Geochemical Flux Estimation of Phosphorus across the Huanghe (Yellow) River Estuary

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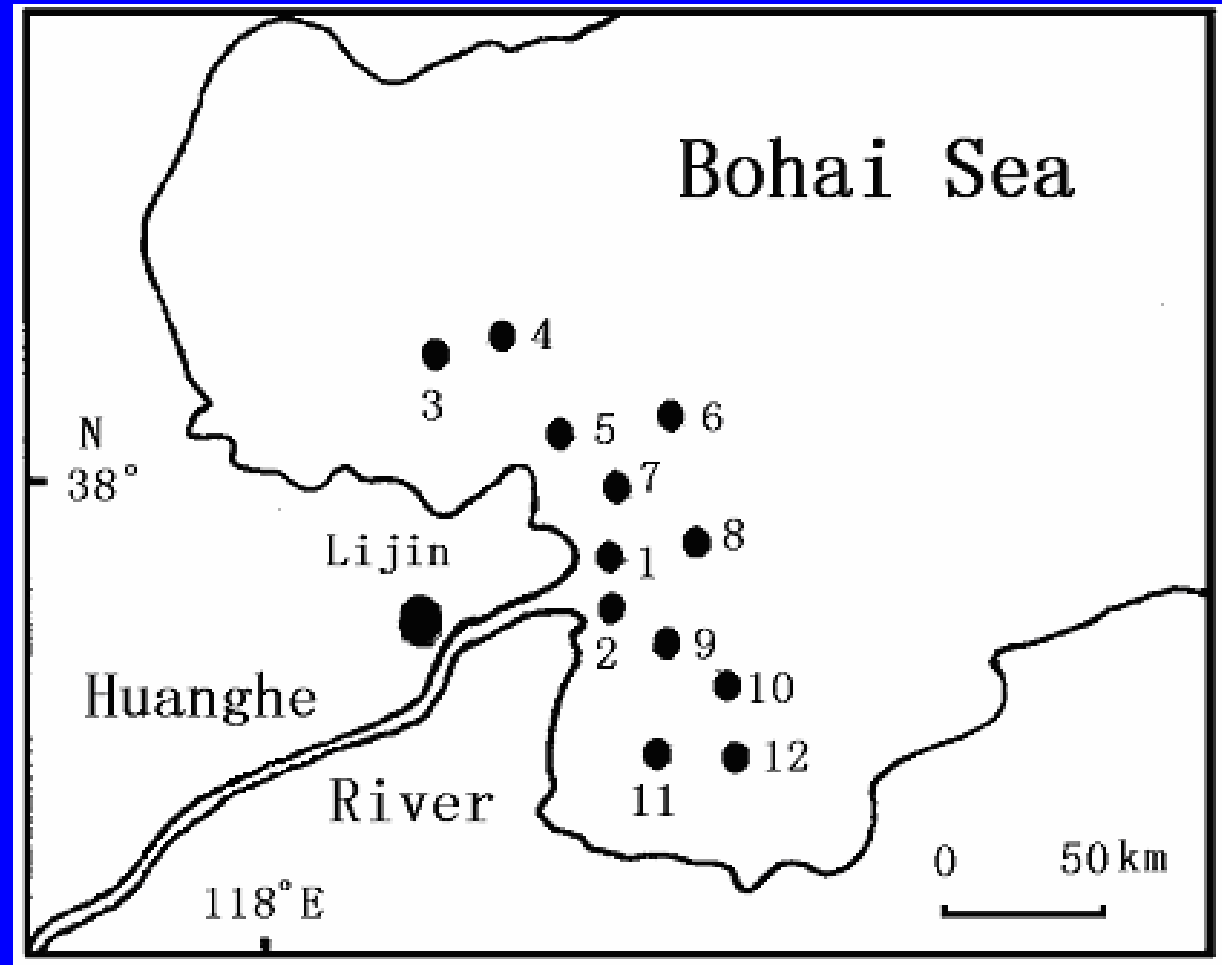   Flux of Water and Suspended Matter from the Huanghe River

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一、Materials and Methods

•Sampling

Twelve samples of surface sediments from the Huanghe River estuary and shelf as well as the river water and suspended samples in Lijin Hydrologic Station near the river mouth were collected in 1998.

