Invited lecture: World Sustainability Conference 2022

Sustainable water pollution control: integrated Water-Energy-Food (iWEF) framework

Gang Pan

York St John University, UK

CONTENTS

- in-situ
- ex-situ

1 Harmful algal bloom control (HAB)

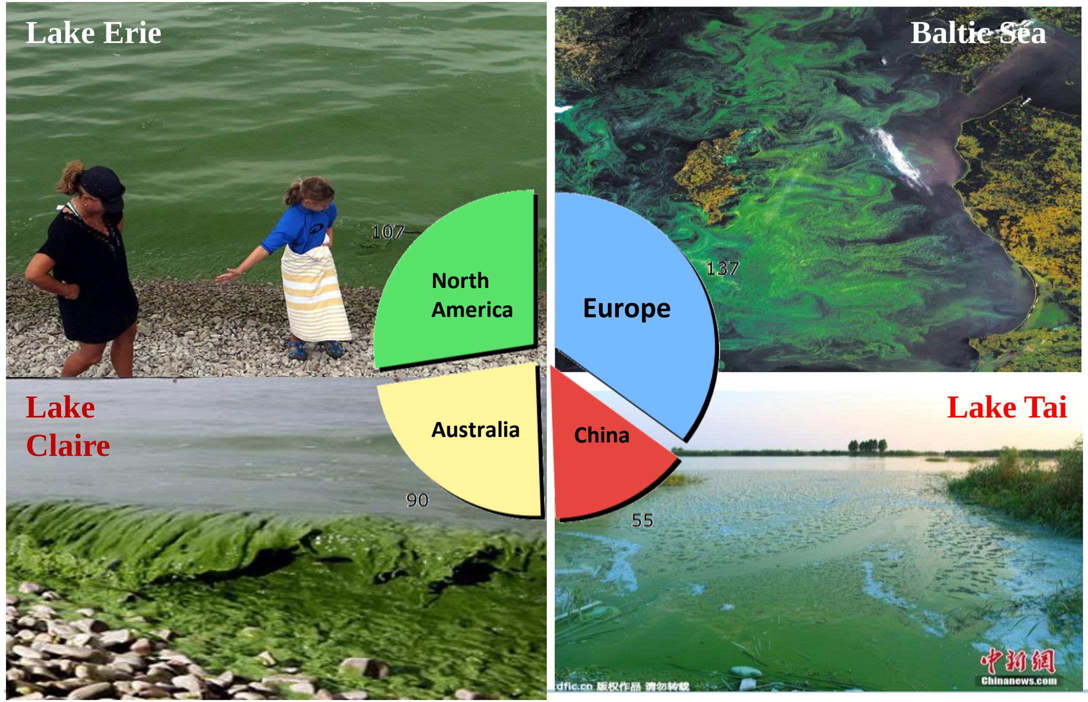
2 Sediment remediation

3 Ecological restoration

4 iWEF (integrated Water-Energy-Food) framework: environmental sustainability

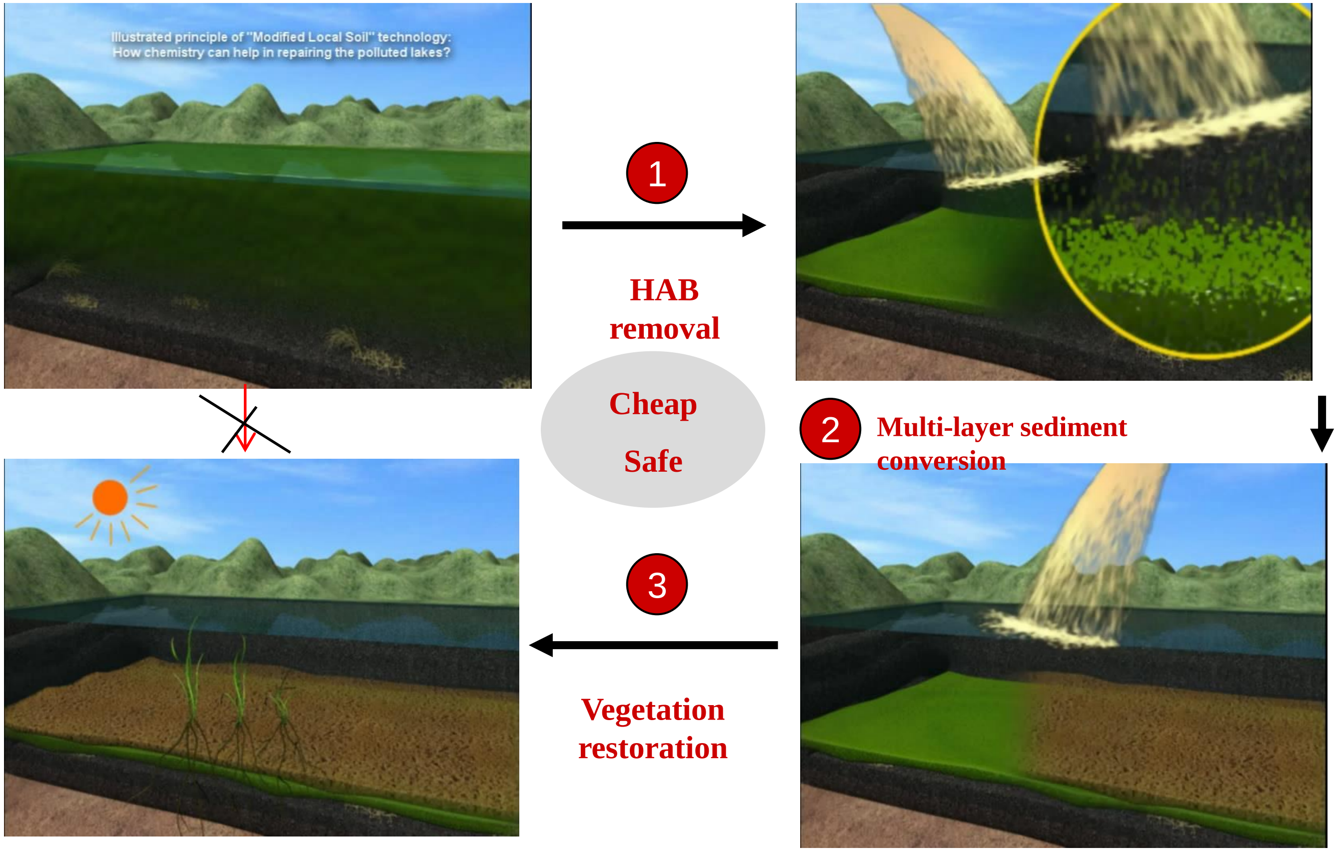
Eutrophication and harmful algal blooms (HABs)

