-risking for the project,” Mr Vorster said.

“But given the history of Iron Valley royalties is between $10-20m a year, it is clearly not enough to fund the Mardie development.
“So while it will always be a very healthy supporting funding mechanism for the company, it is not the main funding source for Mardie.”

Mr Vorster said he was still “absolutely comfortable” with the company’s decision to diversify beyond iron ore.

BCI had experienced previous difficulties from operating a high cost iron ore mine, Nullagine, at a time when the iron ore prices were declining rapidly.

“As BCI found 10 years ago with the Nullagine deposit, it looks excellent when the prices are $100/t, but once they drop below $50/t then the company is in trouble so we never wanted to be in that position again,” Mr Vorster said.

He said BCI had reached “a very important pivot point” after making the transition from being an exploration company three years ago.

“We are now at the cusp of developing into construction and then hopefully into being an operating company and with that will come big changes,” he said.

“We are appointing significantly more people into the company and with that transition comes a change in culture so it is a very exciting time for BCI.”

Mr Vorster said Mardie would supply the salt and potash growth markets in Asia over many decades, with the salt to be used to create tens of thousands of end products, including PVC piping for the construction industry and electric vehicles, glass, paper, paints, parts for aircrafts and more.

“Anything that you touch on an everyday basis that isn’t wood contains an element of salt,” Mr Vorster said. ***AMR***