Nutrient Response to Sewage Abatement in Hong Kong

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Outline

• Background of natural factors influencing water quality

• Anthropogenic inputs – Pearl River discharge
  - Sewage discharge

• Meeting the challenges
  - sewage treatment for Victoria harbor
Why Is Hong Kong Not As Bad As Expected?

- Physical Factors – monsoon winds
  - river discharge and rainfall
  - wind and tidal mixing
- Chemical and Biological factors

These factors govern the ecosystem **sensitivity** to various anthropogenic inputs.

Need to understand how the ecosystem functions.
Northern Gulf of Mexico:

a large area of hypoxia “dead zone” (20,000 km²)
(<2 O₂ mg/L)

South China Sea

- Nutrient-poor sea
- Hong Kong western and southern waters excessive nutrients
Fine resolution land-use 1994 vs 2003
2003 PRD Land-use map

Red = Urban area

From HKSAR Planning Department
Pearl River Estuary & Hong Kong
Wide and Shallow Estuary

Diverse – estuarine to oceanic –
Complex topographically – enclosed bays and islands
Water area = 10 times land area
10 Water Quality Zones in Hong Kong

Figure 1.1 Water Control Zones in Hong Kong
Tidal Mixing

Important in mixing $\text{O}_2$ into bottom waters and nutrients in the water column.
Tidal Height During Neap and Spring Tides
Wind Mixing

- Wind mixing can help reduce the occurrence of hypoxia (mixes O$_2$ from the air into deep waters)
- Reduces the formation algal blooms by dilution.
Fig. 5. Locations of the sampling stations in AFCD phytoplankton monitoring programme.

AFCD Phytoplankton Monitoring Stations
EPD’s Water Quality Monitoring Stations
Increase in TIN and NO$_3$ from 1986-2001

Figure 3.4 Temporal trends of inorganic nitrogen components in the Southern WCZ, 1986 - 2001
Excessive Nutrients Can Cause Low $O_2$ in Bottom water

Nutrients $\rightarrow$ algae $\rightarrow$ plankton $\rightarrow$ fish

Sink

Bacterial decomposition $\rightarrow$ low $O_2$ in bottom water
Studies on population dynamics of HABs will lead to a better understanding of events such as cyanobacterial blooms in the Baltic Sea.

Surface Algal Bloom
Red Tides in Hong Kong during 1983-98 (Yin et al. 2002)
High Number of Red Tides in Eastern Waters

• Most red tides occur in spring when river discharge is low

• Occur in Mirs Bay – far from the Pearl River estuary.
High Biomass Vs Toxic Red Tides

• High biomass algal blooms which cause low O\textsubscript{2} bottom waters seems to be a more serious concern than toxic red tide blooms.
High Biomass Blooms
e.g. Chain-forming Diatoms

*Thalassiosira sp.*
Nutrient Sources

• Sewage – continuous all year – excess phosphorus sewage treatment → ecosystem response (improving)
   BUT – chl biomass increase in southern waters?

• Pearl River discharge
  – summer (rain), excess nitrogen and transported offshore
    - phosphorus potentially controls algal biomass in summer in waters near Pearl River.

HK waters are very productive
Sewage Outfalls in 2001

Figure 1.7 Major public sewage treatment works, outfalls and pollution load in Hong Kong in 2001
Transect from Western Waters Through Victoria Harbor

Legend
- Water sampling stations selected
- Boundary of Special Administrative Region

Figure showing EPD routine water sampling stations

Vertical Mixing in Victoria Harbor
NH₄ is a good marker for sewage input in Victoria Harbor.

Average NH₄ during 1990-2000 for each station across the transect.

From: Yin & Harrison 2005
Mar Poll Bull
**Phosphate**

- Low in dry season
- Little change in the estuarine-influenced waters during wet season
- Higher in Vic. Harbor

From: Yin & Harrison 2005
Mar Poll Bull
Total Inorganic Nitrogen

- Low in dry season
- High in western waters during wet season.

