Screening Filter Materials For Enhancing Phosphorus Removal from Wastewater in Constructed Wetlands

Thi An Hang NGUYEN[1], Ngoc Duy VU[2], Thi Thuong NGUYEN[1], Thi Thom VU[1], Huu Trung LUONG[1], Jun NAKAJIMA[1], Thi Hoang Ha NGUYEN[2], Hong Con TRAN[2], Keisuke SATO[3]

[1]VNU Vietnam Japan University, Vietnam, [2]VNU University of Science, Vietnam, [3]Ritsumeikan University, Japan

Introduction

The phosphorus removal is essential to protect water bodies from eutrophication. Though the constructed wetlands (CWs) is an environmental friendly technology, its application in Vietnam is still limited, due to its low treatment performance of phosphorus. One of the reasons is the use of traditional substrates, which have low adsorption capacity of phosphorus. This study aims at searching for potential filter materials for use as substrates in constructed wetlands to upgrade the phosphorus removal efficiency. This study investigated 6 locally available materials in both raw and modified forms. The potential materials were selected using 5 main criteria and then characterized. The study also proposed the initial idea of using the selected materials in the hybrid adsorption – constructed wetland system.

Objectives

- To identify the potential filter materials for being used as substrate in CWs
- To characterize the selected filter materials
- To propose an initial idea of CW design with the selected filter materials

Materials and Methods

Materials selection

5 selection criteria: abundant availability, high adsorption capacity, good water conductivity, low cost, less side effects

Natural materials

Laterite (LA) | Coral (CR) | Limestone (LS)

Industrial by-products

Coal slag (CS) | Steel slag (SS) | White Hard Clam (WHC)

Materials modification

* To improve P adsorption capacity of materials

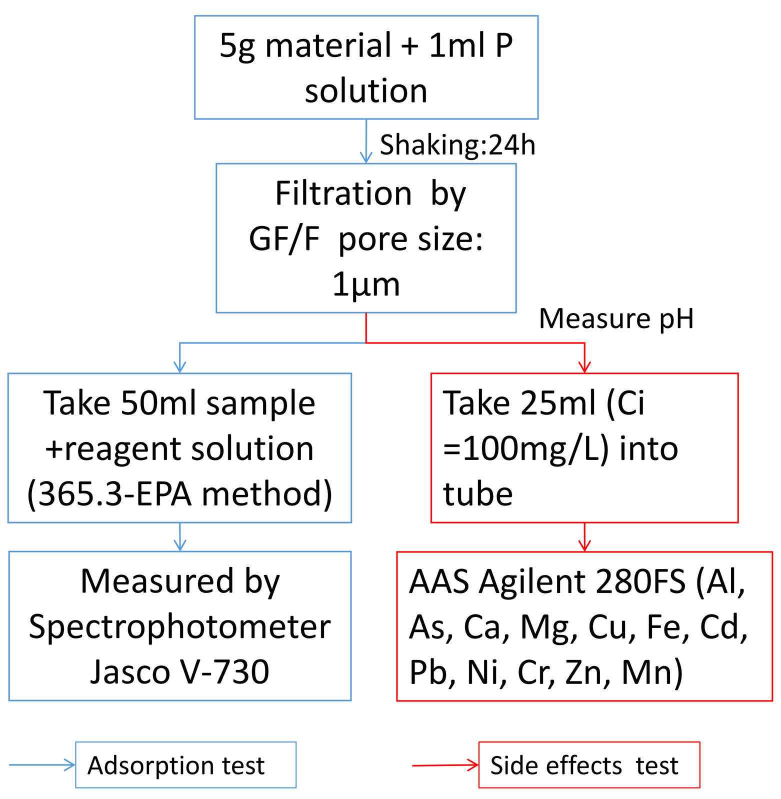
Thermal modification

Material	Modified at
Limestone	800°C
White hard clam	700°C
Coral	700°C

Chemical treatment

Material	Modified by
Laterite	H_2SO_4 0.5M
Coal slag	NaOH 1M, Mg 0.5M
Steel slag	H_2SO_4 0.5M

