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Research on recycling of drinking water treatment residuals in environmental remediation: The past and future

Xiuqing Li (Supervisor: Pro. Yuansheng Pei)

School of Environment, Beijing Normal University

Outline

- **Drinking water treatment residuals**
- **Pollutants adsorption characteristics and mechanisms**
- **Environmental remediation applications**
- **Potential environmental risks**
- **Future perspectives**

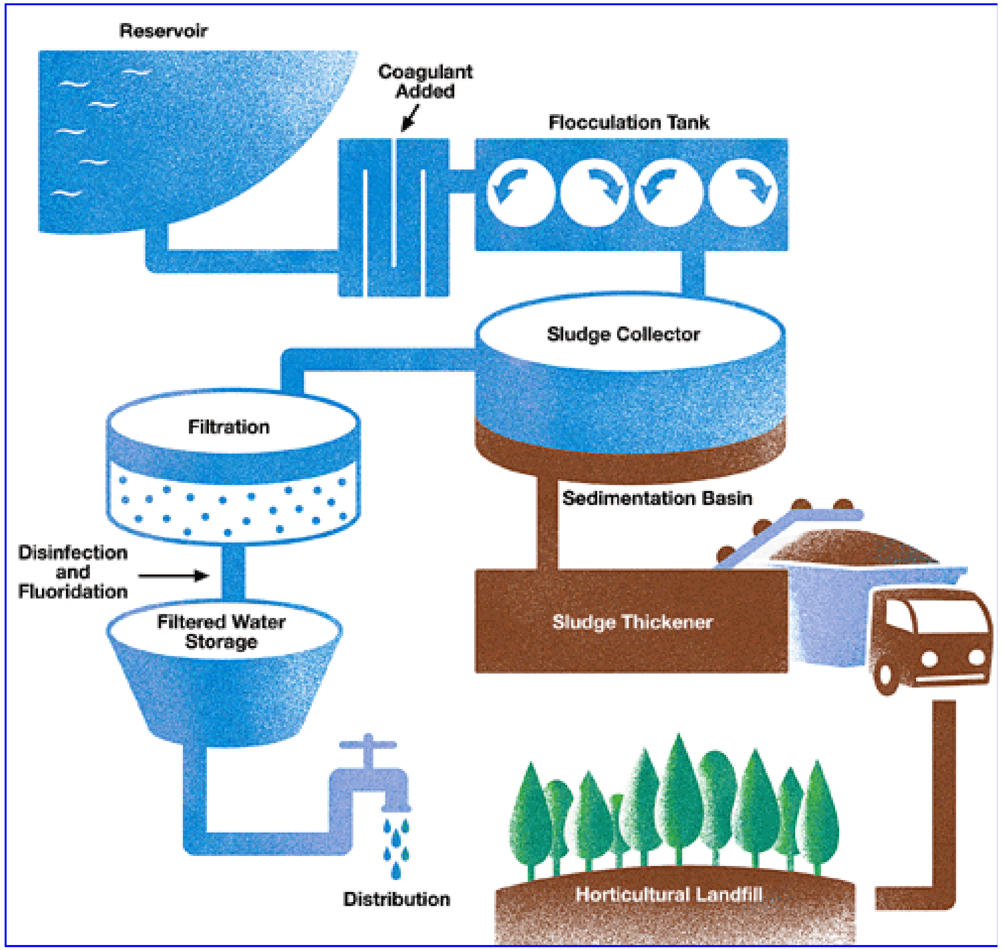
Drinking water treatment residuals (DWTR)

A by-product from drinking water treatment plant

Before dewatering

After dewatering

After drying

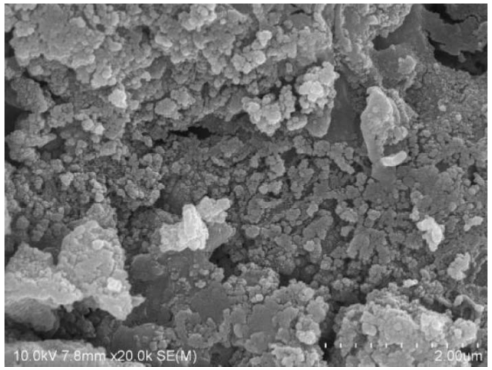


Before dewatering:
Contain water
After dewatering and drying:
Powder form

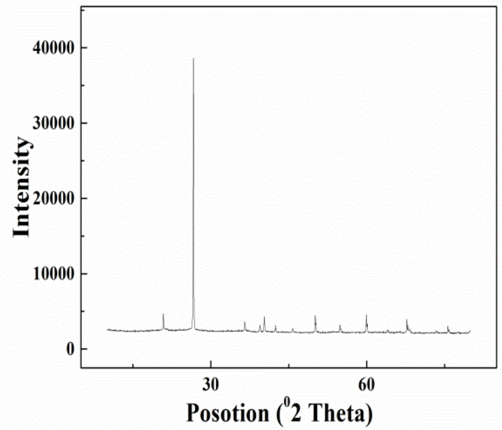
Properties of DWTR

pH	Isoelectric point	Organic matter (mg g^{-1})	Metal contain (mg g^{-1})			
			Fe	**Al**	Ca	Mg
7.0	7.4	58	**100**	**50**	7.9	0.83

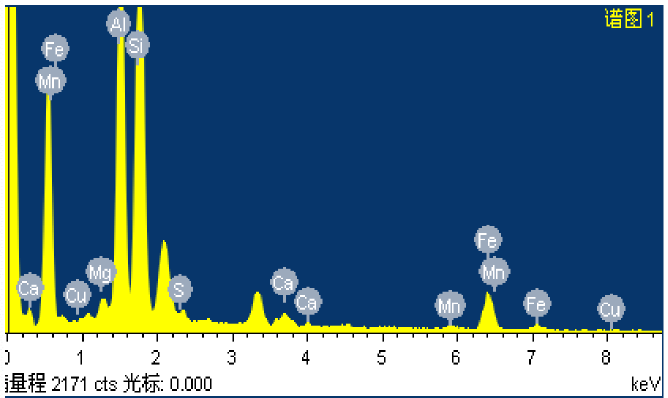
Due to aluminum or iron salt is commonly used as a coagulant in water purification, DWTR composes of high content of Al and Fe;
Al and Fe are in amorphous state.



SEM

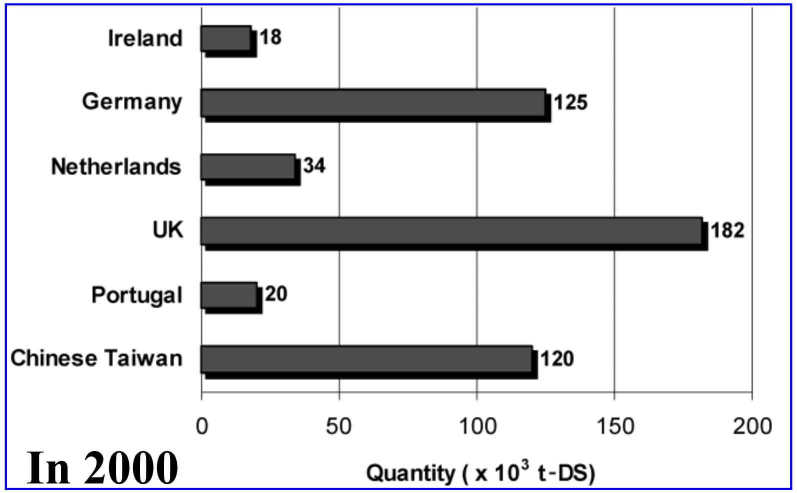


XRD



EDS

Large quantity of DWTR production and its disposal



- **In Europe: several million tons/year (2004)**
- **In Asia:**
  - In China: 1.5-2.4 million ton dry DWTR/year (2009)
  - In Japan: 300 thousand ton dry DWTR/year (2010)
  - In Republic of Korea: 1200 tons/day (2013)

Global daily DWTR production is around 10,000 tons in 1997 and now exceeds 10,000 tons/day.