Global problem reported in 45 countries, affecting 3 billions of population



A difficult issue for public health and water resources management

Introduction of Modified local soil (MLS) technology



MLS principle for shallow lake restoration

Water **2019**, *11*, 1123 3 of 16

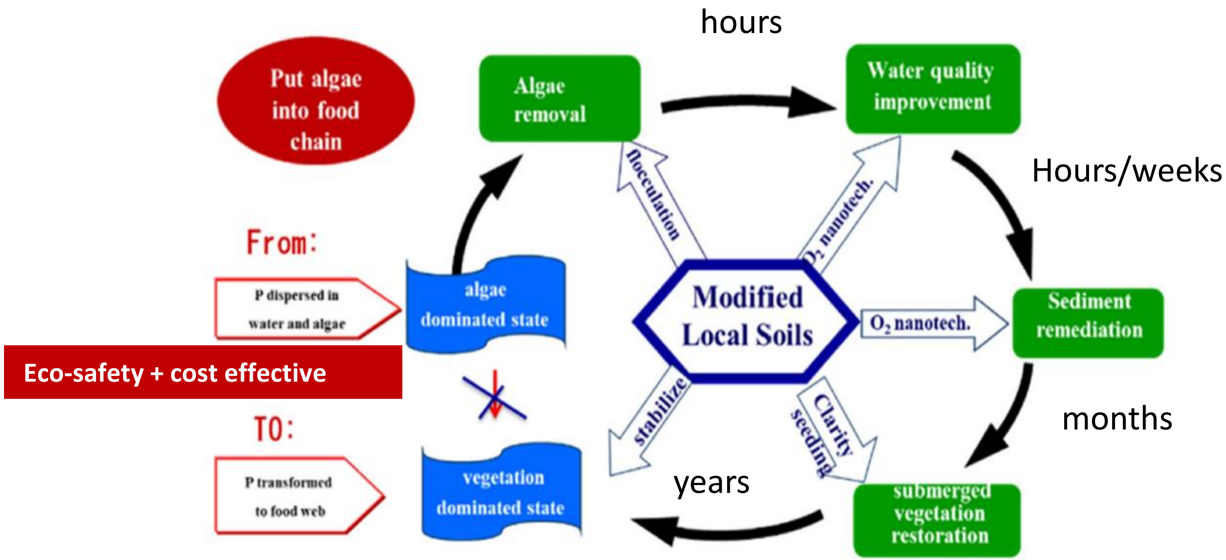
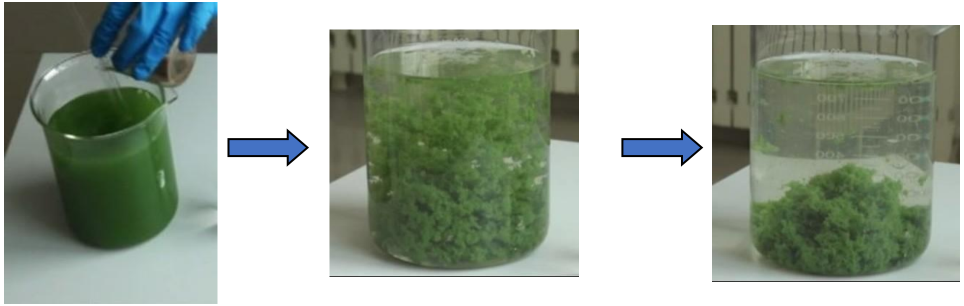


Figure 1. Multi-disciplinary principle of Modified Local Soil (MLS) technology.

ES&T, 2006, 40:1377; ES&T, 2012, 46, 5077; ES&T, 2013, 47, 4555; ES&T, 2013, 47, 9685; ES&T, 2014, 48, 9977; ES&T, 2015, 49, 426; ; ES&T, 2017, 51, 3418; ES&T, 2018, 52, 11778; ES&T, 2018, 52, 8712; ES&T, 2019, 53 (10), 6103; ; ES&T, 2019, 53(13):7175; Environ. Pollut. 2006, 141, 195; Environ. Pollut. 2006, 141, 201; Environ. Pollut. 2006, 141, 206; Ecol. Eng., 2009, 35, 1599; Ecol. Eng., 2011, 37, 302; Harmful Algae, 2011, 10, 381; J. Applied Phycology, 2012, 24, 1183; J. Applied Phycology, 2015; J. Microbiol. Method., 2014, 96, 73; Inland Water, 2014,4, 349; Water Res., 2016, 101:25; Water Res., 2016, 97,11; Water Res., 2016, 97, 133; Water Res., 2016, 97, 19; Water Res., 2019, 165,115005; Water Res., 2019, 150, 191; Water, 2019, 11, 1123; Langmuir, 2016, 32, 11133; Langmuir, 2016, 2016, 32, 11147; Scientific Reports, 2017, 7, 15477; Chemical Society Reviews, 2019, 48, 3740

Algal removal

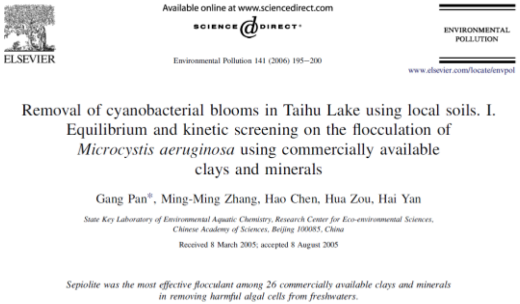


1. **Very low dosage of modified local soil (11mg/L)**
2. **Nutrients removed from water to sediment (with cells)**
3. **Water transparency improvement**

Environ. Pollut. 2006, 141, 195

Environ. Pollut. 2006, 141, 201

Environ. Pollut. 2006, 141, 206



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Environmental Pollution 141 (2006) 195–200
ENVIRONMENTAL POLLUTION
www.elsevier.com/locate/envpol

Removal of cyanobacterial blooms in Taihu Lake using local soils. I. Equilibrium and kinetic screening on the flocculation of *Microcystis aeruginosa* using commercially available clays and minerals

Gang Pan*, Ming-Ming Zhang, Hao Chen, Hua Zou, Hai Yan

State Key Laboratory of Environmental Aquatic Chemistry, Research Center for Eco-environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China

Received 8 March 2005; accepted 8 August 2005

Sepiolite was the most effective flocculant among 26 commercially available clays and minerals in removing harmful algal cells from freshwaters.

