Fundació CTM Centre Tecnològic

Management and treatment of brines in food industry

Xavier Martínez, 14th May 2015

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Brines in food industry

- Salt is used for food conservation
- Agro-food sectors requiering the highest amount of salt:
  - -Meat canning
  - -Pickled vegetables
  - -Dairy products
  - -Fish processing
- Generation of saline effluents during food processing: saline wastewater, brines, osmotic solutions
- Saline effluents polluted with suspended solids, salts and organic matter

Characteristic	Green olives	Cabbage	Cucumber	Prune pickling	Maraschino cherry
pH	3.6–4.3	3.4–3.9	3.6	2.1	
NaCl (g/l)	60.0–90.0	22.0–45.0	150		
Free acidity (g lact./l)	5.0–10.0	0.4–22.0	5.4–15.0	211.0	33.0–34.0
Combined acidity (mEq/l)	0.1–0.2				
Polyphenols (g tannic acid/l)	0.2–0.4				
Colour	0.2–0.6[a]	63.1[b]			
Suspended solids (g/l)	0.2–2.0	9.4	50.0–64.0	78.6–172.5	
Total solids (g/l)	65–100	42.0–75.0	180.0	250.0–320.0	100.0–200.0
BOD_5 (g O_2/l)	14.0–18.0	8.0–28.0	8.6		
COD (g O_2/l)	16.0–26.0	14.0–32.0	16.3		

Brines management in food industry: associated problem

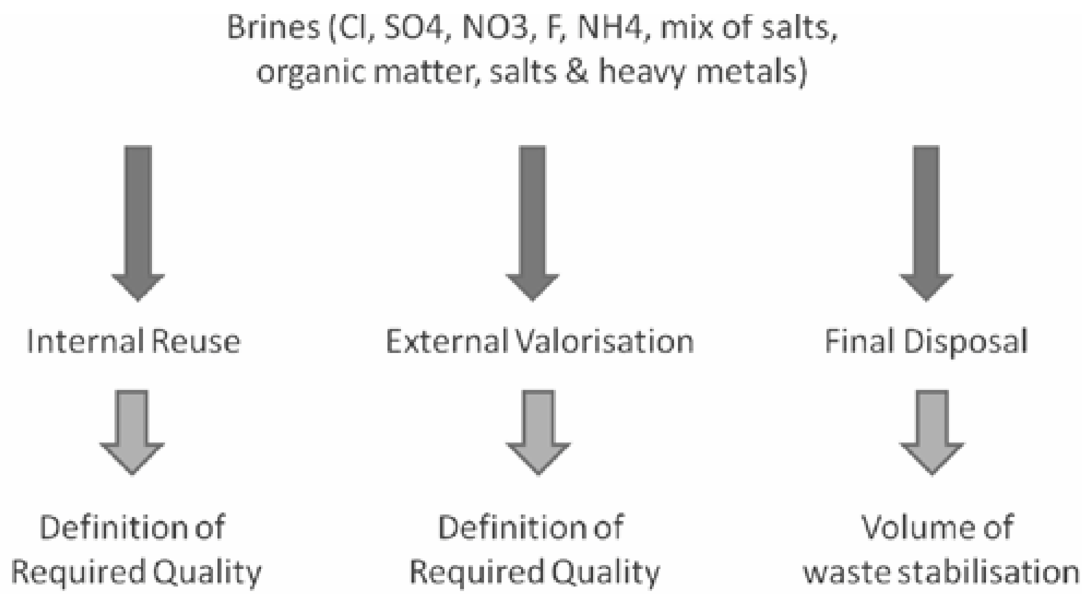
- Brines represents a high proportion of the total contaminating discharge of wastewater.
- Brines can’t be discharged into the main sewer system without treatment.
- Saline effluents are difficult to be treated by means of conventional biological treatments.
- Brine disposal has become an increasingly costly and environmentally challenging issue.

Administrative constrains
Union Directive 2000/60/EC: prevention of saline pollution

Process modification to minimize brine volume generated
Implementation of processes for brine treatment

How to hundle industrial brines?

- Internal valorisation, meaning re-use (after treatment if needed) of the brines in the production site.
- External valorisation, meaning a fit-for-use product which can be re-used in another industrial site/sector.
- Final brine disposal. This is the least preferable pathway but it is unavoidable for some brines which are too difficult to handle or for the by-products coming from the treatments applied to produce brines which are "fit-for-use".



Key points for brine management

Nature of salt and “impurities” present with the salt (organic matter, heavy metals, other salts, suspended solids) are drivers for strategy definition and technology selection.

The most important points regarding salts valorization are:

- Produce salt product “fit-for-use” (food, textiles regeneration, chemical)
- Removal of impurities
- Internal re-use often easier than external valorisation
- Quality/purity has a big influence on price

In disposal, the focus of brine treatment maybe on volume reduction and/or complete liquid elimination.

Existing technologies for brines treatment

- Separative technologies - Membranes technologies (conventional, membrane distillation, forward osmosis, electro-membranes technologies such as electrodialysis)
- Selective removal - Selective precipitation/crystallisation processes, ion exchange and development of selective materials (e.g. for valuable compounds recovery)
- Treatment processes:
  - a final treatment of brines before disposal (evapoconcentration, stabilization, thermal treatment)
  - removal of some polluting compounds regarding re-use of salts (e.g. organic compounds in brines, nitrates)

ZERO LIQUID DISCHARGE (ZLD)
Process that fully remove water from brine stream, so the end product is a solid residue of precipitate salt.

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Existing technologies for brines treatment

Technology	Principle	Concentration	Energy	Attention points
Reverse osmosis	Membrane filtration under high pressure	Limited due to osmotic pressure ~ 100 g/l	3-7 kWh/m³, electric	Fouling, scaling
Electrodialysis	Application ion-selective membrane influx by electrical field	Concentrate to 100 g/l	5-20 kWh/m³, electric	Fouling, scaling
EDBM	Electrodialysis with bipolar membranes	Recovery of acids and lye	5-20 kWh/m³, electric	Pre-treatment, costs of BP membrane
Evaporation	Water evaporation under the influence of temperature	Max. about 500 g/l	20 to 500 kWh/m³ heat-ing (+ 2 kWh/m3 elect.)	Corrosion / scaling
Precipitation / Crystallization	Supersaturation, crystallization	100 %	See evaporation for crystallization	Solids processing
Lyophilization	Water removal through freezing	100 %	approx. 12 kWh/m³, electric or cold	Investments; Recovers pure water and salts

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Evaporation&crystallization

Evaporation can take place in different ways and with different types of evaporators, such as Multi-effect Distillation (MED), Vapour Compression Distillation (VCD) and Multi-Stage Flash (MSF).