Disposal ways

Increase disposal costs

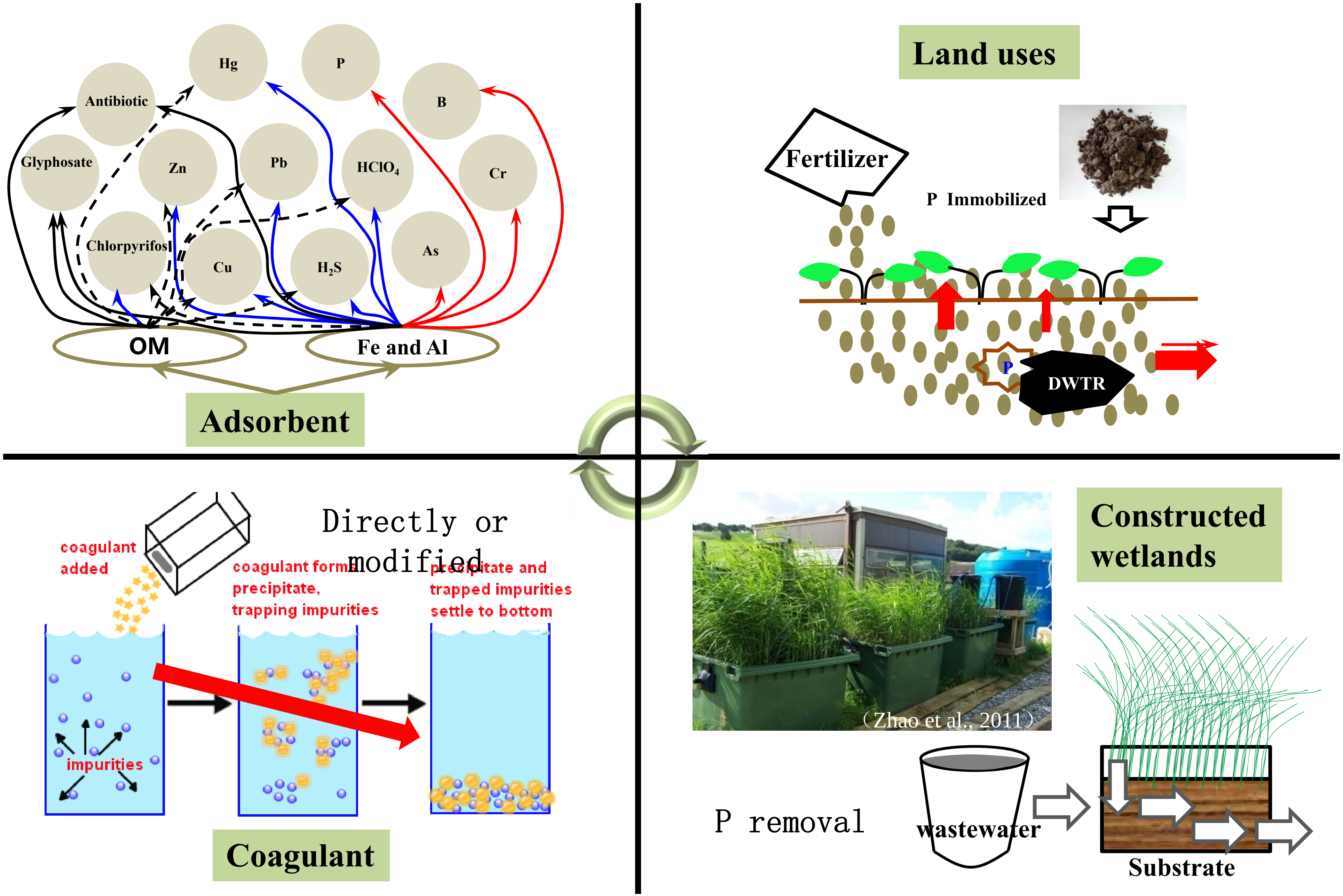
Landfilling

Discharged into drainage systems without any treatment

Increase plant loading

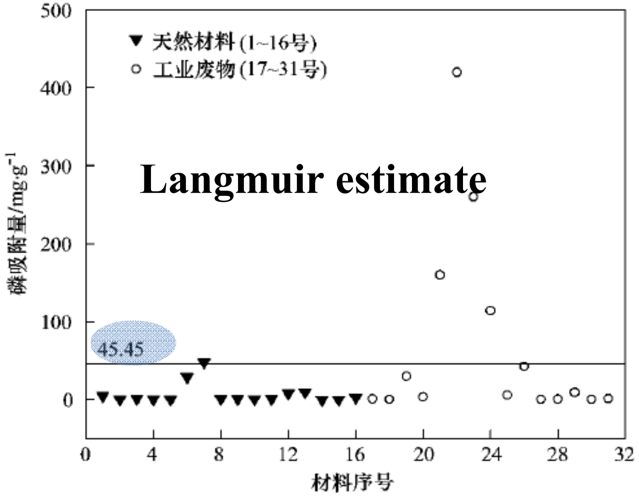
DWTR recycling is necessary

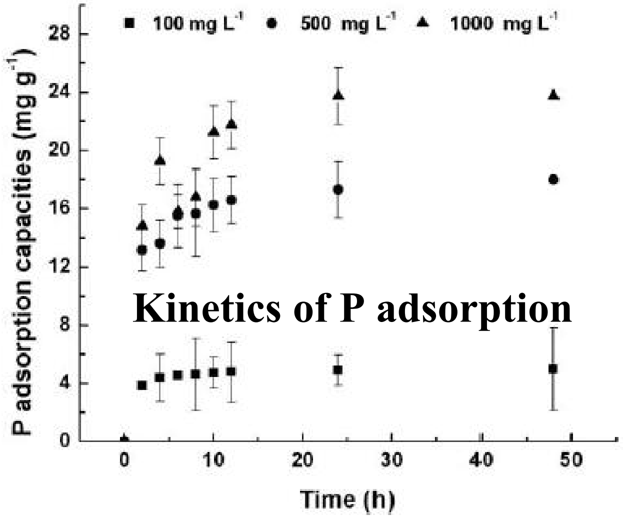
Recent reuse of DWTR

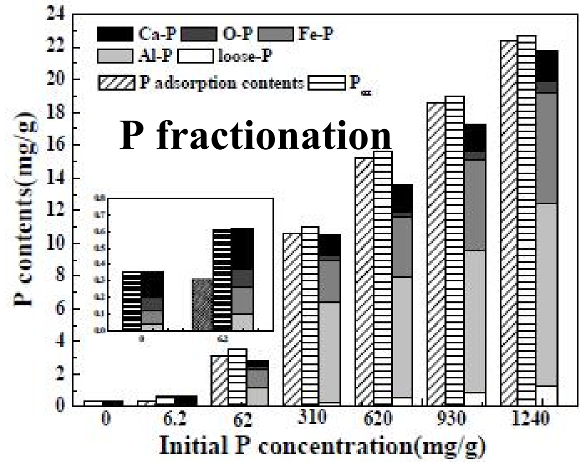


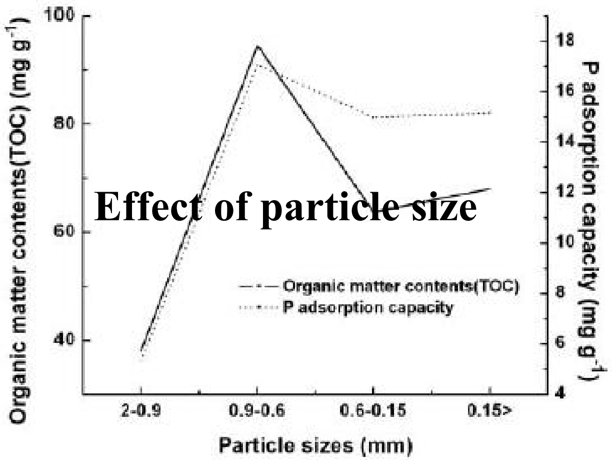
Pollutants adsorption characteristics and mechanisms

