Wetland systems to support quality protection and restoration in urban waterways

人工湿地在城市水系水质改善和保障的应用及案例

Mawuli Dzakpasu, Yucong Zheng, Xiaochang Wang

内容提要 Outline

- 研究背景 Background of research work
- 人工湿地污染河水处理中试 Pilot CWs for polluted river water treatment
- 污染河水处理大型人工湿地建设 Large CW system for polluted river water treatment
- 结语 Concluding Remarks

研究背景
Background of research work

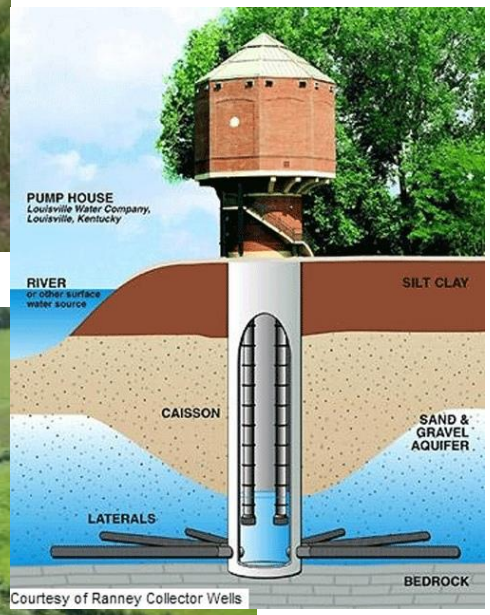
Drivers of urban rivers pollution in China

- Population growth, urbanization, economic development
- Inadequate urban sewerage infrastructure
- Discharge of municipal and industrial wastewater without sufficient treatment
- Climate change

- severe pollution and destruction of the ecological environment along waterways
- ~37 % rivers are polluted and unsuitable as source water for drinking water production (MEP, 2012)

研究背景
Background of research work

Natural treatment of water and wastewater



Benefits of integration of NWTS within the urban environment:

- promote sanitation
- increase the amount of green spaces
- enhance the quality of living

研究背景
Background of research work

Wetlands for water and wastewater treatment

Constructed wetlands (CWs)

- Traditional CWs
  - Free water surface flow CWs (FWS CWs)
  - Subsurface flow CWs (SSF CWs)
    - Horizontal flow CWs (HF CWs)
    - Vertical flow CWs (VF CWs)
- Hybrid CWs
  - VF-HF CWs
  - HF-VF CWs
  - HF-FWS CWs
  - FWS-HF CWs
  - Multi-stage CWs
    - VF-VF-HF CWs
    - VF-HF-FWS CWs
    - VF-HF-VF CWs
    - … …
- Enhanced CWs
  - Artificial aerated CWs
  - Baffled flow CWs
  - Hybrid towery CWs
  - Step feeding CWs
  - Circular flow corridor CWs
  - … …

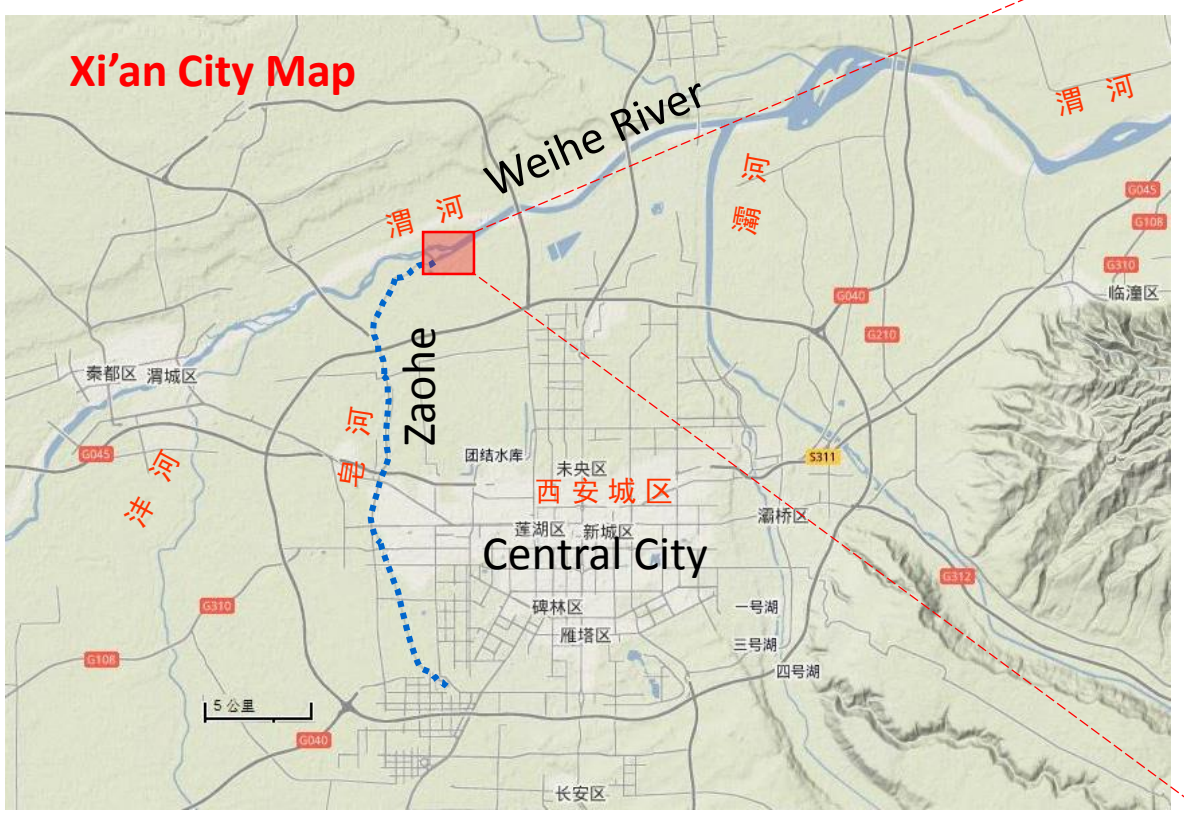
研究背景
Background of research work

Wetlands for water and wastewater treatment

- Gather experience in adopting optimal system configurations, operation parameters, and seasonal changes of performance for the polluted urban rivers in China

研究背景
Background of research work

- 浐河：直排渭河的城市纳污河道 Zaohe – an urban drainage to Weihe River



研究背景
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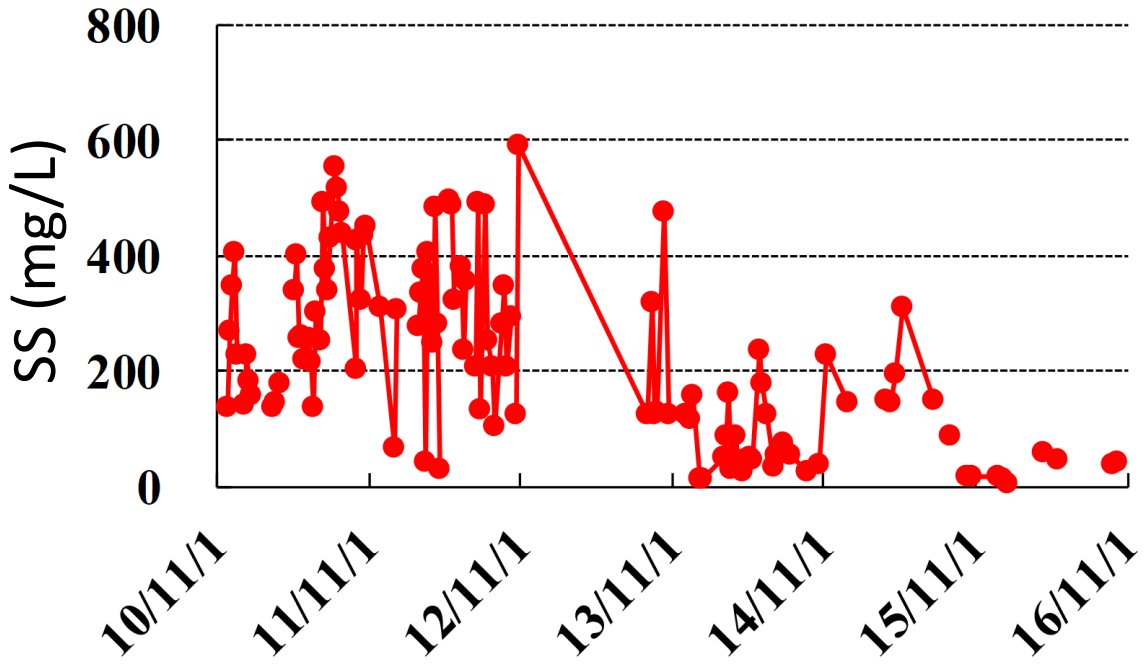
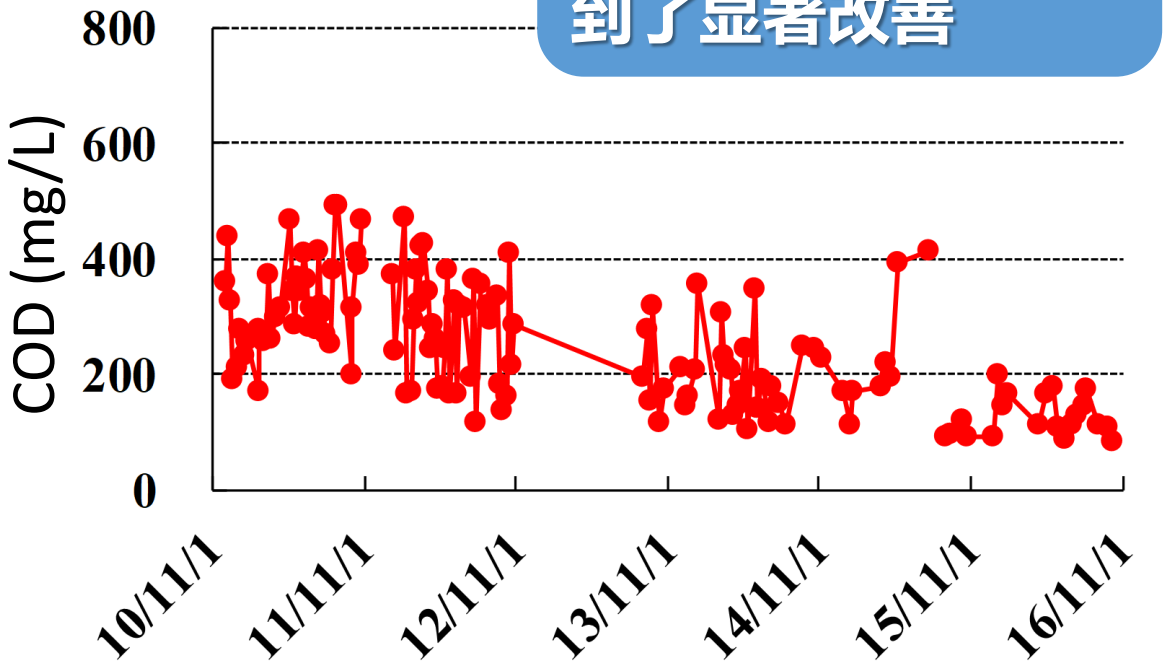
- 皂河：直排渭河的城市纳污河道 Zaohe – an urban drainage to Weihe River