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Environmental Pollution 141 (2006) 201–205
ENVIRONMENTAL POLLUTION
www.elsevier.com/locate/envpol

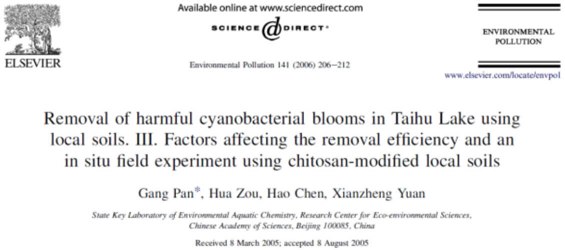
Removal of cyanobacterial blooms in Taihu Lake using local soils. II. Effective removal of *Microcystis aeruginosa* using local soils and sediments modified by chitosan

Hua Zou, Gang Pan*, Hao Chen, Xianzheng Yuan

State Key Laboratory of Environmental Aquatic Chemistry, Research Center for Eco-environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China

Received 8 March 2005; accepted 8 August 2005

Chitosan modification can turn many solids, such as local clays and soils, into highly effective flocculants in removing harmful cyanobacterial blooms in freshwaters.



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Environmental Pollution 141 (2006) 206–212
ENVIRONMENTAL POLLUTION
www.elsevier.com/locate/envpol

Removal of harmful cyanobacterial blooms in Taihu Lake using local soils. III. Factors affecting the removal efficiency and an in situ field experiment using chitosan-modified local soils

Gang Pan*, Hua Zou, Hao Chen, Xianzheng Yuan

State Key Laboratory of Environmental Aquatic Chemistry, Research Center for Eco-environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China

Received 8 March 2005; accepted 8 August 2005

ES&T, 2013, 47, 4555

Environmental Science & Technology
Article
pubs.acs.org/est

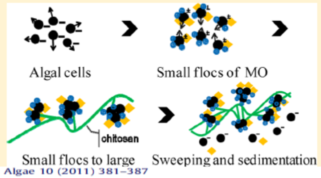
A Universal Method for Flocculating Harmful Algal Blooms in Marine and Fresh Waters Using Modified Sand

Liang Li and Gang Pan*

Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, 10085, China

Supporting Information

ABSTRACT: A universal environmental friendly method was developed to turn sand into effective flocculants for mitigating harmful algal blooms (HABs) in marine and freshwater systems. The isoelectric point of sand was largely increased from pH 4.5 to 10.5 after been modified by *Moringa oleifera* coagulant (MO) abstracted form MO seeds. However, when sand was modified by MO alone, maximum removal efficiencies of 80% and 20% for *Amphidinium carterae* (A.C.) and *Chlorella* sp. (C.S.) in seawater and 60% for *Microcystis aeruginosa* (M.A.) in fresh water were achieved in 30 min. The limited removal improvement was due to the form of only small flocs (20−100 μm) by surface charge modification only. Large flocs



Harmful Algae 10 (2011) 381–387

Contents lists available at ScienceDirect

Harmful Algae

journal homepage: www.elsevier.com/locate/hal

ELSEVIER

2011, 10, 381

Modified local sands for the mitigation of harmful algal blooms

Gang Pan [a,*], Jing Chen [b], Donald M. Anderson [c]

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[b] Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences, Yantai 264003, China
[c] Biology Department, Woods Hole Oceanographic Institution, MS 32, Woods Hole, MA 02543, USA

Contents lists available at ScienceDirect

Water Research

journal homepage: www.elsevier.com/locate/watres

ELSEVIER

WATER RESEARCH

Flocculation of cyanobacterial cells using coal fly ash modified chitosan

CrossMark

Yuting Yuan [a], Honggang Zhang [a], Gang Pan [a, b, *]

[a] Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, 100085, China
[b] School of Animal, Rural and Environmental Sciences, Nottingham Trent University, NG25 0QF, UK

