APPENDIX O

Alaska General Permit - Challenges to the AWP Technologies and the Way Forward

A Presentation to Princess Cruises

Dr Wei Chen (Head of R&D) **22 July 2008**

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Agenda

- New Alaska Standards
- Ammonia and nutrient issue
  - Definitions
  - Ammonia removal - technology review
  - Nitrification and de-nitrification
  - Why a sea trial
- Heavy metals
- MBR operation - key notes

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New Alaska Standards (General Permit)

	Ammonia (mgN/l)	Dissolved Copper (mg/l)	Dissolved Nickel (mg/l)	Dissolved Zinc (mg/l)
Interim standards (2008/2009)	80.4	0.066	0.18	0.23
Long term standards (2010)	2.9	0.0031	0.0082	0.081

- **No AWP can satisfy the 2010 standards**
- **Information retrieval by ADEC during 08/09 seasons**
- **Industry is forced to invest towards solution findings**
- **Interim limits based on 95%ile performance**
- **No dilution or mixing zone**

- **Technologies vs. discharge limits - uncharted area**

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New General Permit - Ammonia Toxicity Limit

ALASKA WATER QUALITY CRITERIA MANUAL
FOR
TOXIC AND OTHER DELETERIOUS ORGANIC AND INORGANIC SUBSTANCES

As amended through May 15, 2003

TABLE IX. TOTAL AMMONIA CHRONIC CRITERIA FOR SALTWATER AQUATIC LIFE

Total Ammonia in mg-N/L at 30 g/kg Salinity

pH	Temperature							
	0°C	5°C	10°C	15°C	20°C	25°C	30°C	35°C
7.0	47	31	22	15	11	7.2	5.0	3.4
7.2	29	20	14	9.7	6.6	4.7	3.1	2.2
7.4	19	13	8.7	5.9	4.1	2.9	2.0	1.4
7.6	12	8.1	5.6	3.7	3.1	1.8	1.3	0.90
7.8	7.5	5.0	3.4	2.4	1.7	1.2	0.81	0.56
8.0	4.7	3.1	2.2	1.6	1.1	0.75	0.53	0.37
8.2	3.0	2.1	1.4	1.0	0.69	0.50	0.34	0.25
8.4	1.9	1.3	0.90	0.62	0.44	0.31	0.23	0.17
8.6	1.2	0.84	0.59	0.41	0.30	0.22	0.16	0.12
8.8	0.78	0.53	0.37	0.27	0.20	0.15	0.11	0.09
9.0	0.50	0.34	0.26	0.19	0.14	0.11	0.08	0.07

TABLE IX. TOTAL AMMONIA CHRONIC CRITERIA FOR SALTWATER AQUATIC LIFE[1]

Total Ammonia in mg-N/L at 10 g/kg Salinity

pH	Temperature							
	0°C	5°C	10°C	15°C	20°C	25°C	30°C	35°C
7.0	41	29	20	14	9.4	6.6	4.4	3.1
7.2	26	18	12	8.7	5.9	4.1	2.8	2.0
7.4	17	12	7.8	5.3	3.7	2.6	1.8	1.2
7.6	10	7.2	5.0	3.4	2.4	1.7	1.2	0.84
7.8	6.6	4.7	3.1	2.2	1.5	1.1	0.75	0.53
8.0	4.1	2.9	2.0	1.40	0.97	0.69	0.47	0.34
8.2	2.7	1.8	1.3	0.87	0.62	0.44	0.31	0.23
8.4	1.7	1.2	0.81	0.56	0.41	0.29	0.21	0.16
8.6	1.1	0.75	0.53	0.37	0.27	0.20	0.15	0.11
8.8	0.69	0.50	0.34	0.25	0.18	0.14	0.11	0.08
9.0	0.44	0.31	0.23	0.17	0.13	0.10	0.08	0.07

Total Ammonia in mg-N/L at 20 g/kg Salinity

pH	Temperature							
	0°C	5°C	10°C	15°C	20°C	25°C	30°C	35°C
7.0	44	30	21	14	9.7	6.6	4.7	3.1
7.2	27	19	13	9.0	6.2	4.4	3.0	2.1
7.4	18	12	8.1	5.6	4.1	2.7	1.9	1.3
7.6	11	7.5	5.3	3.4	2.5	1.7	1.2	0.84
7.8	6.9	4.7	3.4	2.3	1.6	1.1	0.78	0.53
8.0	4.4	3.0	2.1	1.5	1.0	0.72	0.50	0.34
8.2	2.8	1.9	1.3	0.94	0.66	0.47	0.31	0.24
8.4	1.8	1.2	0.84	0.59	0.44	0.30	0.22	0.16
8.6	1.1	0.78	0.56	0.41	0.28	0.20	0.15	0.12
8.8	0.72	0.50	0.37	0.26	0.19	0.14	0.11	0.08
9.0	0.47	0.34	0.24	0.18	0.13	0.10	0.08	0.07

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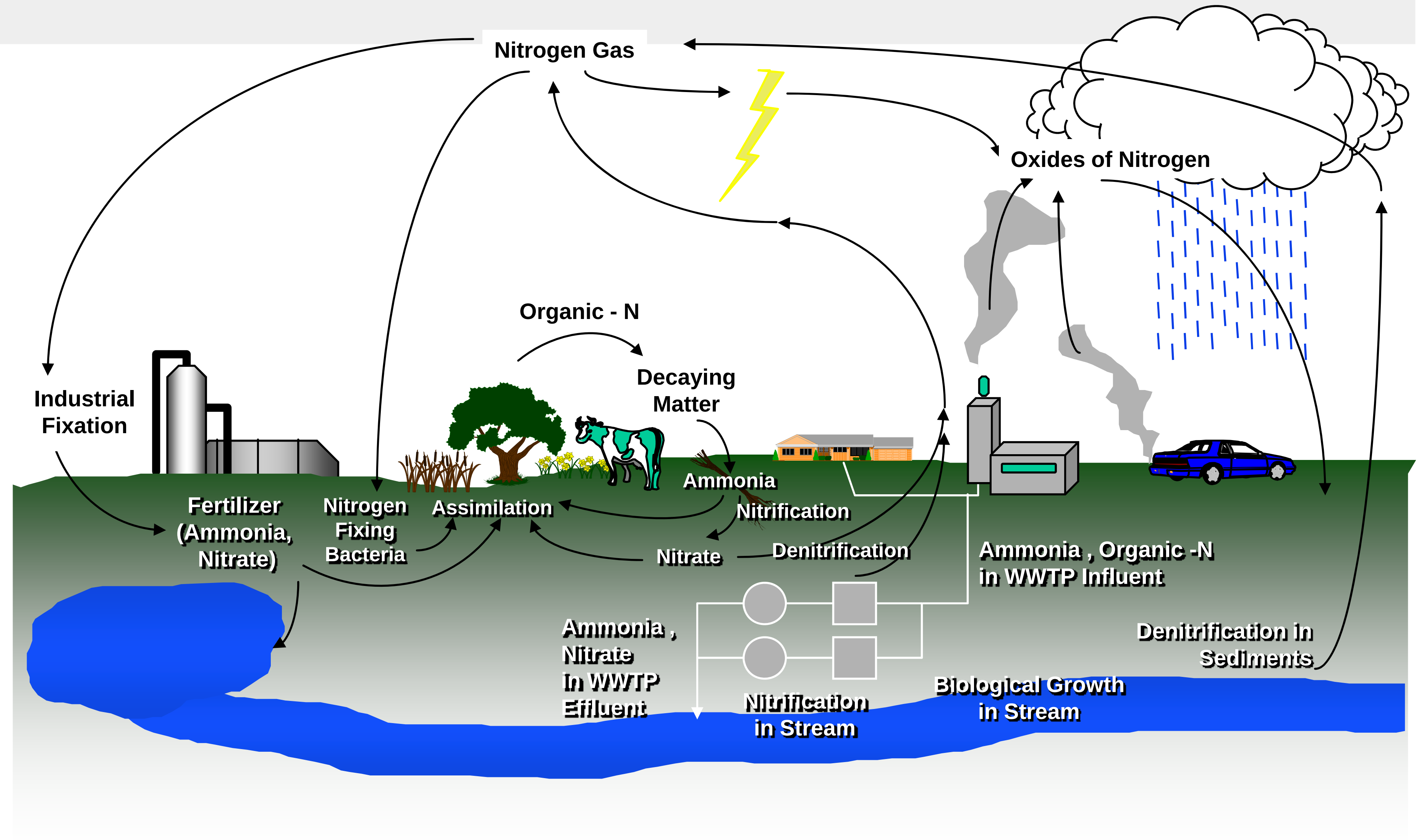
The Nitrogen Cycle



