Effect of Desalination Discharges on Coastal Environments

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Outline

- Theme
- Overview
- About SWCC
- Some impacts of the environment on desalination plants
- Effect of discharges on coastal environments

Theme

- The brine discharged from SWCC's plants has a benign or (at worst) minimal impact on the marine coastal environment.
- However, the plants themselves are subject to severe impacts from adjacent water and surrounding air environments.

Overview

- Much publicity is devoted to the negative effect of desalination plants on the environment
- This claim is rarely supported by experimental evidence
- On the contrary, operation of plants is often jeopardized by problems arising from surrounding environments.

The Saline Water Conversion Corporation (SWCC)

- SWCC is a Government Agency of the Kingdom of Saudi Arabia, responsible for the production of desalinated water.
- ≈60% of freshwater requirement of the Kingdom is met from seawater desalination plants on the shores of the Red Sea and Arabian Gulf.

Production Capacity

- Present capacity of SWCC is ≈3 millions M^3 per day of desalinated water produced from 26 plants at 15 sites:12 sites on the Red Sea and 3 sites on the Arabian Gulf.
- Additional 1.25 millions M^3 are being added from new plants
- Additionally, 74000 MWH of power are also generated by the SWCC plants, with 2400 to be added from new plants.

SWCC needs a clean source water to feed its plants. Therefore, SWCC has great interest in keeping clean environment and has dealt with this issue seriously. As a consequence:

- **The Research Institute is tasked with the responsibility of environmental assessment and corrective remedies.**
- **SWCC also established environment committees in the East and West coasts with environmental personnel in each plant for on-site monitoring.**

Size of Feed and Discharged Water

The product water constitutes only a small fraction of the feed water withdrawn from the sea for desalination.

The larger fraction, a huge quantity of water, is returned to sea in the form of brine reject.

- **For example: the Jubail plants withdraw 400,000 m^3 of seawater/hour.**
- **Of this quantity, 340,000 m^3/hour is discharged back into the sea.**

IMPACT

- **SWCC plants could affect and in turn be affected by the environment.**

- **The impact involves air and coastal water environments.**

Some impacts of environment on Desalination plants include:

- Marine shells clogging intake structures and impeding water flow and heat transfer.
- Seasonal water currents and tide bringing suspended matter and creating filtration problems.
- Dust storms fertilizing coastal water creating algal blooms and associated die offs and filtration problems.
- The nagging problems of membrane fouling.

Effect of Discharges

on Coastal Environments

Intake and Discharge System of Jubail plants

S_1sampling station from open sea, S_2 from Intake bay, S_3 from discharge site

Physico-chemical parameters

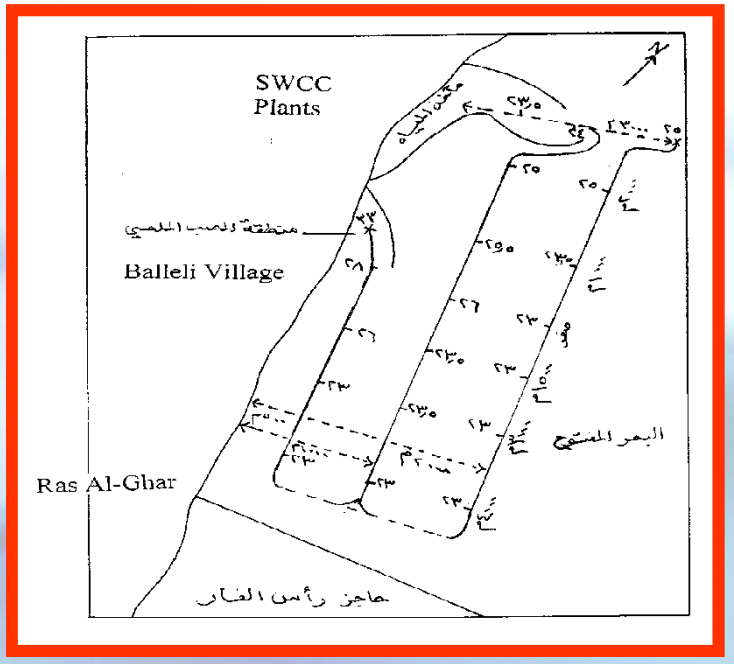
Distribution of major seawater quality parameters during different seasons in the near-shore waters of Jubail Desalination and Power Plants

