Water Environment Protection and Hot topics of Scientific Research

Wang Peifang, Xia Xinghui, Wang Yuchun, Chen Qiuwen

College of Environment, Hohai University
School of Environment, Beijing Normal University
China Institute of Water Resources and Hydropower Research
Nanjing Hydraulic Research Institute

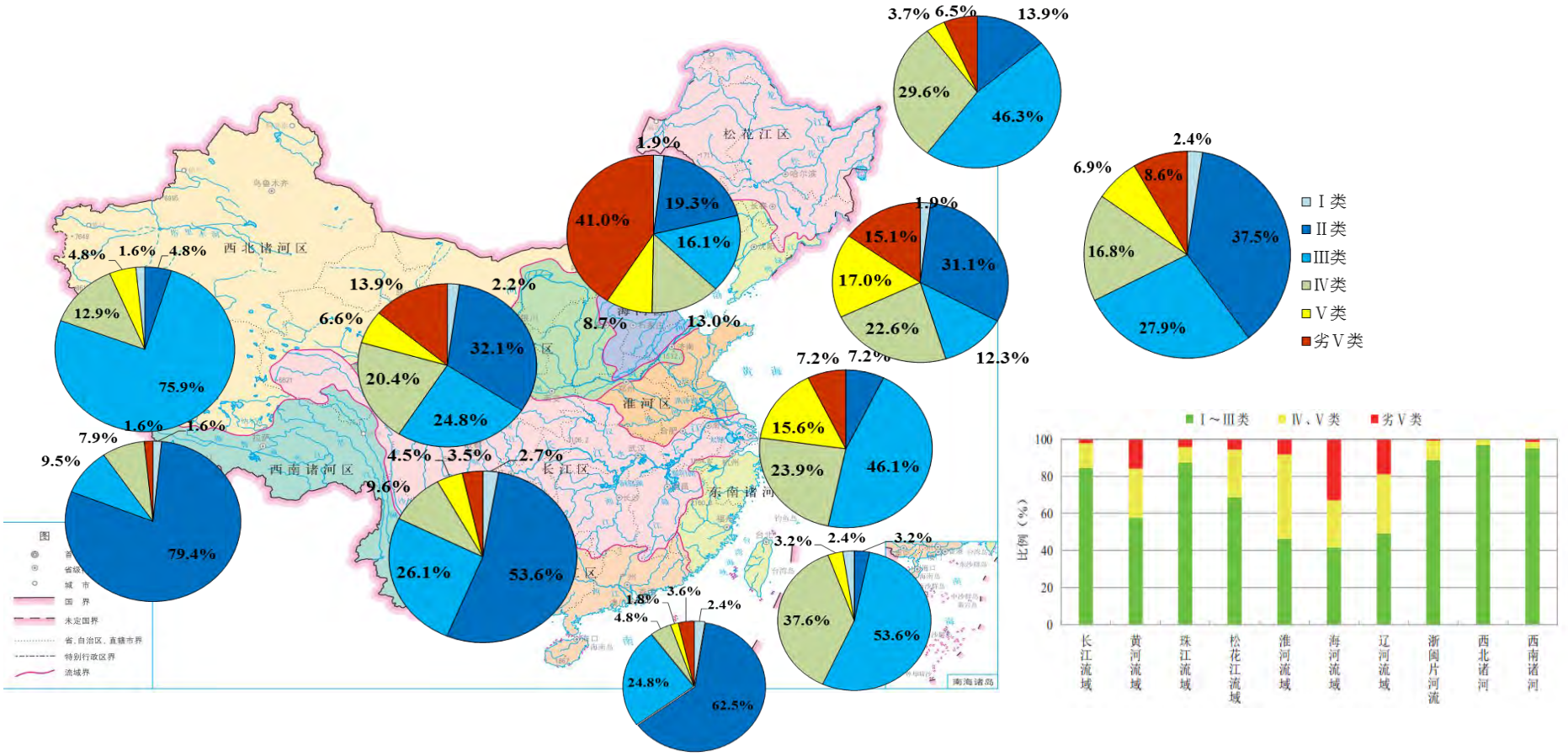
Outline

- **Introduction of Water Environment and Pollution Control in China**
- **Key Technologies and Theory of Pollution Control**
- **Hot Topic of Water Environment Scientific Research**

1. Introduction of Water Environment and Pollution Control in China

1. Background

- Rivers: There are 45,203 rivers with individual catchment area of 50 km^2
- Lakes: There are 2,865 lakes with individual perennial water surface area of 1 km^2
- Reservoirs: totals 98,002, with a combined capacity of 932.312 billion m^3.



There are 1,940 water quality monitoring sections of national surface water, according to ‘Bulletin of Chinese ecological environment’ in 2017,

- I- II-III level water quality account for 67.9%, used for water supply resources
- IV-V and below V level, account for 32.3%
- eutrophic lakes account for 29.5%

Water Pollution Control

Water Quality Improvement

Ecological Conservation

Objects：2020-2035

Water Quality highly improved, Treatment System and Management Regulation Modernization

- Ecological Civilization, Water Pollution Control Law
- Comprehensive regulation of landscape, forest and lake
- National Action Plan for Pollution Control
- National Strategy: Economic Belt of the Yangtze River; Coordinated Development of Beijing, Tianjin and Hebei, The Belt and Road Initiative

Strategies: Integrated river and lake water pollution control and environmental management

- Water Function Division System Planning：A two-level categories, to construct the criteria of water quality and to manage the water environment according to the main function of the water body
- Water Quality Monitoring：to know the water quality of the rivers and lakes in real-time
- Strategy of Water Pollution Control：“Pollution Sources Control - Sewage Interception—pollutants treatment - system restoration”

  Point Pollution Control

  Non-point Pollution Control (Agricultural, Urban runoff,,)

  Water Diversion

  ……..

2. Key Technologies and Theory of Pollution Control

2.1 Waste water treatment and resource reuse

(1) Pollutants removal and resource utilization in municipal wastewater

- Sustainable nitrogen and phosphorus removal technologies
- Resource utilization in sewage sludge

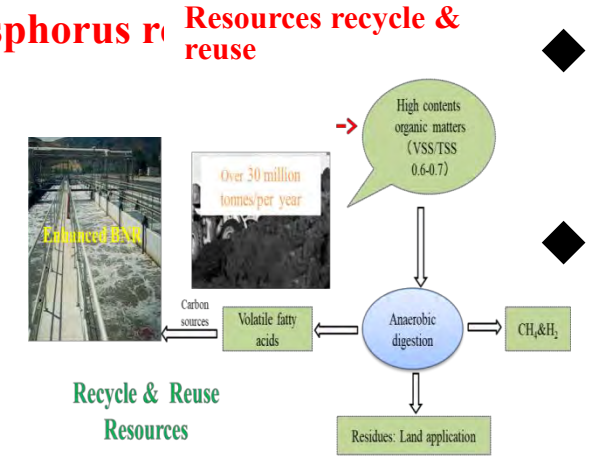
Revealing key factors on nitrogen and phosphorus r

Optimizing wastewater treatment system

Optimized oxidation

Bio-Dopp process in Chengbei WWTP

MBR in Qishuyan WWTP



- How to improve the N and P removal?
- Optimized Hydrodynamic conditions for high effect

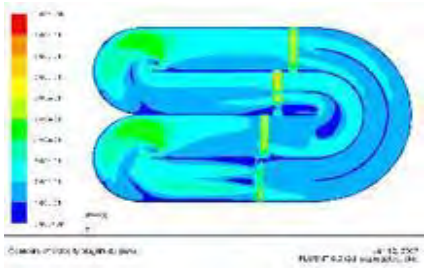
(2) Purification technology and equipment for dispersed residential sewage and aquaculture wastewater

- Function microbial cultivation to improve the N and P removal
- The theory of biotechnology

Jiashun Cao, et al. Water Research , 2017 ;
You et al., Critical Reviews in Environmental Science and Technology, 2017;
Jia-Shun Cao, Jun-Xiong Lin, Fang Fang, et al. Bioresource Technology, 2014

(3) Diagnosis and optimization of wastewater treatment process

- **Biological process simulation and optimization**
- **Hydrodynamics simulation and optimization for wastewater treatment**



Hydrodynamic simulation of oxidation ditch

Biological process simulation of A2/O

Ecological embankment for purifying runoff in Qinhuai river

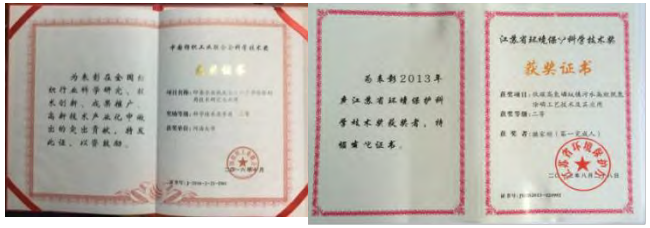
(4) Non-point source pollution control in urban areas

- **Rain Harvesting and utilization**
- **Design of sustainable drainage system**
- **Low impact development**
- **Characterization of rain, storm run-off and Combined Sewer Ov**

The rain collection ditch in the ancient zone of Suzhou

Awards:

- Second prize of National Scientific and Technological Progress
- First prize of Scientific and Technological Progress in Jiangsu Province



Yusheng Li; Jiashun Cao, et al. Environmental Science & Technology Letters. 2016.
Fang Fang et al., Environmental Pollution , 2016

Over 100 publications

Over 30 Patents

2.2 Agricultural non-point pollution control and river water quality improvement

- **TP and TN discharged by agricultural non-point source accounted for 67% and 57% in the river and lake water body of China; making them the major pollution source.**

- China's per capita water resources is only a quarter of the world's.
- The annual agriculture water consumption per ha is more than twice that of developed countries.