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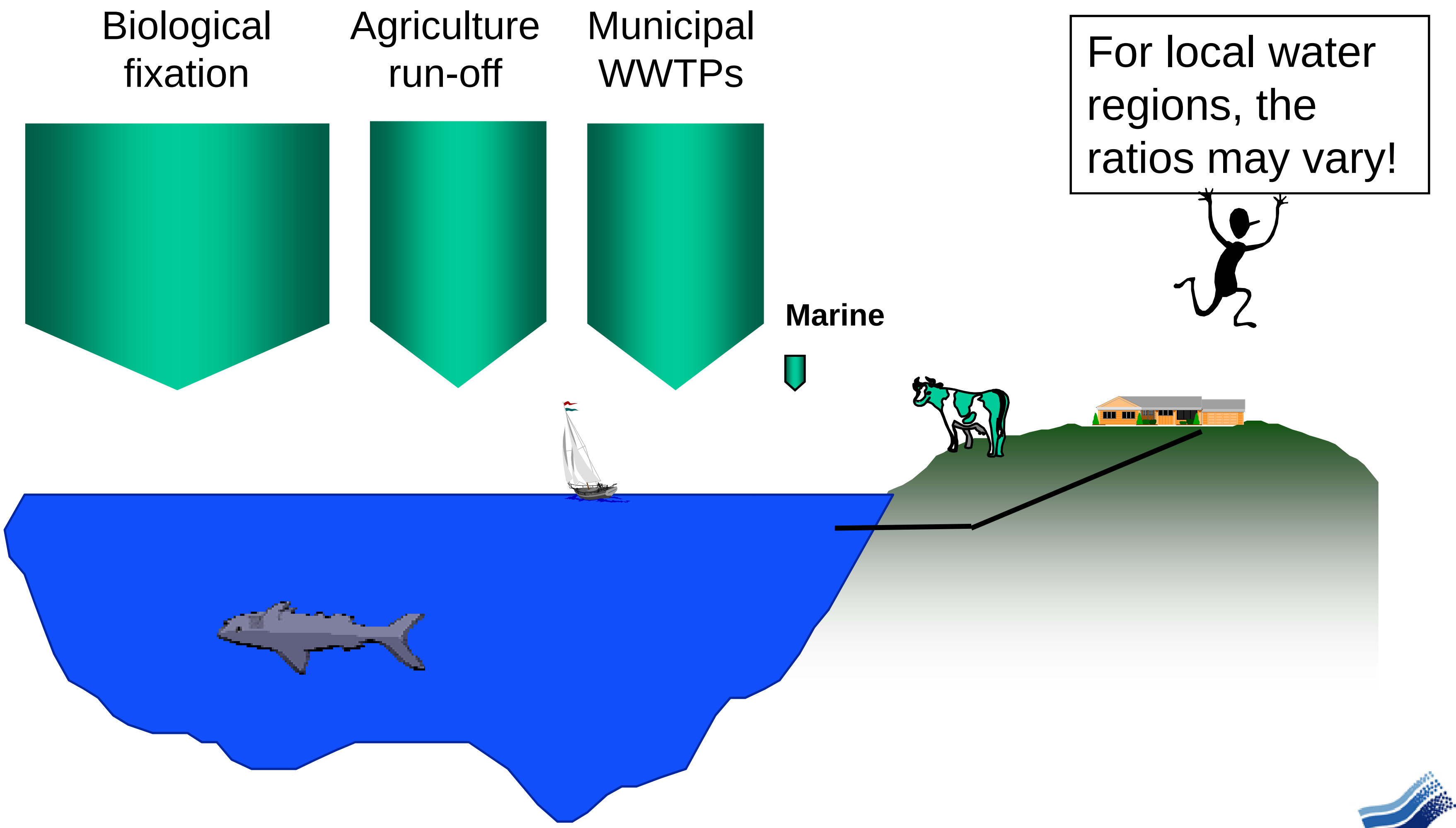
Ocean/Estuary N Influx



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Ammonia and Nutrient Issues

Terminology

Ammonia is toxicity to aqua life. Nitrate and nitrite are far less toxic.

All form of nitrogen compounds (ammonia, nitrate, nitrite) are sources of nutrient to algae, and hence may contribute to algae bloom.

TN = Total Kjeldahl nitrogen (TKN) + Total oxidised nitrogen (TON)
TKN = Ammonia (NH-N) + organic nitrogen
NH-N = Ammonia (NH-N)
TON = nitrite-N + nitrate-N

For a given sample, TN $\geq$ TKN $\geq$ NH-N.

In wastewater, TKN is more than NH-N. TON is absent.

In permeate, TKN is similar NH-N due to hydrolysis of organic N. Present of TON indicates level of nitrification.

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Hamworthy Technology Review

2005 - now

- ✕ Ion-exchange technology - zeolite
- ✕ Ion-exchange technology - resin bed (recommended by USEPA)
- ✕ Advanced oxiditation (independent review)
- ✕ Ammonia stripping
- ✕ Bioaugumentation to existing MBR
- ▸ Biological nitrification and de-nitrification

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Nitrification and De-nitrification

Terminology

Biological nitrification/de-nitrification is the most environmentally friendly and sustainable technology.

1. Carbonaceous BOD Removal (aerobic condition)

$$COHNS + O_2 + \text{nutrients} = CO_2 + NH_3 + \textit{new bacterial cells}$$

2. Nitrification (aerobic condition)

$$NH_4^+ + O_2 + \text{bacteria (Nitrosomonas)} = NO_2^{-1}$$

$$NO_2^{-1} + O_2 + \text{bacteria (Nitrobacter)} = NO_3^{-1}$$

3. Denitrification (anoxic condition)

$$NO_3^- \rightarrow N_2\uparrow$$

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Nitrification Fundamentals

- Two-step reaction:

  NH-N + $O_2 \rightarrow NO_2^-$ (nitrite) + H_2O + H^+ (by Nitrosomonas)

  NO_2^- + $O_2 \rightarrow NO_3^-$ (nitrate) (by Nitrobactor)

  Bacteria involved are generally termed **Nitrifiers** - slow growing and valnerable.