研究背景
Background of research work

- 滱河水质 Zaohe water quality

基于城市污染治理，近年来皂河水质得到了显著改善





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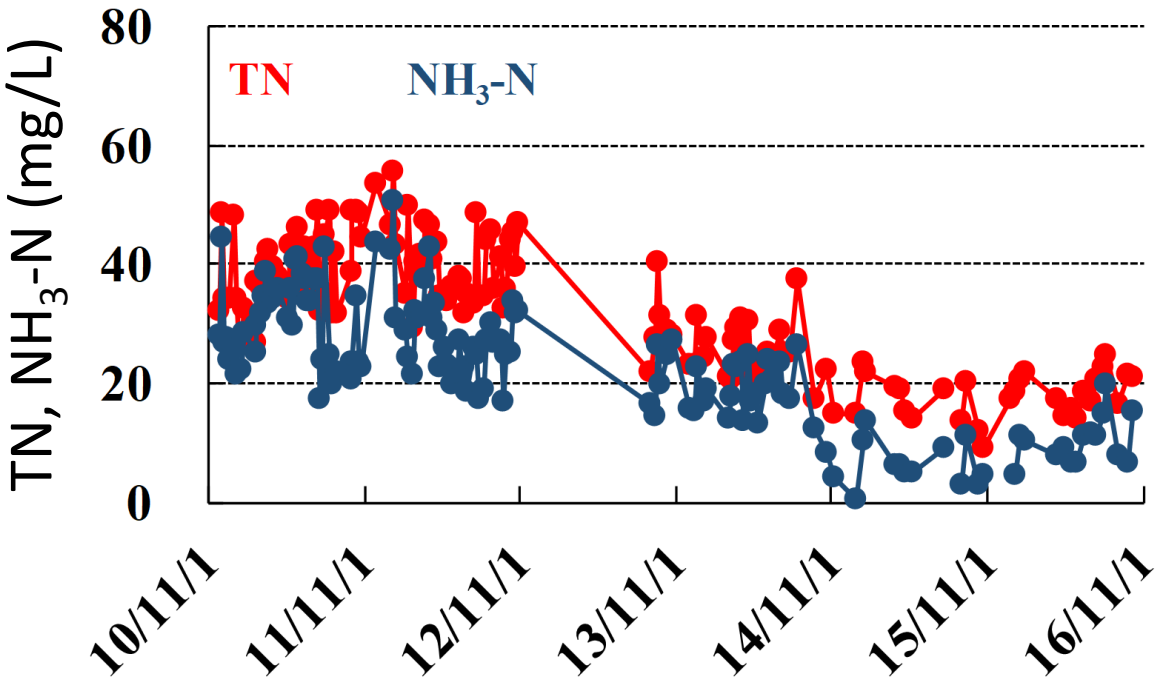

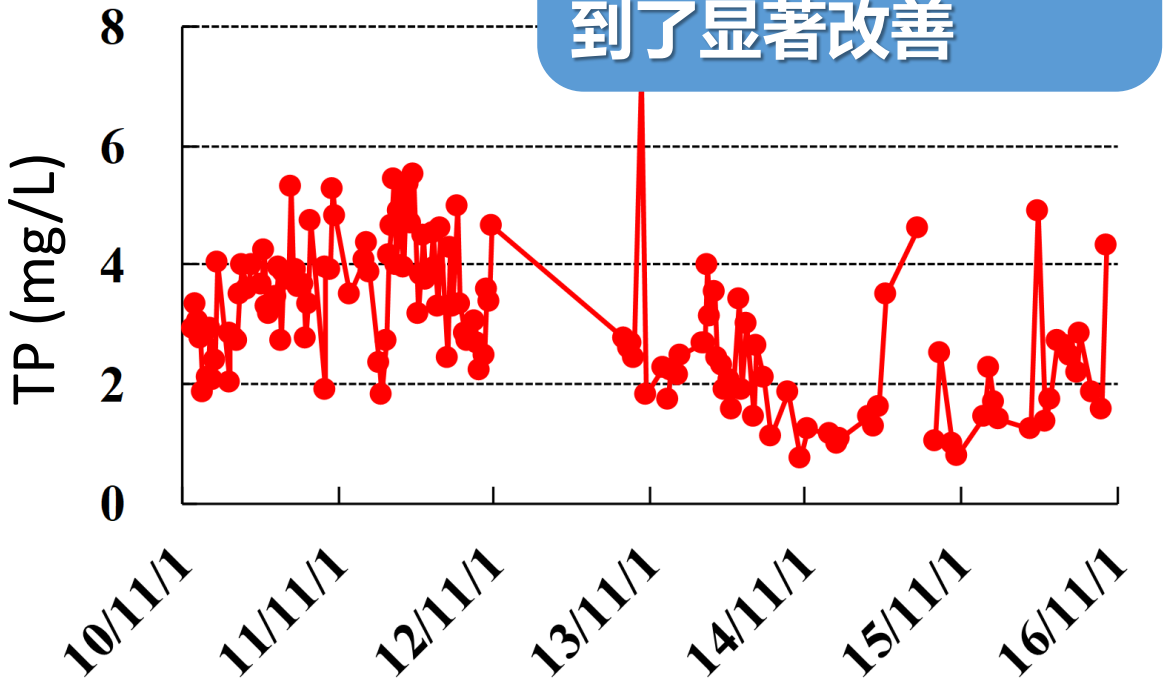

研究背景
Background of research work

- 河水净化的人工湿地应用研究 Project for applying CWs for river water quality improvement

第一阶段：人工湿地中试
1st Stage: Pilot study

- **多种人工湿地单元组合**
- **总面积：8000m²**

Hybrid CW system, Total area: 8000m²

第二阶段：大型人工湿地建设
2nd Stage: Large CW system

- **表流人工湿地系统**
- **总面积：67 ha**

FWS system, Total area: 67 ha

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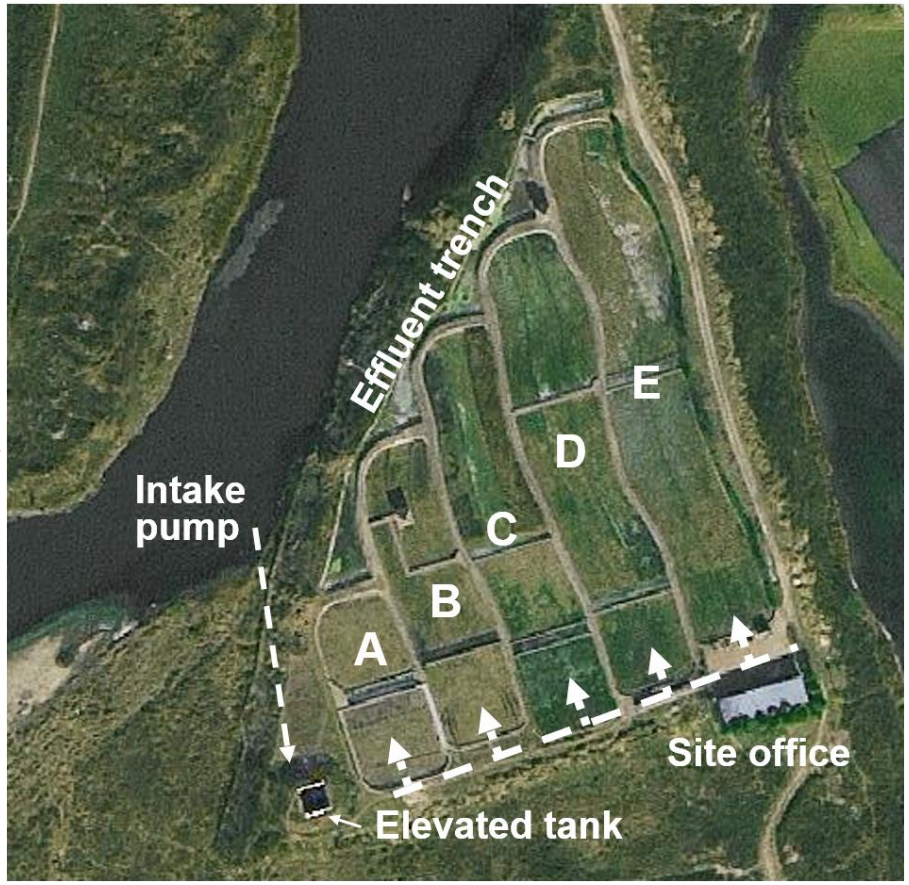
人工湿地污染河水处理中试
Pilot CWs for polluted river water treatment