	Fertilizer	Pesticide
The world's average	131 kg/ha	7 kg/ha
China's average	464 kg/ha	15 kg/ha
Downstream of the Yangtze River	661 kg/ha	20 kg/ha

Excessive fertilization and unreasonable irrigation resulted in the agriculture non-point pollution and eutrophication in the Taihu Lake.

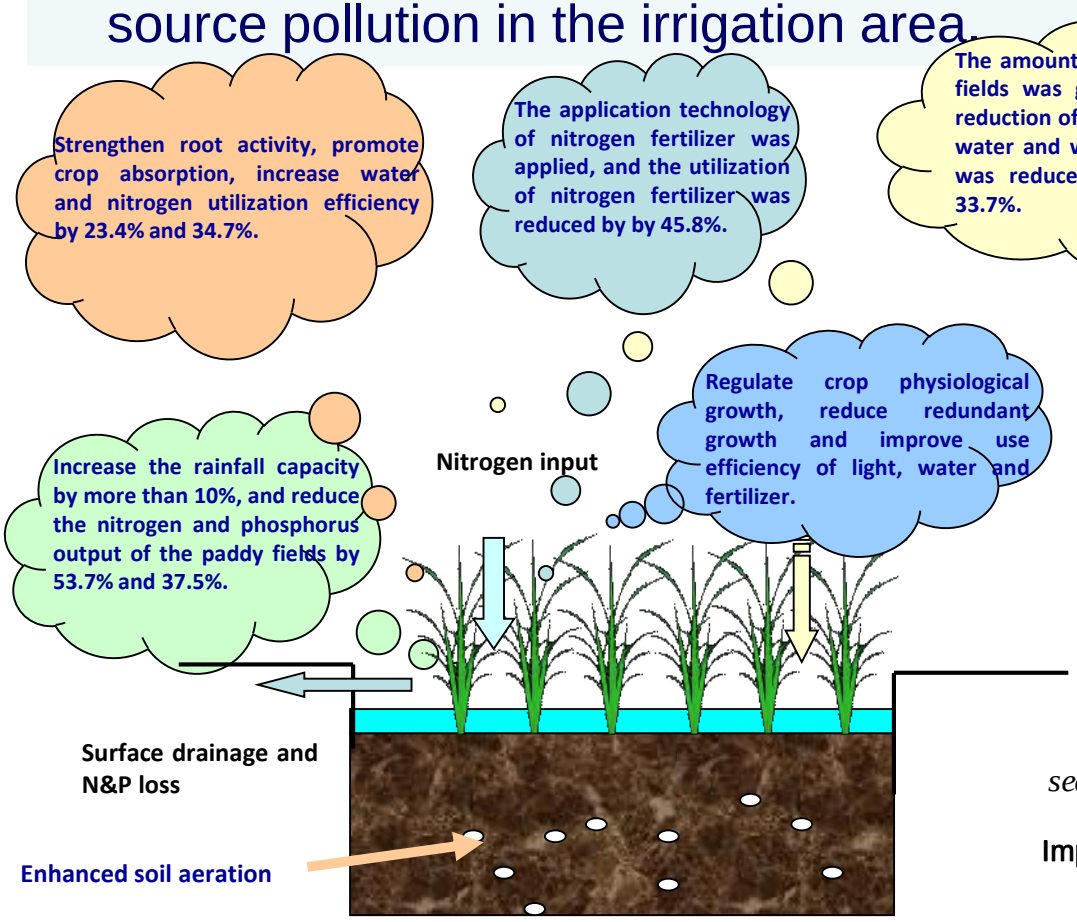
Contents:

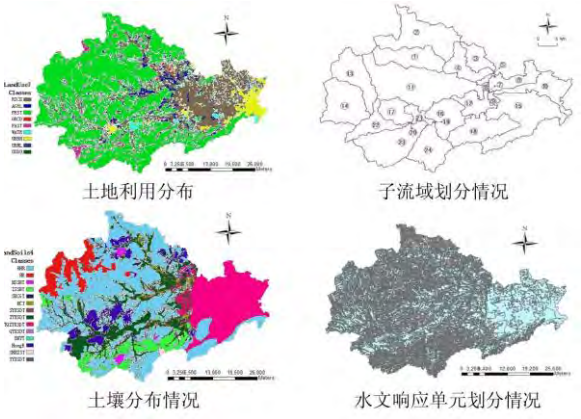
- Water saving and pollution reducing
- Cascade control
- Environmental management

Highlight 1：Synergetic theory of farmland water saving and non-point source pollution control;
Highlight 2：Irrigation and drainage pattern of water-saving and pollution-reducing;
Highlight 3：4 defense lines, including pollution source reduction, riparian and surface wetlands construction along ditches and rivers;
Highlight 4：Intelligent monitoring and optimizing decision-making system.

(1) Generation mechanism and transport model of non-point source pollutants under water-fertilizer regulation

- Our study quantitatively reveals the generation mechanism and transport & transformation process of non-point source pollutants under different water and fertilizer regulation
- Establishing the simulation model of production and loss of non-point source pollution in the irrigation area.





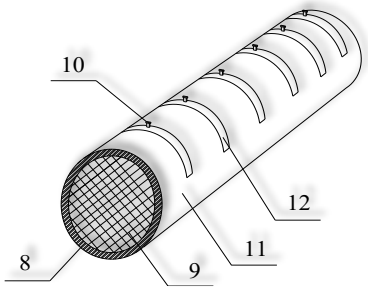
$$SW_t = SW_o + \sum_{i=1}^{i}\left(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{lat} - Q_{gw}\right)$$

$$sed = 11.8(Q \times q_{peq} \times area_{hru})^{0.56} \bullet K \bullet C \bullet P \bullet LS \bullet CFRG$$

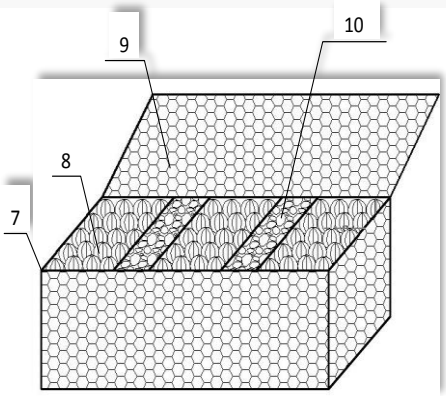
Improvement of calculation structure of non-point source pollution simulation model.

(2) Key technology - Source control technology and equipment

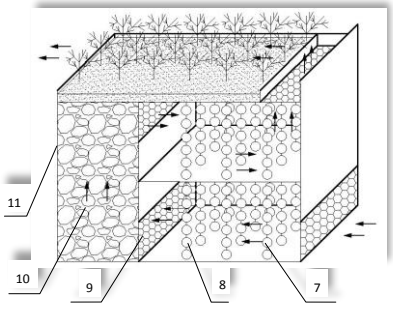
- By using the self-developed porous carrier and high efficiency net pollution coating, water quality enhancement purification device was developed for the first stage of farmland back water
- Portable water purifier and compound artificial wetland purification box were developed to prevent and control non-point agricultural pollution from the source.



Water purification device for the first stage of farmland back water
ZL 201410215464.4

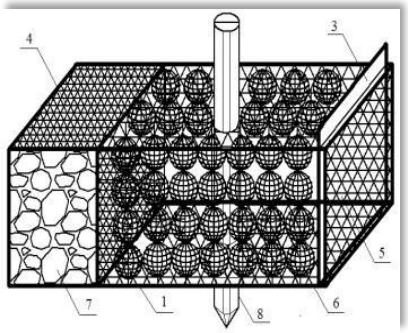


Portable water purifier
ZL 201310283010.6



Compound artificial wetland purification box
ZL 201310283007.4

Three core technologies, such as portable water purifier, were selected into the advanced technology catalogue of water conservation, pollution prevention and water ecological restoration (2015) jointly prepared by the ministry of science and technology and the ministry of water resources.



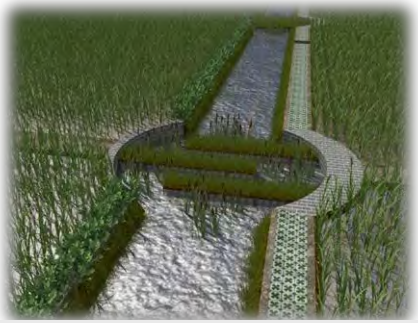
Water purifier equipped on the farmland ridge
ZL 201410068237.3

(3) Construction technology of riparian and surface wetlands along ditches and rivers system in the agricultural area

In order to resolve the insufficient drainage time and low ability of channel purification, flat ladder wetland by drains and multi-stage series 'pearl chain' wetlands were developed and decreased 23%-60% TN and TP;

By using the depression structure of ponds and beheaded rivers, field drainage and purification wetland unit in ditches were developed with a reduction of TN and TP by 42%-63%;

Construction of multilayer composite plant purifying zone in dry ditches and river water were applied as the fourth defense system with the reduction of TN and TP by 10%-20%.