<u>Advantages</u>

- Can produce zero liquid discharge
- Can commercially exploit concentrate
- Recovery of salt and minerals

<u>Disvantages</u>

- Expensive
- High energy consumption
- Production of dry solid waste – precipitates
- Scaling and corrosion

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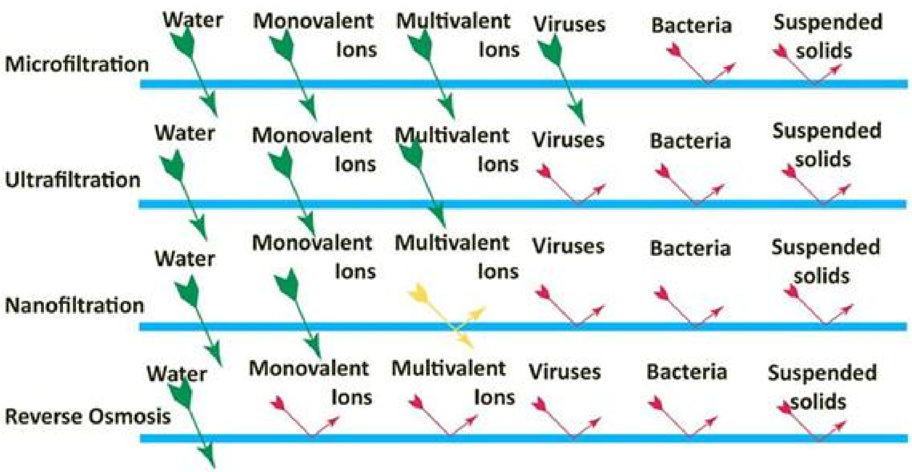
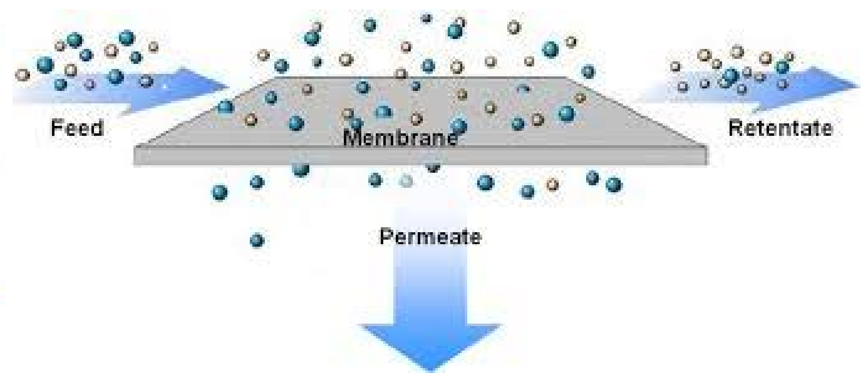
Membrane Technology





Advantages

- Water recovery
- Very large number of separation needs
- Most economical process for salinity reduction associated with secondary effluent (or other wastewater source) TDS levels

Disadvantages

- High cost technology
- Pre-treatment needed for some technologies, solids removal
- Fouling problems
- Concentrate and waste stream disposal issues

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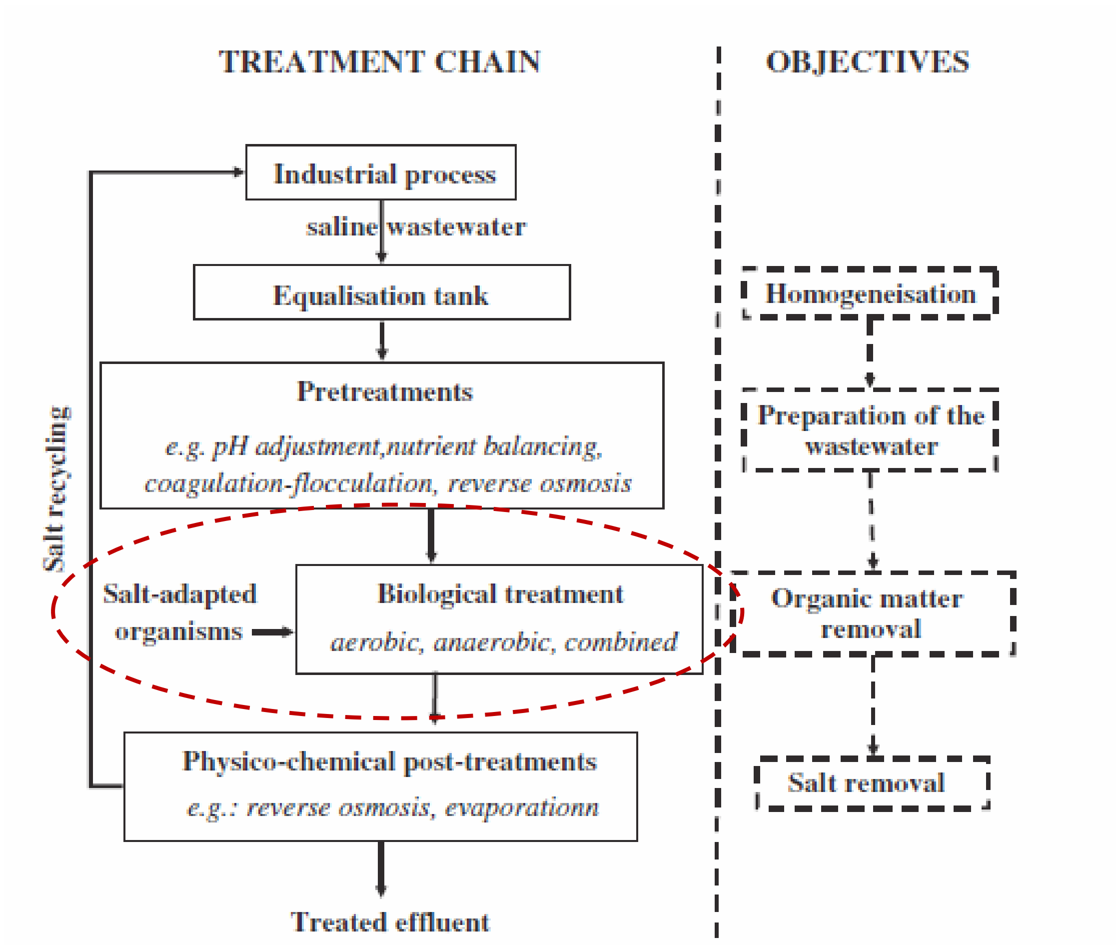
Saline wastewater from food industry: global treatment chain

