BRINE DISPOSAL FROM INLAND DESALINATION PLANTS IN OMAN: PROBLEMS & OPPORTUNITIES

MUSHTAQUE AHMED

DEPT. OF SOILS, WATER & AGRICULTURAL ENGINEERING, SQU

ahmedm@squ.edu.om

Outline

- Introduction
- Brine Production from Desalination Plants
- Brine Disposal Methods
- Current Status of Brine Disposal Technology in Oman
- Innovative Concepts
- Production of Chemical Products: A Case Study

Introduction

- Coastal plants practices ocean disposal
- Number of inland plants are increasing
- Brine disposal from inland plants is a problem – economically and environmentally

Desalination World-wide

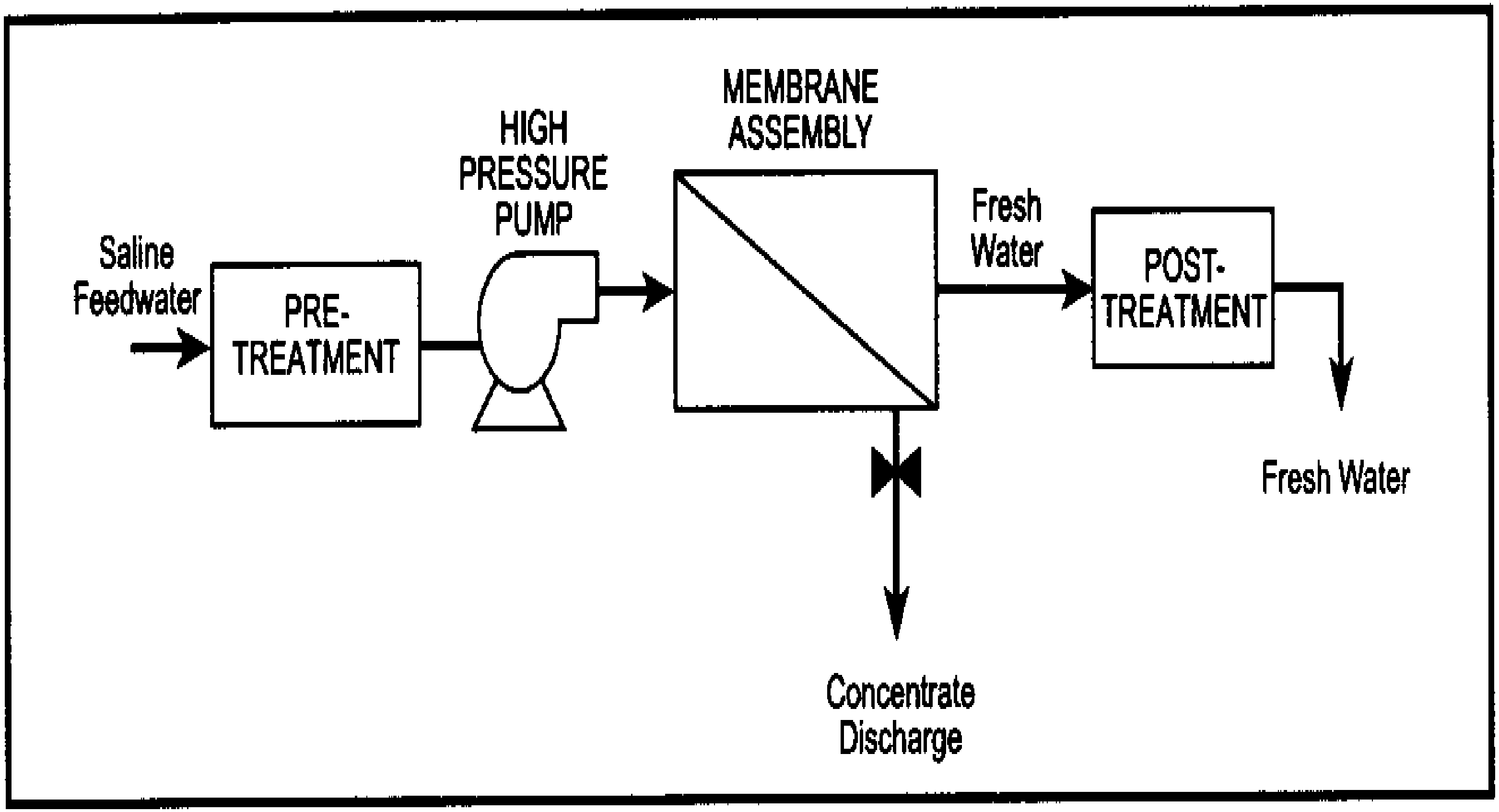
• 2 Mm3/day	1972
• 26 Mm3/day	1999
• 119 Mm3/day	2025