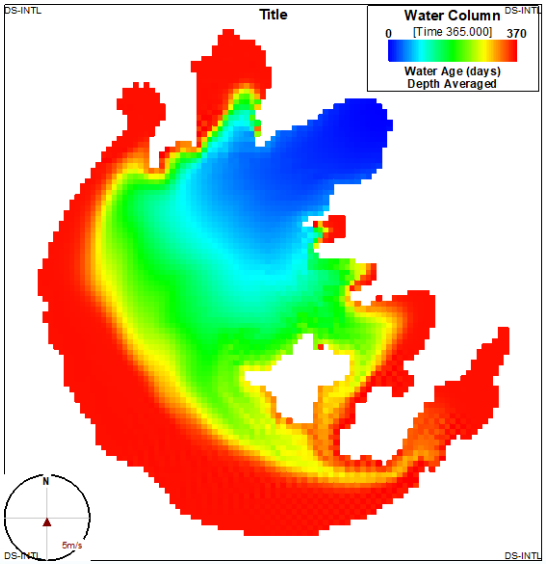


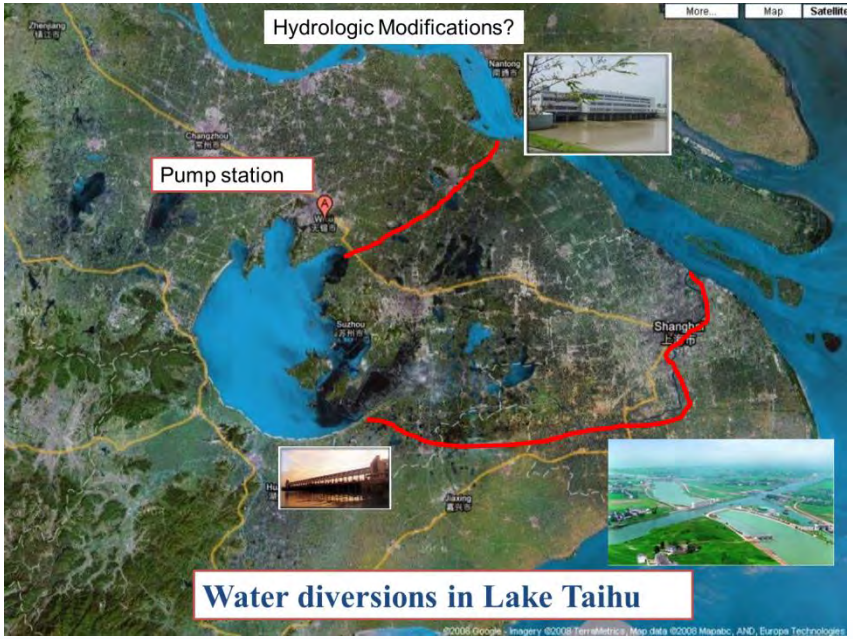

Important breakthroughs were made in solving the synergetic aspects of dry ditch, river drainage and ecological function.

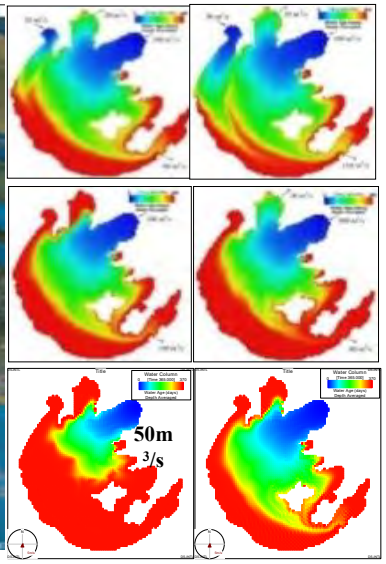
Awards: the first prize of Natural Science of Ministry of Education , 2013
the first prize of National Science and Technology Progress , 2016

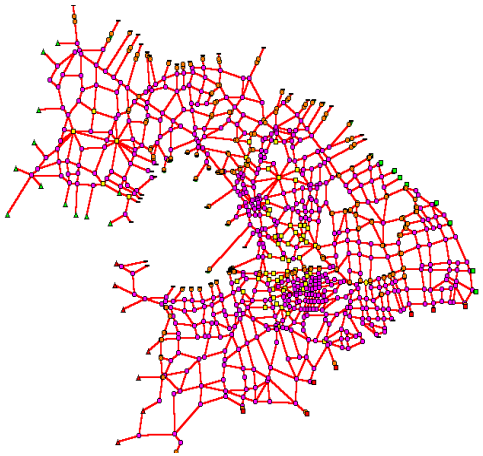
2.3 Water diversion for quality improvement in river networks and lake areas

- Water transfers driven by human activities are important measurement to regional water quantity and quality changes.
- The research difficulties lie in the suddenness and variability of lake hydrodynamic process and internal and external source pollution.









太湖流域模型概化河网图

- Develop multi-elementary module coupling air, water body, and sediments, parameterize key process for sediment release and algae growth.
- Improve the theory of multiple targets for optimizing ecological water transfer and the mechanism of changed limiting factors for nutrients, developing water quantity and quality optimizing technology during water transfer in river network of plain areas.
- Develop ecological models coupling water dynamic and water quality for river basin, river network of plain areas, and lakes.

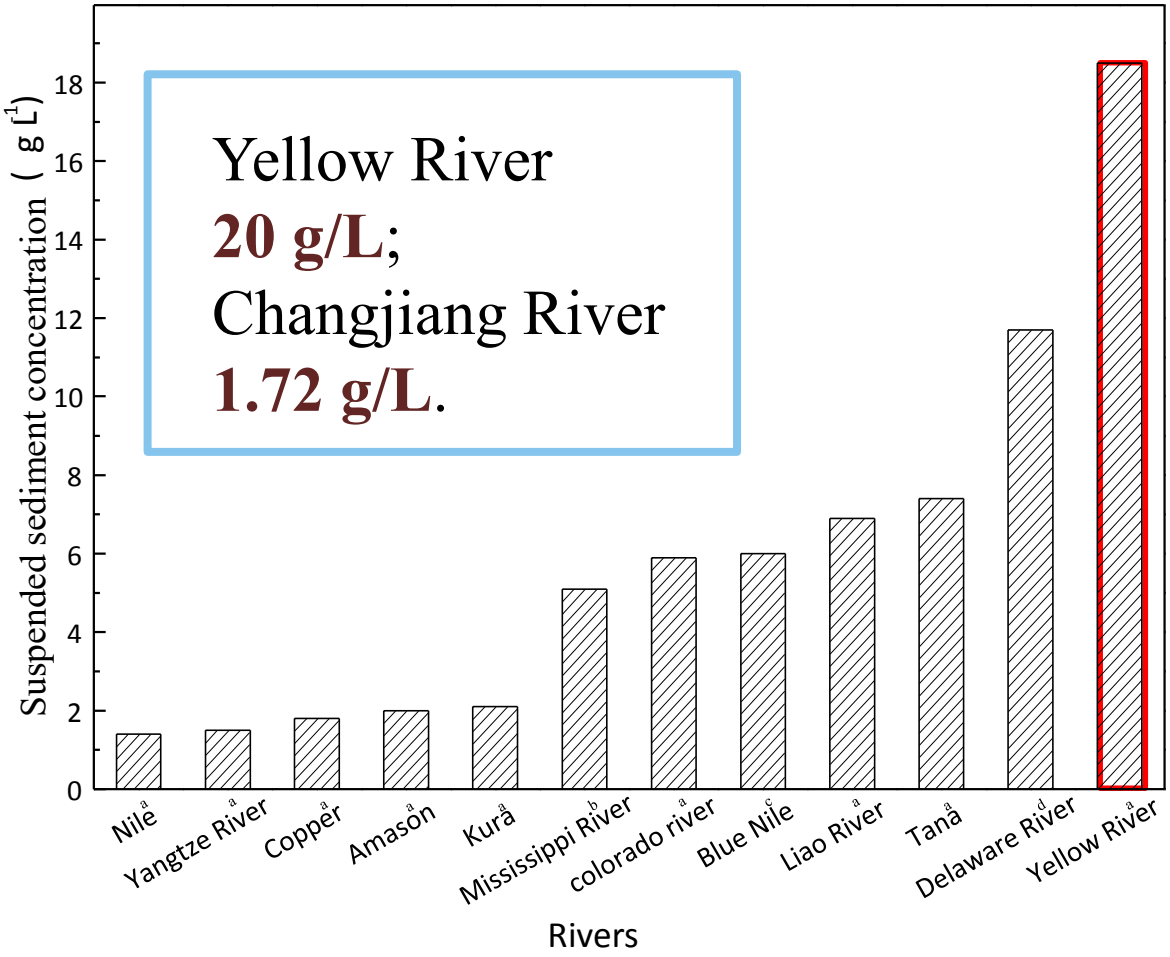
3. Hot Topic of Water Environment Scientific Research