- **Oxygen** requirement 4.6 kg/kg N oxidised
- **Alkalinity** requirement 7.14 kg as $CaCO_3$/kg N oxidised

- Nitrite will accumulate at inhibitive (e.g. low DO) or transition conditions.
- Nitrite is an unstable product in a normal nitrifying AS process.

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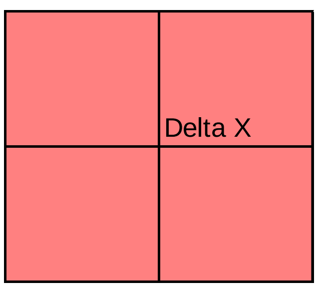
Influential factors to nitrification

- Longer **sludge age** > 8~15 days
  - Nitrifiers grow slower and less
- More aeration demand, DO >1.5~2 mg/l
  - Nitrobacters are inhibited at low DO. (Double of carbon removal)
- Alkalinity demand. Optimum pH 7.5~8.
  - Nitrification tends to reduce pH. Nitrifiers are pH sensitive. Rate at pH6 is 10% of that at pH7.
- Temperature is important, optimal 25 ^{o}C~35 ^{o}C
  - Nitrifiers are temperature sensitive.
- Toxic and inhibitory compounds
  - Nitrifiers are very vulnerable to toxicity and a wide range of organic and inorganic compounds comparing to heterotrophs

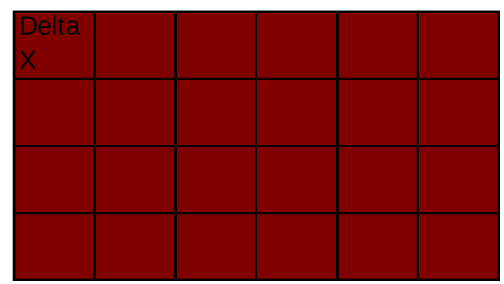
Sludge Age or Mean Cell Retention Time

- Sludge age θ or MCRT
  - θ (day) = biomass in system(kg)/biomass wasted (kg/day)
  - At static state reaching an equilibrium, biomass wasted = biomass grown.
  - In MBR, θ (day)=reactor Vol./wastage Vol. per day.
- How to increase sludge age
  - Increase MLSS by wasting less sludge.
  - Increase reactor volume.



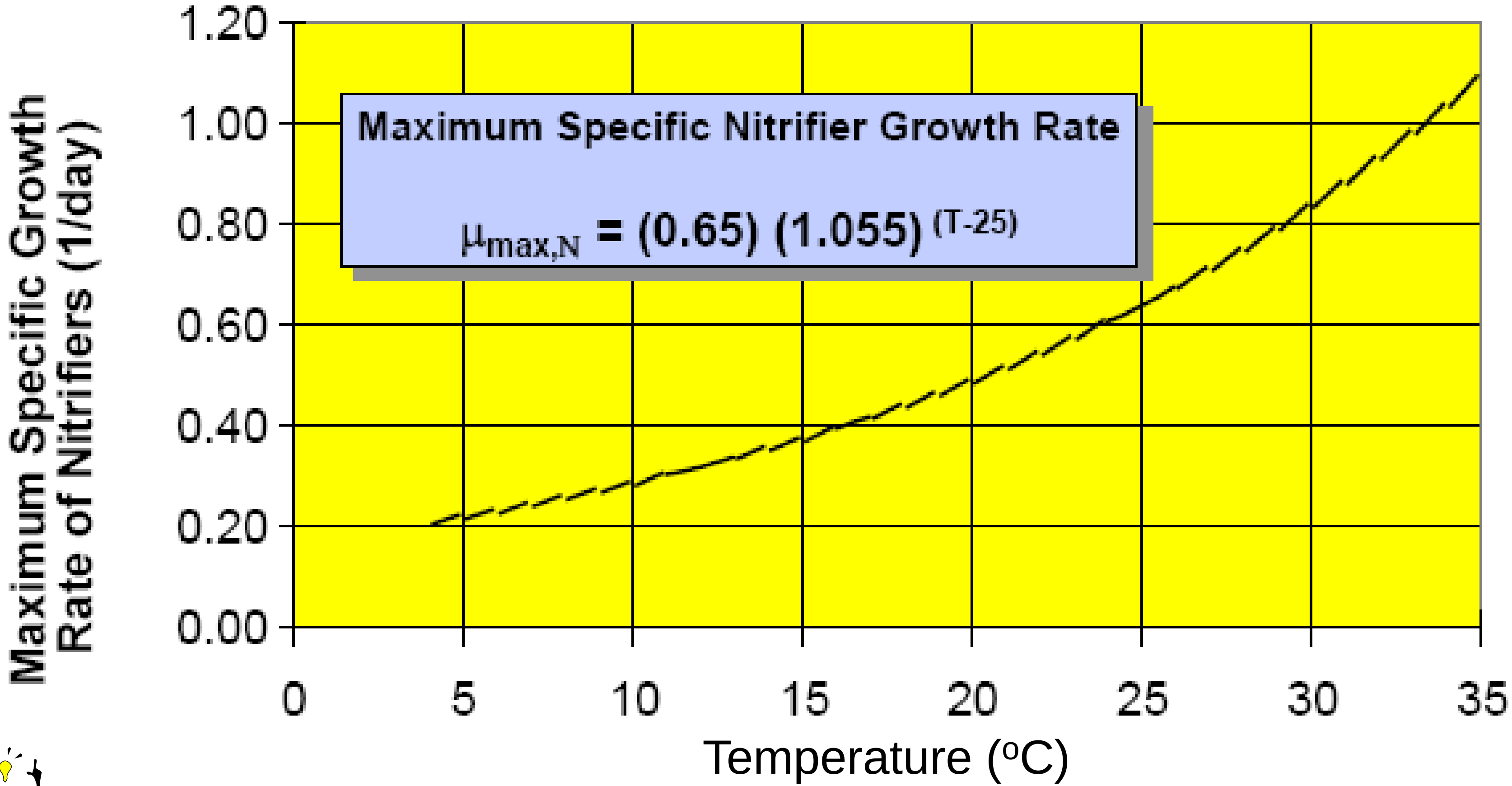
Less nitrifiers due to slow growth - wash-out