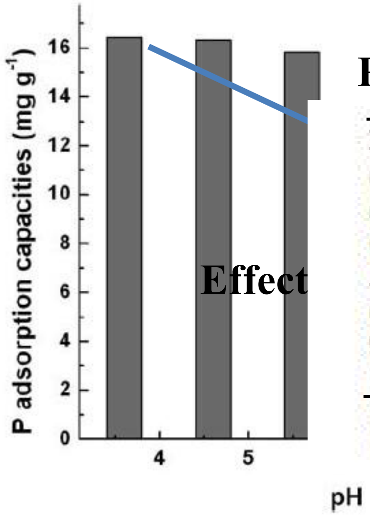
P adsorption characteristics









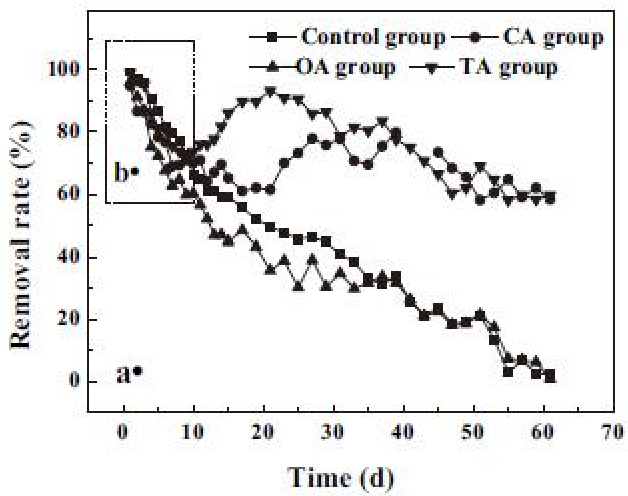


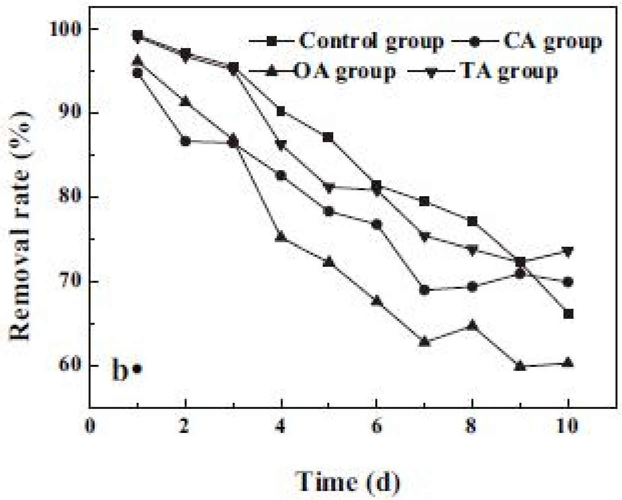
Results of P desorption at different pH values

P_0 (mg/L)	X_{ads} (mg/g)	Desorption (mg/g) pH=3	pH=5	pH=7	pH=9
6.2	0.31	0.00	0.00	0.00	0.00
62	3.04	0.00	0.00	0.11	0.71
310	10.23	0.00	1.02	0.71	2.08
620	14.88	0.05	0.40	1.92	3.10
930	16.74	0.37	0.96	2.57	4.34
1240	19.84	0.59	1.61	3.07	4.96

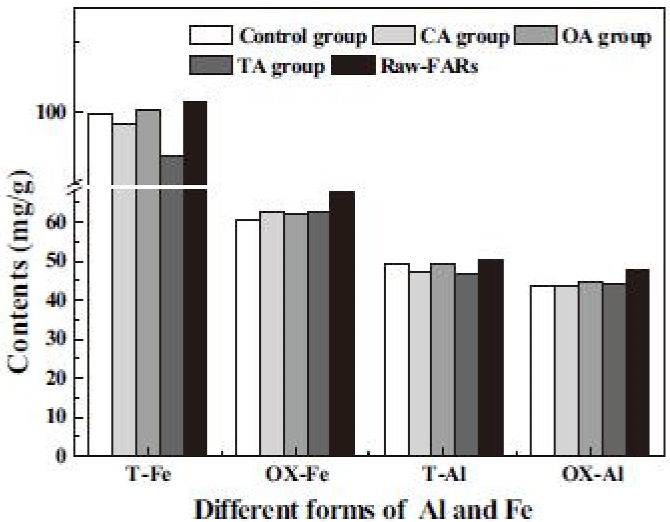
P_0 represents the initial P concentration; X_{ads} represents the amount of P adsorption.

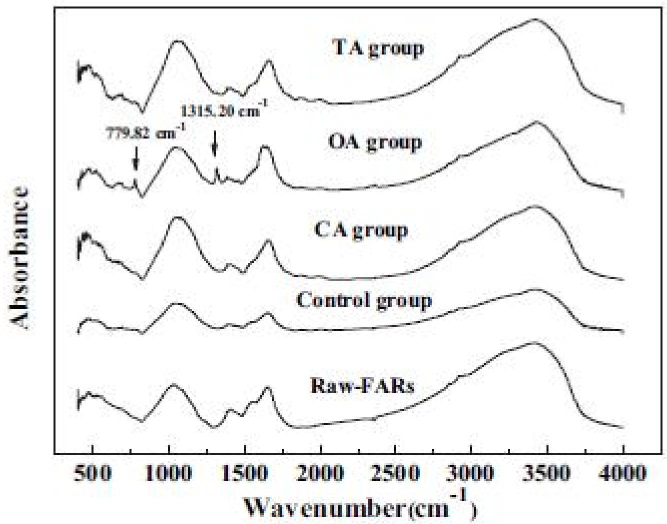
Effect of low molecular weight organic acids on P adsorption