High suspended sediment (SPS) concentration

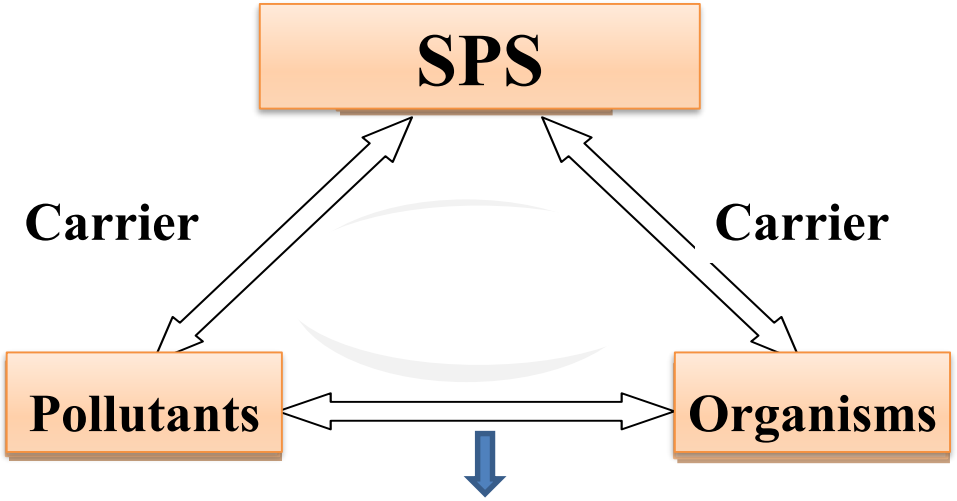
The SPS concentrations in most rivers of China are 10-1000 times of those in other countries

Mississippi River
5.1 g/L;
Delaware River
0.1~11.7 g/L.

Yellow River
20 g/L;
Changjiang River
1.72 g/L.



Effects of SPS on water quality



Growth of microorganisms
Existing forms of pollutants
Bioavailability of pollutants
Transformation of pollutants
Water quality assessment

Effect of suspended sediments on the transportation, transformation and bioavailability of contaminants in aquatic systems

- **Effects of SPS on the transformation of nitrogen and phosphorus**
- **Effects of SPS on the bioavailability of HOCs**

Effects of SPS on the transformation of nitrogen

The distribution and sources of nitrogen compounds in river systems (^{15}N, ^{17}O, ^{18}O)

↓

Effect of suspended sediment on the transformation of nitrogen compounds in river systems

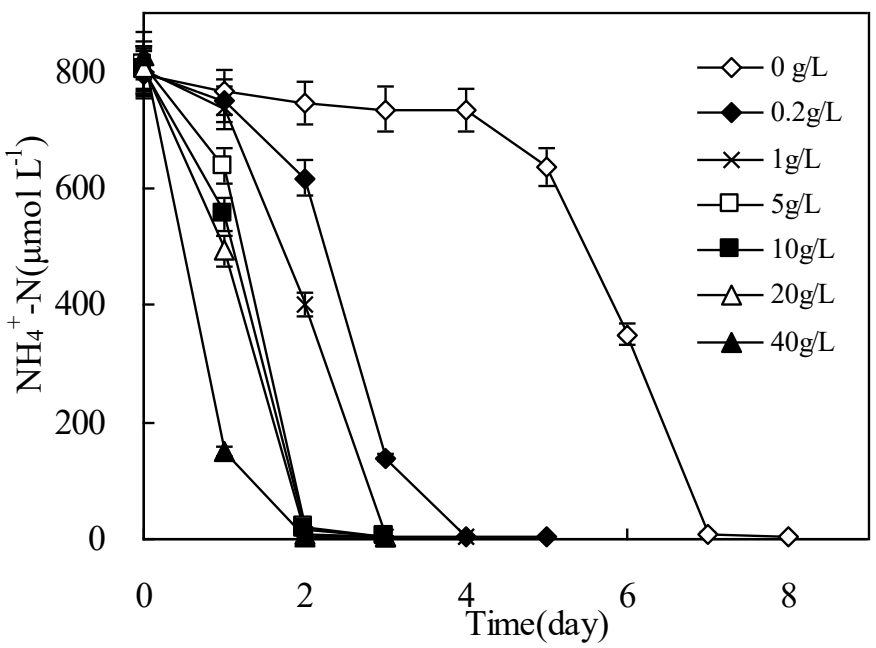
↓

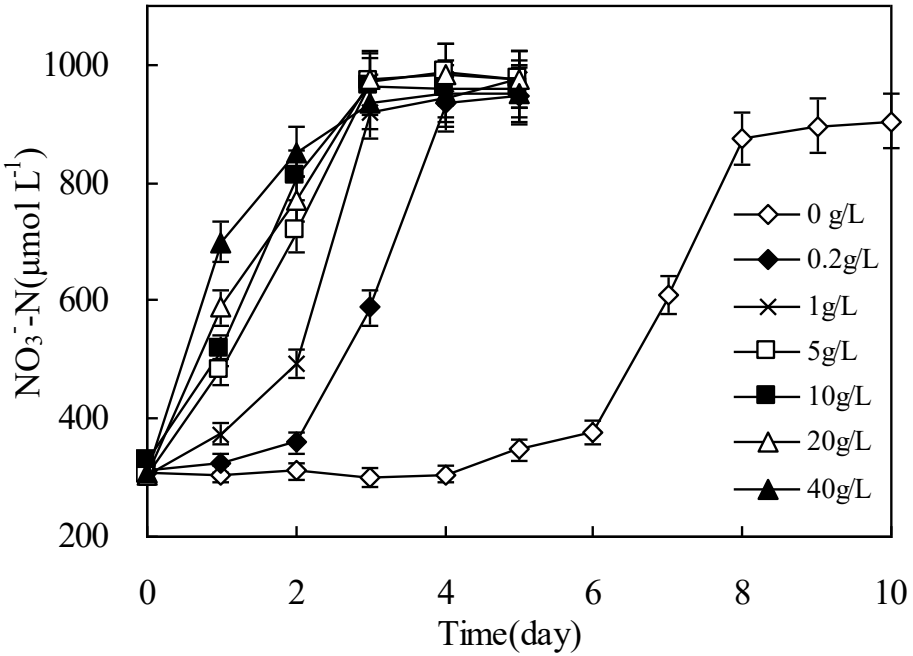
Sorption | ammonification | nitrification | denitrification

Effect of SPS concentration on nitrification rate

(with indigenous microorganism)