More nitrifiers due to longer sludge age



A more stable process due to even longer sludge age

Effect of Temperature



Temperature ↑ → nitrifier growth rate ($\mu=1/\theta$) ↑ → required θ↓

Effect of Temperature - uncertainties

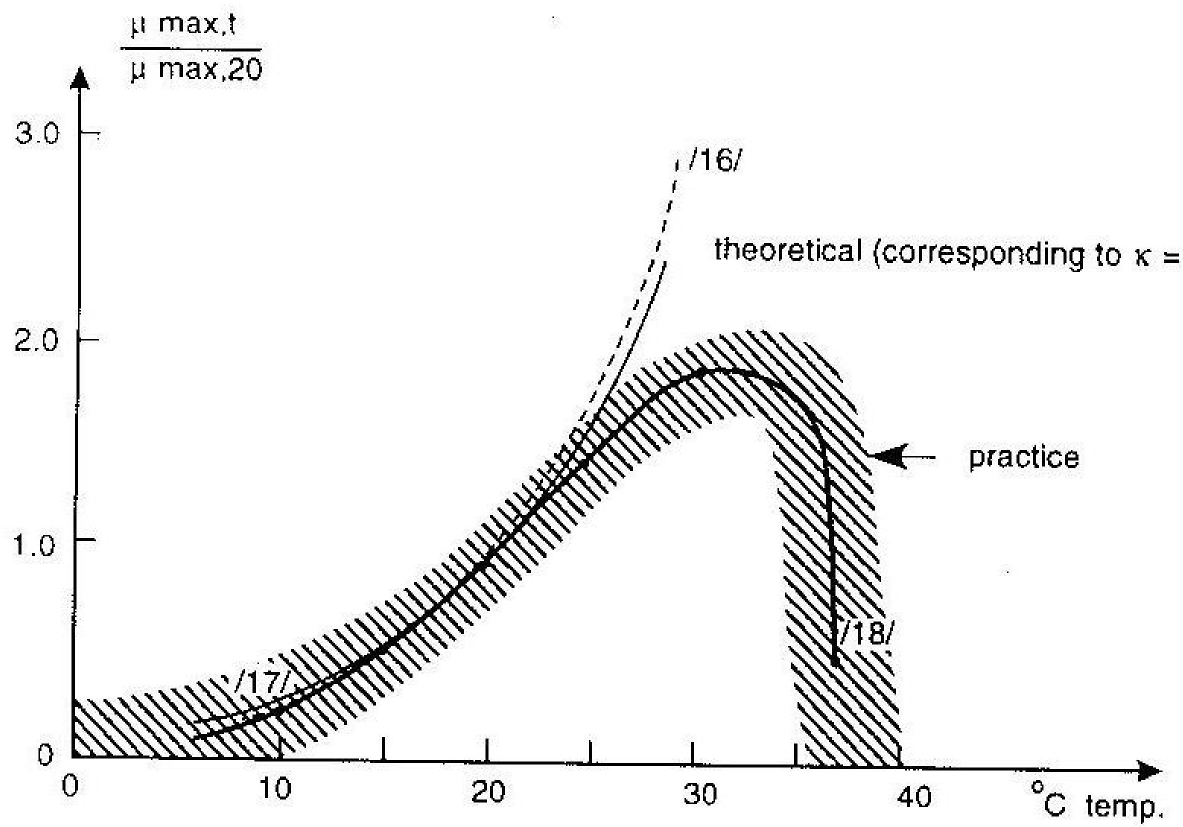


Fig 3.7 *Nitrification as a function of temperature. As opposed to the other biological processes in wastewater treatment, thermophilic nitrifying bacteria are unknown.*

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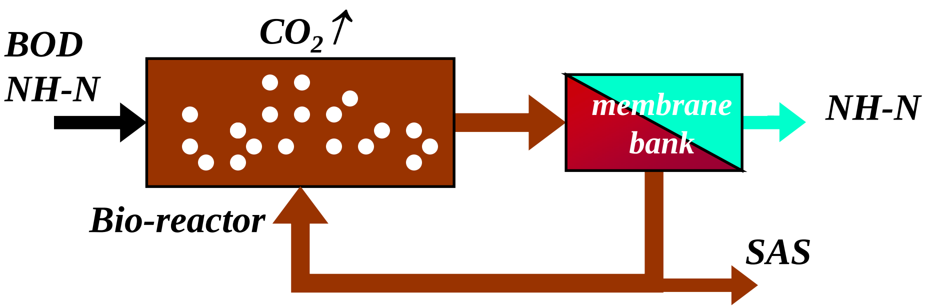
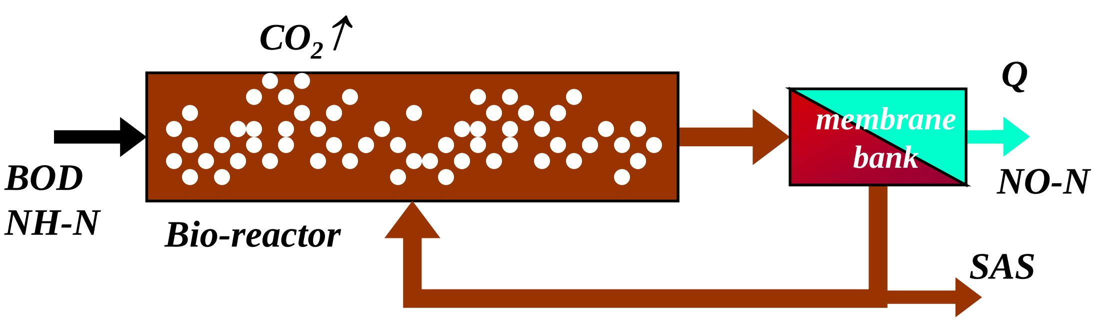
Engineering Implications - Nitrification

- A larger reaction tank, in plug flow
- A higher aeration capacity.
- A better process monitoring/control.
- Potential alkaline dosing system.
- ...



MBR for BOD removal



MBR for Nitrification

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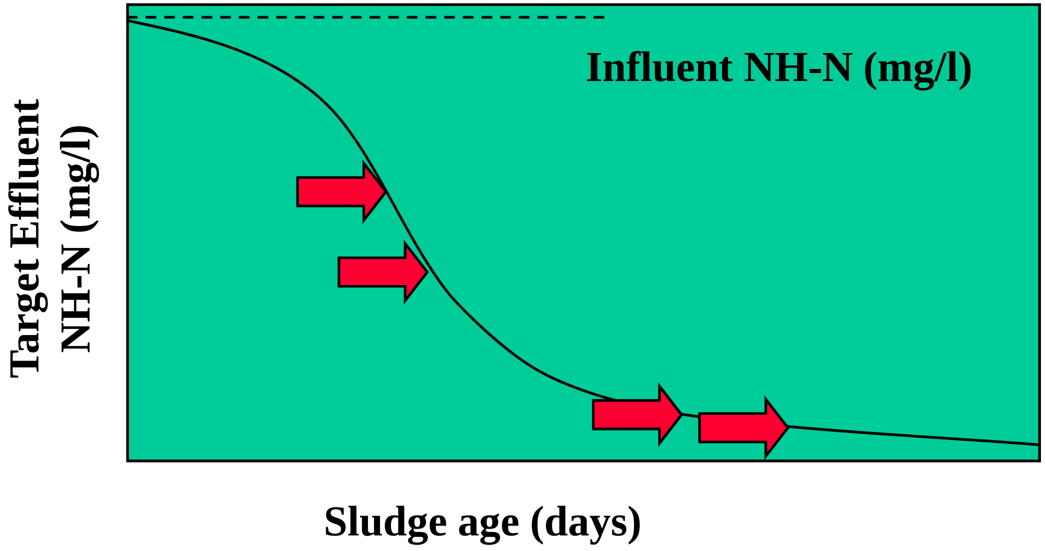
Nitrification Design - Key Factors

- Treatment standards
  - A lower limit for NH-N means nitrifiers have to domain under a low NH-N environment, at a lower growth rate.

$\mu_{NH\text{-}N} = \mu_{NH\text{-}N,\ MAX} \times [NH\text{-}N]/(K_N+[NH\text{-}N])$



- Standards ↑ →design F:M ↓ → Biomass ↑ → Reactor V ↑

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Denitrification Fundamentals

- Anoxic condition - present of Nitrate with absence of DO.
- NO_3^- + Carbon (or BOD) $\rightarrow$ CO_2 + N_2 ($\uparrow$) + OH^- (by heterotrophs)

- Total BOD requirement 2.86 kg/kg N denitrified.
- Alkalinity producted 3.57 kg as $CaCO_3$/kg N denitrified.