From: Yin & Harrison 2005
Mar Poll Bull
Figure 1.7 Major public sewage treatment works, outfalls and pollution load in Hong Kong in 2001
70% of the sewage receives primary treatment at SCI
Transect 1: West → East

Victoria Harbor

Western waters

PO$_4$(uM)

Year

1986 89 92 95 98 01 04-05

S4

S1

S8

PO$_4$(uM)

Year

1986 89 92 95 98 01 04-05

S5

S6

S7

Eastern waters

PO$_4$(uM)

Year

1986 89 92 95 98 01 04-05

Victoria Harbor

Kowloon

Hong Kong

Western waters

Eastern waters
Transect 1: West → East

**Western waters**
- Transect 1 (West)
- Transect 2 (East)
- Victoria Harbor

**Eastern waters**
- Transect 1 (West)
- Transect 2 (East)
- Victoria Harbor

**Chla (ug L⁻¹)**
- S1: Western waters
- S4, S5, S6: Victoria Harbor
- S7, S8: Eastern waters

**Year**

**Map**
- Hong Kong
- Kowloon
- Locations marked with 'S' prefixes for sampling points.
Chl in Southern Waters

Year

Chla (ug L⁻¹)

Southern waters

S9

S10

Year

Chla (ug L⁻¹)

Southern waters

S9

S10

Kowloon

Hong Kong
Figure showing EPD routine water sampling stations

Legend
- Water sampling stations selected

Bottom DO

Year

Shenzhen
New Territories
Lantau Island
Kowloon
Hong Kong

Legend
- Water sampling stations selected
Figure showing EPD routine water sampling stations

Legend
- 12 Water sampling stations selected

Legend
- Year
- 1986 89 92 1995 98 01 04-05

Bottom DO

DO (mg / L)

S9

S10

S11

S12

Year

1986 1995 04-05

DO (mg / L)
Cross-border Influence

(Watershed contribution)

- Pearl River discharge
- Rainfall
Guangdong Province & Pearl River Region
(satellite image courtesy of Pearl River Water Resources Commission, 1998)
HK Nutrient Source 1: Pearl River Estuary

Summer is a Critical Period

Rainfall in HK & Pearl River Discharge during 1990-98

- Kedong Yin, 2003
Nutrient Sources

1) Anthropogenic Sources
   - Sewage  N:P = 8:1
   - Rain     N:P = 50:1
   - River    N:P > 100:1

2) Natural Sources (N:P <16:1)
   from coast - South China Sea

Algae need N:P = 16:1

Excess nitrogen in Summer
NO$_3$ at Humen (a river mouth of the Pearl River)

At River Mouth

$\text{NO}_3$ (µM)

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160

4 5 6 7 8 9 10 11 12 1 2 3 4 5

2002 2003

100 µM
Monthly Average of total inorganic nitrogen during 1991-2000 (Yin 2002)
(Yin 2002)
Unused Nitrogen in Summer in Western and Southern waters

Potential P limitation in summer near estuary

Unused N (exported offshore)?

Add more P

N used up and more algal biomass is produced
Ecosystem Responses to Input of Nutrients

Riverine, Atmospheric Input

Phosphorus control

Algal Biomass Increase

Excess Nitrogen

Resuspension

Sinking

Benthic-Pelagic exchange

$O_2$ Decrease
Only Episodic Low $O_2$ Events – Late Summer

- **Good Physics**
  - wind and tidal mixing and tidal currents dilute the algal biomass.
  - Shallow water depth

- **Good Chemistry**
  - low phosphorus compared to some rivers
Summary

- Excess nitrogen in summer in western and southern waters.

- P is potentially the most limiting nutrient since N/P ratios are high in the estuarine influenced western waters in summer.

- At the present, removal of P would more likely control algal biomass production.

- Improving conditions in Victoria Harbor due to sewage abatement.