P adsorption and side effects test



Permeability

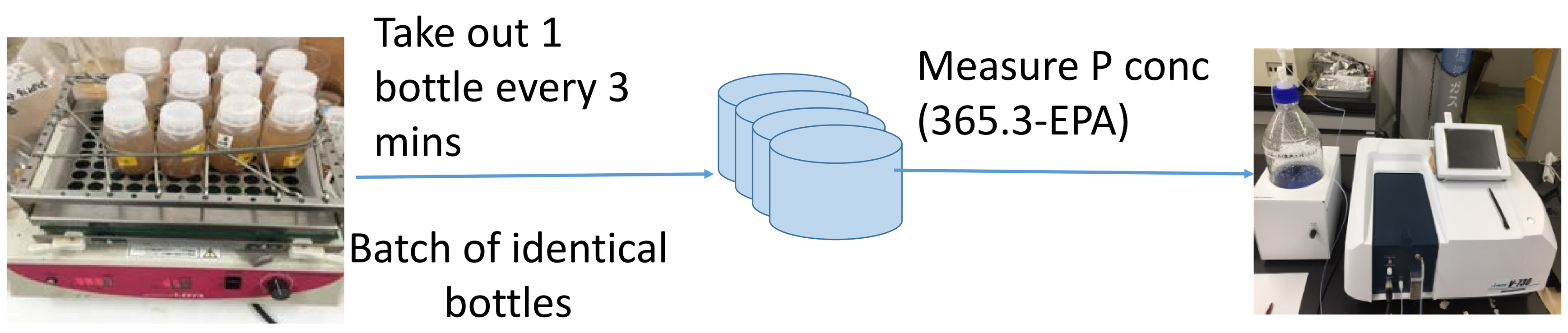
Based on Darcy's Law to find permeability constant of materials

$$Q = KA\frac{\Delta h}{L}$$

Q: Fluid flow (cm³/s);
K: Permeability constant (cm/s);
A: Cross sectional area (cm²);
Δh: Difference in height of water (cm);
L: Flow length (cm)

Kinetic batch experiment

3 g of granular materials is added with 75 mL of synthetic P solution (C_i = 200mg/L) for phosphorus adsorption over time



Contact Information

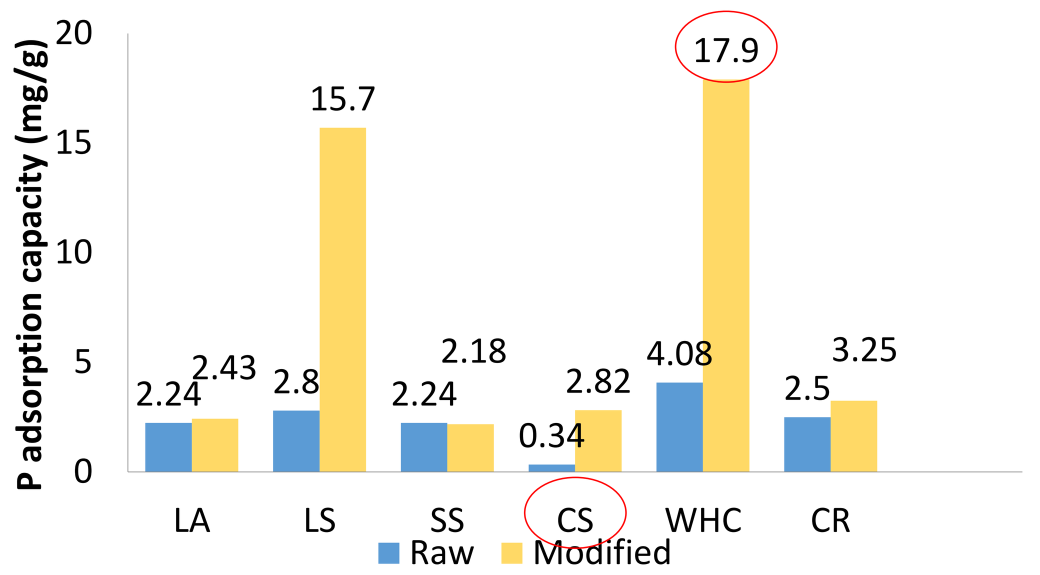
Corresponding author: Dr. Nguyen Thi An Hang
Affiliation: VNU Vietnam Japan University (VJU)
Email: nta.hang@vju.ac.vn **Mobile phone:** (+84) 98 898 5148