- 中试系统概要 Outline of the pilot CW system

2010年建成位于皂河畔的人工湿地中试系统

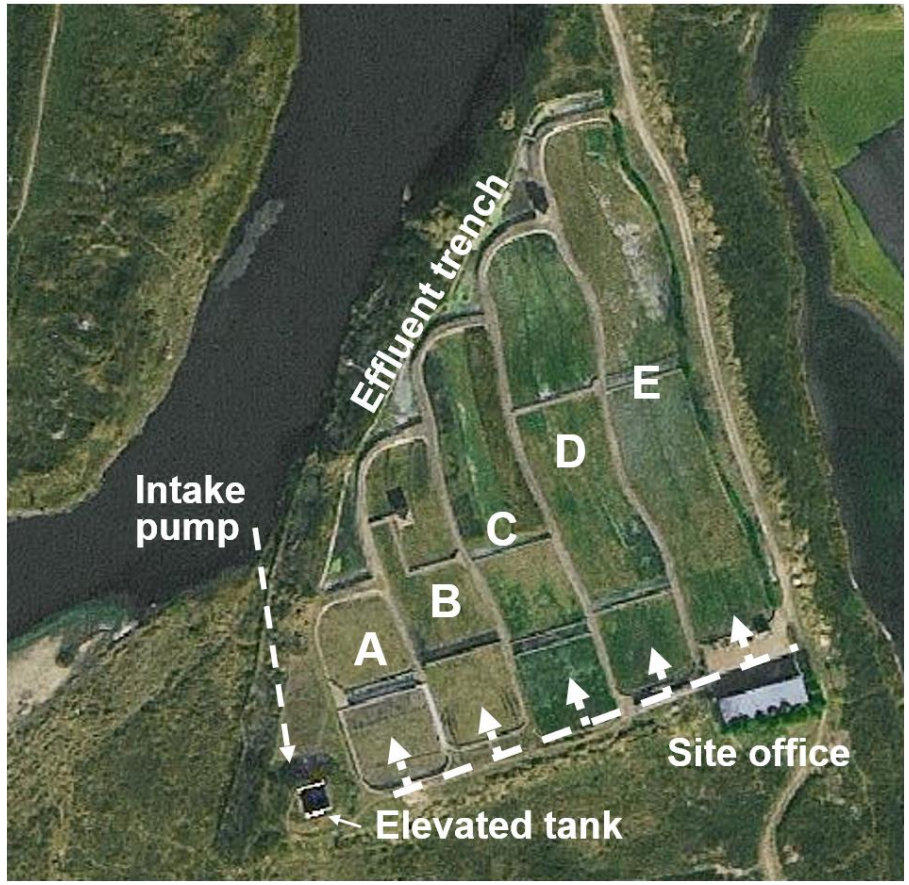
A pilot CW system was implemented in 2010



人工湿地污染河水处理中试
Pilot CWs for polluted river water treatment

- 中试系统概要 Outline of the pilot CW system

CW series	System configuration	Average flow rate (m^3/d)	Stage	Length×Width×Height (m×m×m)	Filter media
A	SSF	65	SSF	34×20×0.8	Gravel
B	SSF+FWS	65	SSF	17×20×0.8	Slag
			FWS	40×20×0.6	Sand
C	SSF+FWS	65	SSF	34×20×0.8	Gravel
			FWS	40×20×0.6	Sand
D	SSF+FWS	65	SSF	17×20×0.8	Gravel
			FWS	69×20×0.6	Sand
E	FWS+FWS	90	FWS	45×20×0.6	Sand
			FWS	45×20×0.6	Sand
Total		350			



人工湿地污染河水处理中试
Pilot CWs for polluted river water treatment

- 中试系统概要 Outline of the pilot CW system

人工湿地污染河水处理中试
Pilot CWs for polluted river water treatment

- 中试系统的湿地植物 Plants in the pilot CWs

香蒲 *Typha orientalis*

芦苇 *Phragmites australis*

人工湿地污染河水处理中试
Pilot CWs for polluted river water treatment

- 中试系统的四季景象 Pilot CWs in different seasons

人工湿地污染河水处理中试
Pilot CWs for polluted river water treatment

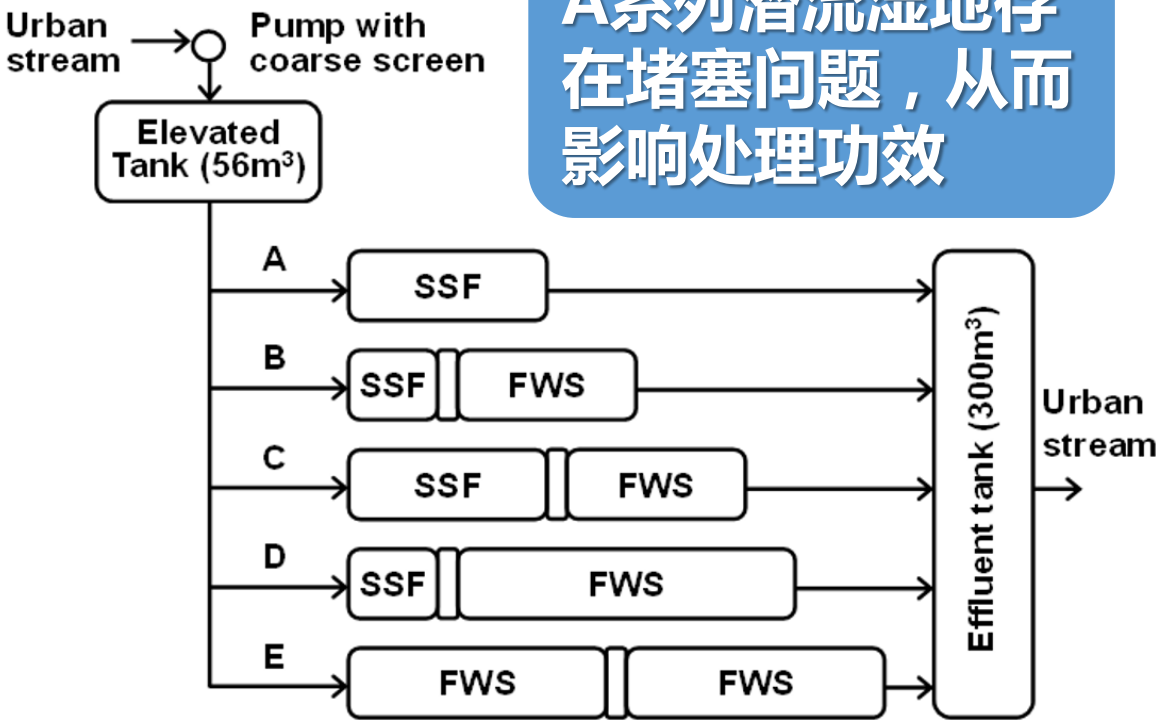
- 污染物去除的总体功效 Pollutants removal

Period	Parameter	Unit	SS	COD	BOD_5	NH_3-N	TN	TP
2011 – 2013 平均	Influent	mg/L	294.2	296.6	92.4	28.6	38.9	3.6
	Effluent	mg/L	22.8	77.8	6.5	10.8	15.7	1.0
	Removal	%	92.3	73.8	93.0	62.2	59.6	72.2
2014 – 2016 平均	Influent	mg/L	87.2	176.1	44.6	13.2	21.3	2.2
	Effluent	mg/L	15.7	55.0	5.7	3.8	8.1	0.8
	Removal	%	82.0	68.8	87.2	71.2	62.0	63.6
一级A排水标准 Class I-A			10	50	10	5	15	0.5
一级B排水标准 Class I-B			20	60	20	8	20	1.0

- 后三年的河水水质较前三年有了大的改观 Influent quality got better since 2014
- 湿地净化的水质达到了一级B排水标准 Treated water quality can meet Class I-B