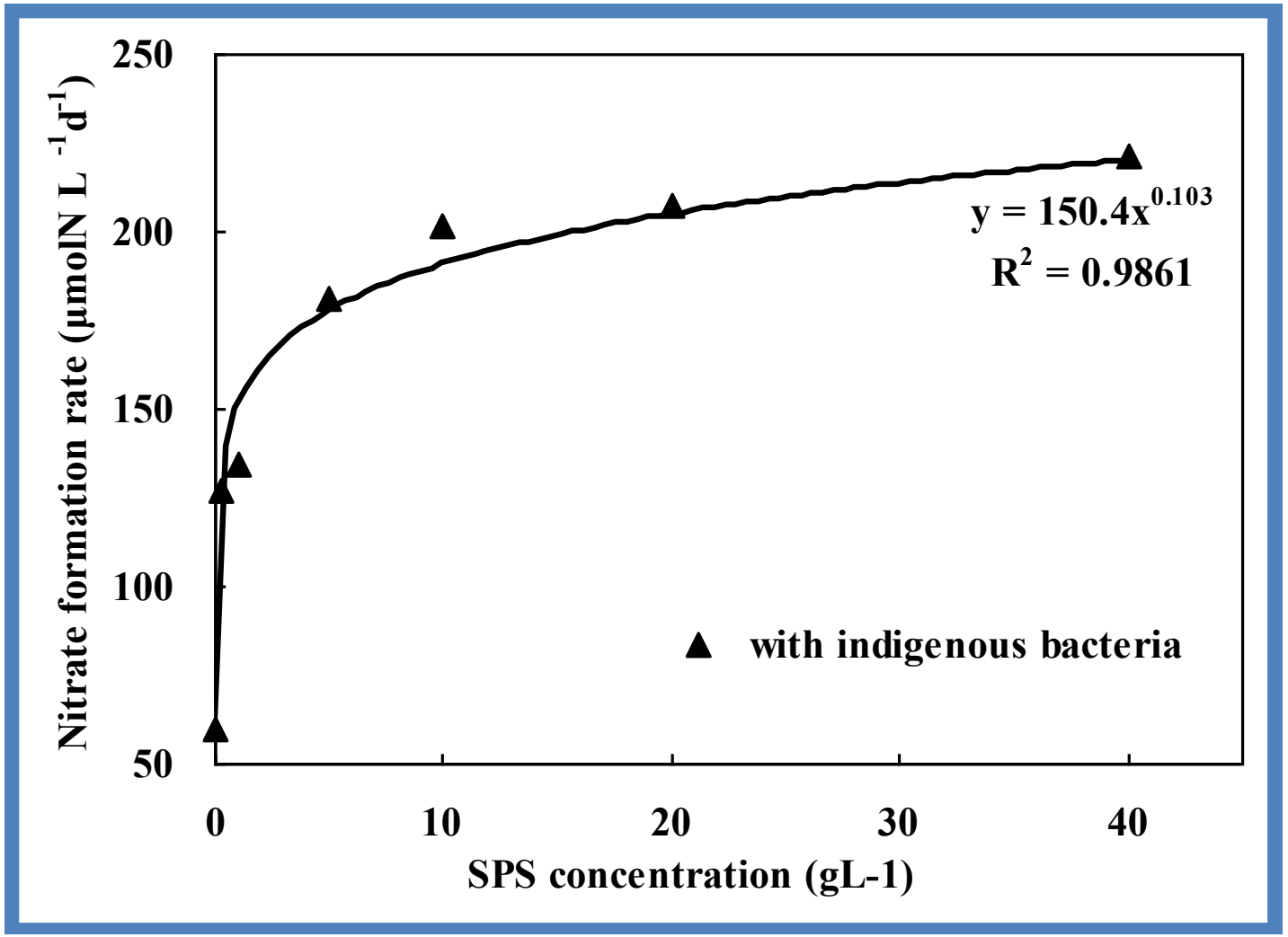
ammonia－nitrite－nitrate





- **Nitrification rate increased with the SPS concentration.**

Xia et al., ES&T, 2009

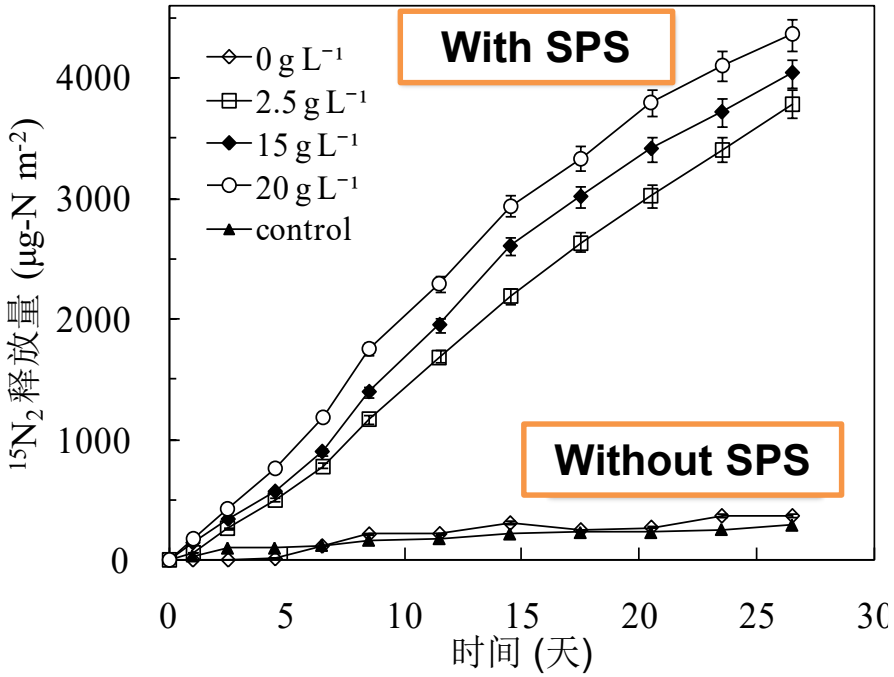


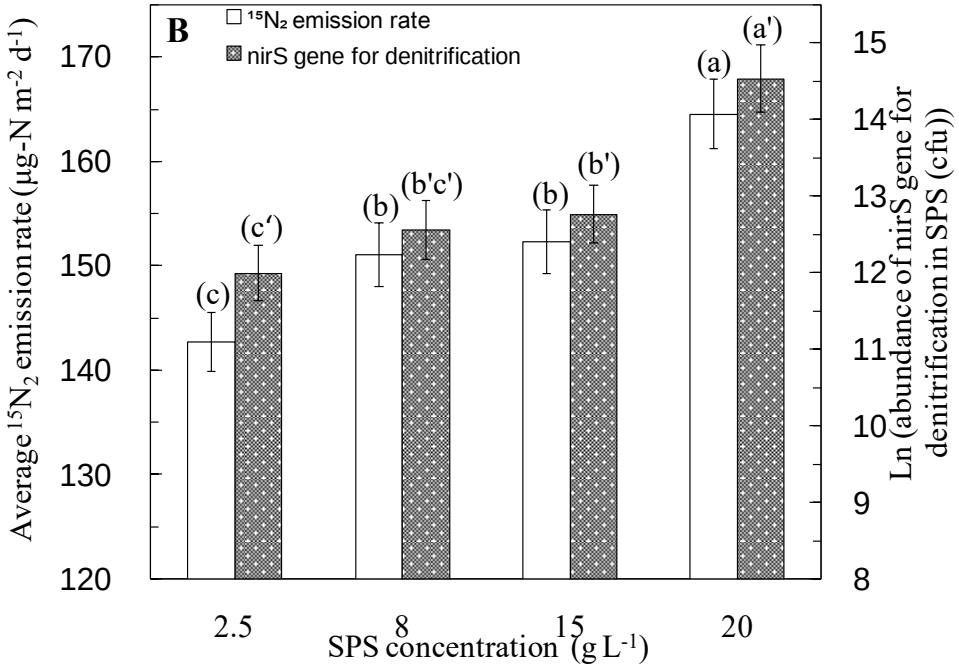
The average nitrification rate for the first three days increased with SPS concentration as a power function.

Effect of SPS on denitrification in overlying water of rivers

Effect of SPS on denitrification in oxic overlying water：

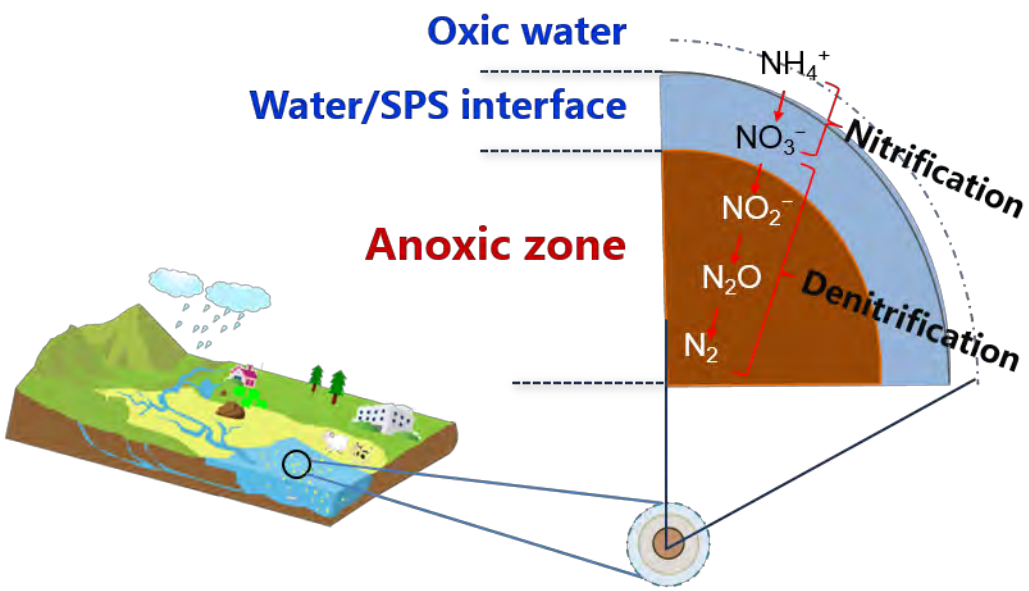
Denitrification can occur in the oxic overlying water with SPS