Water Res., 2016, 97, 11

Water Res., 2016, 97, 19

Water Research 97 (2016) 19–25

Contents lists available at ScienceDirect

Water Research

journal homepage: www.elsevier.com/locate/watres

ELSEVIER

WATER RESEARCH

Removal of *Microcystis aeruginosa* using cationic starch modified soils

CrossMark

Wenqing Shi [a], Wanqiao Tan [a, b], Lijing Wang [a], Gang Pan [a, *]

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Water Res., 2019, 165, 115005

Water Research 165 (2019) 115005

Contents lists available at ScienceDirect

Water Research

journal homepage: www.elsevier.com/locate/watres

ELSEVIER

WATER RESEARCH

Amphoteric starch-based bicomponent modified soil for mitigation of harmful algal blooms (HABs) with broad salinity tolerance: Flocculation, algal regrowth, and ecological safety

Check for updates

Xiaoguang Jin [a, b, e], Lei Bi [a], Tao Lyu [c, d, **], Jun Chen [a, b], Honggang Zhang [a], Gang Pan [a, b, c, d, *]

[a] Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, 100085, China
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[c] School of Animal, Rural, and Environmental Sciences, Nottingham Trent University, Brackenhurst Campus, Nottinghamshire, NG25 0QF, United Kingdom
[d] Centre of Integrated Water-Energy-Food Studies (iWEF), Nottingham Trent University, Nottinghamshire, NG25 0QF, United Kingdom
[e] School of Environment, Tsinghua University, Beijing, 100084, China

Lake Tai Pilot (50,000 m² enclosure)

Engineering equipment

第一代喷洒船(2008):

第二代喷洒船(2009):

第三代喷洒船(2012):

小型水域喷洒设备(2013):

Emergency cleaning up of HAB in Tanxi Bay, LakeTai (2019)

Ximo Lake in Hunan 2018

Monitoring of long-term ecological responses in 100,000 m2 Liaoyangyuan Bay of Lake Tai

Ecological Engineering 37 (2011) 302–308

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

ELSEVIER

In-lake algal bloom removal and submerged vegetation restoration using modified local soils

Gang Pan*, Bo Yang, Dan Wang, Hao Chen, Bing-hui Tian, Mu-lan Zhang, Xian-zheng Yuan, Juan Chen

Research Center for Eco-environmental Sciences, Chinese Academy of Sciences, 18 Shuangqing Road, Beijing 100085, China

Table 2
Composition changes of phytoplankton.

Position	Time	Composition of phytoplankton (%)						
		Cyanophyta	*Chlorophyta*	*Bacillariophyta*	*Cryptophyta*	*Euglenophyta*	*Chrysophyta*	*Xanthophyta*
Inside bay	August	98.2	0.01	1.7	–	–	–	–
	October	66.9	23.2	3.6	4.4	1.1	-	0.7
	December	26.4	37.4	15.4	7.5	-	6.7	6.6
Outside bay	August	98.1	0.01	1.8	–	–	–	–
	October	21.6	30.8	25.4	15.9	3.7	2.9	–
	December	38.6	28.2	16.0	8.1	-	-	9.1

Table 3
Composition changes of zooplankton.

Position	Time	Composition of zooplankton (%)		
		Cladocera	*Copepods*	*Rotifera*
Inside bay	August	50.0	13.0	37.0
	October	37.3	5.1	57.6
	December	18.0	14.8	67.2
Outside bay	August	50.0	13.0	37.0
	October	35.0	8.0	57.0
	December	17.0	20.5	62.5

Table 5
Comparison of biodiversity index inside and outside the bay.

Position	Time	$\bar{d}$		
		Phytoplankton	Zooplankton	Zoobenthos
Inside bay	August	0.091	0.979	0.087
	October	0.949	0.837	0.633
	December	1.562	0.858	1.011
Outside bay	August	0.091	0.979	0.087
	October	1.559	0.889	0.741
	December	1.439	0.920	0.779

Fig. 2. Severe HAB inside the bay before the treatment (photo taken before the treatment on 13th August 2006).

1 day

Fig. 4. One day after treatment using MLS-IER technology (photo taken on 14 August 2006).

4 month

Fig. 11. Submerged vegetation was successfully restored 4 months after the treatment (photo taken on the 1 December 2006).