- Comparing to a Nitrifying alone process
  - Denitrification reduces the total power consumption.
  - Denitrification assists to stabilise the alkalinity balance.

Conditions for Denitrification

- Need DO <0.3 mg/l.
    - DO inhibits denitrification.
    - To limit DO in re-circulation
    - To avoid air entrapment in anoxic zone mixing etc.
    - To avoid cascading
- Need readily degradable organic materials.
    - Govern the reaction rate, hence the size of anoxic tank.
- Less sensitive to pH in a range 6.5~8.
- Higher temperature benefit reaction rate.
- Less sensitive to inhibitory compounds.
    - If nitrification goes well, there will probably be no inhibition of denitrification.

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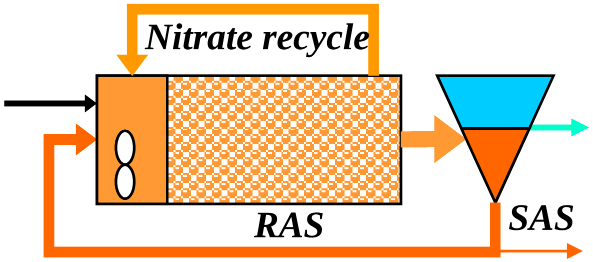
Effluent NO-N and Recirculation R



- With single anoxic zone, NO-N target achievable by a pre-denitrification process is limited.
- $NO\text{-}N_x / NO\text{-}N_e = R+1$
  - $NO\text{-}N_x$ - nitrate produced in aeration tank, mgNO-N/l
  - $NO\text{-}N_e$ - effluent NO-N concentration, mgNO-N/l
- Greater amount of NO-N produced requires a greater R to achieve the same NO-N effluent concentration.
- R is also limited due to recirculation of DO.
- Typical R = 2~4. For MBR, R can be higher.

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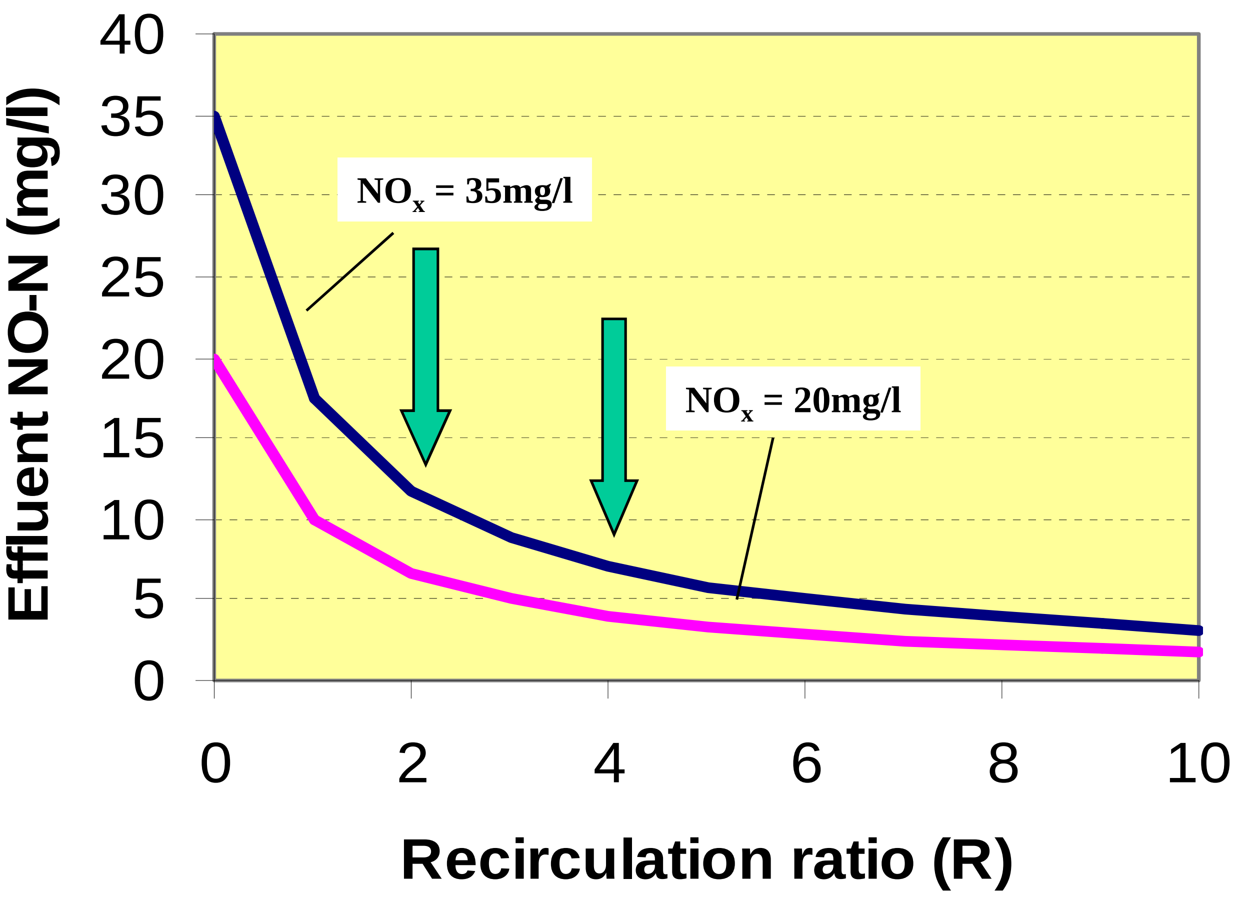
Effluent NO-N and Recirculation R



Typical TN Removal Performance

- **Largely depending on carbon source and C/N ratio**
- **Largely depending on fluctuations**
- **50~60% for single anoxic zones**
- **70~90% for double anoxic zones.**

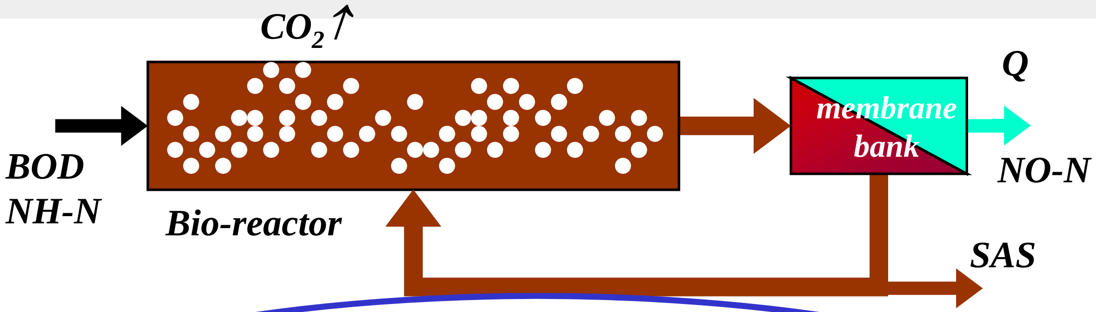
Anoxic Zone Design

- **Suitable conditions**
  - **Effective submersible mixing; No/low DO;**
  - **Carbon source and its quality.**