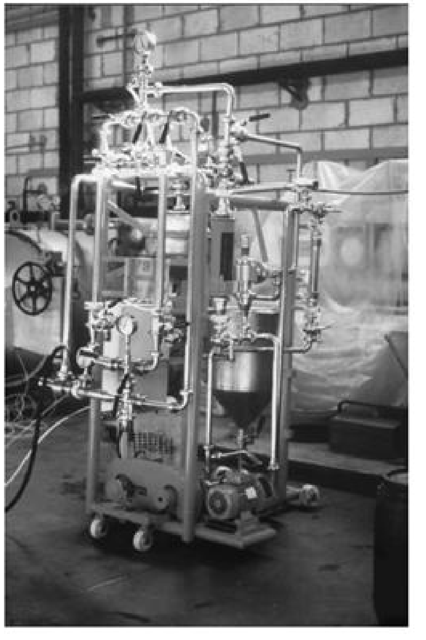


Biological treatment recomended before physico-chemical treatment

Table olive production: Fermentation brine treatment

- Brine represents 70% of the pollutant load and 20% of volume
- Elimination systems: evaporation in shallow ponds

- Other options for brine management:
  - Elimination using :
    - ✓Evaporation with cogeneration
    - ✓Membrane filtration
  - Reuse in the final product: fermentation brine has similar composition to final packing solution
    - ✓Treatment with active carbon
    - ✓Membrane filtration
  - Production of useful substances



La Española experiences

Brine

↓

Evaporation combined to advanced oxidation technologies

↙ ↘

900L Destilled Water	88kg salt
↓	↓
Reuse in the process	*Salt for animal feed*

- ✓Brines reuse
- ✓Reduction of wastewater treatment cost
- ✓Reduction of water consume

http://www.cleanwatertech.com/

Table olive production: ZLD process for water reuse

Tri Valley Growers (TVG) Inc. (California)

OLIVE PROCESS WATER RECYCLING, Oberti

PROBLEM
Waste water containing salt and oil

TSS	TDS	BOD	FOG	pH
Olive Fibers	*Salt*	*A Concern*	*Olive Oil*	*High*

Steps to solve the problem

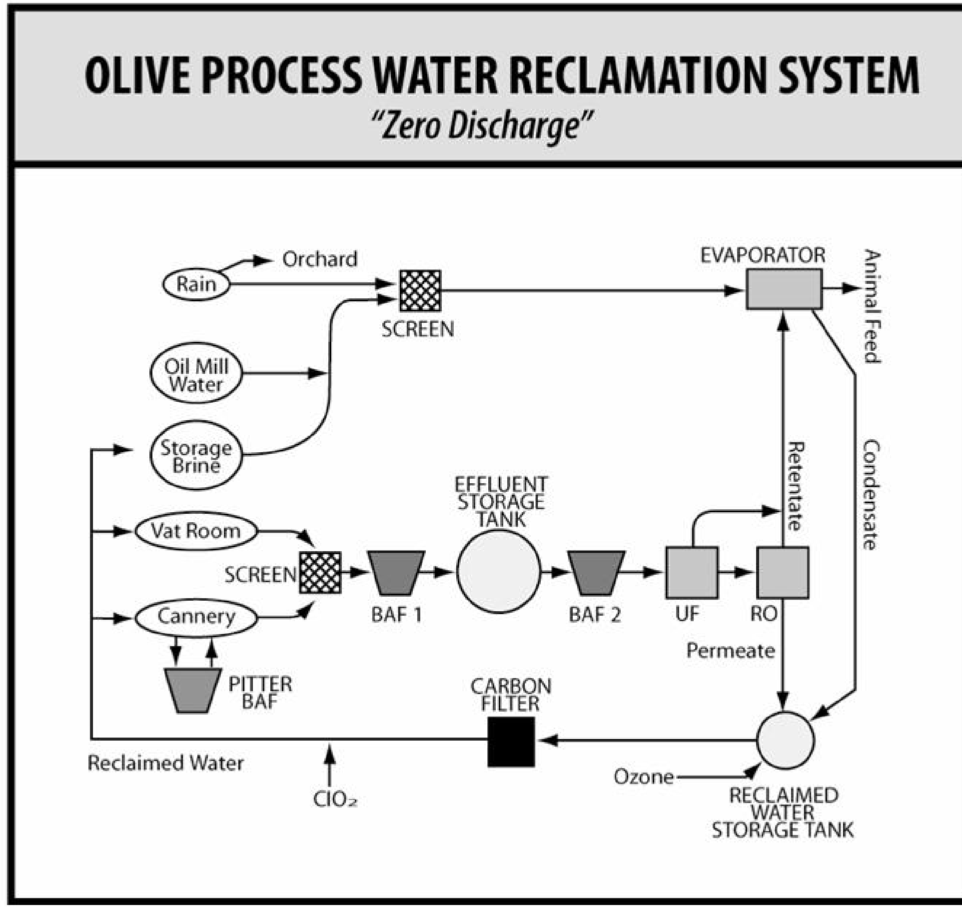
Remove Coarse Suspended Solids by	SCREENING
Remove Oil and most Suspended Solids by	BAF
Remove very fine Suspended Solids by	UF MEMBRANE SYSTEM
Remove Dissolved Solids by	RO MEMBRANE SYSTEM

End product uses

Remove and Concentrate UF and RO Retentates by EVAPORATION and use as Amimal Feed

Re-use Permeate and Condensate in factory - (zero discharge)