Desalination 2013

- 17,277 commissioned desalination plants
- 80.9 Mm3/day production
- 59% seawater, 22% brackish water, 9% river and 5% wastewater
- Saudi Arabia 9.2 Mm3/day, UAE 8.4 Mm3/Day and Spain 3.8 Mm3/day

Desalination Oman

- 90 Mm3/yr in 2006
- 221 Mm3/yr demand in 2013 (15% annual increase)
- Demand is met mostly by large desalination plants
- Large number of small desalination plants are in operation in inalnd areas



Basic components of a reverse osmosis plant USAID

Brine Production is Common to all Categories of Desalination

$CF = 1/(1-R)$

CF = Concentration Factor

R = Fractional Recovery

Brine Quality Depends on:

- Quality of the feed water
- Desalination technology used
- Percent Recovery
- Chemical additives used

Thermal Desalination Plant Brine

- Corrosion products (metals)
- Antiscaling additives (polycarbonic acids, polyphosphates)
- Antifouling additives (mainly chlorine and hypochlorite)
- Halogenated organic compounds formed after chlorine addition
- Antifoaming additives
- Anticorrosion additives
- Oxygn scavengers (sodium sulfite)
- Acid
- The concentrate
- Heat

Types of Wastes in RO Plants

- Pre-treatment wastes
- Brine (membrane concentrate)
- Cleaning waste
- Post-treatment waste
- Chemicals such as NaoCl, Free Cl2, FeCl3, Alum, Sodium Hexameta phosphate, EDTA, Citric acid, Sodium polyphosphate

Options for Brine Disposal from Desalination Plants

- Lined evaporation ponds
- Deep well injection
- Disposal in surface water bodies
- Through pipeline to municipal sewers
- Concentration into solid salts
- Irrigation of plants, land disposal

Factors Influencing Selection of Disposal Method

- Volume or quantity of brine
- Quality of brine
- Location
- Availability of receiving site
- Regulations
- Costs
- Public acceptance

From a survey in the USA (Mickley, 2006)

- 48% disposal to a surface water
- 23% wastewater treatment plant
- 12% land application
- 10% deep well injection
- 6% evaporation ponds

Evaporation Ponds

- Average evaporation rate is used
- Lower evaporation due to salinity (70%)
- Large area needed
- Liners are to be used
- Negev desert, 5000 m3/day permeate, 384 m3/day brine (92% recovery), 65,000 m2 evaporation pond, 8.5 cents/m3 of permeate cost for brine disposal
- Enhanced evaporation

Zero Liquid Discharge (ZLD)

- Brine is treated further
- More water is produced (thermal desalination, ED, RO after removing scale forming constituents)
- Dry salts are the final products
- High cost
- Mostly used in the industries

Cost of Brine Disposal

- Highly variable
- 5-33% of desalination cost (1996 survey)

Current Status of Brine Disposal Technology in Oman

- 22 govt. owned plants (Al-Ajmi & Rahman, 2001)
- PDO (14 plants in 2006), Police, MOH, MOD also own plants
- Most inland plants are RO type of small capacities

Disposal Methods

Location	Disposal Method	Comments
Adam	Evaporation Pond	Leakage suspected
Haima	Evaporation Pond	Leakage suspected
Esherjah	Evaporation Pond	Holes in liner
Hitam	Disposal to unlined borehole	Potential for GW pollution
Zaher	Disposal to unlined borehole	Potential for GW pollution
Assadonat	Disposal to unlined borehole	Potential for GW pollution
Abu-Mudhaibi	Disposal to unlined borehole	Potential for GW pollution
Safah	Evaporation pond	Well managed disposal system

Characteristics of Brine

EC	9.8 to 61.2 dS/m
pH	3.07 to 8.1 dS/m
SAR	16.21 - 67.68
Fe	< 0.05 - 0.43 mg/l

Other heavy metals - Trace

Performance of Evaporation Ponds

Location	Major Ion	Ratio
Haima	Ca	1.08
	Mg	1.08
	Na	1.12
	CI	1.06
	SO4	1.0
	Fe	1.29
	EC	1.08

Cost of Disposal (Evaporation Pond Construction)