- **Analytical Methods**
    - The method (Ruttenberg, 1992) for extracting different forms of P in sediments quantified five sedimentary P reservoirs: loosely sorbed P (Ads-P), Fe bound P (Fe-P), authigenic apatite plus biogenic apatite plus $CaCO_3$- associated P (CFAP-P), detrital apatite P (FAP-P), and organic bound P (Org-P).
    - Phosphate in the extracts after each step was analyzed by the standard phosphomolybdate blue spectrophotometric method.
    - Dissolved inorganic P and dissolved total P in filtered water were determined and the dissolved organic P in filtered water was simply estimated as the difference between dissolved total P and dissolved inorganic P.

二、 Results and Discussion

- Distributions of P

  - The concentrations of different forms of P in river water, suspended matter near the river mouth and in surface sediments of the estuary and nearby shelf, are summarized in the following table.

  - Table1. Concentrations of different forms of phosphorus in various phases

Sample	Ads-P	Fe-P	Auth-P	Detr-P	Org-P	Total P
River water						
Lijin	Inorg-P 0.020	Org-P 0.016				
River suspended matter						
Lijin	8.2	101.6	210	218	268	806
Estuarine sediment						
1	1.9	91.7	275	137	27	533
2	0.7	125.1	249	107	45	527
Mean	1.3	108.4	262	122	36	530
Shelf sediment						
3	9.8	165.1	296	84	102	657
4	5.6	149.7	291	73	135	654
5	7.3	125.9	249	116	63	561
6	7.0	142.5	288	72	82	591
7	6.4	146.5	266	66	56	541
8	8.3	164.5	276	92	68	609
9	5.7	92.5	314	79	42	533
10	8.7	158.2	290	85	51	593
11	6.7	128.8	298	73	53	560
12	4.5	69.6	332	70	23	499
Mean	7.0	134.3	290	81	68	580
SD	1.6	33.1	23	15	32	51

Units are microgram of P per gram of sample.

– Approximately 70% of the suspended matter carried in the Huanghe River is rapidly deposited and sinks inside the estuary within 15 km off the river mouth based on the variation of salinity (Qin and Li, 1982).

– "Estuary" here refers to the shallow seabed within a range of 15 km off the river mouth, while "nearby shelf" refers to the seabed outside. Therefore, our study was correspondingly focused on these two areas separately.

- The dominant P-bearing component in the suspended matter and surface sediments is authigenic P (26-59% of total P), followed by detrital P (11-32%), Fe bound P (11-28%), and organic P (5-34%). Adsorbed P (0.1-1.5%) exists in minor quantity.

- There are distinct decreases in Org-P, Detr-P, and total P, and increases of Auth-P and Fe-P in the sediments after deposition of suspended matter in the estuary and shelf.

- A distinct drop in Org-P after deposition of suspended matter in the river and/or shelf is likely due to microbial activity in the buried sediment. The microbial processes, which include the decomposition of organic matter, should lead to loss of organic bound P from sediments. The drop of Org-P leads to a significant drop of total P.

- **Flux of Water and suspended Matter from the Huanghe River**

  - As the foundation of P flux estimation, the flux of water and suspended matter from the Huanghe River to the Bohai Sea must be estimated first.

  - The mean annual discharge of water and suspended matter from 1990 to 2000 in Lijin Hydrologic Station are shown in Table 2, which are used to represent the flux of water and suspended matter from the Huanghe River.

The mean annual flux of water （$\times 10^8 m^3$） and suspended matter ($\times 10^{11} kg$) from the Huanghe River to the Bohai Sea

|	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Mean
Water	264	122	134	185	218	137	155	18	106	68	49	154
S.M.	4.69	2.49	4.72	4.21	7.08	5.69	4.38	0.16	3.65	1.92	0.22	4.31

Because it was drought in the drainage basin in 1997 and 2000, both data were eliminated from the mean calculation for their unusual low.