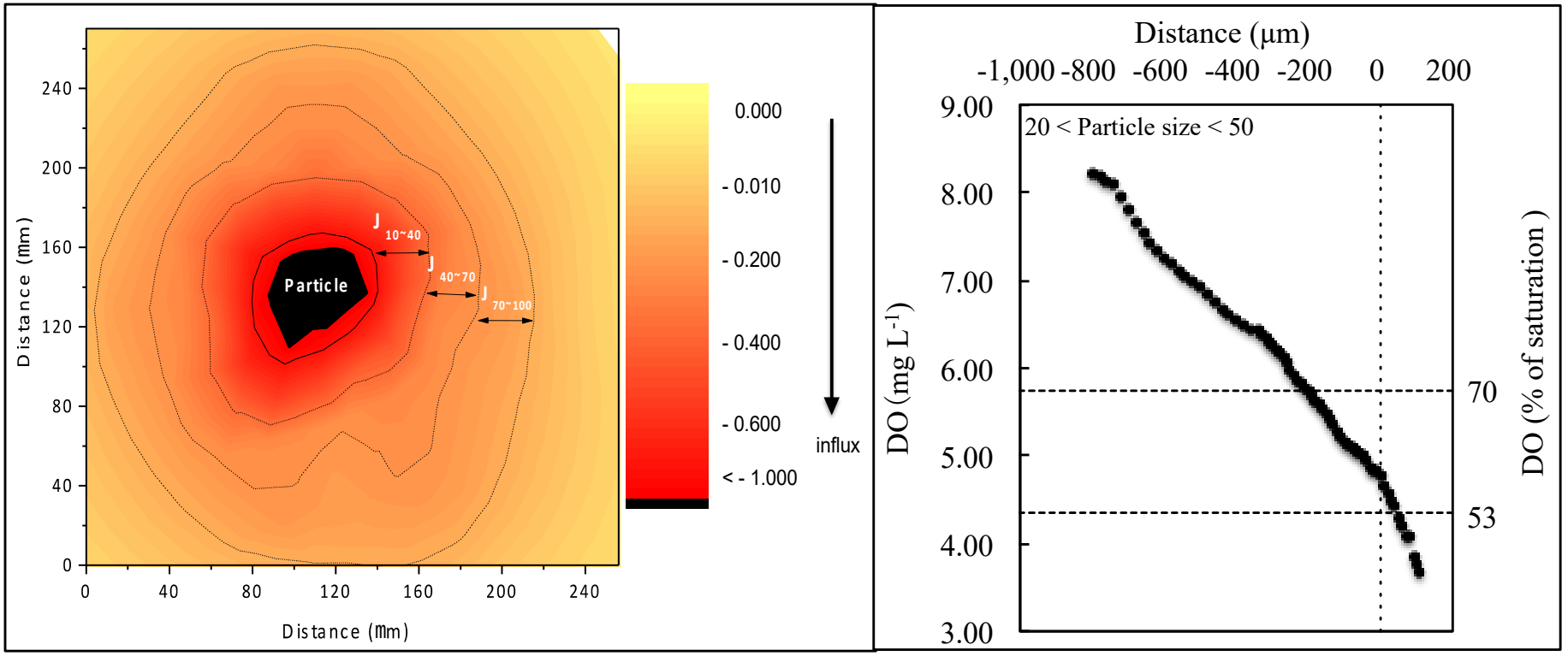
^{15}N labeling experiment results

Liu and Xia et al., ES&T, 2013



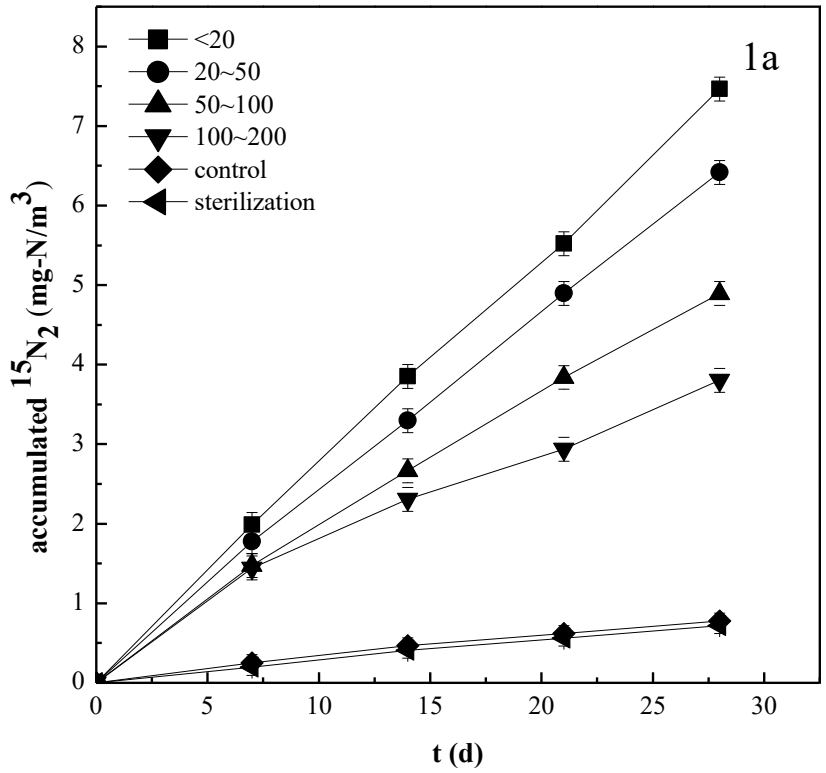
- ✓ Oxygen consuming caused by organic matter decomposing associated with SPS
- ✓ Microorganism respiration associated with SPS
- ✓ Uneven distribution of oxygen caused by SPS

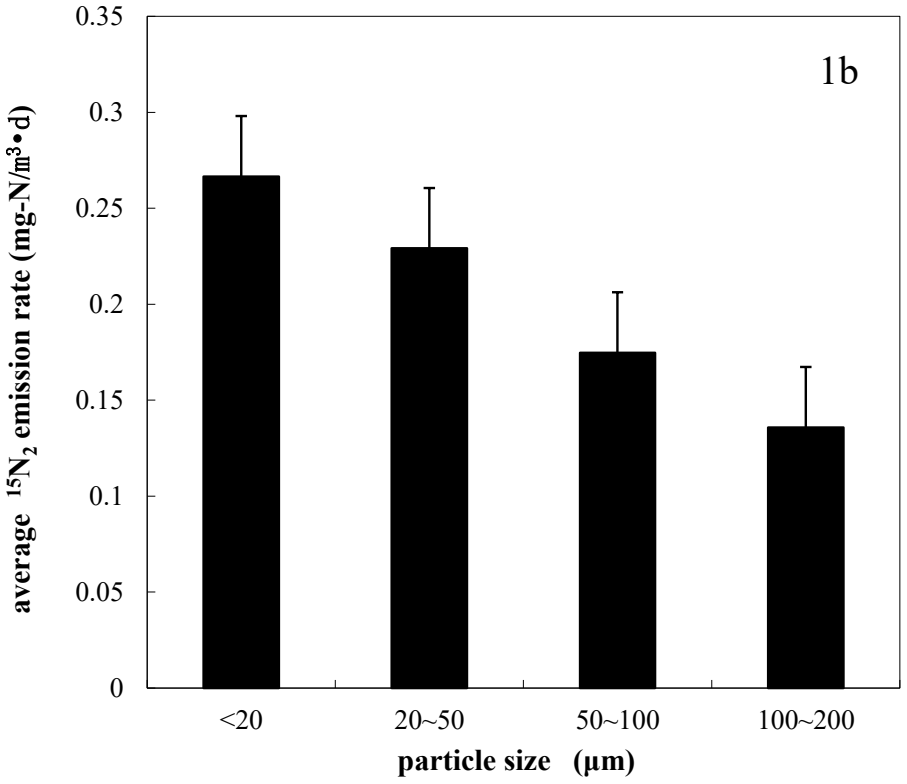
- **The anoxic/low oxygen conditions around SPS leads to the occurrence of denitrification in the oxic overlying water with SPS.**



- **DO concentration decreased from the outside to the inside of SPS.**

With ^{15}N-NO_3 labeling experiment, the N_2 and N_2O emission rates during denitrification