人工湿地污染河水处理中试
Pilot CWs for polluted river water treatment

- 不同湿地系列的功效比较 Pollutants removal in different series



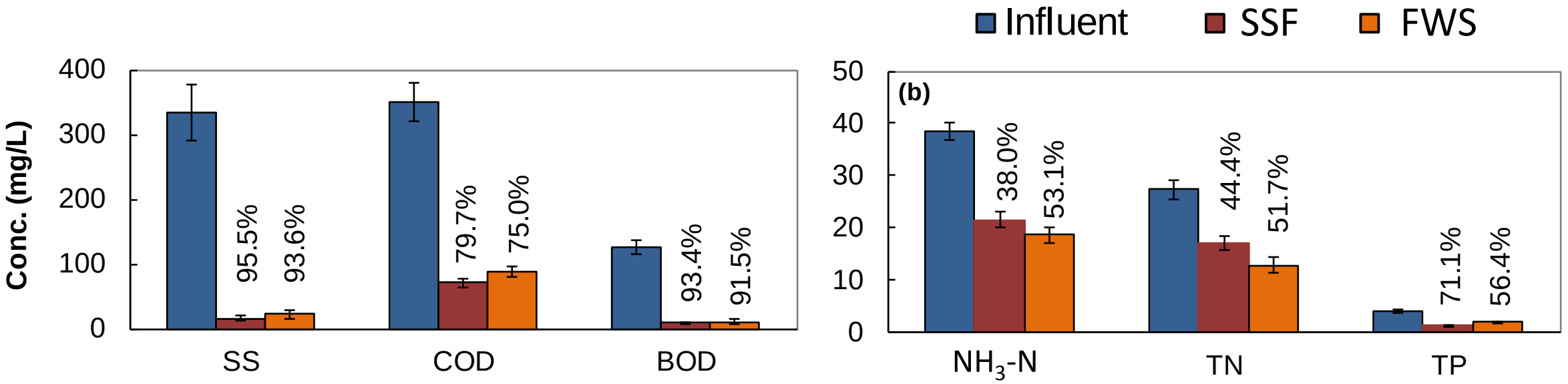
A系列潜流湿地存在堵塞问题，从而影响处理功效

平均污染物去除率 Average removal (%)

Item	A	B	C	D	E
SS	96	96.3	95.9	96.7	96.2
COD	80.7	80	79.7	79.8	76.1
BOD	91.9	95.4	96.7	96.2	93.9
TN	29.1	56.6	65.2	68.8	73.2
NH_3-N	17.3	58.1	70.2	72.1	78.7
TP	51.3	71.8	79.5	79.5	76.9

人工湿地污染河水处理中试
Pilot CWs for polluted river water treatment

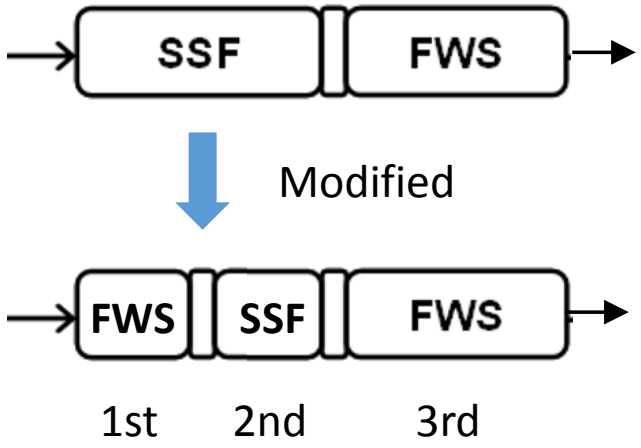
- 表流和潜流湿地单元比较 Comparison of FWS and SSF cells

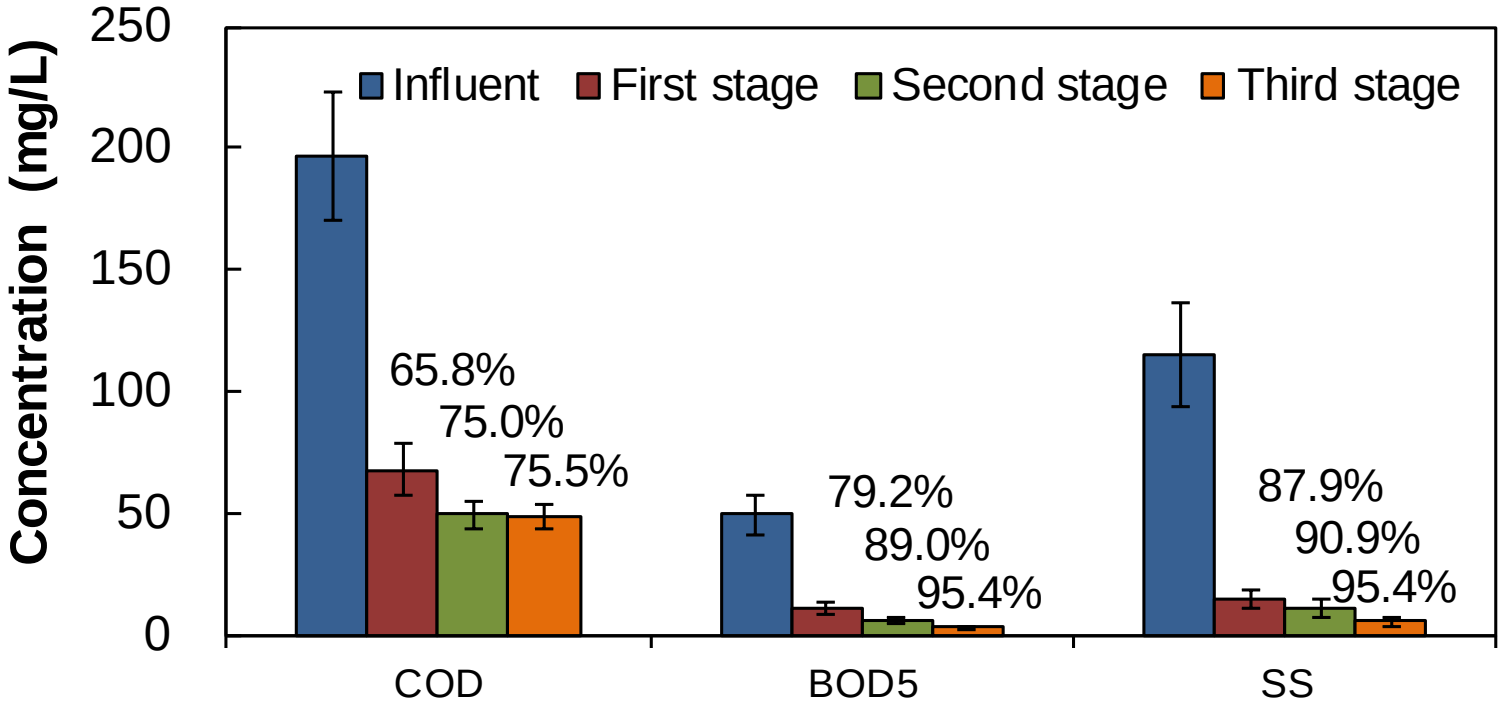


- 表流湿地FWS：有利于污染河水中氮的去除 Favors nitrogen removal
- 潜流湿地SSF：有利于污染河水中有机物和磷的去除 Favors organic and P removal

人工湿地污染河水处理中试
Pilot CWs for polluted river water treatment

- 前置表流单元对潜流湿地功效的改善 Effect of FWS pretreatment on SSF cell





- 充分发挥了第一级FWS对SS和有机物的去除作用 Significant removal of COD、BOD and SS in the first FWS cell

人工湿地污染河水处理中试
Pilot CWs for polluted river water treatment

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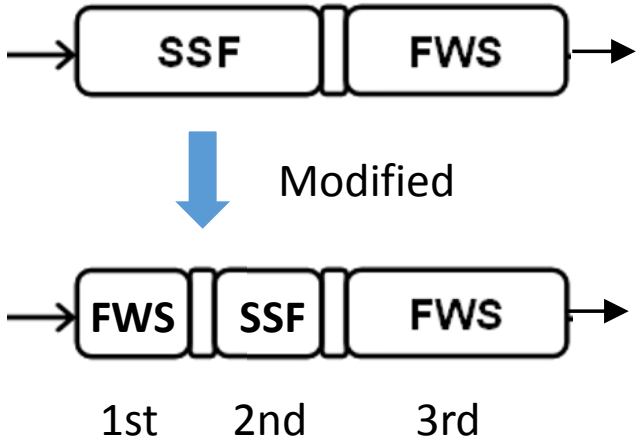
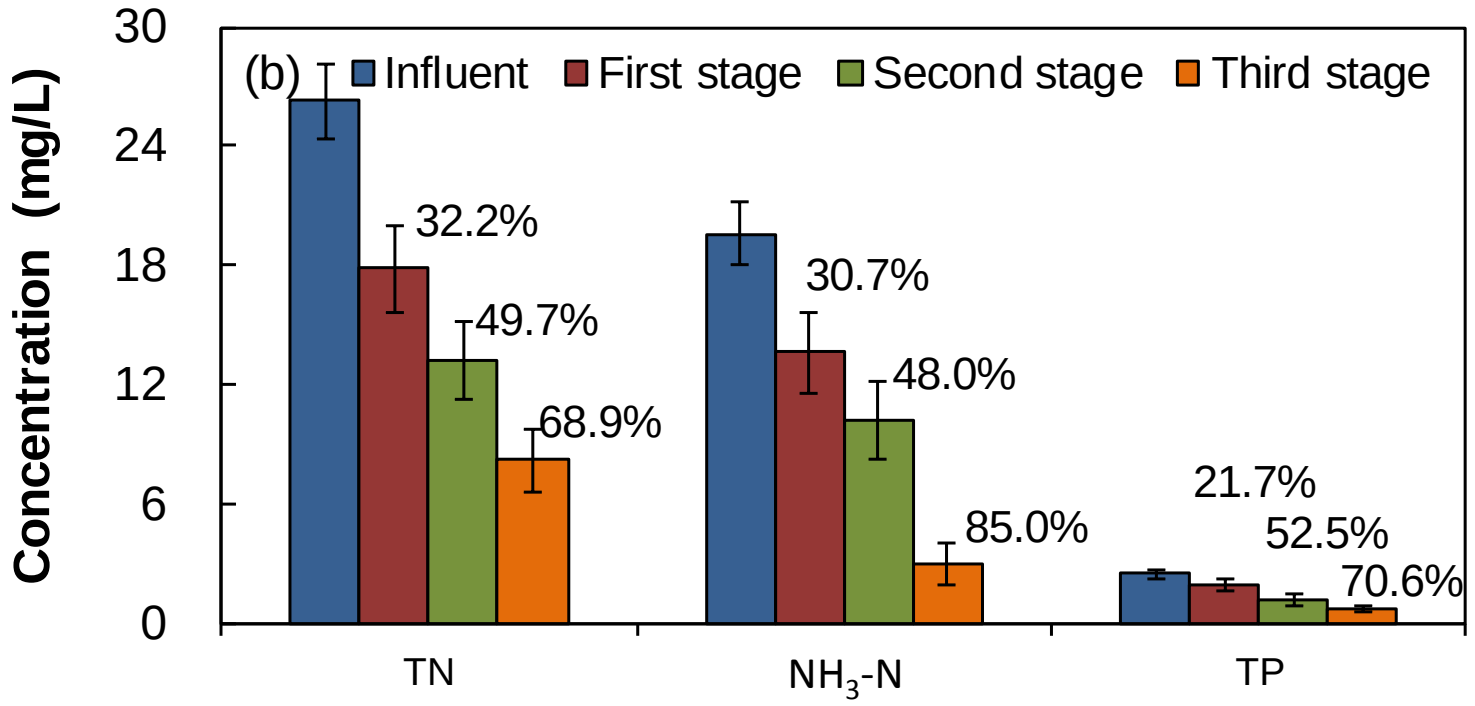




