River Nutrient Transport from Watersheds to Indian Ocean Coastal Systems: Amount, Forms and Sources

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Nutrient Sources to the Indian Ocean Basin

- Rivers
- Atmospheric Advection
- N₂-fixation
- Advection
- IN THE BEGINNING -

Biological N2-fixation → Water runoff → River export to Coastal Ecosystems

P Weathering
- NOW -

6.5 bill. People
(>1.2 bill. Indian Ocean)

- Fertilizer
- N2-fixation - crops
- Manure
- Sewage
- Combustion FF = NOy dep.
- Altered water runoff
  - Dams
  - Consumptive water use

N2-fixation
P Weathering

Increased River Inputs of N & P to Coastal Ecosystems
Watersheds that Drain into the Indian Ocean Basin

~170 watersheds
Vorosmarty et al. 2000
Global NEWS

Global (N)utrient (E)xport from (W)ater(S)heds

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Global NEWS Models

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12 papers *Global Biogeochemical Cycles*, special section Dec. 2005
Overview

- **Spatial variation** in river export of N, P & C
- **Total river export** of N, P & C
- **Watershed sources** contributing to river export (natural and anthropogenic)
- **Scenario for year 2030**
Approach

Measured Export by Range of Rivers

Model Predict Export
\[ f \text{ (Inputs, Sinks, Hydrology in Watersheds)} \]

+ 

Spatially Explicit Global Data Bases

Spatial Pattern Nutrient Export Globally
NEWS Model Inputs
0.5° x 0.5° databases

Natural
N₂-Fixation
P Weathering

Anthropogenic
Fertilizer (by crop type)
Manure (by animal type)
N₂-fixation - crops
Sewage (treatment level)
Atmos. Dep. NO₃

Water Runoff
Consumptive Water Use
N & P Removal in rivers and reservoirs

River export of
DIN, DIP
DON, DOP
Contributions of agricultural sources

Based on e.g.:
• Spatial land use distribution
• Crop types (FAO)
• Fertilizer consumption (FAO)

- Inorganic fertilizer
- Manure
- N₂ fixation
- Harvesting & grazing
Contributions of agricultural sources

Based on e.g.:
• Spatial distribution of livestock
• Livestock numbers (FAO)
• Animal species (FAO)
• Type of livestock: “intensive or extensive”

- Inorganic fertilizer
- Manure
- N₂ fixation
- Harvesting & grazing
N Atmos. Deposition

- Modeled (Dentener et al.) function of e.g.,
  - Fossil fuel combustion
  - Climate
  - Atmospheric circulation
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0.5° x 0.5° databases

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River export of DIN, DIP, DON, DOP

Export to mouth of river
Comparison of NEWS–DIN Model–Predicted & Measured Export for Range of World Rivers (1990’s)

Modeled DIN export (kg N basin\(^{-1}\) year\(^{-1}\))

Measured DIN export (kg N basin\(^{-1}\) year\(^{-1}\))

R\(^2\)=0.79

(Dumont et al. 2005)
Comparison of NEWS-DIN Model-Predicted & Measured Export for Range of World Rivers

- **Modeled DIN export** (kg N basin$^{-1}$ y$^{-1}$)
- **Measured DIN export** (kg N basin$^{-1}$ y$^{-1}$)

Log-log graph showing the comparison of modeled and measured DIN export for various rivers. The graph includes data points for ChangJiang, Rhine, Mississippi, Indus, Elbe, Yukon, Kolyma, Kamkatcha, and Susquehanna. The data points are categorized into two subsets, with data subset 1 represented by darker symbols and data subset 2 by lighter symbols.

Key:
- $R^2 = 0.79$
- Ganges/Brahmaputra

Authors: S.K. Mukhopadhyay & T.K. Jana

DIN for tributary Ganges/Brahmaputra in India (current)
Prediction of DIN yield

(kg N km^{-2} y^{-1})

Spatial Patterns
DIN Export by Rivers

(kg N/km² watershed/yr)

Excerpt from Dumont et al. 2005
Spatial Patterns
DIN Export by Rivers

(kg N/km² watershed/yr)

DIN Yield (kg N km⁻² y⁻¹)

0 - 15
16 - 40
41 - 70
71 - 110
111 - 190
191 - 350
351 - 570
571 - 880
881 - 1220
1221 - 5217

Arabian Sea
Bay of Bengal

494 3,600

Total Export – $10^9$ g DIN/yr
Spatial Patterns  
DIN Export by Rivers

(kg N/km² watershed/yr)

- Ganges/Brahmaputra accounts for 60% of river DIN load to BB
- DIN load to BB+AS accounts for 20% of total global DIN export

494 3,600

Total Export - $10^9$ g DIN/yr
Global NEWS Models

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Spatial Patterns

DIP Export by Rivers

(kg P/km² watershed/yr)

25

99

Total Export – $10^9$ g P/yr

Modified from Harrison et al. 2005
### Global NEWS Models

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Natural
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Consumptive Water Use
N & P Removal in rivers and reservoirs

River export of
DIN, DIP
DON, DOP
DIN Export
Variation in Dominant Source

DIN River Export Variation in Dominant Source

Overall Contribution

- N Atmos. Dep.
- Sewage
- Fertilizer
- N2-Fixation
- Manure

Dominant source of DIN export
- Sewage point sources
- Fertilizer
- Manure
- Biological N2 fixation
- Nitrate deposition
Variation in Dominant Source of DIP Export

Future Scenario - Yr 2030

Human Population

1990
1.2 billion

2030
2.0 billion
Percent change DIN export 2030 relative to 1990

Legend

Percent Change DIN Export

-68 - 28%
-27% - 0
0 - 20%
20 - 45%
45 - 160%
160 - 290%
290 - 490%
490 - 1285%
Future Directions

- Model refinement for Indian Ocean region - updating of databases, comparisons with local data, scenarios.....
- Seasonal variation - pre-post-monsoon
- Transport of river inputs to shelf and interior locations
- Effects on C, N and P cycling and production in IO
Acknowledgments

- Global NEWS workgroup
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- GEF
- NSF
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