	Sampling sites			
Parameters/Seasons	**Intake Bay**	**Open Sea**	**Outfall Mixing Bay**	**Recovery Zone (1 Km)**
Sea surface temperature (0C)				
Winter	17.90 ± 0.85	17.80 ± 1.06	27.30 ± 2.47	20.50 ± 4.95
Spring	24.42 + 5.10	24.00 ± 4.09	33.08 ± 4.06	25.91 ± 5.59
Summer	30.25 ± 0.35	30.75 ± 1.06	37.25 ± 0.35	34.38 ± 3.71
Fall	27.00 ± 1.41	27.00 ± 1.41	34.50 ± 0.71	30.00 ± 2.82
Conductivity (Milli seimens/cm)				
Winter	57.28 ± 4.70	57.58 ± 5.90	67.33 ± 1.23	60.15 ± 6.15
Spring	58.83 ± 1.33	59.56 ± 3.11	65.55 ± 2.65	61.21 ± 1.62
Summer	63.85 ± 1.77	63.73 ± 1.66	69.53 ± 2.65	68.58 ± 3.57
Fall	61.15 ± 1.49	61.60 ± 0.00	67.40 ± 4.53	64.43 ± 1.66
pH				
Winter	8.36 ± 0.00	8.38 ± 0.02	8.39 ± 0.02	8.39 ± 0.00
Spring	8.29 ± 0.06	8.31 ± 0.06	8.32 ± 0.05	8.31 ± 0.05
Summer	8.34 ± 0.06	8.35 ± 0.06	8.34 ± 0.04	8.34 ± 0.06
Fall	8.60 ± 0.22	8.61 ± 0.21	8.63 ± 0.24	8.67 ± 0.17
Dissolved Oxygen (mg/L)				
Winter	6.88 ± 0.56	6.98 ± 0.41	6.36 ± 0.61	6.65 ± 0.00
Spring	6.66 ± 0.52	6.85 ± 0.79	6.18 ± 0.49	6.27 ± 0.54
Summer	5.24 ± 0.68	5.46 ± 0.27	5.34 ± 0.44	5.17 ± 0.29
Fall	5.22 ± 1.09	4.89 ± 0.69	4.86 ± 0.45	5.17 ± 0.00

Temperature profile

Temperature profile at Jubail plants at 500,1000 and 2000m from intake and discharge sites.

- Temperature stabilizes at 500-1000m beyond the discharge point



Effect of Discharges on Primary Productivity in Terms of Chlorophyll

Location	Chlorophyll Concentration (mg/m^3)			
	Discharge site	500m from discharge	1000m from discharge	Open sea
Jubail (depth ~4m)	0.50	2.50	2.60	2.60
Jeddah (depth 30m)	*0.51	0.32	0.22	0.22

Note: At Jubail normal primary production regained at 500m from discharge site.

At Jeddah discharge site is more productive than open sea.

Plankton groups and numbers in Jubail and Jeddah Coasts

Group	Location : Jubail			Jeddah	
	Open sea[1]	Intake bay[2]	Discharge site[3]	Intake zone	Discharge site
A. Phytoplankton (cell/m^3) Diatoms	3.42 x 10^5	2.14 x 10^5	1.48 x 10^5	A.Phytoplankton[4] 2.98 x 10^4	5.79 x 10^4
Dinoflagellates	4.29 x 10^4	2.71 x 10^4	7.67 x 10^3	-	-
Blue-green bacteria	6.84 x 10^5	1.39 x 10^5	1.23 x 10^6	-	-
B. Zooplankton (No./m^3) Protozoa	4.93 x 10^3	5.93 x 10^3	8.09 x 10^3	B. Zooplankton[5]	7.10 x 10^4
Coelenterates	1.59 x 10^3	1.85 x 10^3	9.92 x 10^3		
Nematodes	2.19 x 10^3	1.06 x 10^3	1.92 x 10^3		
Annelida	5	4	10		
Mollusca	2.75 x 10^3	5.5 x 10^2	1.92 x 10^3		
Crustaceans	4.41 x 10^4	7.52 x 10^4	3.56 x 10^4		
Echinoderms	1.25 x 10^3	12	50		
Chordata (fish eggs, fish larvae and tunicates)	4.09 x 10^4	8.70 x 10^4	3.17 x 10^4		

Notes on Plankton

- The distribution of the major plankton groups are similar in feed and discharge zones
- Only Echinoderms seem to be impacted by the brine discharge, and reasons other than brine may contribute to their scarce presence in the brine discharge area e.g. impingement and entrainment
- The major groups of phyto- and zooplankton could form a healthy base of food chains in feed and discharge water zones.