Plant	Capacity m^3/d	Recovery Rate %	Design Wastewater volume m3/d	Cost USD	Pond Size m^2	Unit cost per m^2 (USD)	Cost per m^3/d of wastewater capacity
Al-Haj	100	40	150	153,423	13200	11.6	1023
Adam	1000	75	333	384157	57600	6.7	1154
Khum Khum	100	45	122	65629	1200	54.7	538
Esherjah	100	42	138	184766	13200	15.0	339
Haima	100	38	163	121360	15041	8.1	745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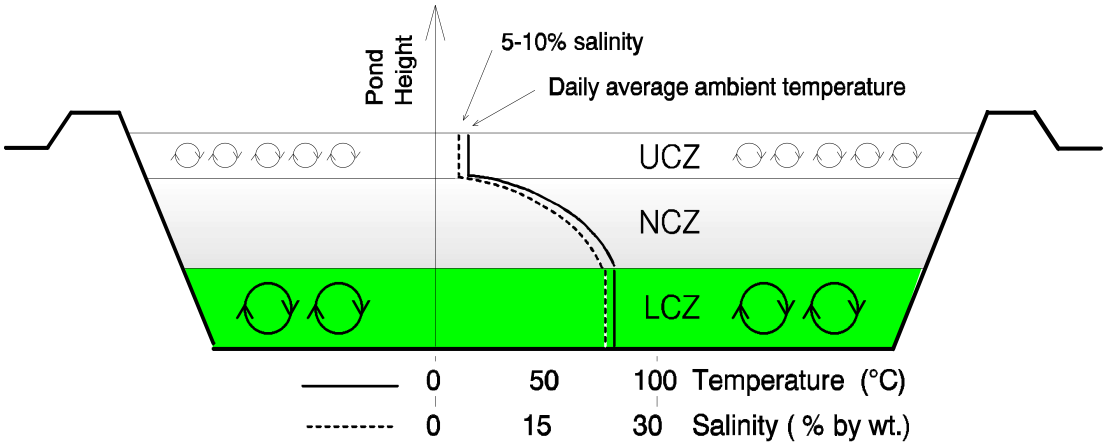
POSSIBLE BRINE REUSE POTENTIAL

- Fish culture (Baramundi, Red Snapper, Black Bream, Mullet, Tilapia, brine shrimp)
- Algae production
- Agriculture (salt tolerant crops)
- Solar pond
- Mineral recovery

Solar Ponds

- Energy is stored in highly dense concentrated brine
- 10,000 m2 solar pond in Australia produced enough energy to run a 500 m3/day desalination plant for 160 days a year
- Solar ponds can produce electricity at 12 cents/kWh

Salt Gradient Non-Convective Solar Pond
Source: Burston and Akbarzadeh, 1995



MINERAL RCOVERY (SAL-PROC)

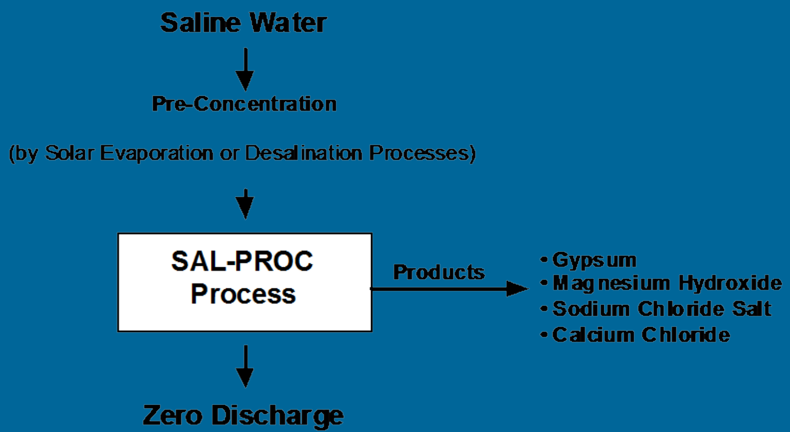
- HIGH VALUE SALTS & FERTILIZERS
- QUALITY FEEDSTOCK FOR MANUFACTURE OF MAGNESIUM METALS & ALLOYS
- INORGANIC FIRE RETARDANTS
- BUILDING PRODUCTS
- SEALANTS
- FLOCCULATING AGENTS