Treatment of 264m^3 per day



http://www.cleanwatertech.com/

Table olive production: ZLD process for water reuse

Evaporator

Membrane Filtration

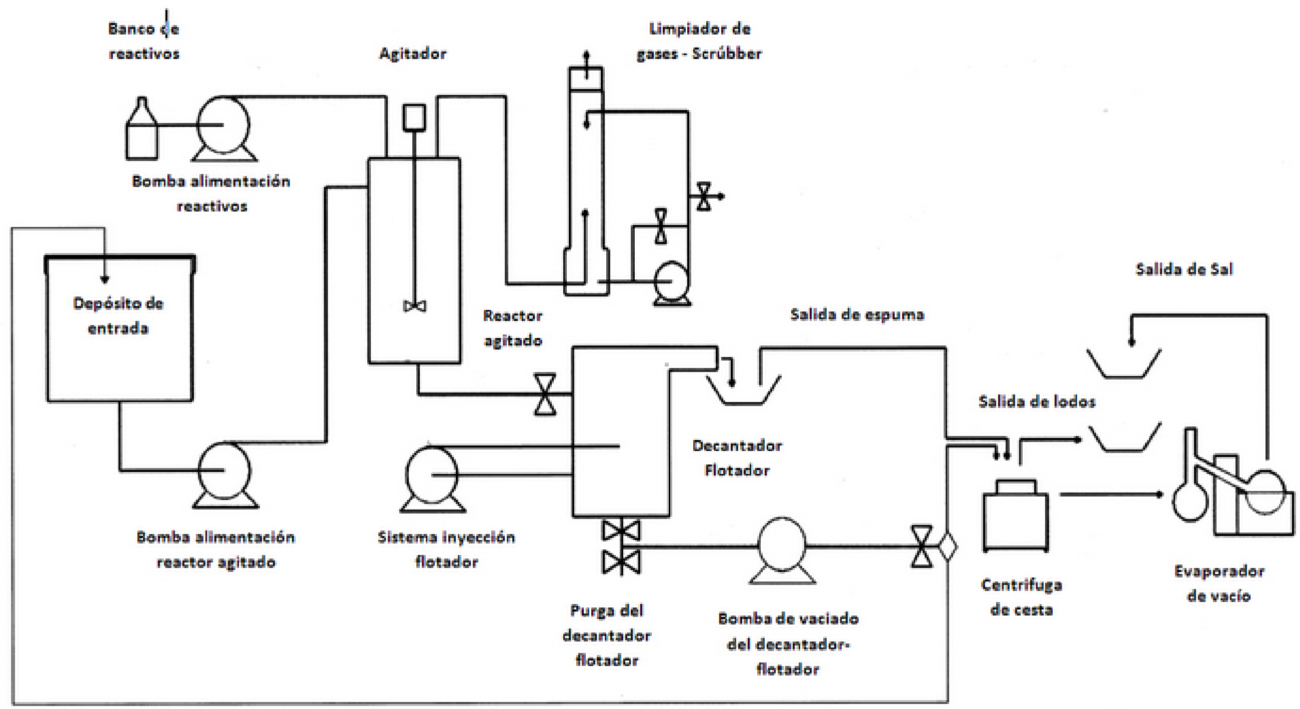
AVERAGE WATER COMPOSITION at Oberti Olive Company				
Sample	FOG mg/L	TSS mg/L	COD mg/L	APC cfu/ml
Plant Effluent	450	900	8,000	3,000,000
After Screening	400	500	7,600	3,000,000
After BAF 1	15	20	3,800	800,000
After BAF 2	3	4	3,200	200,000
After UF	2	1	2,900	4,000
After RO	0	0	45	50

http://www.niroinc.com/

http://www.cleanwatertech.com/
http://www.gea-wiegand.com/

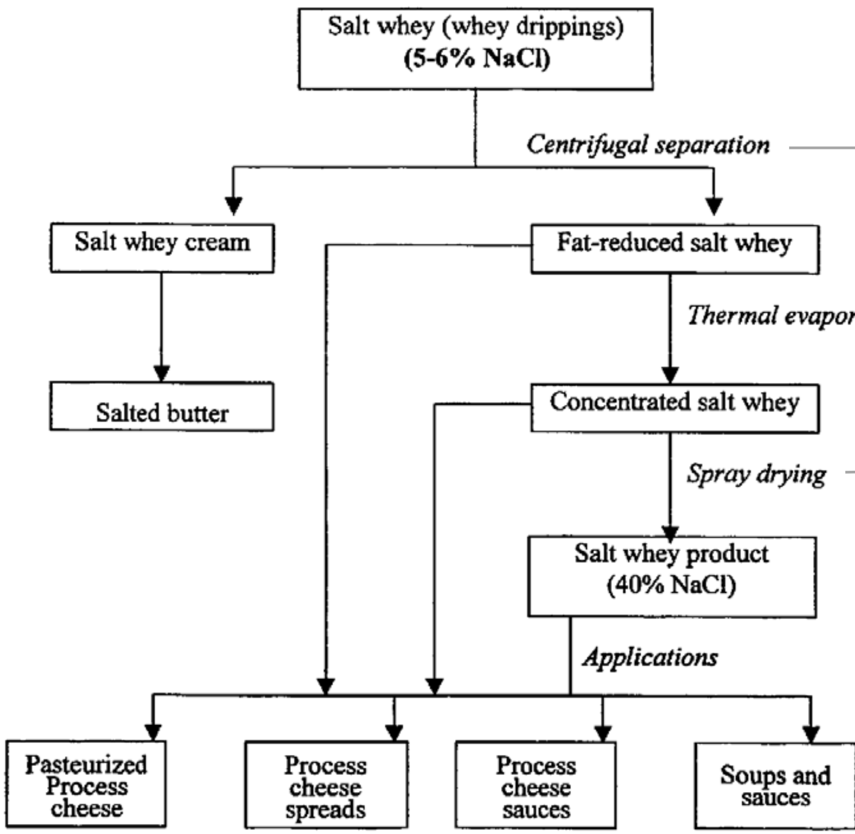
Brine treatment in meat industry

- Process evaluation at pilot scale.
- Reduction of the brine management cost (40%).
- Valorization of wastes obtained: salts and extracted proteins can be sold or used as fertilizers and food for pets.
- Distilled water obtained can be reused.