Results

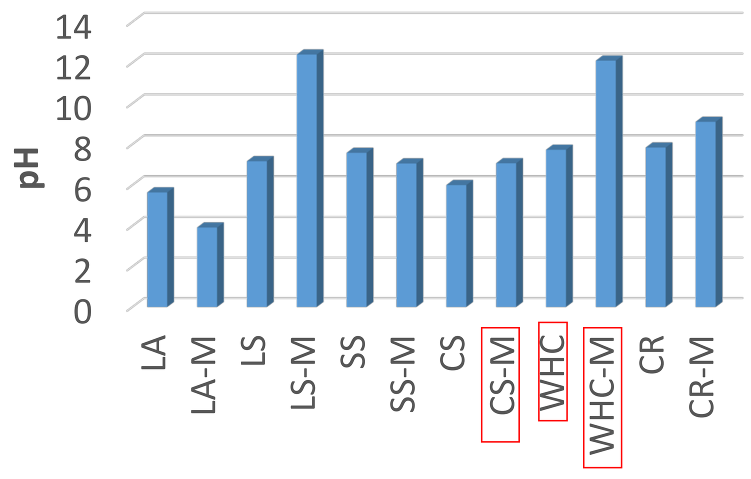
Screening filter materials

Phosphorus adsorption capacity of materials in previous studies

Materials	P sorption capacity (mg/g)	Reference
Bauxite	0.61	Drizo et al., 1999
Zeolite	0.043	ZhenWang et al., 2013
Volcanic	0.227	ZhenWang et al., 2013
Broken bricks	0.594	ZhenWang et al., 2013
Sand (I-II)	0.43-0.44	Zhu et al., 1997
Sand (I-IV)	0.13-0.29	Ádám et al., 2007
Gravel (R/G)	0.03/0.05	Mann and Bavor, 1993



Comparison of adsorption capacity of investigated materials (C_i = 200mg/L, shaking for 24h at 120rpm, dose 5g/125ml, T= 27°C)



pH of post-adsorption solution

Permeability of investigated materials and gravel, coarse sand

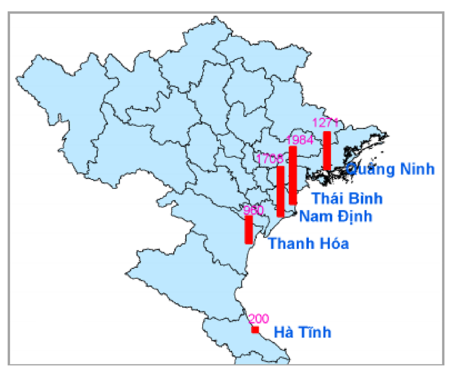
Sample	Permeability constant (K) (cm/s)
LA	4.7
CS	8.5
LS	1.2
WHC	4.5
WHC-M	4.6
SS	2.2
Gravel	1.0
Coarse sand	0.1 – 1
	(Size: 1.4 – 2.2mm)

Heavy metals release in post-adsorption solutions

Samples	As	Cd	Cr	Cu	Mn	Ni	Pb	Zn	Hg	Fe
WHC-M	<0,002	<0,002	<0,002	<0,002	<0,002	0,042	<0,002	<0,002	<0,0002	<0,002
WHC	<0,002	<0,002	0,005	<0,002	0,005	0,011	<0,002	0,116	<0,0002	0,475
SS	<0,002	<0,002	0,005	0,011	0,374	0,009	0,007	0,088	<0,0002	1,11
LS	<0,002	0,002	0,003	<0,002	0,013	0,003	0,012	0,108	<0,0002	0,79
CS-M	<0,002	<0,002	0,012	<0,002	0,067	0,029	0,003	0,348	<0,0002	0.104
LA	0,021	<0,002	0,006	<0,002	0,033	0,009	0,002	0,162	<0,0002	0,59
QCVN (mg/L)	**0.05**	**0.1**	**1**	**2**	**1**	**0.5**	**0.5**	**3**	**0.005**	**5**