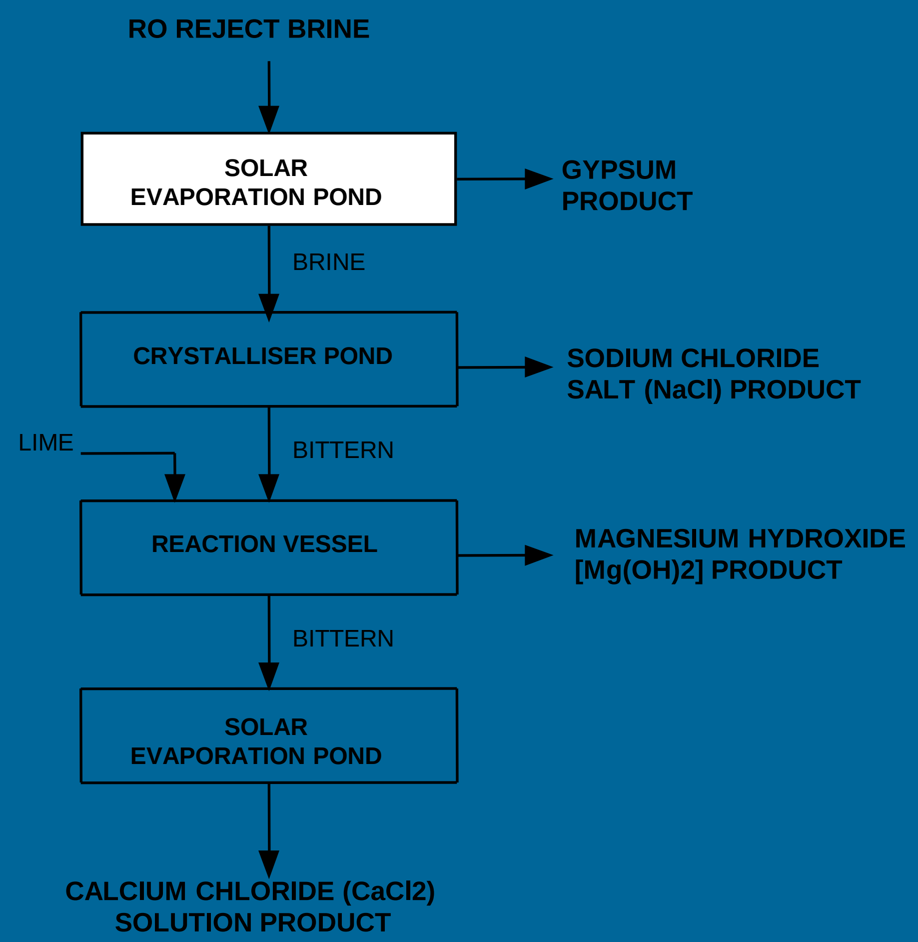
SAL-PROC

- Integrated process for sequential extraction of dissolved elements from inorganic saline waters in the form of valuable chemical products in crystalline, slurry and liquid forms
- The process involves multiple evaporation and/or cooling, supplemented by mineral and chemical processing.
- No hazardous chemical is used in the process.
- Waste discharge is minimized (almost zero)

THE CHALLENGE
- EFFICIENCY
- ECONOMICS
- ENVIRONMENTAL

THE OPPORTUNITIES .....


Saline Water
Pre-Concentration
(by Solar Evaporation or Desalination Processes)
SAL-PROC Process
Products
• Gypsum
• Magnesium Hydroxide
• Sodium Chloride Salt
• Calcium Chloride
Zero Discharge


RO REJECT BRINE
SOLAR EVAPORATION POND
GYPSUM PRODUCT
BRINE
CRYSTALLISER POND
SODIUM CHLORIDE SALT (NaCl) PRODUCT
LIME
BITTERN
REACTION VESSEL
MAGNESIUM HYDROXIDE [Mg(OH)2] PRODUCT
BITTERN
SOLAR EVAPORATION POND
CALCIUM CHLORIDE (CaCl2) SOLUTION PRODUCT