***ES&T* video contest:**
http://www.youtube.com/watch?v=viGBR6fxkbk

Research Brief

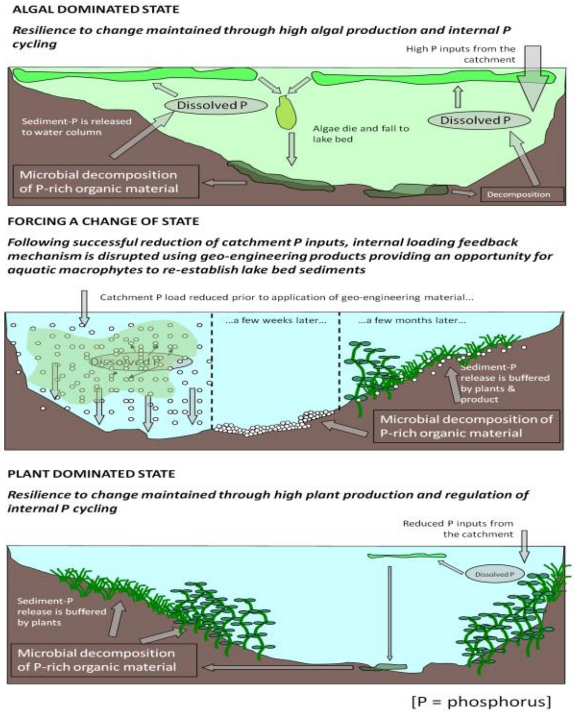
Inland Waters, 2014, 4 (4). 349-356

Geoengineering in lakes: welcome attraction or fatal distraction?

Eleanor B. Mackay[1], Stephen C. Maberly[1], Gang Pan[2], Kasper Reitzel[3], Andy Bruere[4], Nicholas Corker[5], Grant Douglas[6], Sara Egemose[3], David Hamilton[7], Tristan Hatton-Ellis[8], Brian Huser[9], Wei Li[10], Sebastian Meis[11], Brian Moss[12], Miquel Lürling[13], Geoff Phillips[14], Said Yasseri[15], and Bryan M. Spears[16*]

What does geoengineering do?

The premise of geoengineering in lakes is to manipulate biogeochemical processes known to improve ecological structure and function. It most commonly focuses on the



the water column, the materials strip out dissolved phosphorus as they sink to the bed sediments, where they may continue to act to reduce diffusion of dissolved phosphorus from the lake bed to the water column (e.g., Robb et al. 2003, Reitzel et al. 2005, Pan et al. 2006, 2012a, Meis et al. 2012). The range of products used is growing and includes engineered materials, commercially available salts, modified local soils, and industrial by-products (Hickey and Gibbs 2009). Substances are also currently being developed to flocculate phytoplankton; modify dissolved oxygen, carbon, and nitrogen concentrations; and to encourage spread of desirable plants through propagule dispersal (Pan et al. 2011a, 2011b, van de Weyer et al. 2014). Manipulation of benthic bacterial communities through increasing redox status, using materials capable of delivering oxygen microbubbles, has also been used (Pan et al. 2012b). Perhaps the most widespread use of the approach, however, has been the liming of lakes to reduce the effects of acidification (Guhrén et al. 2007, Angelar and Goedkoop 2010).

The global market for geoengineering materials is difficult to define because published data on the number and size of treated lakes and ponds are limited. With respect to phosphorus inactivation, however, about 50 lakes have been treated with aluminium-based compounds in the United States over the last 5 years (B. Huser, pers. comm.), while in 2013, Phoslock, a lanthanum-modified bentonite clay product, was added to at least 30 lakes across the world (S. Yaseri, pers. comm.), and modified local soil materials were used in several waterbodies in China (G. Pan, pers. comm.).