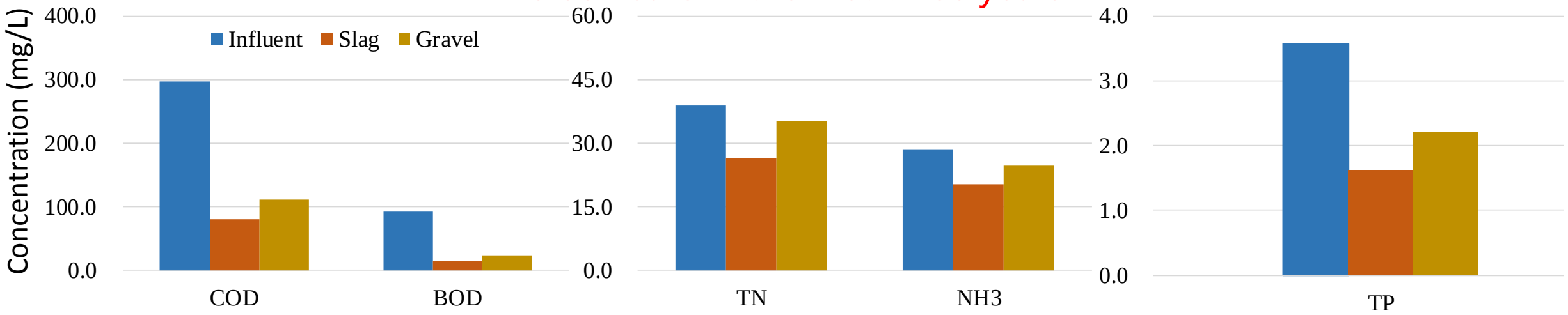
- 有效提升了第二级SSF的脱氮作用作用 Significant removal of TN and NH_3-N in the SSF cell

人工湿地污染河水处理中试
Pilot CWs for polluted river water treatment

- 砾石和炉渣作为湿地基质的比较 Comparison of gravel and slag as substrates

对等条件下两组湿地前三年的污染物去除平均功效

Two SSF cells in the first three years



- 炉渣湿地对各种污染物均具有更好的去除效果 Considerably higher removal of pollutants by the CW with slug as substrate

人工湿地污染河水处理中试
Pilot CWs for polluted river water treatment

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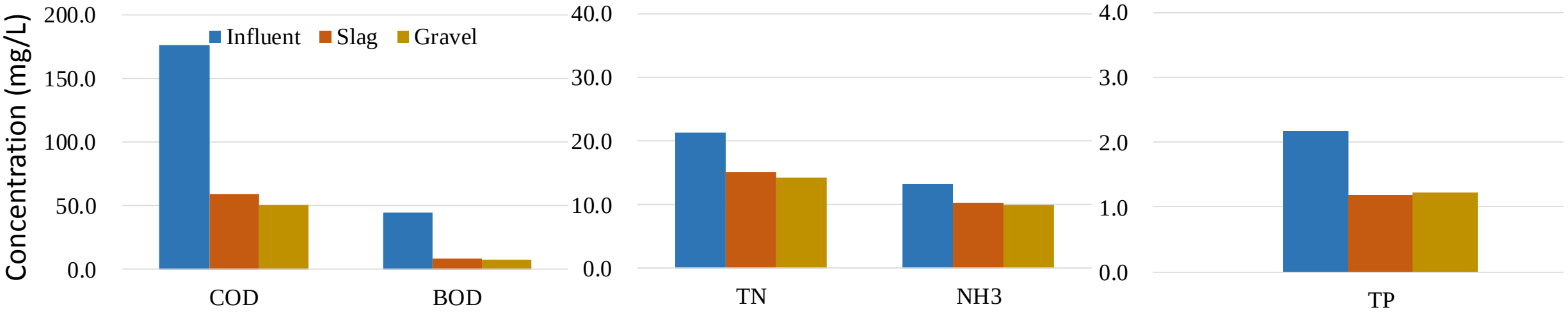
对等条件下两组湿地后三年的污染物去除平均功效

Two SSF cells in the second three years

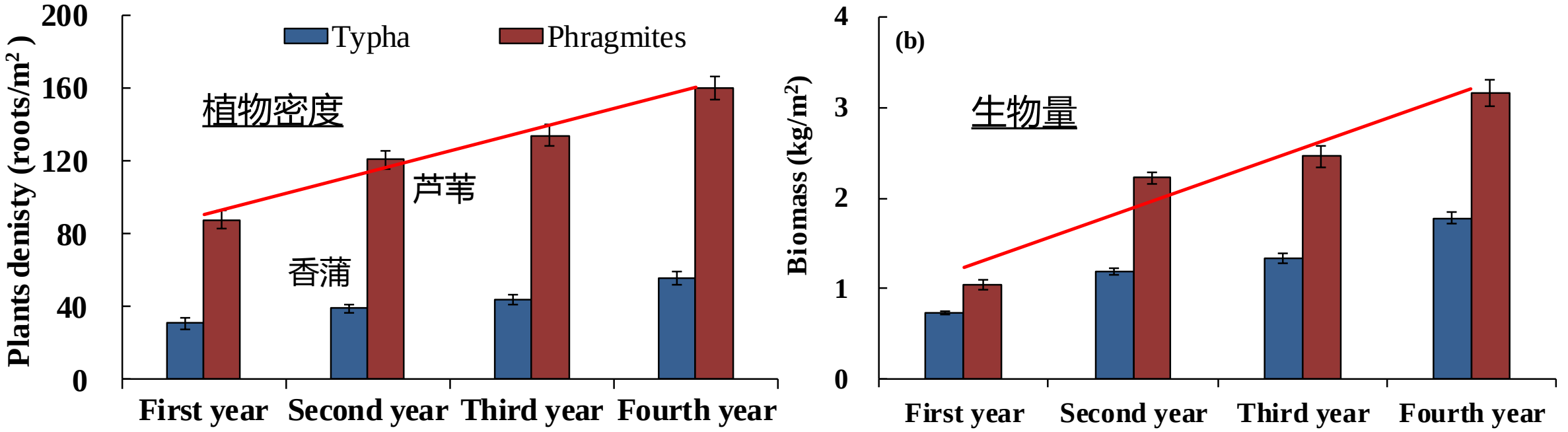


- 三年之后炉渣湿地对各种污染物的去除效果明显下降，而砾石湿地反而体现出其优势 Opposite tendency was seen in the second three years