THICKENING
AND
WASHING
CIRCUIT

Constituent	Bahja Plant 1	Bahja Plant2	Rima	Nimr Plant1	Nimr Plant2	Marmul Plant 2	Marmul Plant1
	Brine	Brine	Brine	Brine	Brine	Brine	Brine
TDS	23500	22800	25750	19600	19140	4570	4510
Total Alkalinity	27	19	358	618	595	403	396
Calcium hardness	4800	4450	7160	4150	3775	1303	1287
Magnesium hardness	1772	1895	2760	1417	1269	761	795
Total hardness	6572	6345	9885	5567	5044	2664	2082
Calcium	1920	1780	2850	1660	1510	522	515
Magnesium	430	460	670	344	308	185	193
Sodium	6030	5860	5600	5045	5100	750	740
Potassium	215	225	152	143	140	32	32
Carbonate	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Bi-Carbonate	33	23	437	754	725	491	483
Sulphate	2944	2857	2806	2223	2137	1700	1672
Chloride	11945	11613	13438	9788	9567	1106	1125
Nitrade	10	15	14	16	16	15	16
Total Iron	0.68	0.58	0.35	0.32	0.3	0.16	0.12
Manganese	0.05	0.05	0.05	0.52	0.32	0.03	0.03
Reactive Silica	21	14	15	19	13	16	11
Strontium	1.4	1.2	1.82	0.8	0.9	1.38	1.48
Fluride	0.38	0.45	0.45	0.4	0.36	0.37	0.47
Theoretical TDS	23533	22837	25766	19617	19155	4573	4548
Total Ions	23550	22849	25985	19994	19518	4819	4789
pH Value @ 25 C	4.43	3.86	6.75	6.7	6.77	7.34	7.3
Electrical Conductivity mS/cm @ 25 C	35.5	34.6	38.7	30.6	29.9	6.29	6.3

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	Bahja	Nimr	Marmul	Rima
Capacity ML/yr	219	310	548	110
Saline discharge (ML/yr)	75	135	150	45
Brine salinity TDS g/l	23.1	19.4	4.5	25.7
An annual salt load t/yr	1730	2600	680	1160
Specific features	very low bicarbonate		High bicarbonate, low salinity, low magnesium	Low bicarbonate

RO Plant	Bahja 1 & 2	Rima	Nimr 1 & 2	Marmul 1 & 2
(Treatment Option 1)				
Gypsum (tonnes)	350	204	475	
Sodium Chloride Salt (t)	1000	510	1385	
Magnesium Hydroxide (t)	75	68	97	
Calcium Chloride	240	295	385	
(Treatment Option 2)				
Precipitated Calcium Carbonate (t)	370	320	532	
Sodium Sulphate (t)	225	130	304	
Sodium Chloride Salt (t)	1100	560	1850	
Magnesium Hydroxide (t)	35	36	51	
Bittern (ML)	1.5	1.0	2.5	
(Treatment Option 3)				
Gyps & Magnesium Carbonate Admixture (t)				220
Sodium Sulphate (t)				180
Sodium Chloride Salt (t)				115
Magnesium Hydroxide (t)				37
Calcium Chloride (t)				55

Product Name	Chemical Composition	Physical Form	Indicative Price	Potential Applications/Markets
Gypsum-Magnesium Hydroxide	$CaSO_4.2H_20$ $+Mg(OH)_2$	Fine grain slurry	$150/tonne	• Sodic soil remediation • Fertiliser additive • Drip feed application
Magnesium Hydroxide	$Mg(OH)_2$	Fine grain slurry	$400/tonne	• Wastewater treatment • Agriculture • Cattle feedstock additive • Refractories
Sodium Chloride (Halite)	NaCl	Crystalline salt	$70/tonne	• Food processing • Agriculture • Chlor-alkali
Precipitated Calcium Carbonate (PCC)	CaCO3	Fine grain, crystalline	$300-$900/tonne	• High value paper coating pigment. • Filler in plastics paint, ink, and sealant production.
Sodium Sulphate	Na2SO4	Crystalline	$170-$200/tonne	• Pulp and paper industries
Calcium Chloride	$CaCl_2$	Concentrated Solution (35-38%)	$220/tonne	• Road base stabilisation • Sodic soil remediation • Dust suppression • Drip feed application

VALUE OF PRODUCT YIELD (USD)

RO PLANT	Bahja 1 & 2	Rima	Nimr 1 & 2	Marmul 1 & 2
Treatment 1	113,000	87,000	160,000	
Treatment 2	255,000	200,000	380,000	
Treatment 3				57,000

Conclusions

- Various disposal options currently in use
- Potential for groundwater contamination
- Leakage in evaporation ponds suspected
- Very little monitoring and reporting on brine and disposal systems
- Specific regulations lacking
- Mineral recovery is feasible

Research Needs

- Resource Recovery
- Low cost evaporation ponds
- Enhanced evaporation
- Effect of brine on soil and groundwater
- Beneficial uses of evaporation ponds

Acknowledgement

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