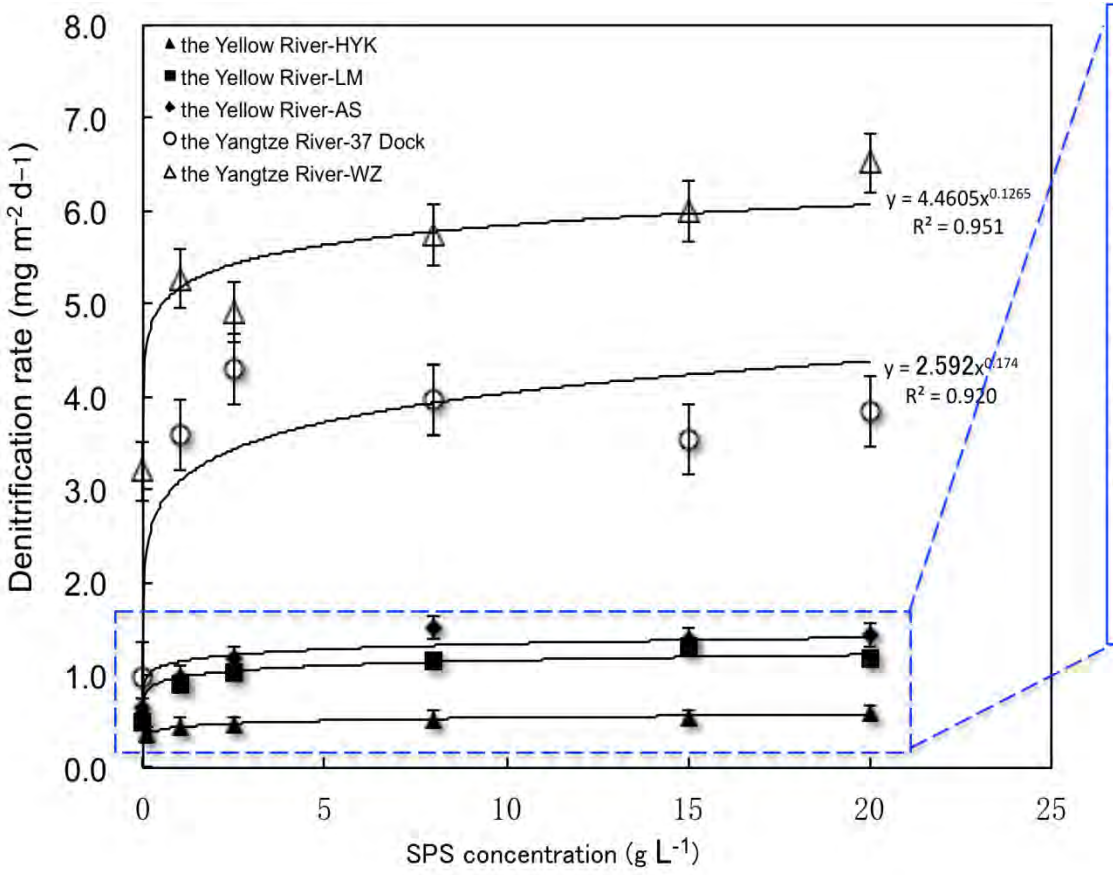


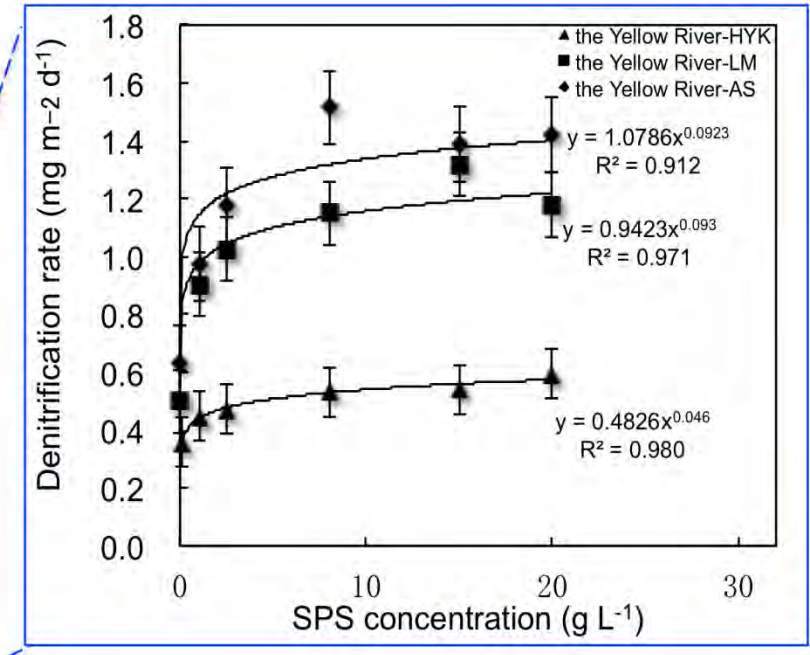


- Denitrification rate was negatively correlated with SPS particle size;
- The emission rate of $^{15}N_2$ was the highest for <20 μm SPS, and it was twice that of 100–200 μm SPS.

Xia et al., ES&T, 2017

Effect of SPS on coupled nitrification-denitrification in rivers



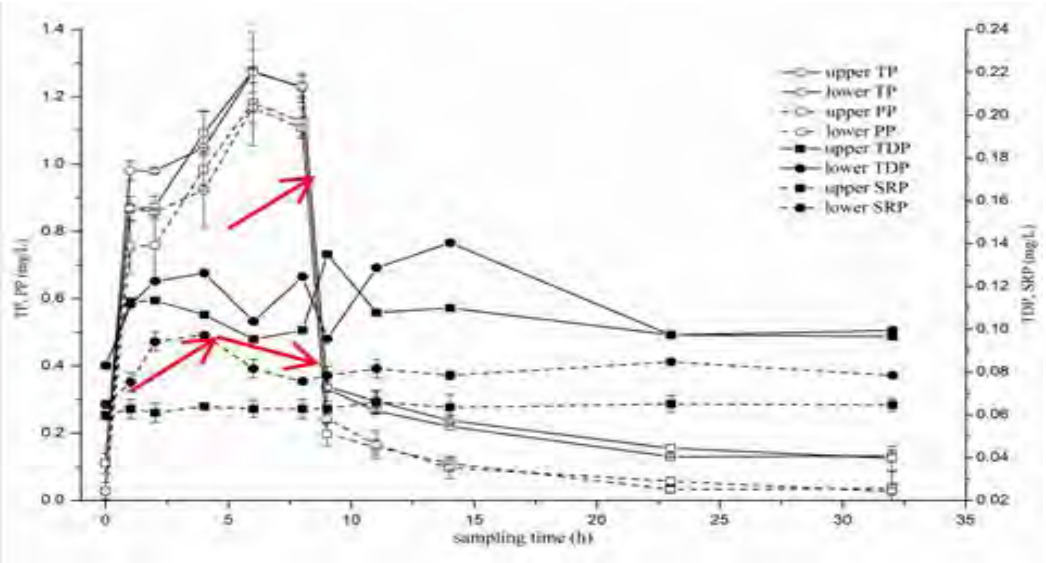


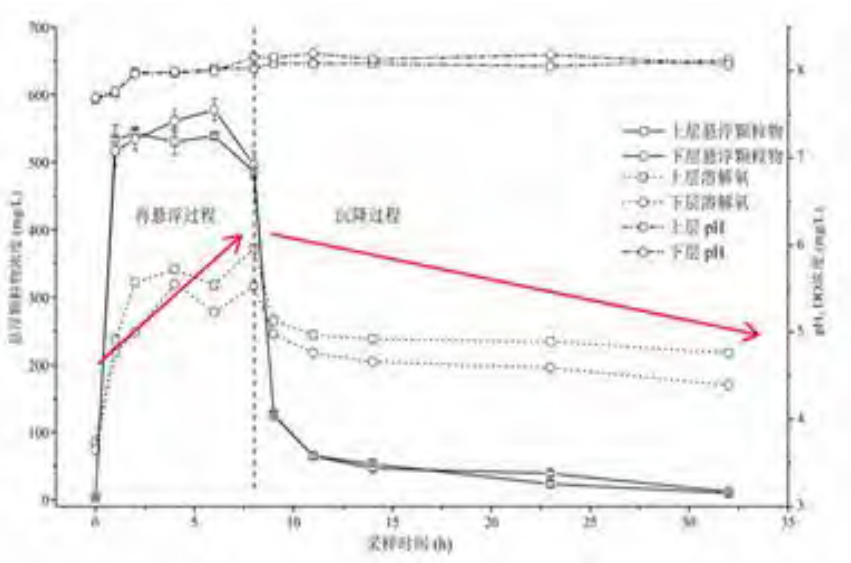
Bed sediment-Suspended sediment-Water system

- $^{15}N_2$ production rate from $^{15}NH_4$ increased with SPS concentration as a power function ($y=a \cdot [SPS]^b$).

Xia et al., Science of the Total Environment, 2017

Effect of SPS on Phosphorous Transformation (during the sedimentation and resuspension)

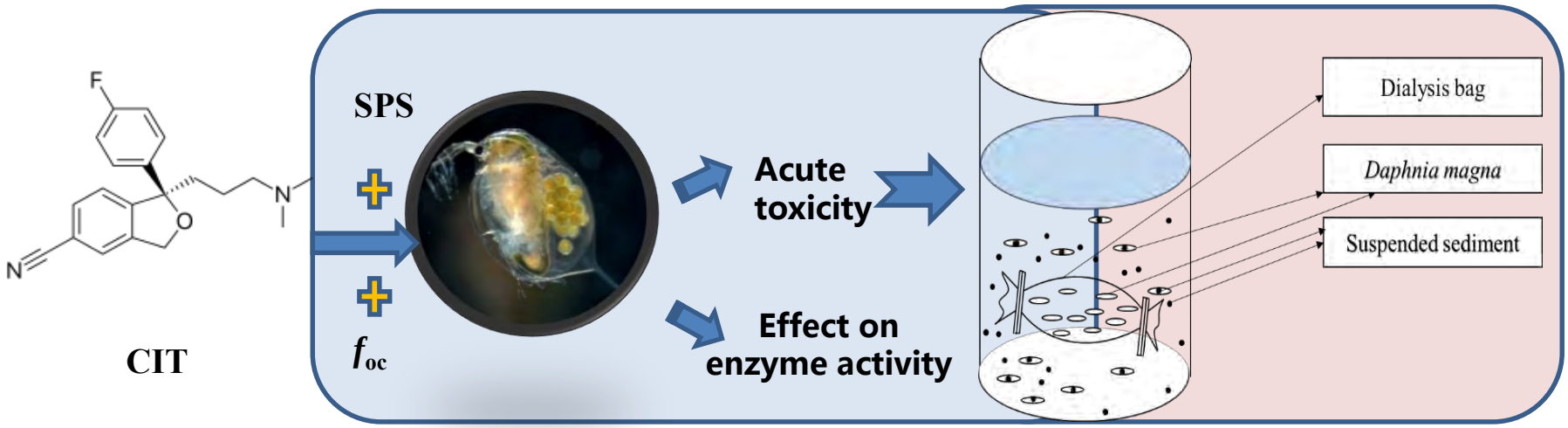




- The content of particulate phosphorus (PP) and total phosphorus (TP) decreased sharply along with sedimentation of SPS;
- The oxygen enrichment caused by sediment resuspension could promote the formation of amorphous oxides and subsequent adsorption of phosphorus ;
- sedimentation could promote the transformation of phosphorus from mobile forms to non-mobile forms.