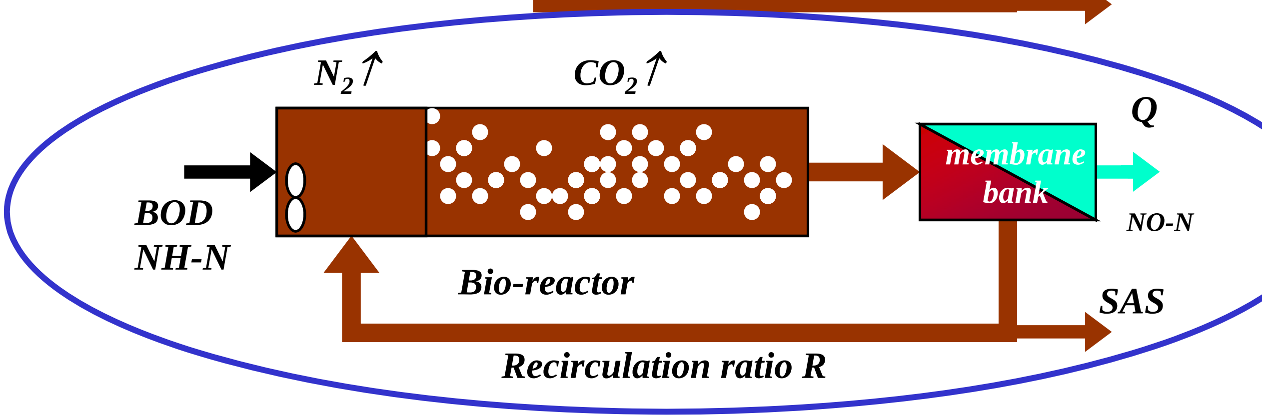
- **Nitrate recycle rate**
  - **Determine effluent nitrate target;**
  - **Determine amount of nitrate to be denitrified;**
  - **Determine a suitable and practical configuration.**

- **Anoxic volume**
  - **Estimate denitrification rate;**
  - **Consider wastewater fluctuations.**

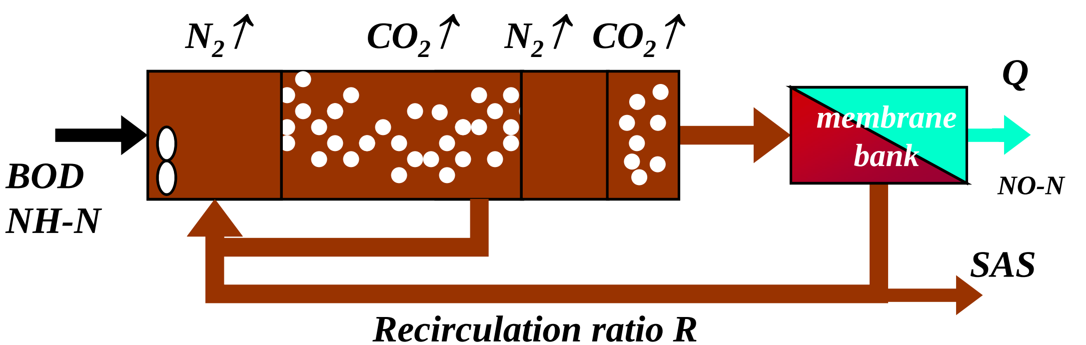
MBR for Nitrogen Removal on Ship



MBR for Nitrification



MBR for TN removal
(pre-denitrification)



MBR for TN removal
(two anoxic zones)

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Ship Applications - Issues

- Space constraints
- Sludge age control
- Process monitoring
- Coping with variations in loading, temperature, peak conditions.
- MBR sludge may need outlet other than O/B discharge.
- Dedicated resources
- Training and general process knowledge

Ship Applications - Capital Costs Implications

- Additional reaction tankage - not significant if integral/structure tanks are used.
- Additional Monitoring - not significant
- Optimisation of ship wastewater buffering capacity - not significant
- Provision for sludge dewatering is sensible.
- Opex implication > Capex implication

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Trial Proposal

Why sea trial

- **Uncertainties related to fluctuations in concentrations, temperature, flow etc.**
- **Little research on ship board applications**
- **Is 2.9 mg/l daily maximum discharge limit feasible to ship board application?**
- **Demonstrate commitment by the industry.**
- **Trial results obtained will provide foundation to support further discussions with regulators.**

Trial Proposal

Why Hamworthy

- In depth knowledge and know-how on MBR technology.
- In house expertise on biological nitrification/de-nitrification.
- The trial is to be conducted professionally.
- On-line monitoring system to provide abundant information.
- Partial nitrification in the existing MBR processes.
- To involve independent party if required (e.g. university).
- Dedicated and leading marine technology provider familiar with marine rules, regulators and other stakeholders in cruise community.

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Heavy Metal Performance - USEPA Ship Surveys

Copper - Dissolved (microgram/Litre)

Parameters	Oosterdam (HAL)	Oosterdam (HAL)	Veendam (HAL)	Island (Princess)	Norwegian Star (NCL)
AWP supplier	Rochem	Rochem	Zenon	Hamworthy	Scanship
Technologies	Reverse osmosis	MBR	MBR	MBR	Hybrid
Copper - in	109 (70.6~205)	100 (56.6~153)	59 (34~136)	44.7 (25.2~79.8)	113 (84.3~135)
Copper - out	18.3 (2.96~47)	15.8 (3.6~53.9)	8 (5.6~11)	16.9 (13.1~25.7)	6.51 (4.31~11.3)
Copper – source water	14.0	14.0	59.7	479	288
Equipment blank	Not tested	Not tested	3.1	3.6	Not tested
Limits 08/09	66	66	66	66	66
Limits 2010+	3.1	3.1	3.1	3.1	3.1

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Heavy Metal Performance - USEPA Ship Surveys

Copper - Dissolved (microgram/Litre)

- **All technologies achieved similar level of removal.**
- **None of the technologies meet the proposed limit.**
- **There is no evidence the limit can be economically met.**
- **Levels in equipment blank are higher than compliant limit.**
- **Levels in source water are higher than compliant limit.**
- **Hugh variations in source water concentrations**
- **Conclusion - address at source**

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Heavy Metal Performance - USEPA Ship Surveys

Zinc - Dissolved (microgram/Litre)

Parameters	Oosterdam (HAL)	Oosterdam (HAL)	Veendam (HAL)	Island (Princess)	Norwegian Star (NCL)
AWP supplier	Rochem	Rochem	Zenon	Hamworthy	Scanship
Technologies	Reverse osmosis	MBR	MBR	MBR	Hybrid
In	170 (130~252)	521 (409~644)	318 (111~634)	100 (83.4~119)	99.9 (61~132)
Out	279 (147~605)	755 (354~1360)	353 (164~553)	205 (51~223)	656 (553~883)
Source water	24.9	24.9	8.4	33	Not tested
Equipment blank	Not tested	Not tested	Not tested	Not tested	Not tested
Limits 08/09	230	230	230	230	230
Limits 2010+	81	81	81	81	81

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Heavy Metal Performance - USEPA Ship Surveys

Zinc - Dissolved (microgram/Litre)

- **All technologies showed a significant increase in concentration.**
- **None of the technologies meet the proposed limit.**
- **There is no evidence the limit can be economically met.**
- **Conclusion - address at source**

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Heavy Metal Performance - USEPA Ship Surveys

Nickel - Dissolved (microgram/Litre)