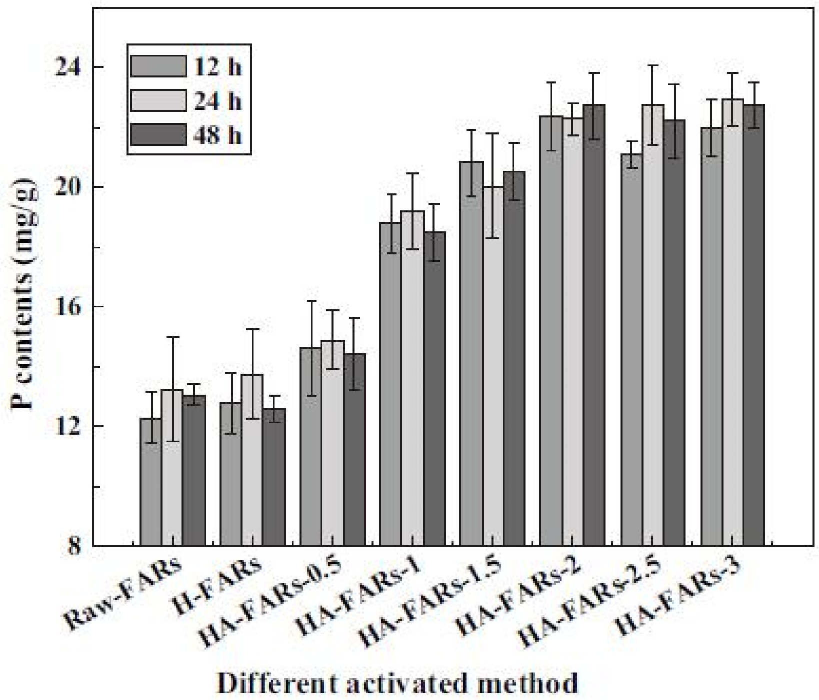


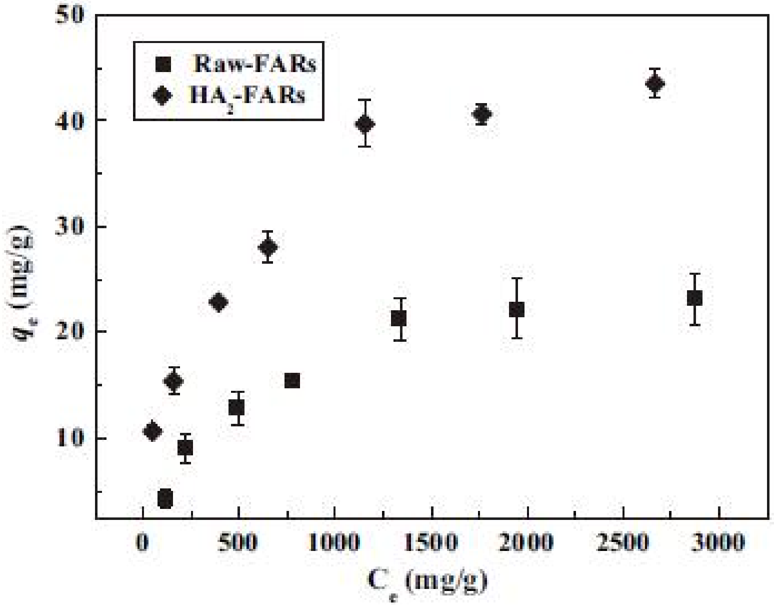
LMWOAs can promote P adsorption through activating crystalline Fe/Al and preventing crystallization of amorphous Fe/Al to increase P adsorption sites, and can also inhibit P adsorption by competition with adsorption sites.





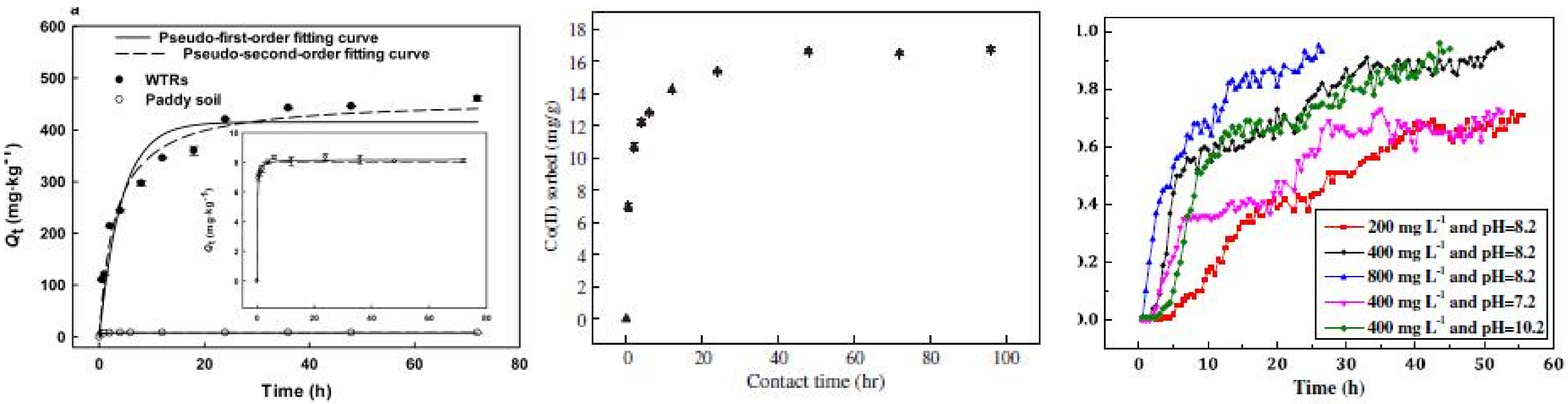
Effect of sequential thermal and acid activation on P adsorption





The optimal conditions were determined as thermal activation at 600 ◦C for 4 h followed by hydrochloric acid activation at 2 mol/L with a 1:1 solid to liquid ratio.

Organophosphorus pesticide, heavy metal, and hydrogen sulfide adsorption



DWTR exhibited a high adsorption capacity for chlorpyrifos, cobalt and hydrogen sulfide.

A higher chlorpyrifos sorption capacity of 424.0 mg/kg for DWTR;

High maximum sorption capacity of Co(II) is 17.31 mg/g;

The highest hydrogen sulfide adsorption capacity is about 40 mg/g at pH 7.2

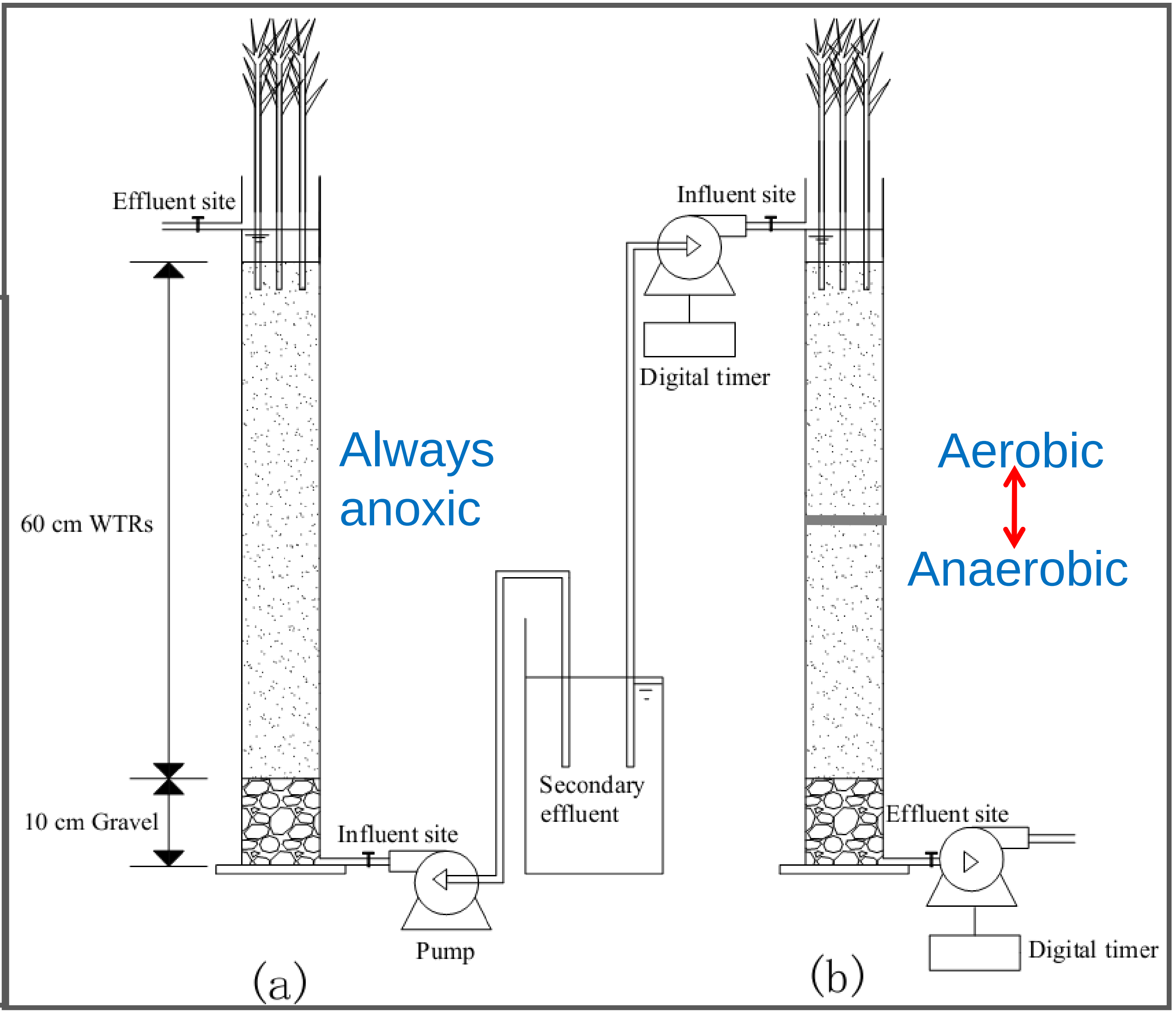
Environmental remediation applications

As a substrate in constructed wetlands

(a) CFCW: Continuous flow constructed wetland

(b) TFCW: Tidal-flow constructed wetland

- **Diameter: 9.3 cm**
- **Height: 90 cm**
- **DWTR dry weight: 1.2 kg**
- **Porosity: 39%**
- **Working volume: 2.0 L**
- **Plants: *Phragmites australis***
- **TFCW: Wet/Dry: 22:2**