=> Heavy metals release were lower than permissible levels

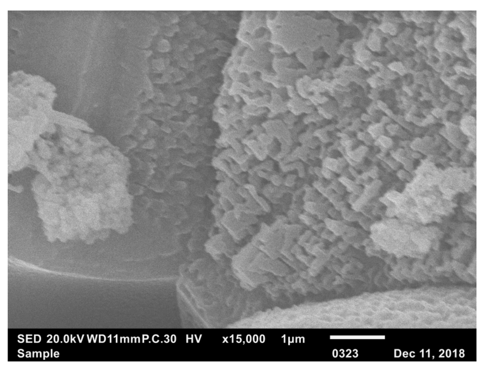
Characteristic of WHC-M



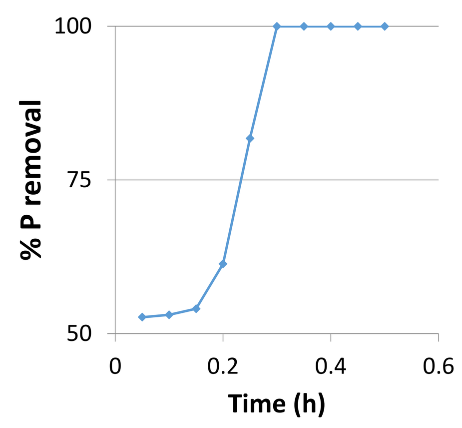
Distribution of WHC in Northern Vietnam

Quantity of WHC in coastal provinces in the north and north central region

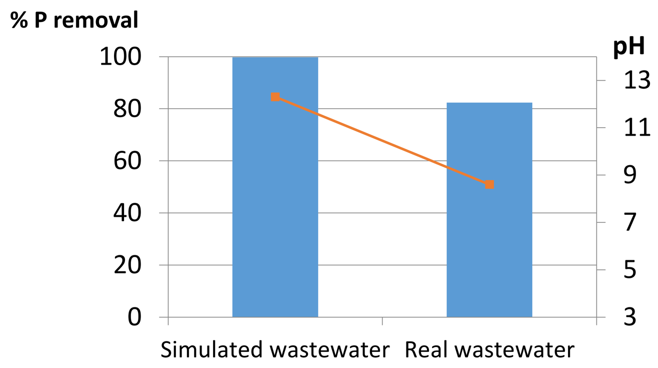
Province	Quantity (ton/year) Lowest	Highest	Average
Quang Ninh	0.6	60	9.2 ± 1.8
Thai Binh	30	700	137.5 ± 20.5
Nam Đinh	10	1000	144.7 ± 20.5
Thanh Hoa	3.5	200	46.5 ± 5.5
Ha Tinh	2.5	250	35.7 ± 7.2



SEM observation of WHC-M

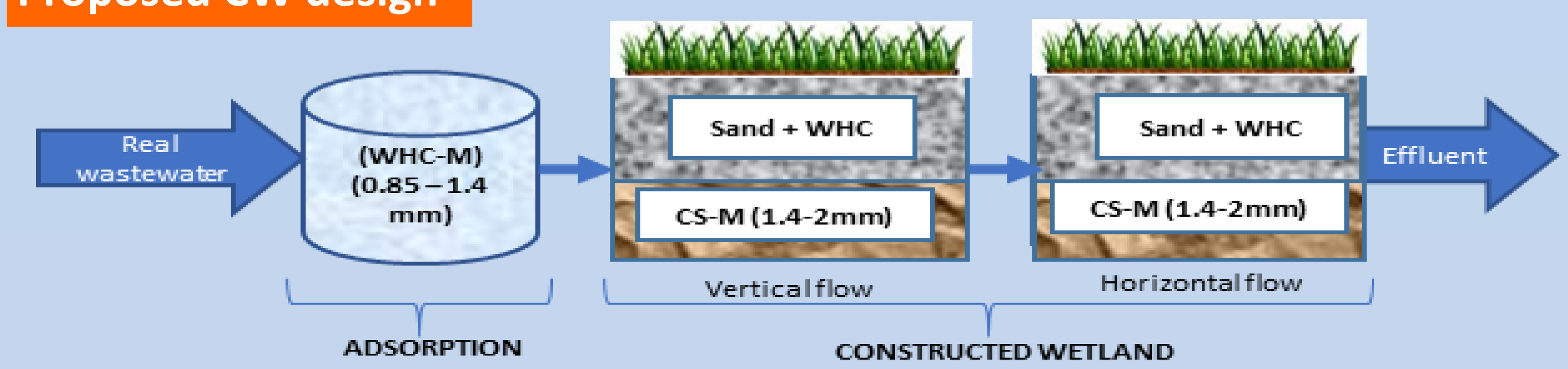


Kinetic test of WHC-M



P adsorption capacity of WHC-M by real wastewater and simulated wastewater

Proposed CW design



Conclusions

- Among investigated materials, WHC-M shows the highest P adsorption capacity while CS yields the highest modification efficiency.
- Optional modification of WHC is 700°C, 3h.
- CS, WHC, WHC-M seems to be suitable for being used as the substrate in CWs.
- Initial design of CWs combining adsorption and CWs is proposed.