Salty Cheese Whey treatment in dairy industry

WO2004049828A1: Salt whey product and method of making
Recovery and reuse of salt whey from cheesemaking as a salt substitute and whey protein source in food processing



Fat removal
Also skimming, or microfiltration

Concentration
Also RO

To obtain powder product
Also roller or drum drying

Table 3. Composition of salt whey products

Product	Total Solids	Fat	Protein	Ash	Salt	Lactose[1]
	(%)					
Salt Whey	12.61	0.82	1.26	5.48	5.10	5.04
Separated Salt Whey	11.95	0.24	1.17	5.46	4.94	5.08
Condensed Salt Whey	28.41	0.56	2.91	13.18	12.00	11.77
Dried Salt Whey (Salt Whey Product)	96.73	1.97	10.12	44.80	40.11	39.84
Salt Whey Cream	75.47	70.97	0.96	1.67	1.43	1.87

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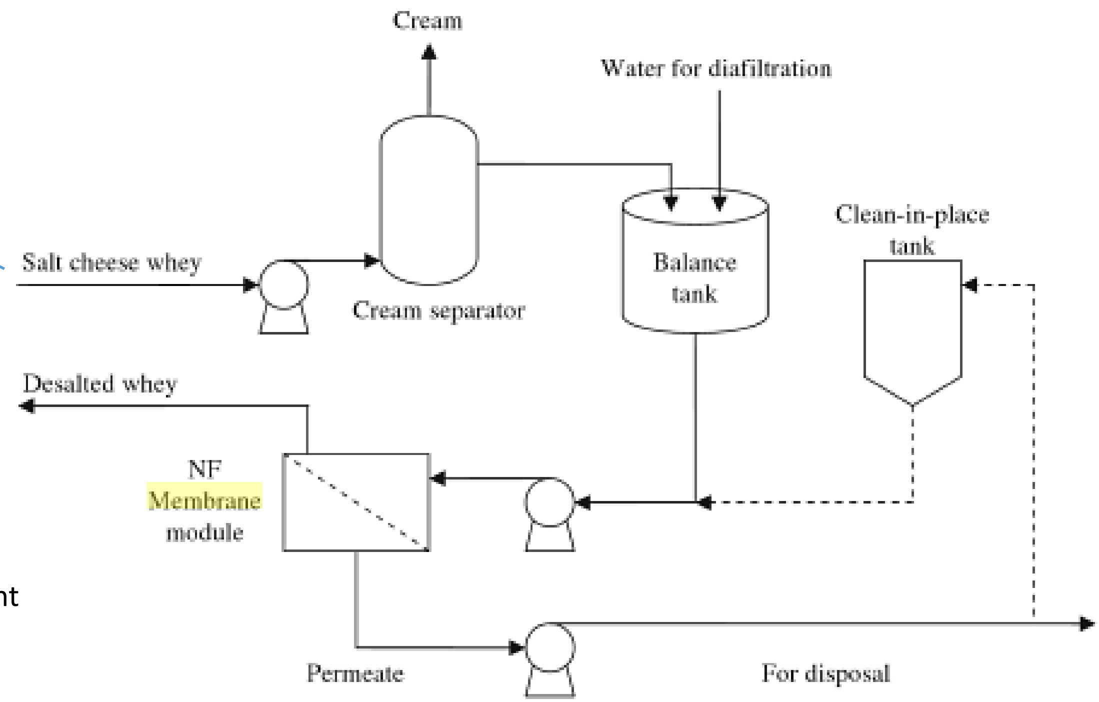
Salty Cheese Whey treatment in dairy industry

Solids content: 4-6%
BOD 45.000 mg/L

Mixed with normal whey

Divalent salts (i.e. CaCl2), sugars, proteins, and other higher molecular weight components.



NaCl

NF system retains whey proteins and lactose whilst allowing salts to pass through to the permeate stream. Whey concentration up to 25% TS, allowing for its re-use .