- **Flux of P**
  - The calculated P flux from the Huanghe River to the Bohai Sea was in three forms: dissolved P flux, solubilized P flux, and buried P flux.
  - Dissolved P flux represents the dissolved P output directly by river water.
  - Solubilized P flux represents the P solubilized to the seawater from the river-derived suspended matter during transport and deposition on the seafloor.
  - Buried P flux represents the river-derived P deposited and buried on the seafloor.

Distributions of different forms of phosphorus in solid phase
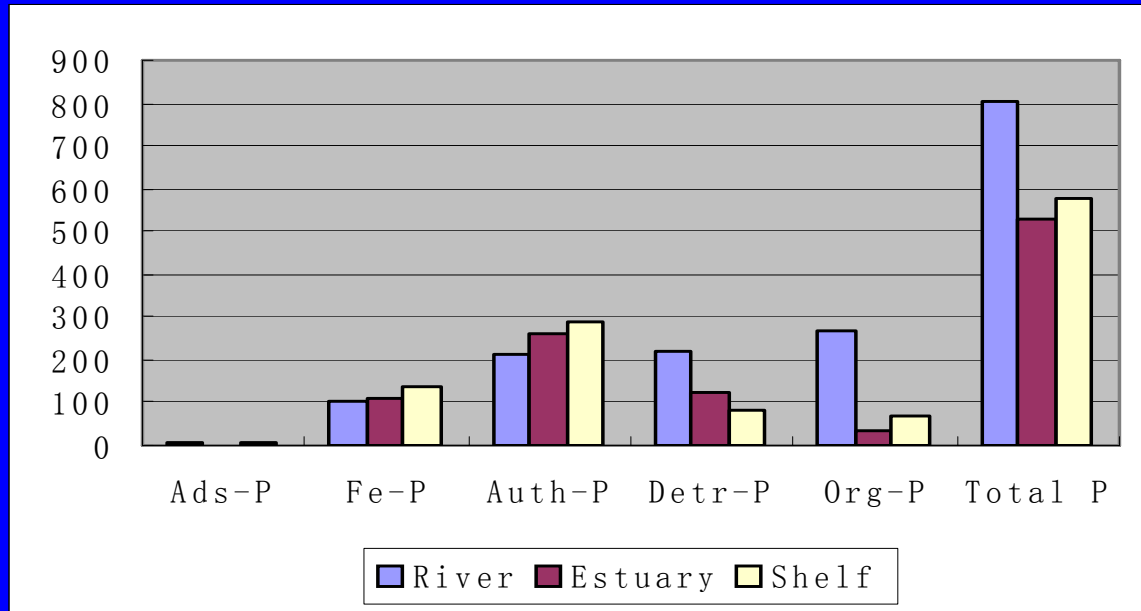
- Comparison between suspended matter from the river and surface sediments from the estuary and nearby shelf indicates a clear decrease in the content of total P upon deposition. This decrease represents the addition to seawater of P originally in solid form prior to burial in the sediments.

Annual flux of different forms of phosphorus （×10⁸g）

from the Huanghe River to the Bohai Sea

Form	Flux
Dissolved inorganic P	3.08
Dissolved organic P	2.46
Total dissolved P	5.54
Solubilized P from estuary	832.7
Solubilized P from shelf	292.2
Total solubilized P	1124.9
Buried P in estuary	1599.0
Buried P in shelf	749.9
Total buried P	2348.9

三、 Conclusions

- A dissolved P flux of 5.5×10^8 grams per year, solubilized P flux of 1125×10^8 grams per year, and buried P flux of 2349×10^8 grams per year from the Huanghe River to the Bohai Sea were calculated using the concentrations of P determined in the water column, suspended matter and surface sediments.

- Because of the high suspended load and low discharge of the Huanghe River, the contribution of dissolved P carried directly in solution by the river is only a minor component of the available P in the studied area.

- More than two-thirds of the total P transported by the Huanghe River is deposited and buried in marine sediments.

- Decomposition of riverine organic matter that releases organic bound P might be an essential source of dissolved/solubilized P in this sea.

Thanks!