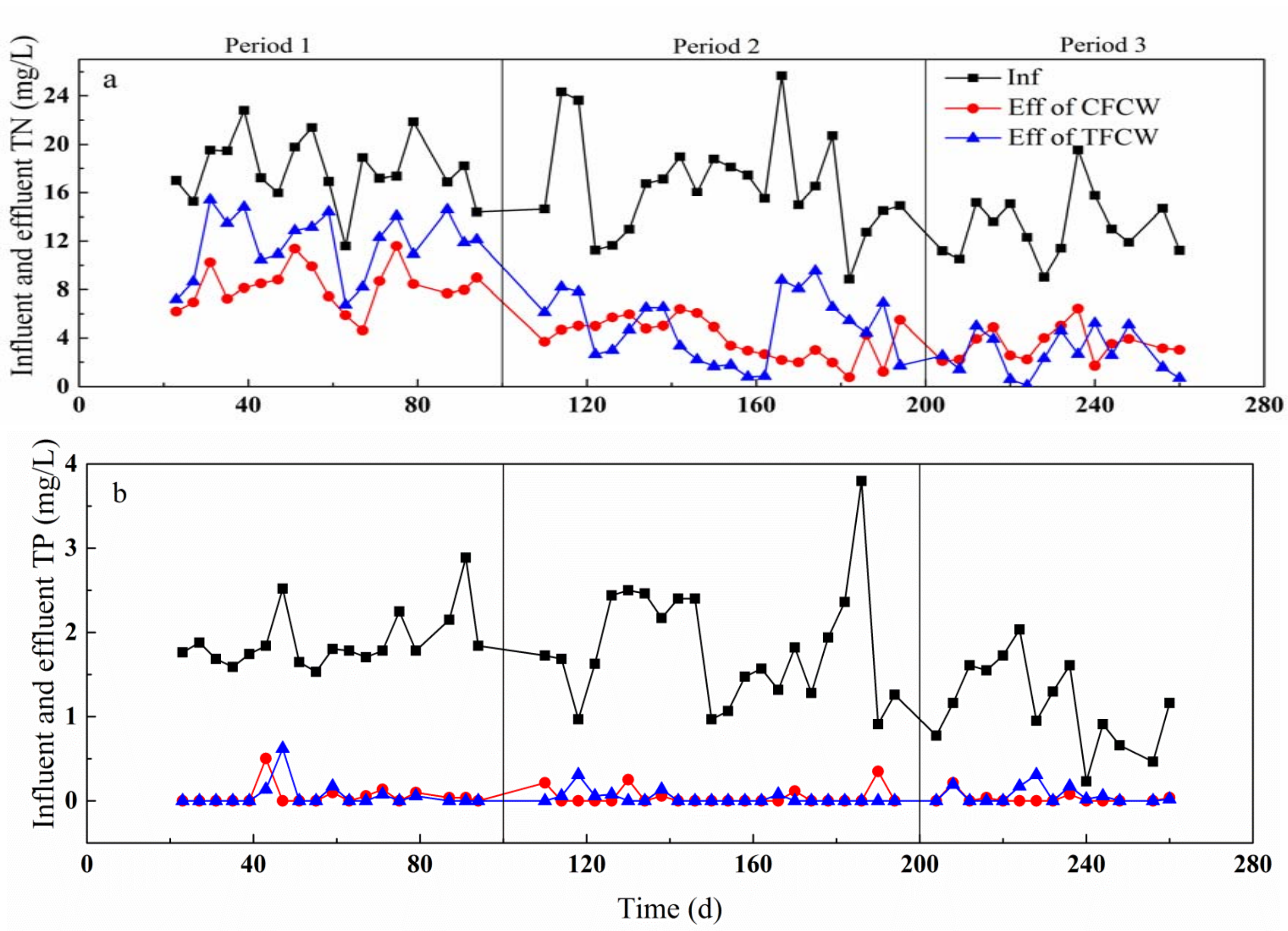
As a substrate in constructed wetlands

Fluctuant TN

remvoal

CFCW: 3.00 g N/m^3

TFCW: 2.38 g N/m^3



Stable TP removal

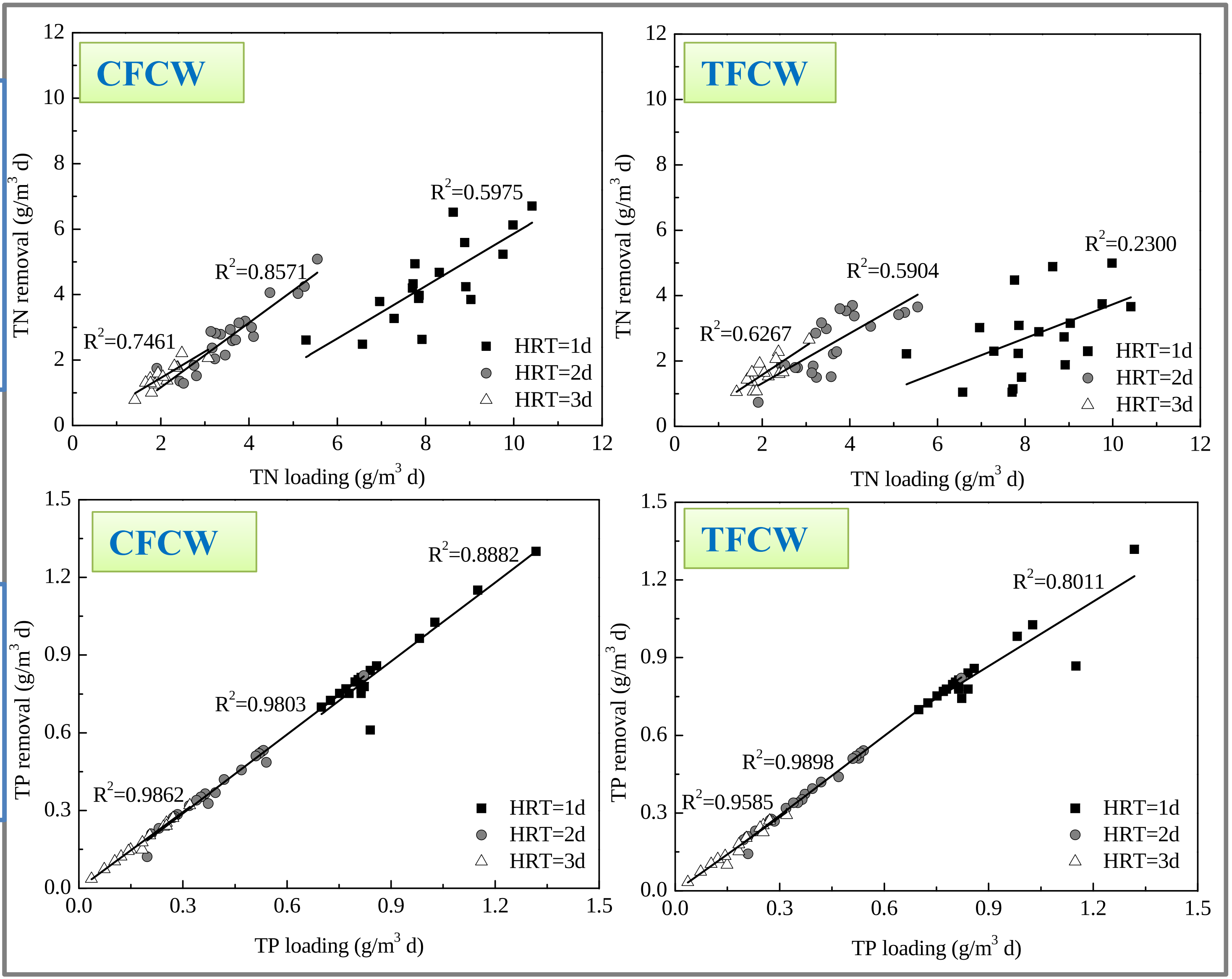
Removal rate: >95%

Life time: >10 years

Effect of HRT

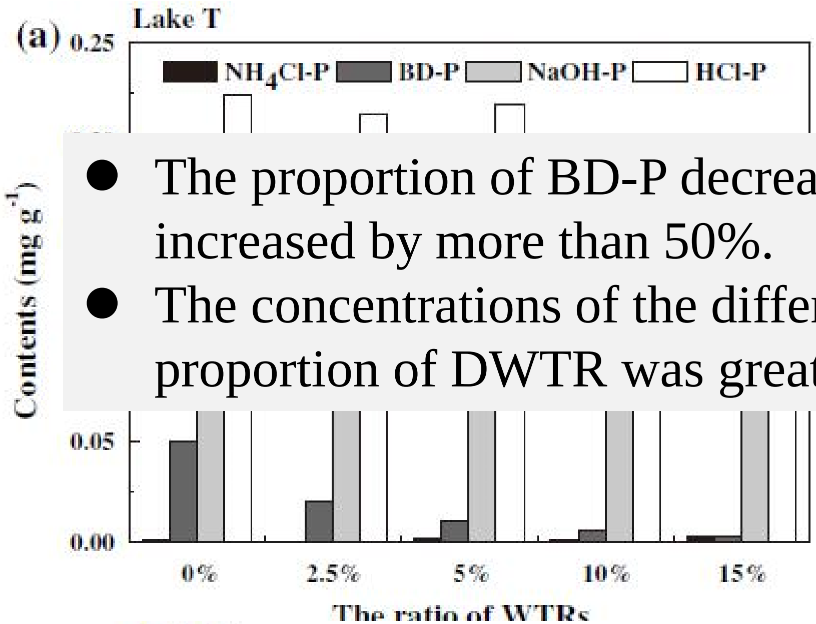
Longer HRT, TN removal efficiency and stability increased

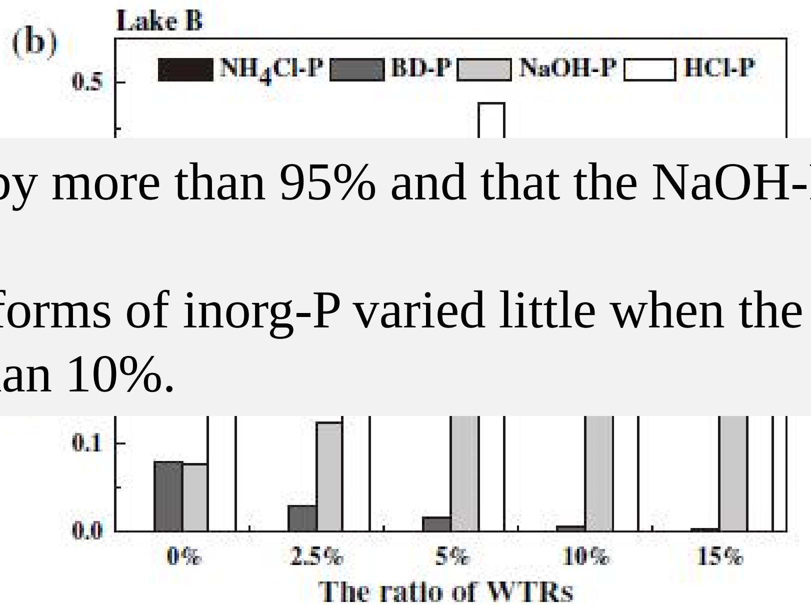
The TP removal was stable under three HRTs