http://www.mmsx.com/

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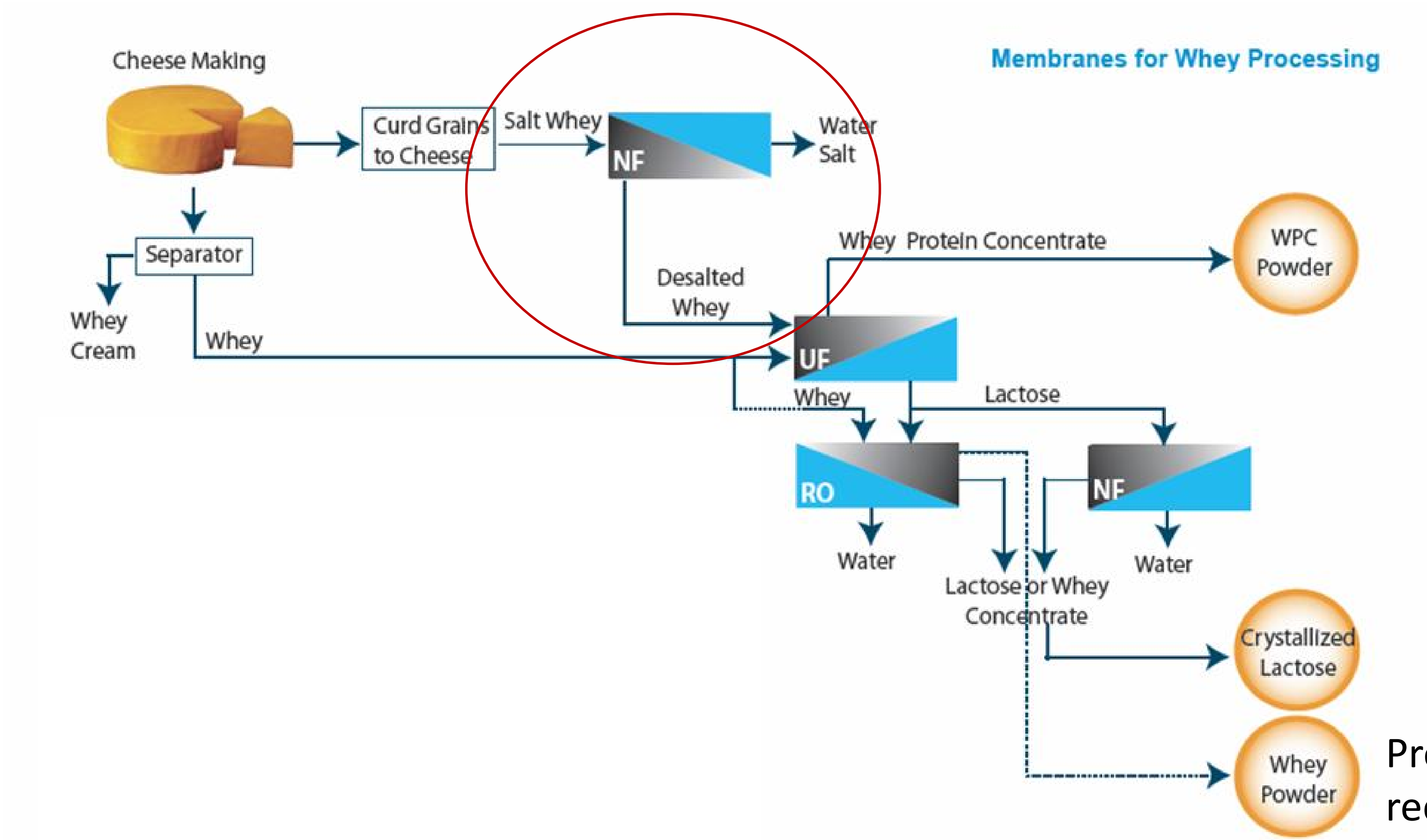
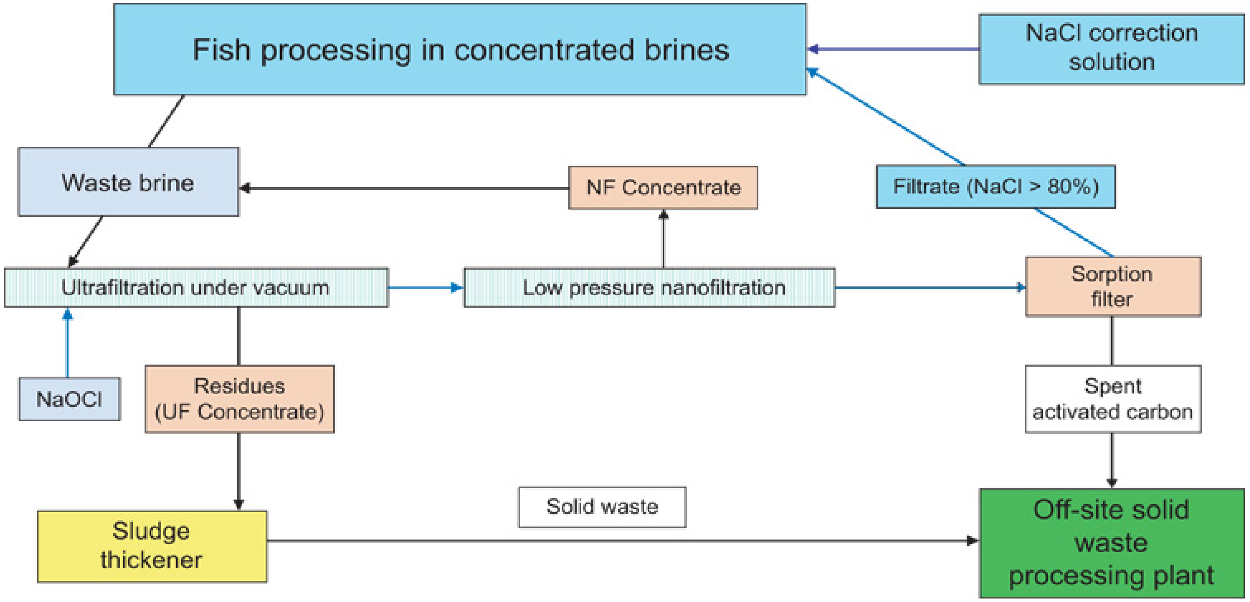
Salty Cheese Whey treatment in dairy industry