Wang et al., Environmental Science and Pollution Research, 2015 ;
Hu Bin, Wang Peifang, Wang Chao , Environmental Pollution, 2017*

Effect of suspended sediment (SPS) on the biotoxicity of citalopram (CIT)



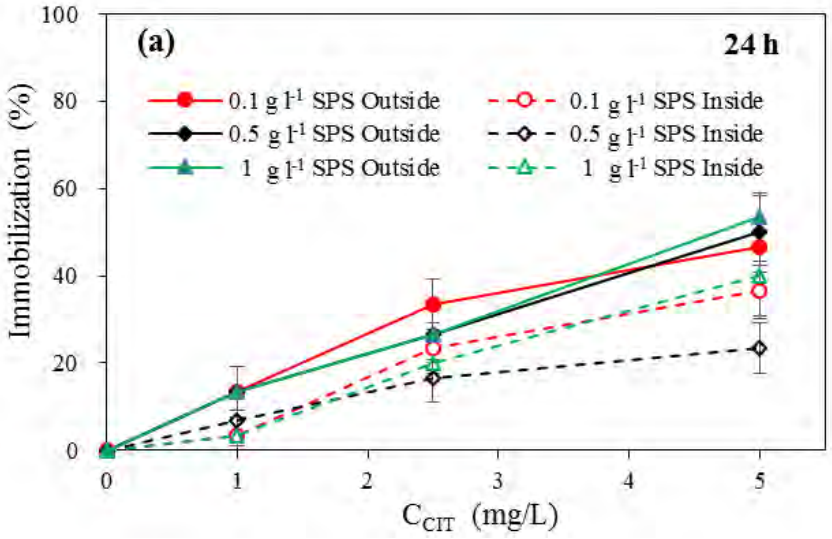
Keep the total concentration of citalopram being constant in water-SPS system

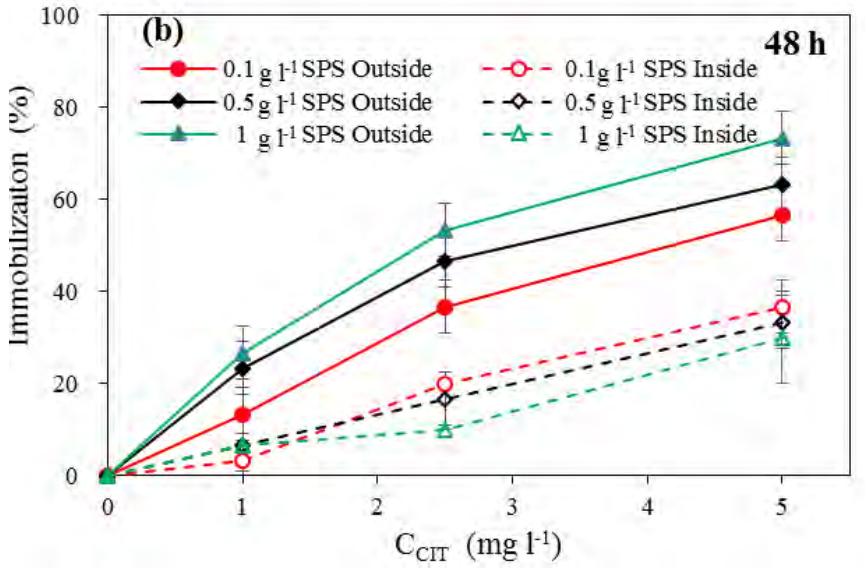
SPS has affected the distribution of CIT :

SPS reduces CIT concentration in water through adsorption

f_{oc} in SPS reduces the concentration of dissolved CIT in water

Effect of suspended sediment (SPS) on the biotoxicity of citalopram (CIT)





Keep the dissolved concentration of citalopram being constant in water-SPS system

- **SPS promotes the biotoxicity of CIT in *Daphnia magna***
- **SPS reduces the ability of organisms to remove free radicals.**

$$\text{Contribution ratio of pyrene sorbed on SPS to the total immobilization (\%)} = \frac{\text{Immobilization caused by pyrene sorbed on SPS}}{\text{Immobilization caused by total pyrene in the system}} \times 100$$

	Yangtze River		Yellow River	
	0-50μm	50-100 μm	0-50μm	50-100 μm
Total immobilization caused by total pyrene in water-SPS system (%)	**48.9**	**64.4**	**35.6**	**46.7**
Immobilization caused by pyrene sorbed on SPS (AOC+BC+minetal) (%)	**30.9**	**46.4**	**17.6**	**28.7**
Contribution ratio of pyrene sorbed on SPS to the total immobilization (%)	**63.2**	**72.1**	**49.4**	**61.4**
Bioavailable fraction of pyrene sorbed on SPS (%)	**19.9**	**45.2**	**17.0**	**33.2**

Contribution ratio of pyrene sorbed on the SPS to the total immobilization (SPS=1g/L)

Zhang and Xia et al., ES&T, 2015

Bioavailable fraction of pyrene sorbed on various components:

AOC > mineral > BC

Bioavailable fraction (%)	Yangtze River		Yellow River	
	0-50μm	50-100 μm	0-50μm	50-100 μm
Bioavailable fraction of pyrene sorbed on AOC	**32.5**	**67.3**	**22.4**	**49.6**
Bioavailable fraction of pyrene sorbed on BC	**11.8**	**16.8**	**10.2**	**9.11**
Bioavailable fraction of pyrene sorbed on mineral	**20.1**	**46.0**	**21.0**	**41.3**

Xia et al., Environmental pollution, 2016

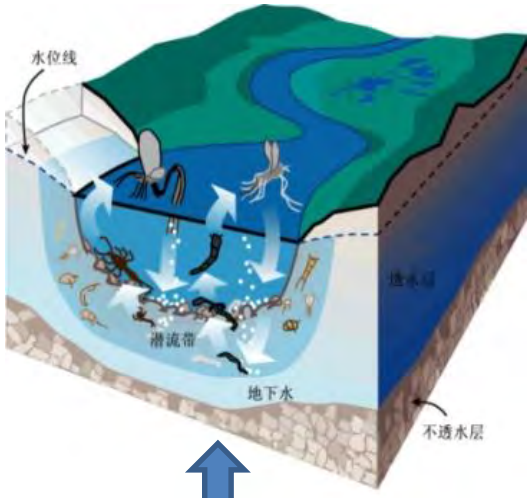
Normally, the concentration of HOCs in the water phase, which can pass through the 0.45 μm filter membrane, is used to conduct water quality assessment.

- The results suggest that the HOCs associated with SPS should be considered for the accurate estimation of HOC toxicity and establishment of water quality criteria for HOCs in natural waters, especially for the rivers with high SPS concentrations.
- In addition to SPS concentration, both the composition and grain size of SPS should be taken into account in the water quality assessment.

Future Study

Human activities (dams and reservoirs) climate change

Source



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Mass Flux

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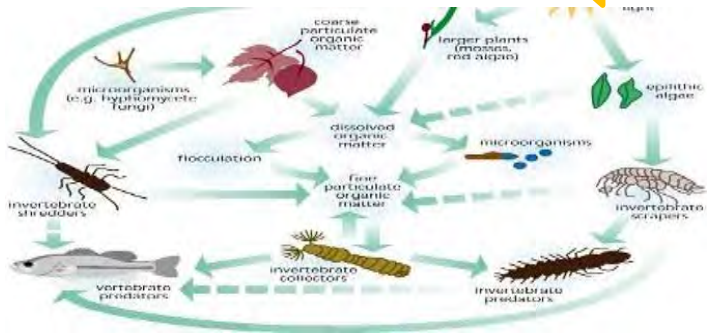
- ✓ Contaminants： Nutrients； Heavy Metals; ECs; Nano-particles…..
- ✓ “ground water-Surface water-SPS-sediment ”



Water Ecosystem

Research content

Research focus and key innovation

- Study area：Jinsha River, Lancang River, Yaluzangbu River in southwest China; Yangzte River and Yellow River and its estuary;
- Cumulative effect of runoff: Hydrology, water temperature, hydrodynamics, microorganism;
- Environmental cumulative change: Transport and transformation of C, N, P, Si and heavy metals, organic pollutants in river-reservoir systems;
- Bioaccumulation effect: Effect Mechanism of microbial community and functional bacteria on material transformation

Supporting projects

- Key Program of National Natural Science Foundation of China
- General Program of National Natural Science Foundation of China
- National Key Plan for Research and Development of China

Hot Topics

- **Multi-media interface migration and transformation of emerging contaminants: in situ passive sampling（pst）and quantitative detection technologies**
- **Bioavailability and ecotoxicological effects of typical pollutants: combining the active and passive biological monitoring methods**
- **Ecological risk assessment of complex polluted water environment**
- **Degradation and removal mechanism of emerging contaminants in water: achieving rapid and efficient degradation**

Thank you for your attention !