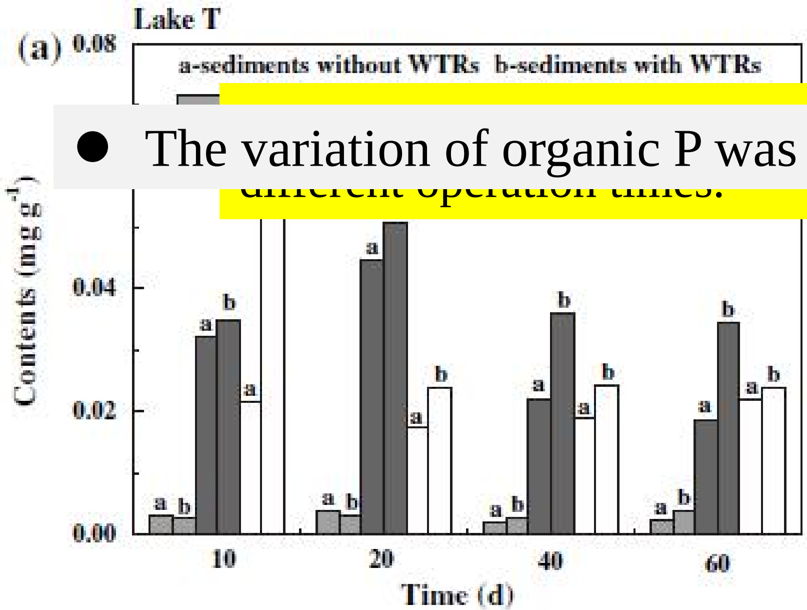
- ◆Both continuous and tidal flow operated DWTR-CWs achieved satisfactory nitrogen and phosphorus removal in short HRTs (1-3 d)
- ◆Longer HRTs were more favourable for pollutants removal
- ◆The leaching of Fe/Al from DWTR-CW were minor
- ◆The DWTR-CW was suitable for sewage tertiary treatment

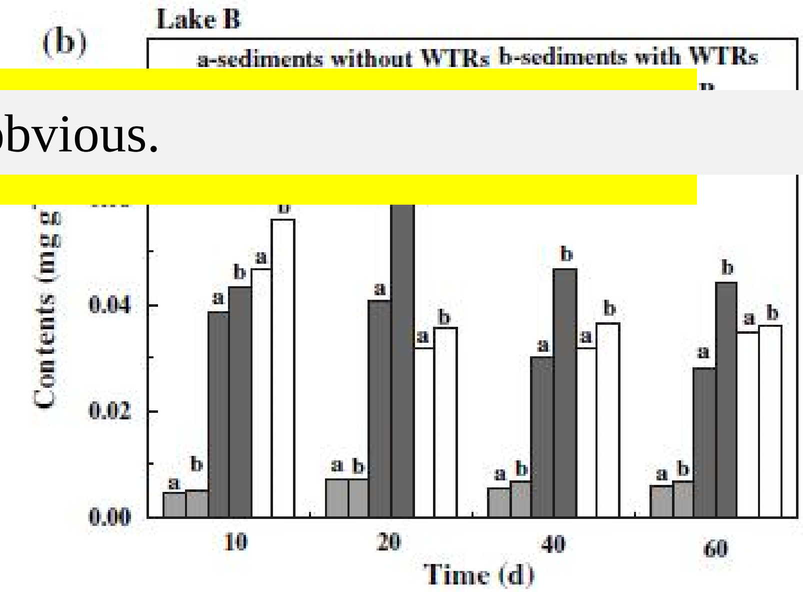
As an amendment for in situ remediation of P-contaminated sediments