Products recovery

http://www.kochmembrane.com/

Brines treatment from fish processing

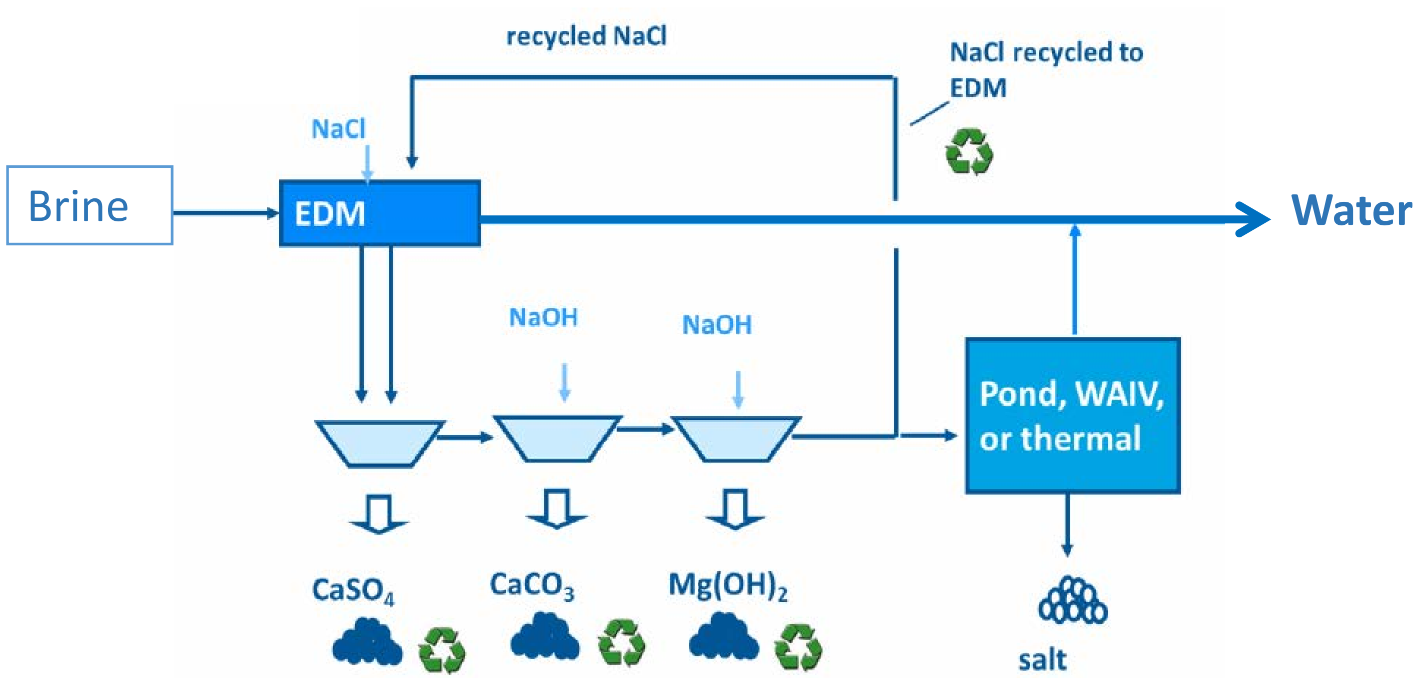


Pollutants	Units	Concentration, mg/l				
		Waste brine	After UFV	After NF	After SF	Limits
pH	pH	6-8	6-8	6-8	6-8	6-8
Total nitrogen	mg/l	500	300-500	50-100	<30	<30
Oil and grease	mg/l	120-50000	10-150	0,5-5	<0,1	<45
Total phosphorus	mg/l	400	120	10	<10	<25
Sulphates, SO_4^{2-}	mg/l	200	200	<10	<10	<100
COD	mgO_2/l	1000-60000	420	<30	<10	250
Suspended solids	mg/l	500	0,1	-	-	-
Chlorides, Cl^-	g/l	120-160	120-160	100-136	100-136	120-160

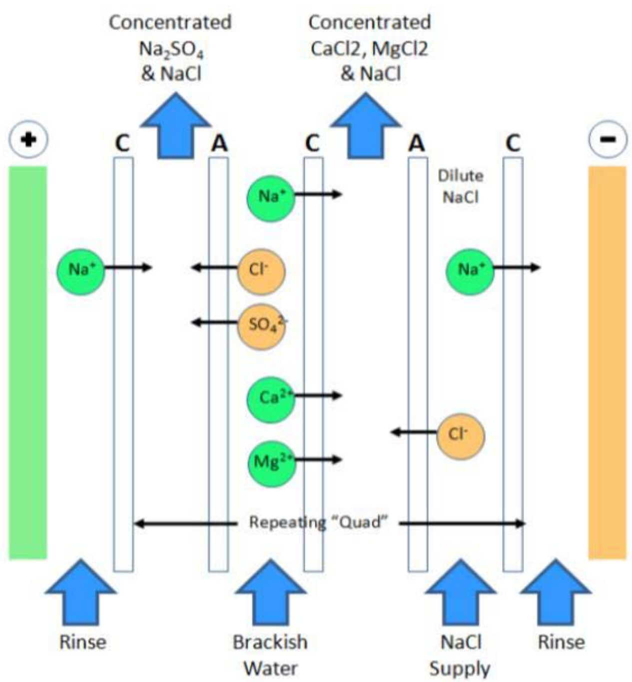
http://www.hydropark.ru/projects.en.htm

Zelda Project

New Zero Liquid Discharge technology for brine teratment: brine treatment based on a combination of electro-separation processes and valuable compound recovery.



Electrodialisys Metathesis stage

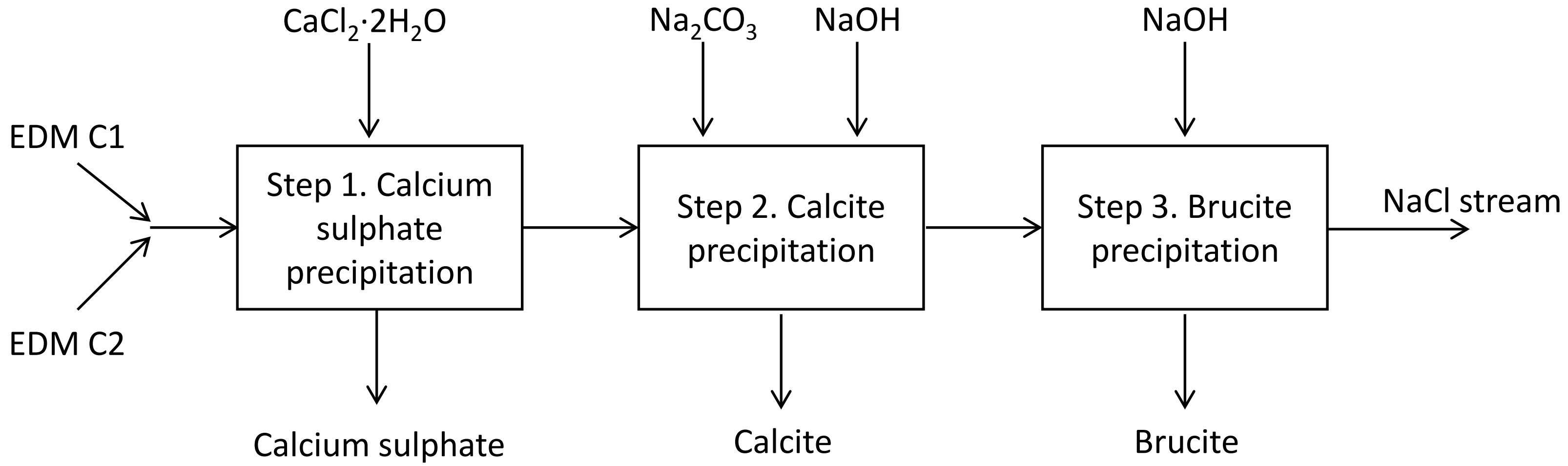


Treatment capacity: $1m^3/h$

Feed (RO brine streams)	5 – 20 g/L TDS
Feed (NaCl feed)	20 – 30 g/L
Output (diluate) streams (adapting design is allowed)	0.02 – 3 g/L TDS
Output (concentrate) streams (adapting design is allowed)	30 – 120 g/L TDS

- Separation of the multivalent anions and cations in two different waste streams
- Highly concentrated waste streams can be obtained without precipitation