Parameters	Oosterdam (HAL)	Oosterdam (HAL)	Veendam (HAL)	Island (Princess)	Norwegian Star (NCL)
AWP supplier	Rochem	Rochem	Zenon	Hamworthy	Scanship
Technologies	Reverse osmosis	MBR	MBR	MBR	Hybrid
In	13.8 (12.6~15.5)	27.8 (21.1~33.3)	22.7 (16~33.3)	15.7 (11.3~22.8)	10.3 (9.12~11)
Out	<3.3 (0.3~5.24)	29.4 (22.8~41.2)	15.5 (8.4~23.5)	14.1 (11.4~19.3)	12.8 (8.52~17.5)
Source water	3.62	3.62	14.5	2.8	3.76
Equipment blank	Not tested	Not tested	Not tested	Not tested	Not tested
Limits 08/09	180	180	180	180	180
Limits 2010+	8.2	8.2	8.2	8.2	8.2

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Heavy Metal Performance - USEPA Ship Surveys

Nickel - Dissolved (microgram/Litre)

- **None of the technologies meet the proposed limit.**
- **There is no evidence the limit can be economically met.**
- **Conclusion - address at source.**

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Current MBR Operation - ammonia issue

Dilution by grey water

Indicative Effect of Grey Water Dilution to Ammonia Concentration				
Waste streams	Ammonia in combined black and grey water (mgN/l)	BOD/Ammonia ratio of the combined wastewater	Treated water due to biomass growth/disposal (mgN/l)	Reduciton (%)
Blk+50% sanitary	150	3.8	122	19%
Blk+100% sanitary	82	4.8	62	24%
Blk+sanitary +laundry	68	5	51	25%
Blk+sanitary +laundry+ galley	50	8	30	40%
Blk+sanitary +laundry+ galley +pulper water	50	11	23	55%

- Princess AWP partial-treatment configuration is a low risk, sustainable wastewater management system.

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Current Operational Issue - Partial Nitrification

Partial Nitrification

Table 3. 2005 Large Ships Unannounced Sampling Results for Conventional Pollutants

Vessel	Sample Date	Ammonia as N	pH	Biochemical O_2 Demand	Chemical O_2 Demand	Total Suspended Solids	Free Chlorine	Residual Chlorine	Fecal Coliform Bacteria by MPN	Conductivity	Oil & Grease	Total Organic Carbon	Alkalinity	Total Nitrate	Total Phosphorus	Total Kjeldahl Nitrogen	Total Settable Solids
	Detection Limit	0.10	0.10	2.00	10.00	4.00	0.10	0.10	2.00	2.00	5.00	1.00	2.00	1.00	0.05	1.00	4.00
	Units	mg/l	s.u.	mg/l	mg/l	mg/l	mg/l	mg/l	MPN/100 ml	umhos/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Alaska Water Quality Standards		20*	6.5-8.5	N/A	N/A	N/A	0.0075	N/A	14**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	SS***
Carnival Spirit	6/4/05	0.41	7.08	10.6	ND	ND	ND	ND	ND	30.6	ND	5.8	14.7	ND	ND	2.14	ND
Carnival Spirit	7/16/05	0.24	9.5	5.24	ND	ND	ND	ND	ND	104	ND	ND	46.8	0.21	ND	ND	ND
Coral Princess	5/25/05	25	7.61	ND	47	ND	ND	ND	ND	614	ND	18	97.6	9.6	11	25.4	ND
Coral Princess	7/12/05	32	7.45	6.51	47	ND	ND	ND	ND	850	19	20	131	9.2	14	35.8	ND
Dawn Princess	5/27/05	74	7.45	ND	88	ND	ND	ND	ND	939	ND	22	230	0.18	9.6	73.7	ND
Dawn Princess	7/28/05	23	7.16	7.91	61	ND	ND	ND	ND	922	9	21	113	14	14	22.4	ND
Diamond Princess	5/23/05	41	7.27	ND	51	ND	ND	ND	ND	1240	ND	17	82.9	30	14	35.6	ND
Diamond Princess	7/18/05	79	7.77	2.39	72	ND	ND	ND	ND	1840	ND	19	382	21	11	85.8	ND
Island Princess	5/24/05	34	7.52	13.7	55	ND	ND	0.11	ND	838	ND	16	121	21	19	36.2	ND
Island Princess	7/13/05	14	7.32	2.27	68	ND	ND	ND	ND	656	ND	20	47.5	22	14	13.7	ND
Mercury	6/5/05	0.61	7.45	ND	ND	ND	ND	ND	ND	33.9	ND	ND	14.9	ND	ND	1.47	ND
Mercury	7/24/05	ND	8.85	ND	ND	ND	ND	ND	ND	42.5	ND	ND	21	ND	ND	2.43	ND

ND means not detected

* Ammonia standards are based on temperature, pH and salinity. This standard is from Table IX in the *Alaska Water Quality Criteria Manual for Toxics and Other Deleterious Organic and Inorganic Substances* using a ph 7.8, salinity of 20 g/kg and temperature between 10-15 degrees Celsius

** Standard used for the consumption of raw shellfish

*** Alaska Water Quality Standards definition- No measurable increase in the concentration of settleable solids above natural conditions, as measured by the volumetric Imhoff cone method.

Current Operational Issue - Partial Nitrification

Partial Nitrification

Table 3 continued

Vessel	Sample Date	Ammonia as N	pH	Biochemical O_2 Demand	Chemical O_2 Demand	Total Suspended Solids	Free Chlorine	Residual Chlorine	Fecal Coliform Bacteria by MPN	Conductivity	Oil & Grease	Total Organic Carbon	Alkalinity	Total Nitrate	Total Phosphorus	Total Kjeldahl Nitrogen	Total Settable Solids
	Detection Limit	0.10	0.10	2.00	10.00	4.00	0.10	0.10	2.00	2.00	5.00	1.00	2.00	1.00	0.05	1.00	4.00
	Units	mg/l	s.u.	mg/l	mg/l	mg/l	mg/l	mg/l	MPN/100 ml	umhos/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Alaska Water Quality Standards		20*	6.5-8.5	N/A	N/A	N/A	0.0075	N/A	14**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	SS***
Norwegian Dream	6/26/05	41	6.77	160	285	ND	ND	ND	ND	921	ND	92	119	ND	0.56	51.8	ND
Norwegian Dream	7/24/05	13	6.38	12.4	38	ND	ND	ND	ND	735	ND	22	59.1	ND	0.089	14.6	ND
Norwegian Spirit	5/24/05	18	6.52	ND	56	ND	ND	0.17	ND	623	ND	9.4	48	0.89	ND	20.5	ND
Norwegian Spirit	7/26/05	16	6.87	2.88	40	ND	ND	ND	ND	529	ND	9.4	64.7	0.3	0.085	16.8	ND
Norwegian Star	6/14/05	46	6.62	3.64	90	ND	ND	ND	ND	1040	ND	14	94.1	ND	ND	47.8	ND
Norwegian Star	7/19/05	50	7.74	ND	30	ND	ND	ND	ND	983	ND	18	113	1.3	0.11	40.5	ND
Norwegian Sun	6/1/05	28	7.13	6.37	26	ND	ND	ND	6	788	10	12	60.6	1.4	0.15	31.7	ND
Norwegian Sun	8/17/05	36	7	6.78	58	ND	ND	ND	ND	1440	ND	15	82.6	ND	0.24	39.6	ND
Oosterdam	6/27/05	21	7.52	32.3	95	6	ND	ND	6	477	ND	22	143	ND	1.5	20.7	ND
Oosterdam	8/8/05	17	7.59	14.6	68	ND	ND	ND	ND	361	ND	21	94.9	ND	2.6	18.8	0.1
Regal Princess	6/3/05	49	6.9	4.98	178	ND	ND	ND	ND	2010	ND	56	64.1	53	24	45.9	ND
Regal Princess	9/10/05	30	7.88	9.61	109	ND	ND	0.19	20	697	ND	29	80.6	25	6.8	34	ND

ND means not detected

* Ammonia standards are based on temperature, pH and salinity. This standard is from Table IX in the *Alaska Water Quality Criteria Manual for Toxics and Other Deleterious Organic and Inorganic Substances* using a ph 7.8, salinity of 20 g/kg and temperature between 10-15 degrees Celsius

** Standard used for the consumption of raw shellfish.

*** Alaska Water Quality Standards definition- No measurable increase in the concentration of settleable solids above natural conditions, as measured by the volumetric Imhoff cone method.