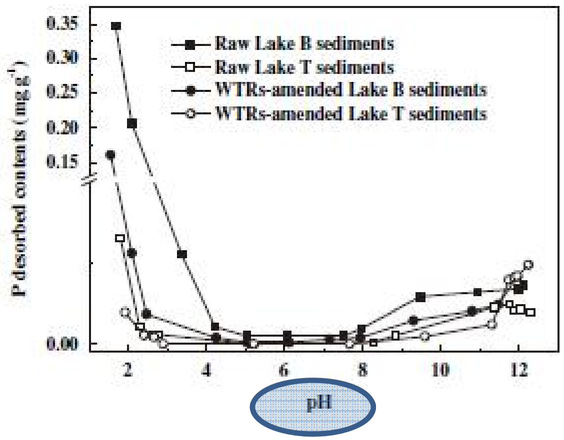
- The proportion of BD-P decreased by more than 95% and that the NaOH-P increased by more than 50%.
- The concentrations of the different forms of inorg-P varied little when the proportion of DWTR was greater than 10%.



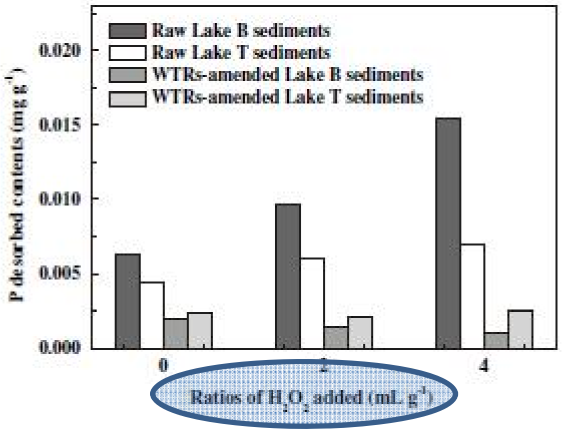


- The variation of organic P was not obvious.

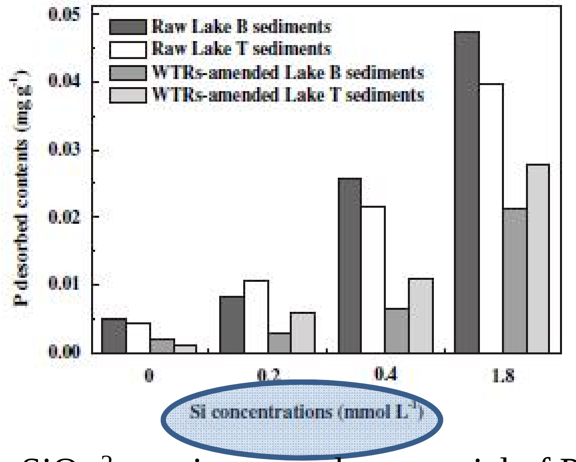
Infulence facters



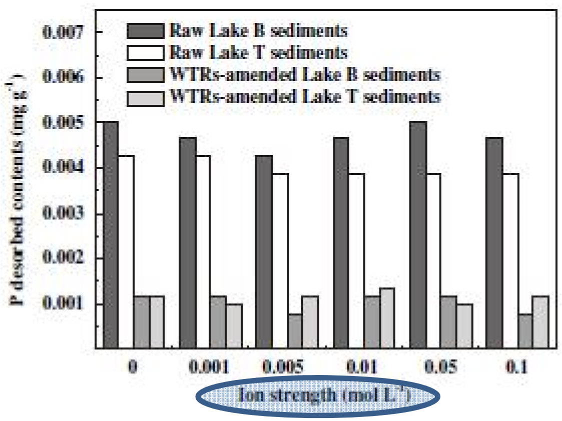
P was more stable in the DWTR amended sediments than in the raw sediments under the regular pH range of 5-9.



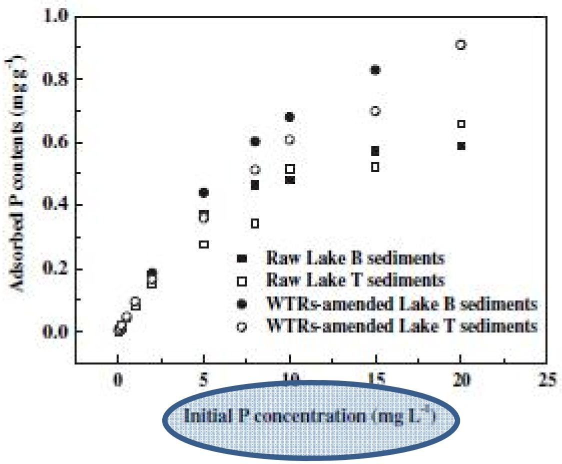
Organic matter in the sediments has little effect on the stability of P in the DWTR-amended sediments.



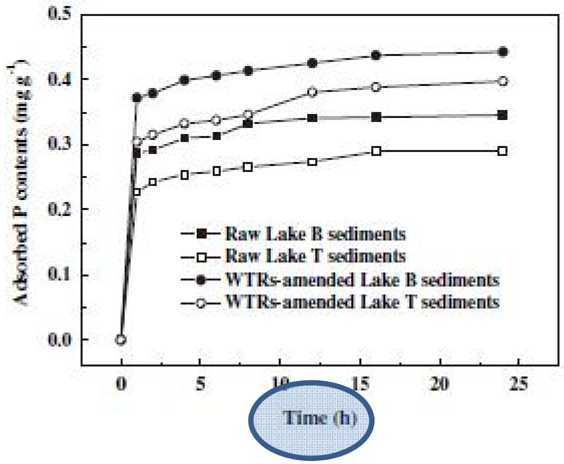
$SiO_4{}^{2-}$ can increase the potential of P desorbed, but, DWTR-amended sediments have a lower P desorbed potential.



DWTR can make P more stable in lake sediments under varying ion strength



DWTR can increase the P adsorption capability of the sediments.



DWTR can increase the initial P adsorption rate of the sediments

Infulence facters

- ◆ Effects of light, microbial activity, and sediment resuspension on the phosphorus immobilization capability of DWTR in lake sediment;
- ◆ Effect of hydrogen sulfide on phosphorus lability in lake sediments amended with DWTR;
- ◆ Effect of settling on the P immobilization capabilities;
- ◆ Effect of dosage of DWTR for effective phosphorus immobilization in sediments.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journal homepage: www.elsevier.com/locate/ecoleng

A method for determining the treatment dosage of drinking water treatment residuals for effective phosphorus immobilization in sediments

Changhui Wang[a], Jincheng Liang[a], Yuansheng Pei[a,*], Laura A. Wendling[b,1]

[a] The Key Laboratory of Water and Sediment Sciences, Ministry of Education, School of Environment, Beijing Normal University, Beijing 100875, PR China
[b] CSIRO Land and Water, Centre for Environment and Life Sciences, Private Bag 5, Wembley, WA 6913, Australia

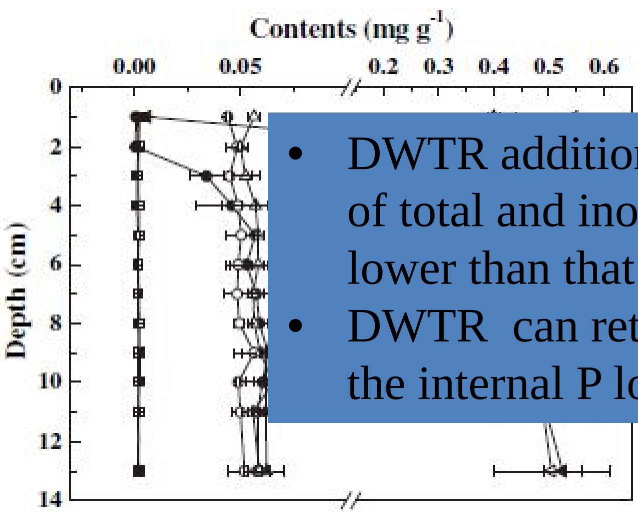
P release character of sediment after amended by DWTR

Effect of WTRs on the qualities of the overlying water under various DO levels in the oxygen enriching process.