ZLD stage



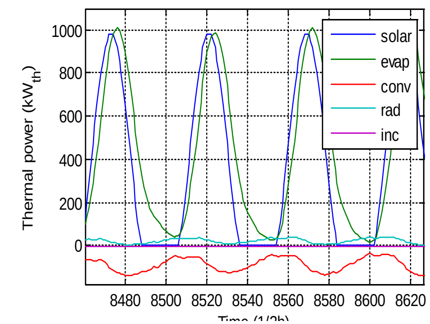
This stage must be evaluated and adapted according different brine composition

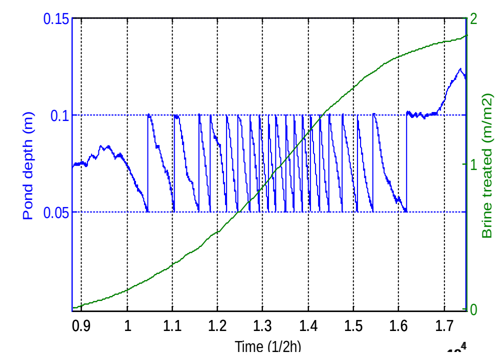
ZLD stage: treatment of NaCl stream by solar evaporation

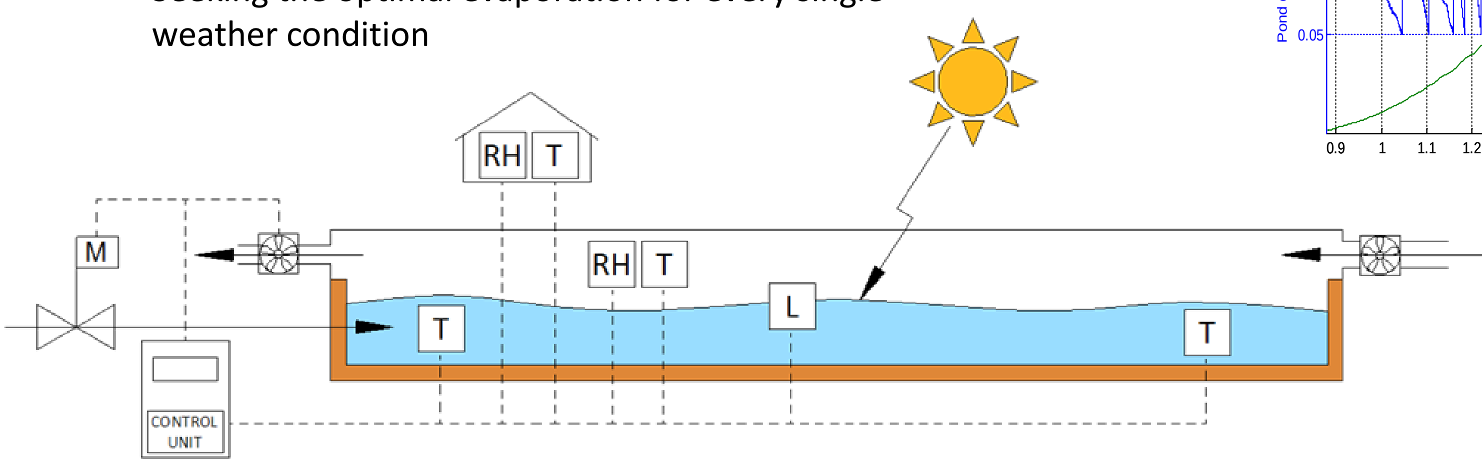
Technology description

- Evaporative technology based on:
  - Minimal air volume contained within the greenhouse
  - Brine depth control
  - Inner temperature and humidity control
  - Thermal isolation of the pond
  - Air flow speed over the evaporation film
- Based on solar energy
  - Electrical consumption only due to humidity removal fans
- Advanced control strategy
  - Model based control
  - Model predictive control
  - Seeking the optimal evaporation for every single weather condition

Heat transfer components and depth of the pond along one year, according to the model developed at CTM



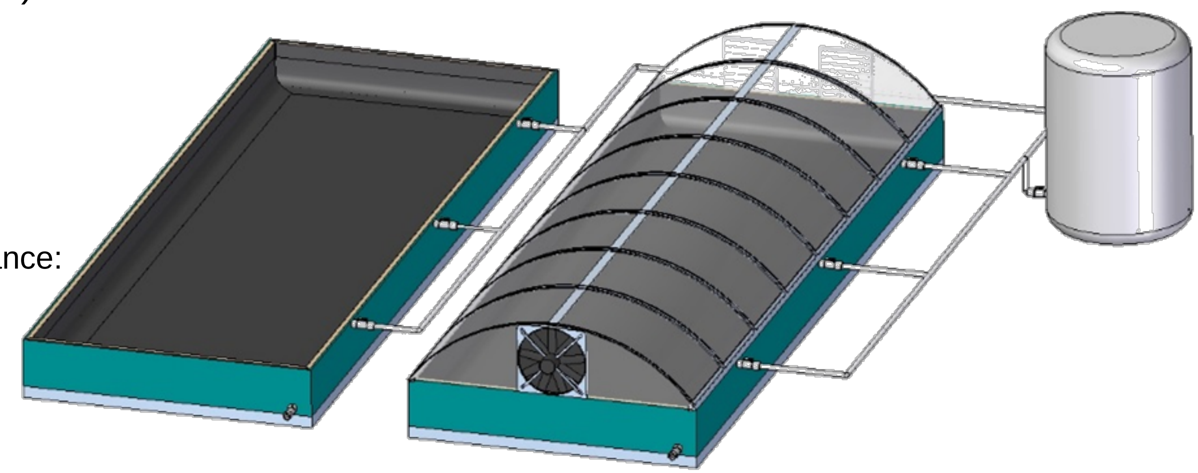




ZLD stage: treatment of NaCl stream by solar evaporation

Pilot plant description

- Brine evaporation to obtain dry salt
- 2 ponds for comparison between **natural** evaporation and **advanced** evaporation
- Located in Almería, (bests solar irradiation of Spain)
- Brine treated near saturation (30%)



Specifications

- Advanced evaporation estimated perfomance: 2 $m^3/m^2 \cdot year$
- Natural evaporation estimated performance: 1,2 $m^3/m^2 \cdot year$
- Pond surface: 25 m^2
- Total evaporation surface: 50 m^2
- Total plant capacity: 80 $m^3 \cdot year$

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