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Current Operational Issue - Partial Nitrification

Partial Nitrification

Continued Compliance Sample

Company Name: Admiralty Environmental

Mailing Address: 431 N. Franklin St., Suite 101
Juneau, AK 99801

Vessel Name: Star Princess

Sample Number:

Sample Date:

Sample Time:

Analyte (Parameter)	FLAG	Result	UNITS	ANALYSIS DATE (MM-DD-YYYY)
Biochemical O2 Demand, 5 Day		6.8	mg/l	6/27/2008
Chlorine, Free		ND	mg/l	6/25/2008
Chlorine, Residual		ND	mg/l	6/25/2008
Fecal Coliform Bacteria		4	cts/ 100 ml	6/25/2008
pH		6.67	S.U.	6/25/2008
Total Suspended Solids		ND	mg/l	6/27/2008
Copper - dissolved		55.5	µg/L	7/8/2008
Nickel - dissolved		15.7	µg/L	7/8/2008
Zinc - dissolved		119	µg/L	7/8/2008
Ammonia as N		32	mg/L	7/3/2008
Nitrate as N		36.9	mg/L	6/26/2008

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Current Operational Issue - Partial Nitrification

Partial Nitrification

Continued Compliance Sample

Company Name: Admiralty Environmental

Mailing Address: 431 N. Franklin St., Suite 101
Juneau, AK 99801

Vessel Name: Golden Princess

Sample Number:

Sample Date:

Sample Time:

Analyte (Parameter)	FLAG	Result	UNITS	ANALYSIS DATE (MM-DD-YYYY)
Biochemical O2 Demand, 5 Day		2.7	mg/l	5/16/2008
Chlorine, Free		ND	mg/l	5/15/2008
Chlorine, Residual		ND	mg/l	5/15/2008
Fecal Coliform Bacteria		ND	cts/ 100 ml	5/15/2008
pH		6.98	S.U.	5/15/2008
Total Suspended Solids		ND	mg/l	5/22/2008
Copper-dissolved		8.3	µg/L	05/21/2008
Nickel-dissolved		6	µg/L	05/21/2008
Zinc-dissolved		180	µg/L	05/21/2008
Nitrogen, Ammonia (As N)		29	mg/L	05/27/2008
Alkalinity, Total (As CaCO3)		63	mg/L	05/27/2008
Chemical Oxygen Demand		30	mg/L	05/23/2008
Nitrogen, Kjeldahl, Total		35	mg/L	05/22/2008
Nitrogen, Nitrate-Nitrite (as N)		24	mg/L	05/22/2008

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Current Operational Issue - Partial Nitrification

Partial Nitrification

Priority and Conventional Pollutants Sample

Company Name: Admiralty Environmental
Sample Number: AE 2081
Mailing Address: 431 N. Franklin St., Suite 101
Juneau, AK 99801
Sample Date: 30/06/2008
Sample Time: 14:25
Vessel Name: Golden Princess

Analyte (Parameter)	FLAG	Result	UNITS	ANALYSIS DATE (MM-DD-YYYY)	ANALYSIS TIME (HH:MM:SS)
Biochemical O2 Demand, 5 Day		3.2	mg/l	01/07/2008	16:00
Chlorine, Free		ND	mg/l	30/06/2008	14:25
Chlorine, Residual		ND	mg/l	30/06/2008	14:25
Fecal Coliform Bacteria		2	cts/ 100 ml	30/06/2008	17:00
pH		7.47	S.U.	30/06/2008	14:25
Total Suspended Solids		ND	mg/L	07/07/2008	09:58
Copper-dissolved		5.1	µg/L	07/08/2008	16:16
Nickel-dissolved		5.3	µg/L	07/08/2008	16:16
Zinc-dissolved		93	µg/L	07/08/2008	16:16
Nitrogen, Ammonia (As N)		42	mg/L	07/08/2008	15:55
Nitrogen, Nitrate (As N)		2.36	mg/l	02/07/2008	11:48:00
Alkalinity, Total (As CaCO3)		160	mg/L	07/08/2008	22:00
Chemical Oxygen Demand		53	mg/L	07/09/2008	09:00
Nitrogen, Kjeldahl, Total		52	mg/L	07/10/2008	10:32
Nitrogen, Nitrate-Nitrite (as N)		14	mg/L	07/08/2008	09:57

Current Operational Issue - Partial Nitrification

Partial Nitrification

Priority and Conventional Pollutants Sample

Company Name: Admiralty Environmental **Sample Number:**

Mailing Address: 431 N. Franklin St., Suite 101 **Sample Date:**

Juneau, AK 99801 **Sample Time:**

Vessel Name: Diamond Princess

Analyte (Parameter)	FLAG	Result	UNITS	ANALYSIS DATE (MM-DD-YYYY)
Biochemical O2 Demand, 5 Day		3.05	mg/l	19/06/2008
Chlorine, Free		ND	mg/l	18/06/2008
Chlorine, Residual		ND	mg/l	18/06/2008
Fecal Coliform Bacteria		ND	cts/ 100 ml	18/06/2008
pH		7.8	S.U.	18/06/2008
Total Suspended Solids		ND	mg/L	06/24/2008
Copper-dissolved		8.6	µg/L	06/24/2008
Nickel-dissolved		15	µg/L	06/24/2008
Zinc-dissolved		84	µg/L	06/24/2008
Nitrogen, Ammonia (As N)		100	mg/L	06/26/2008
Nitrogen, Nitrate (As N)		5.33	mg/l	20/06/2008
Alkalinity, Total (As CaCO3)		460	mg/L	06/23/2008
Chemical Oxygen Demand		71	mg/L	06/26/2008
Nitrogen, Kjeldahl, Total		130	mg/L	06/27/2008
Nitrogen, Nitrate-Nitrite (as N)		ND	mg/L	06/26/2008

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Current Operational Issue - Partial Nitrification

Solutions (2008)

- Low pH
  - Most probably caused by partial nitrification.
  - Increase plant capacity
  - Increase desludge (new technical bulletin)
- High Ammonia
  - Most probably caused by less dilution from grey, or uneven distribution of black water.
  - May possibly caused by secondary release of ammonia from biomass if unaerated for prolonged period.
  - Increase grey water.
  - Check ISF filtrate flow rate.
  - Minimise external source of ammonia - such as nutrient solution.
- Sea trial for biological nitrification and denitrification.

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Conclusions

- MBR Operational improvement during 08/09 seasons.
- Ammonia removal sea trial on Golden Princess

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