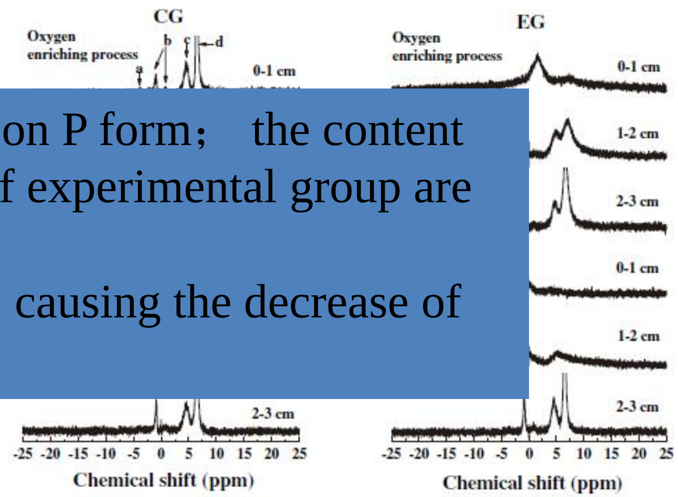
DO levels (mg L^{-1})	Times (days)	SRP (mg L^{-1})		Fe (mg L^{-1})		Al (mg L^{-1})		pH	
		CG[a]	EG[b]	CG	EG	CG	EG	CG	EG
<1 Low	7	0.32	0.051	0.0031	0.039	0.0081	0.14	7.4	7.4
	14	0.32	0.062	0.012	0.059	0.010	0.14	7.3	7.2
	21	0.41	0.040	0.0093	0.068	0.0042	0.12	7.1	7.2
2–4 Moderate	28	0.21	0.033	0.0051	0.055	0.0027	0.078	7.0	7.1
	35	0.23	0.022	0.0050	0.043	0.0026	0.12	7.0	7.1
	42	0.21	0.046	0.0044	0.041	0.0053	0.046	7.0	7.1
5–8 High	49	0.11	ND[c]	0.0044	0.029	0.0033	0.052	7.0	7.1
	56	0.17	ND	0.0051	0.022	0.010	0.050	7.1	7.1
	63	0.11	ND	0.0038	0.021	0.0064	0.046	7.0	7.1

[a] Represents control group.
[b] Represents experimental group.
[c] Represents not detected.

In high DO level, the P removal rate of overlying water can reach 100%.
In different DO levels, the Al and Fe are stable.
DWTR addition has little effect on pH of overlying water.



Fractionation of P in different layers of sediments



^{31}P NMR patterns of the surface 0–3 cm sediments

- DWTR addition has obvious effect on P form； the content of total and inorganic phosphorus of experimental group are lower than that in control group.
- DWTR can retained the released P, causing the decrease of the internal P loading.

As a promising amendment for soil pollution control

- **The feasibility of reusing DWTR as a amendment to enhance the soil retention capacity to organophosphorus pesticide (OPPs)**

DWTR were found to enhance the retention capacity of glyphosate and chlorpyrifos in agricultural soil, reducing the bioavailability of chlorpyrifos and improving the physical and chemical properties of soil (e.g. soil pH and cation exchange capacity).

- **The feasibility of reusing DWTR to remedy soil contaminated with multiple metals**

DWTR can be used to remedy soil contaminated with multiple metals, but comprehensive studies are needed before practical applications of this work

JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY
Article
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Feasibility of Using Drinking Water Treatment Residuals as a Novel Chlorpyrifos Adsorbent

Yuanyuan Zhao,[†] Changhui Wang,[†] Laura A. Wendling,[‡] and Yuansheng Pei*[,†]

[†]The Key Laboratory of Water and Sediment Sciences, Ministry of Education, School of Environment, Beijing Normal University, Beijing 100875, People's Republic of China

[‡]Centre for Environment and Life Sciences, CSIRO Land and Water, Private Bag 5, Wembley, WA 6913, Australia

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Investigation on reusing water treatment residuals to remedy soil contaminated with multiple metals in Baiyin, China

Changhui Wang, Yuanyuan Zhao, Yuansheng Pei*

The Key Laboratory of Water and Sediment Sciences, Ministry of Education, School of Environment, Beijing Normal University, Beijing 100875, PR China

JOURNAL OF ENVIRONMENTAL SCIENCES 34 (2015) 133–142

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Use of Fe/Al drinking water treatment residuals as amendments for enhancing the retention capacity of glyphosate in agricultural soils

J Soils Sediments (2017) 17:889–900
DOI 10.1007/s11368-016-1586-z

SOILS, SEC 1 • SOIL ORGANIC MATTER DYNAMICS AND NUTRIENT CYCLING • RESEARCH ARTICLE

Behavior of chlorpyrifos and its major metabolite TCP (3,5,6-trichloro-2-pyridinol) in agricultural soils amended with drinking water treatment residuals

Yuanyuan Zhao[1,2] • Laura A. Wendling[3] • Changhui Wang[4] • Yuansheng Pei[1]

Potential environmental risks

- Chemical toxicity of DWTR-metal lability

✓ The extractability of Al, Fe, As, Ag, Ba, Be, Ca, Cd, Co, Cr, Cu, Hg, K, Mg, Mn,Mo, Na, Ni, Pb, Sb, Se, Sr, V, and Zn in six DWTR collected throughout China;
✓ Effect of pH on metal lability in DWTR;
✓ Metal lability in air-dried and fresh dewatered DWTR;
✓ Effect of anaerobic incubation on metal lability in DWTR.

DWTR contained various metals, and had relatively high contents of Al and Fe. Different DWTR often had different properties and metals contents and lability, but most of metals in DWTR were largely in stable forms (BCR non-extractable). DWTR also could be considered non-hazardous according to the Toxicity Characteristic Leaching Procedure used in the USA. In most cases, DWTR application had low pollution risks for lake water and sediment, but the lability of Mn in DWTR requires further assessment prior to field application.

- Ecotoxicity of DWTR

✓ Assessed the effects of DWTR on luminescence and growth of *Aliivibrio fischeri;*
✓ Evaluates the ecotoxicity of DWTR on a green alga (*Chlorella vulgaris*);
✓ Analyzed the response of Daphnia magna (*D. magna*) to exposure to DWTR and sediments with and without DWTR addition

We found that DWTR was nontoxic to aquatic organisms on different trophic levels and application of DWTR to control sediment pollution didn’t cause any adverse effect to aquatic organisms.

Future perspectives

- The filed-scale studies are ongoing, particularly the contaminants (P, heavy metals, organic pollutants) immobilizing performance and potential toxicity of DWTR being evaluated.
- A new type DWTR is being explored based on DWTR P adsorption characteristics. The modification technology and combined with other materials are being adopted to obtain an ideal P remediation materials.
- In addition, the DWTR in powder form may lead to clogging in kinds of filtration systems. The low hydraulic conductivity hampers the number of cycles of DWTR. Efforts are needed to develop granular DWTR, and the attempts to granulate DWTR have already been carried out. The preliminary performance evaluation showed that the granular DWTR exhibited strong P adsorption capability and good mechanical stability.

Future field-scale experimental site

Three kinds of granular DWTR

THANK YOU !