Concentration of nutrients at Jubail and Jeddah

Nutrient (µg/l)	Jubail			Jeddah	
	Open sea	Intake bay	Discharge site	Open sea	Discharge site
A. A.Inorganic nutrients (µg/l) 1. Ammonia -N	1.7 – 8.9	0.8 – 8.5	0.5 – 0.7	1.4 – 4.6	1.7 – 3.5
2. Nitrite -N	0.5 – 1.4	0.2 – 3.0	0.05 – 0.1	0.02 – 0.2	0.03 – 0.2
3. Nitrate-N	1.4 – 6.0	1.6 – 5.3	0.5 – 2.0	0.5 – 0.9	0.2 – 1.2
4. Phosphate-P	1.7 – 6.5	1.9 – 4.6	0.2 – 0.3	0.03 – 0.2	0.1 – 0.3
5. Silicate –S B. Organic nutrients (mg/l)	BDL – 0.1	BDL – 0.1	BDL	BDL	BDL
1. Dissolved sugars	0.5 – 0.8	0.9 – 1.5	3.9 – 5.0	0.34 – 0.42	0.17 – 0.25
2. Dissolved nitrogen	0.2 – 0.3	1.5 – 2.1	4.9 – 6.1	0.02 – 0.05	0.02 – 0.03
3. TOC	2.1 – 2.6	1.6 – 2.4	2.9 – 3.5	1.9 – 2.9	1.9 – 2.9

BDL = Below detection limit

Increased organic matter in discharge due to organic decomposition by chlorine

Metals in the Coastal Waters of Jubail and Jeddah

Trace Metal[1]	Concentration (µg/l)				
	Jubail			Jeddah	
	Open sea	Intake bay	Discharge site	Open sea	Discharge site
1. Iron	0.34 – 5.86	0. 45 – 6.20	0.6 – 7.0	2.9 – 3.9	3.9 – 4.2
2. Nickel	0.16 – 1.40	0.25 – 1.40	0.25 – 1.50	0.90 – 1.0	0.17 – 1.2
3. Copper	0.35 – 2.60	0.65 – 3.70	0.6 – 4.0	1.0 – 1.0	0.95 – 1.1
4. Chromium	0.60 – 0.20	0.00 – 0.17	0.00 – 0.05	ND	ND

[1]These metals are normally associated with corrosion
- No difference between source and discharge waters
ND = Not detected

Toxic Effects of Brine Discharge

- Cumulative findings of our research show that the brine discharged from SWCC's plants has a benign or (at worst) minimal impact on marine coastal environment.
- Still there are claims that effluents are potentially harmful to coastal environment.
- A direct way to address these concerns involves exposing selected marine organisms to brine discharge, measuring their biological response and assessing any deviation from norm.

Toxic Effects of Brine Discharge

- We assessed the comparative *in vitro* toxicity of water from the discharge site of Jubail compared to feed water using *artemia* cysts and a bioluminescent bacterium

RESULTS:

- No difference in the hatching and survival of larval *artemia.*
- No difference in emission of light by the bioluminescent bacterium.

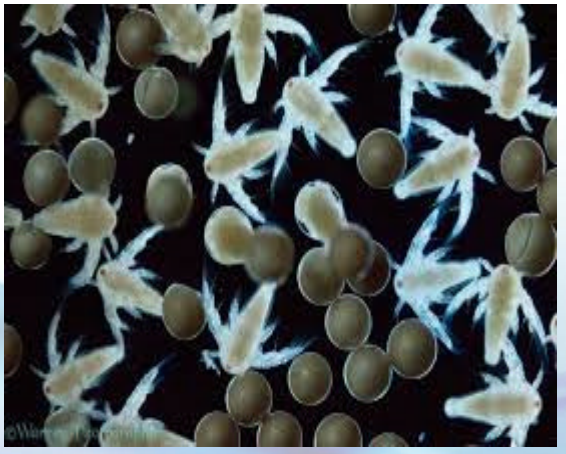
Brine Shrimp Hatching and Larval Mortality Rates

Source water	Hatching Rate (%)	Larval Mortality Rates (%)			
		24h	48h	72h	96h
Discharge	≥ 98	None	None	3.3 ± 7.5^{a}	26.7 ± 14.9^{b}
Feed	≥ 98	None	None	5.7 ± 9.3^{a}	21.2 ± 17.0^{b}