人工湿地污染河水处理中试
Pilot CWs for polluted river water treatment

- 表流湿地中植物种植的作用 Plant action in FWS cells

香蒲和芦苇同密度种植后的长势 Plants growth after plantation



- 芦苇具有更旺盛的长势 Phragmites grow faster than Typha

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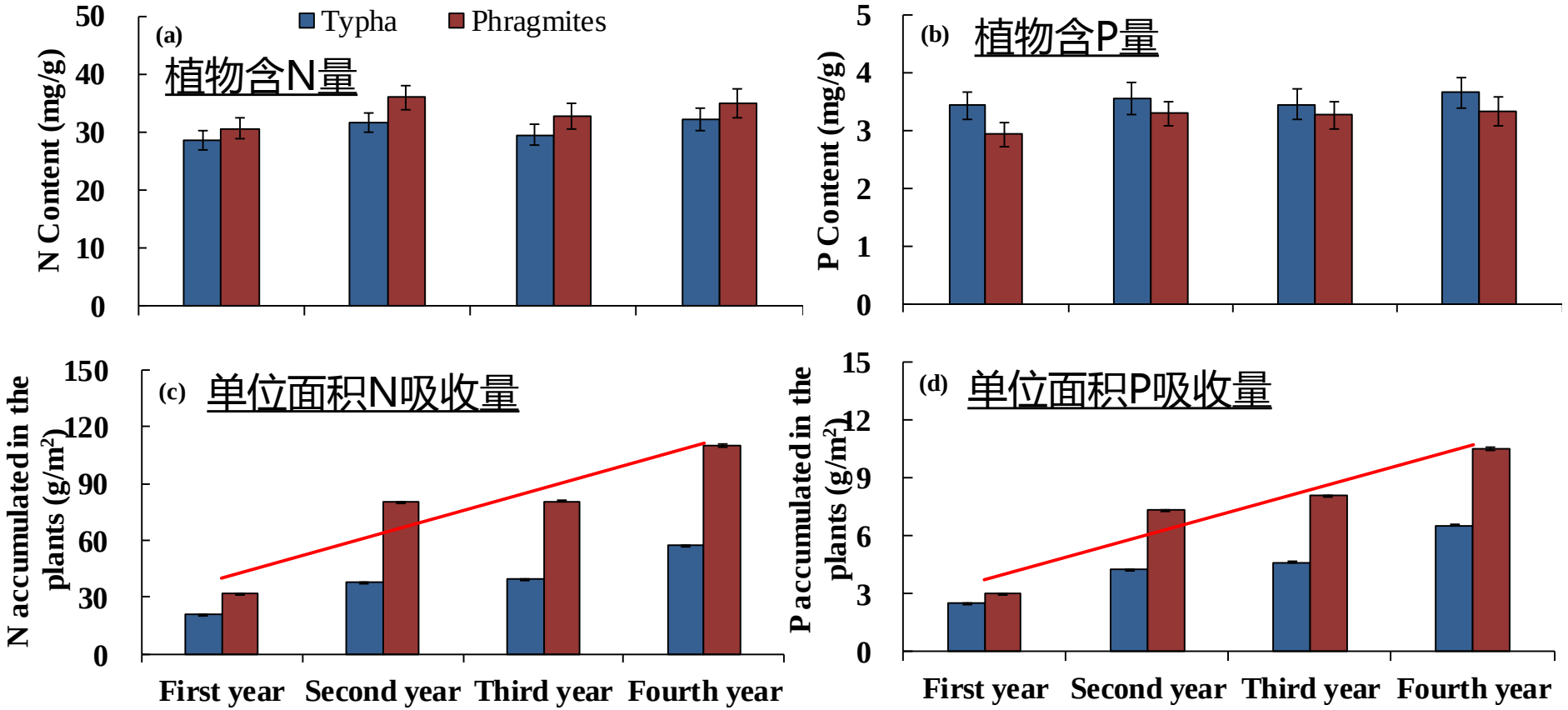

- 植物对氮和磷的吸收量在四年间持续增加
  Increasing N and P uptakes in four years

人工湿地污染河水处理中试
Pilot CWs for polluted river water treatment

- 湿地植物收割管理的作用 Effect of plant harvest and management

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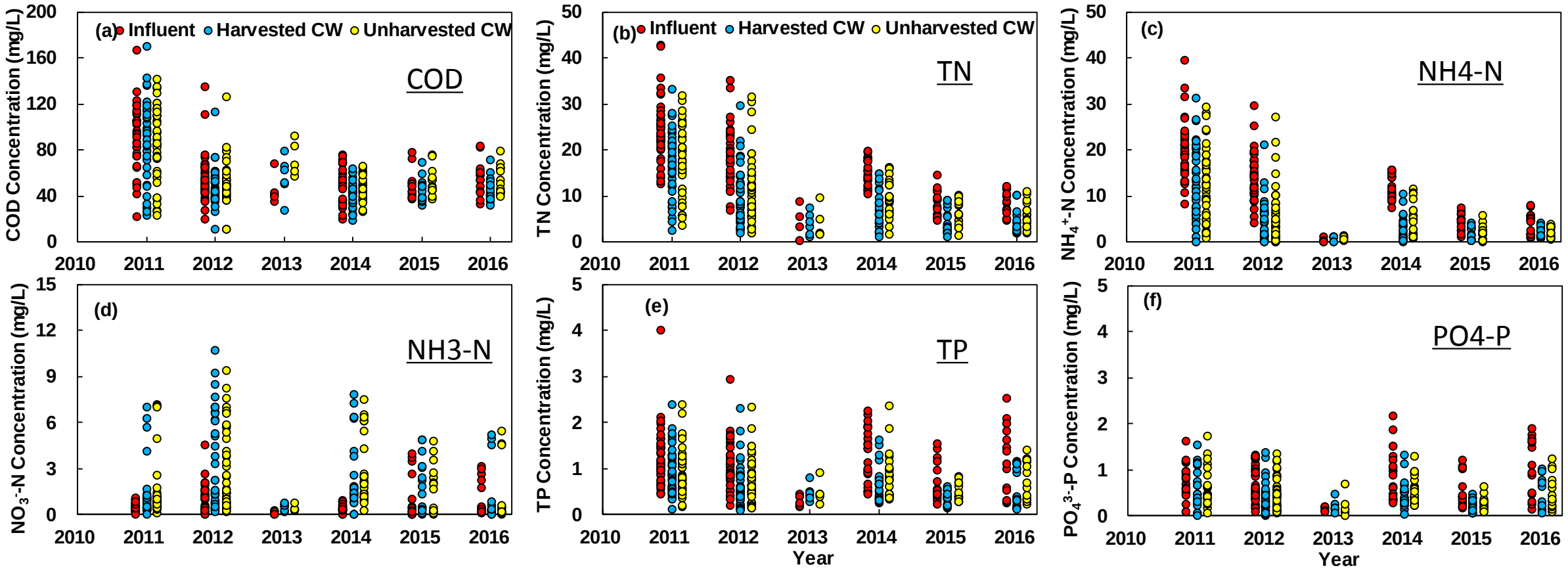

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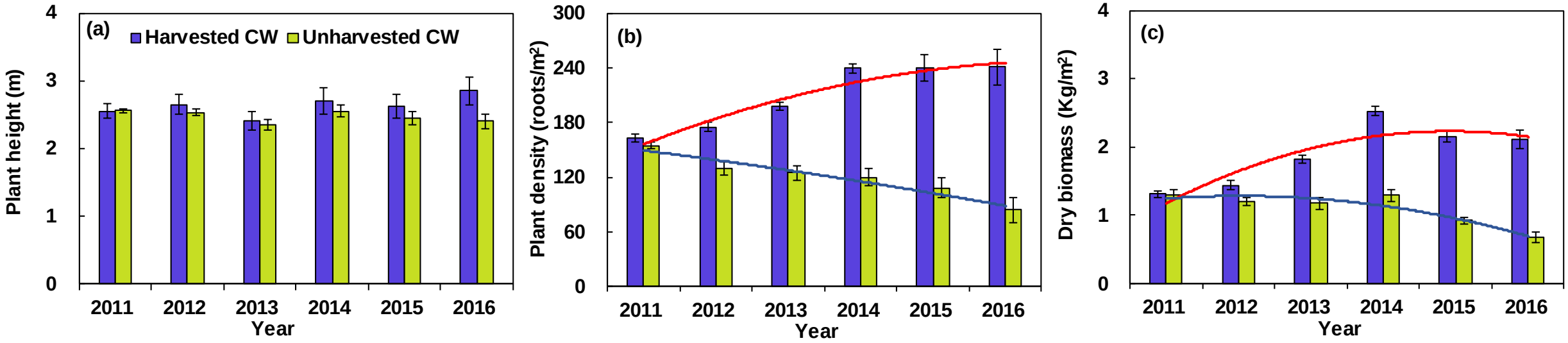
收割管理对植物长势的影响 Harvest management and plant growth



- 收割与否对植物高度影响较小 Harvest affects little on plant height
- 收割湿地中植物生物量在第四年左右逐渐稳定 Plant mass stabilized after 4 yr.
- 收割湿地植物量达到未收割湿地的3倍 Three time difference in dry biomass