[a,b] Means with same letter superscript are not different (n = 50, ANOVA and t-test, P=0.05)

No difference in hatching rate or larvae survival between discharge and feed waters

Stages in Brine Shrimp Life Cycle



Cysts and
Hatching Larvae

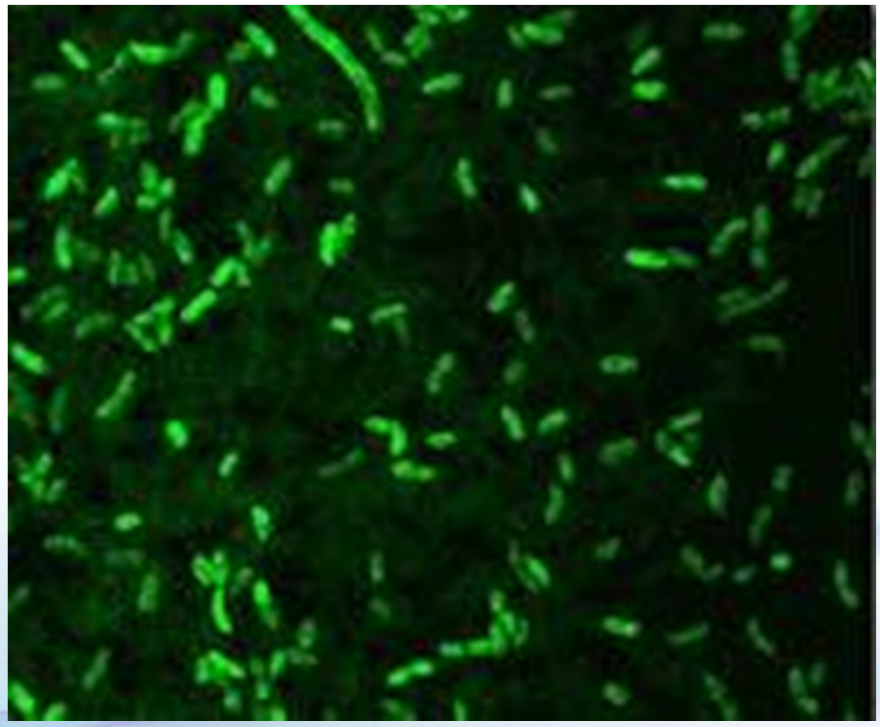
Larva

Adult

Inhibition of Bacteria Bioluminescence

Source	% Inhibition	Difference*
Open seawater	8.2 ± 5.3	Control
Intake bay	9.9 ± 5.8	Not Significant
Discharge site	9.7 ± 4.9	Not Significant
Feed water + Antifoam	9.0 ± 5.1	Not significant
Feed water + Antiscalant	10.4 ± 5.9	Not significant

*(n=10, ANOVA and t-test, P=0.05)



Luminescent bacteria

Reasons for Benign Effects of Discharge

1. Inherent mitigating design

- The discharge channel of Jubail plants is designed as such that it dissipates temperature.
- The channel is ~1.5 Km long and is cascading to the discharge point with strong mixing and air contact that reduce temperature and replenish Oxygen.
- The added volume of cooling water in the discharge also helps in diluting chemical additives and salinity.

2. Dilution Effect

- **Significant and immediate dilution by cooling water (heat rejection)**

Dilution Effect of Cooling Water

Total intake (ex: Jubail)	12 (≈ 12 millions m^3/day)
Cooling (heat rejection)	9
Product	1
Reject	2
Brine discharge	11
Assume salinity	40‰

2/3 of make-up is rejected

1/3 product

Salinity of rejected portion of make-up is $\frac{3}{2} \text{ x } 40 = 60‰$

Salinity of 9 parts cooling is 40‰

$$Final\ \ Salinity\ \ \frac{2}{11}\ x\,60\ +\ \frac{9}{11}\ x\,40\ =\ 10.9 + 32.7 = 43.6$$

∴ **Salinity increases by only 3.6‰ or 9%**

CONCLUSIONS

- An environmental database has been established for the Arabian Gulf and Red Sea coastal and open sea waters opposite the SWCC Jubail and Jeddah desalination and power plants.

- The data clearly show that the brine discharged from SWCC's plants has a benign or (at worst) minimal impact on the marine coastal environment.

- Desalination plants should not be falsely implicated in any negative impact upon coastal water environments. Any report about coastal water pollution from the desalination plants should be interpreted with caution.

Thank You