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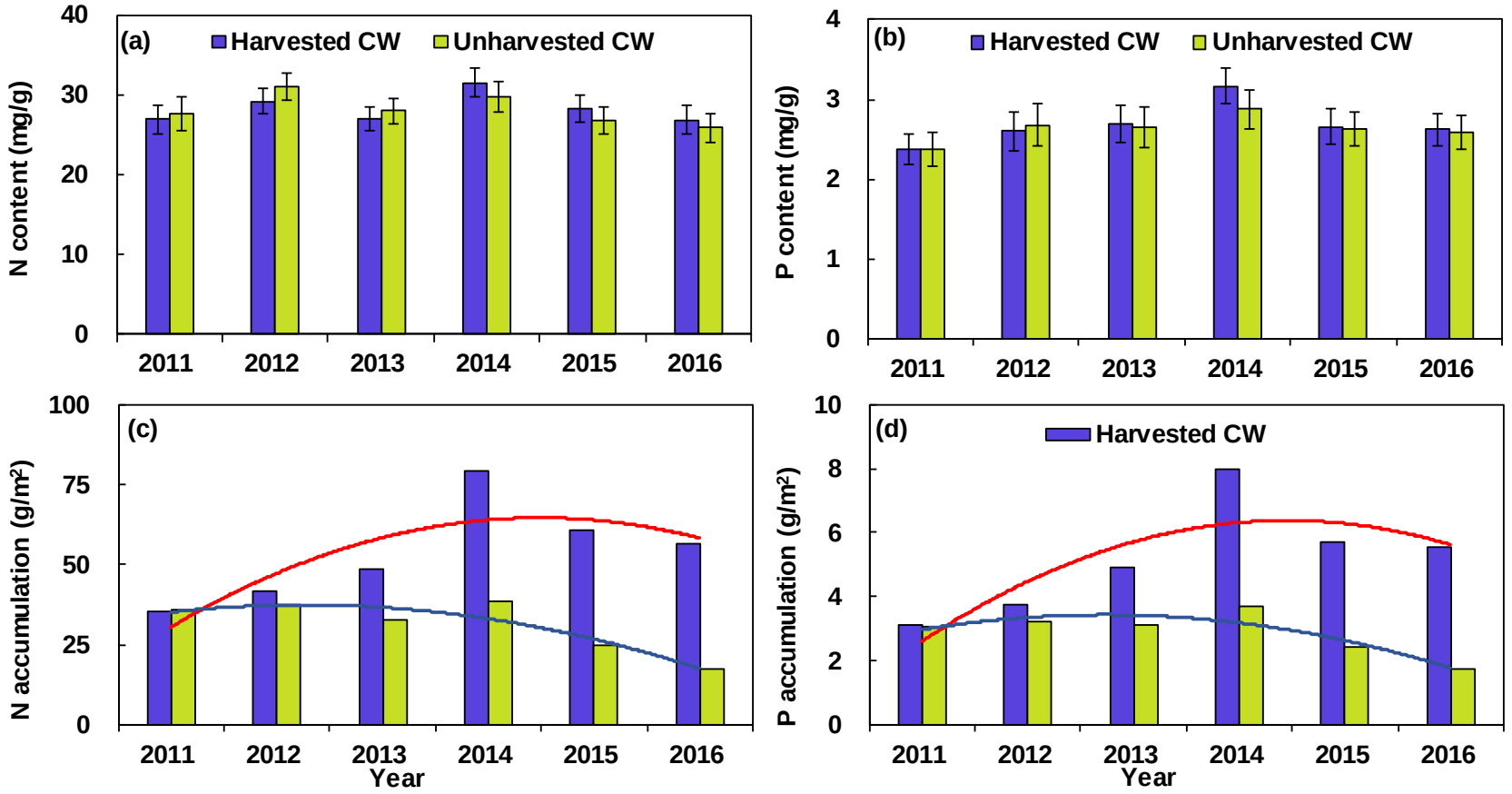

- 植物氮磷吸收去除量与其生物量显著相关，收割湿地植物氮磷吸收量均为未收割湿地的3倍以上
  N and P uptake relates closely with plant biomass

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Pilot CWs for polluted river water treatment

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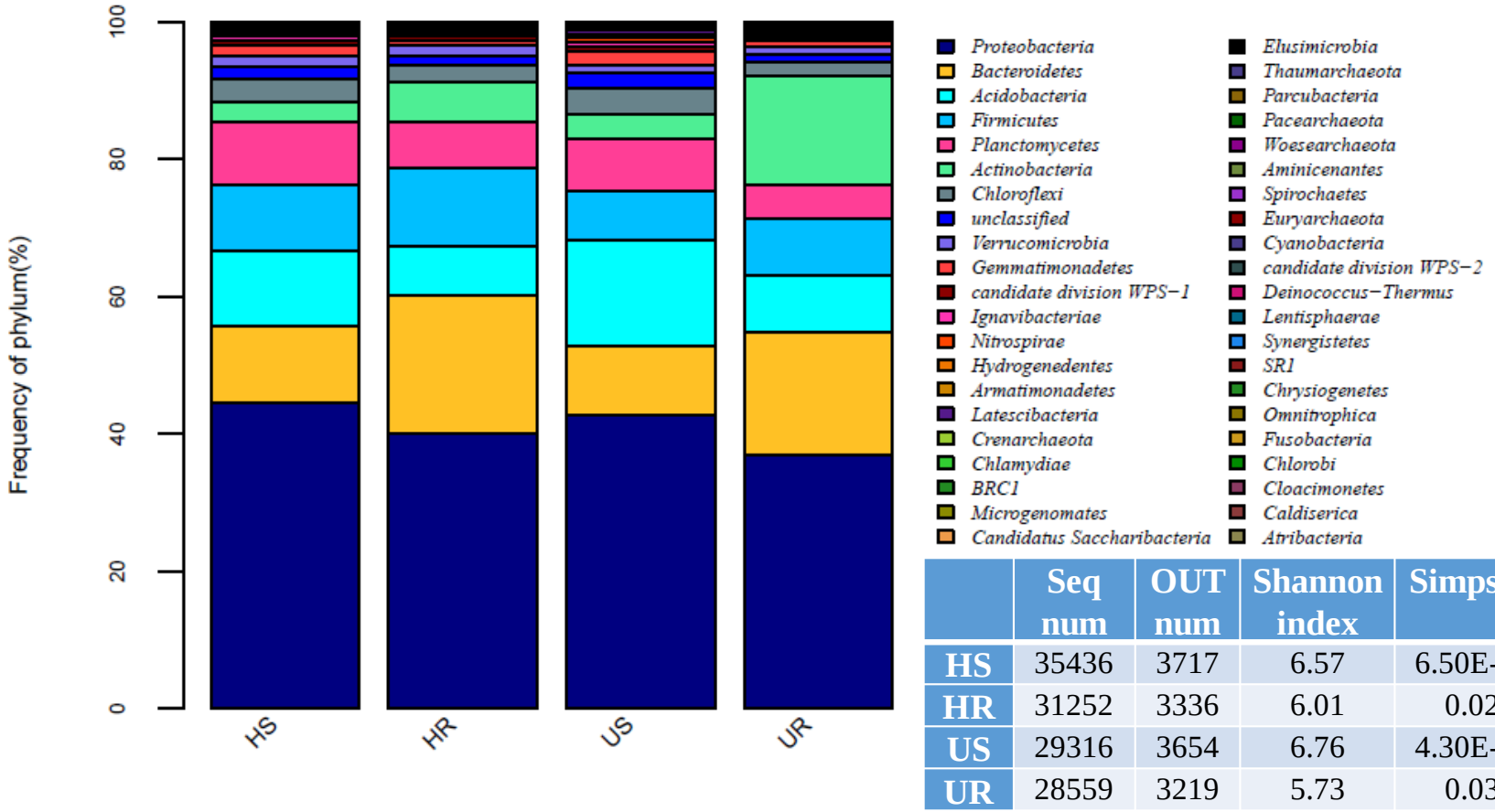

- 收割湿地内的微生物丰度和多样性均高于未收割湿地
  The microbial abundance and diversity in harvested CWs were higher than the unharvested CWs

	Seq num	OUT num	Shannon index	Simpson	ACE index	Chao1 index	Coverage
HS	35436	3717	6.57	6.50E-03	5250.48	4979.58	0.96
HR	31252	3336	6.01	0.02	5006.72	4781.51	0.96
US	29316	3654	6.76	4.30E-03	5119.69	4941.36	0.95
UR	28559	3219	5.73	0.03	6613.62	5165.37	0.95

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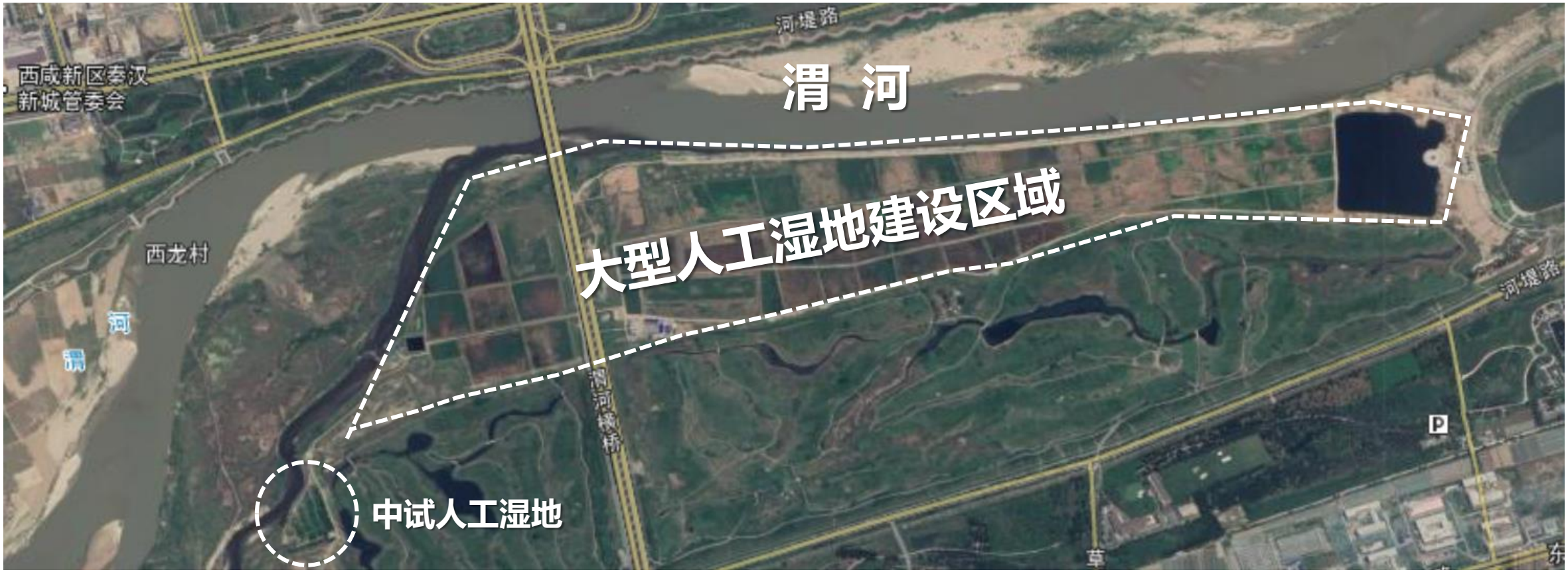
污染河水处理大型人工湿地建设
Large CW system for polluted river water treatment

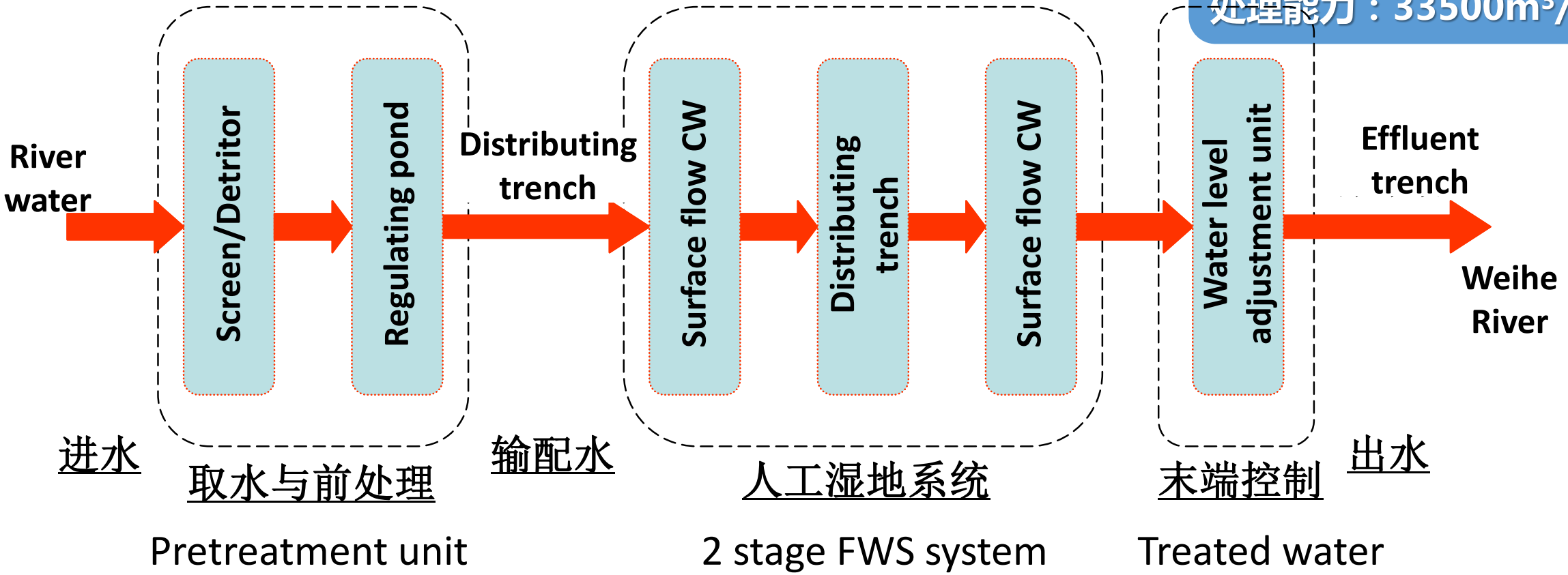
- 湿地位置图 Location map



污染河水处理大型人工湿地建设
Large CW system for polluted river water treatment

湿地面积：67ha
水力负荷：0.05m/d
处理能力：33500m³/d

- 基本工艺流程 Process flow



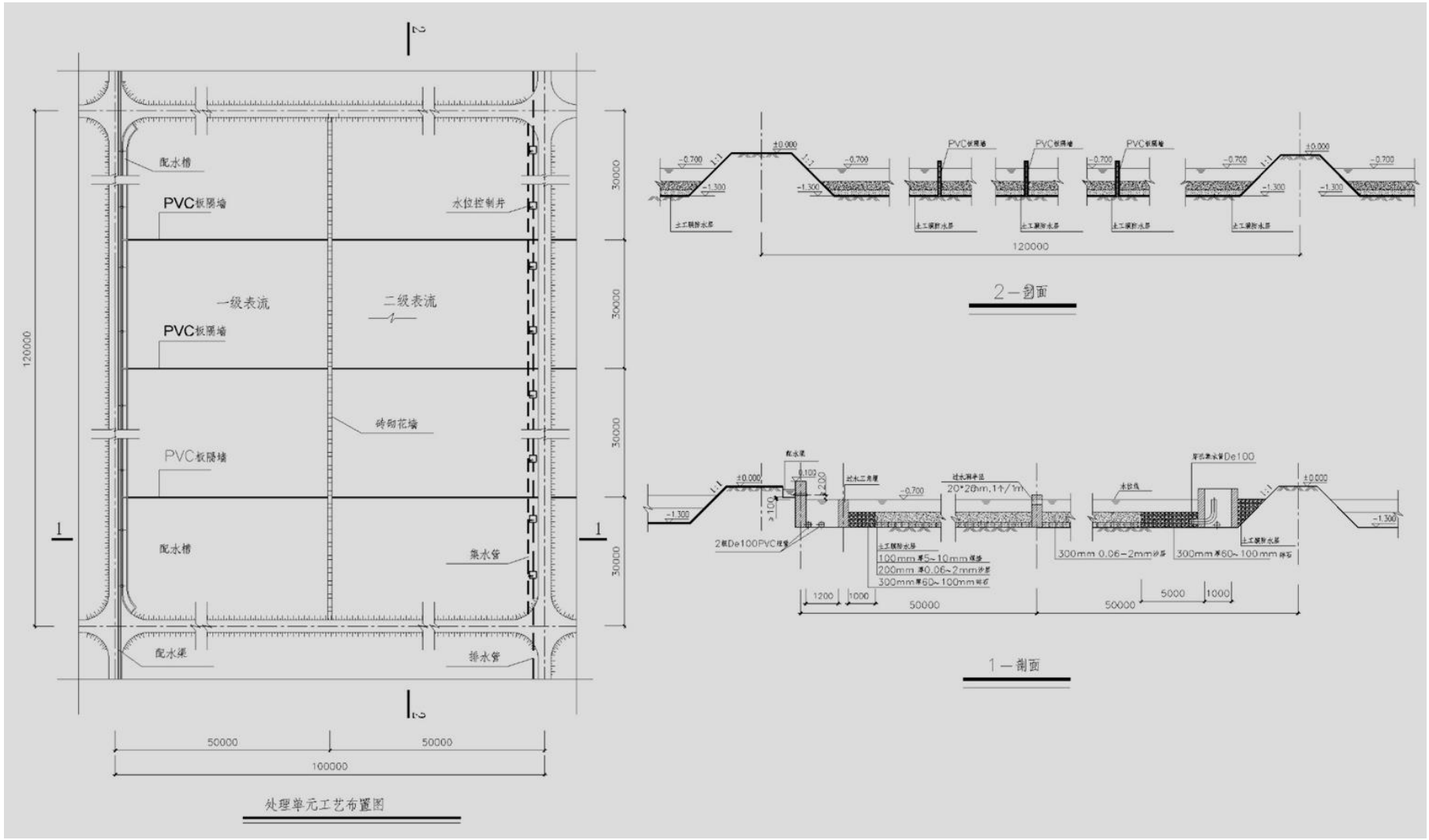
污染河水处理大型人工湿地建设
Large CW system for polluted river water treatment

- 湿地平面布置 System layout

湿地面积：67ha
水力负荷：0.05m/d
处理能力：33500m³/d

污染河水处理大型人工湿地建设
Large CW system for polluted river water treatment

- 设计图
  System design
  - 每一湿地单元为两级，中间通过穿孔墙整流
    Each CW unit is composed of two FWS cells



污染河水处理大型人工湿地建设
Large CW system for polluted river water treatment

- 处理效果 Treatment results

科目 Item	COD	BOD	SS	TN	NH_3-N	TP
进水平均值 Influent (mg/L)	208.0	59.0	195.3	21.9	14.3	1.8
处理水平均值 Effluent (mg/L)	61.2	16.1	14.2	12.4	7.6	1.06
平均去除率 Removal (%)	70.6	72.8	92.7	43.3	46.8	40.6

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- 结语 Concluding Remarks

结语 Concluding Remarks

- Illustration of how Nature-based Solutions, with specific reference to Constructed Wetlands, can be used as a part of an integrated approach to achieving regional water quality improvements

- Experiences have been gained through this project but it is seen that more work needs to be done to embed Constructed Wetlands as standard practice in securing water quality of urban waterways

谢谢！

Thanks for listening!