Sediment remediation using oxygen nanobubble materials

Environmental Science & Technology Article

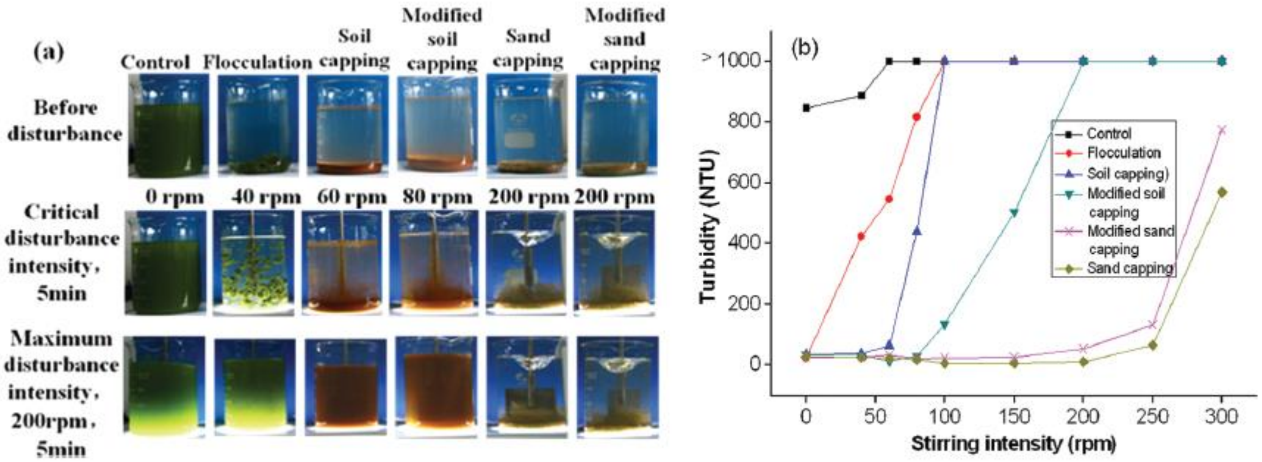


Figure 1. The effect of MLS-capping on resuspension reduction (a) and the turbidity caused by different disturbance intensities (b), where 1000 NTU is the maximum limit of the instrument. The critical disturbance intensity means the disturbance intensity at which resuspension occurs.

Physical: MLS capping reduces algal floc resuspension to maintain water transparency

MLS capping: chemical and microbial regulation inhibits the release of nutrients from sediment

ES&T, 2012, 46, 5077

Environmental Science & Technology

Article

pubs.acs.org/est

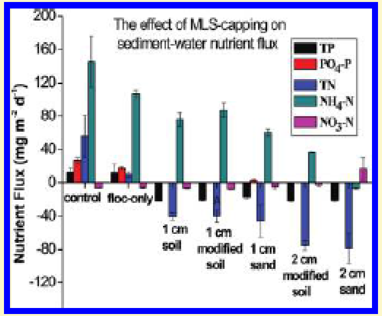
Reducing the Recruitment of Sedimented Algae and Nutrient Release into the Overlying Water Using Modified Soil/Sand Flocculation-Capping in Eutrophic Lakes

Gang Pan,[†,*] Lichun Dai,[†] Liang Li,[†] Linchen He,[†] Hong Li,[†] Lei Bi,[†] and Ramesh D. Gulati[‡]

[†]Research Center for Eco-environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China

[‡]Netherlands Institute of Ecology, Wageningen, The Netherlands

ABSTRACT: The effect of simultaneously removing algal blooms from water and reducing the resuspension and nutrient release from the sediment was studied using modified local soil/sand flocculation-capping (MLS-capping) in simulated water-sediment systems. Twenty one sediment cores in situ with overlying water containing algal blooms were collected from Meiliang Bay of Lake Taihu (China) in July 2011. The algal cells in the water were flocculated and sunk to the sediment using chitosan modified local soils, and the algal flocs were capped with modified and nonmodified soil/sand and then incubated at 25 °C for 20 days. In the MLS-capping treated systems, the TP concentration was reduced from 2.56 mg P L^{-1} to 0.06–0.14 mg P L^{-1} and TN from 14.66 mg N L^{-1} to 6.03–9.56 mg N L^{-1} throughout the experiment, whereas the sediment to water fluxes of TP, TN, PO_4–P, and NH_4–N were greatly reduced or reversed and the redox potential remarkably increased compared to the control system. A capping layer of 1 cm



MLS flocculation-capping to degrade algae toxins

Environmental Science & Technology

ES&T, 2015, 49, 426

Article

pubs.acs.org/est

Simultaneous Removal of Harmful Algal Blooms and Microcystins Using Microorganism- and Chitosan-Modified Local Soil

Hong Li[†,‡] and Gang Pan[*,†]

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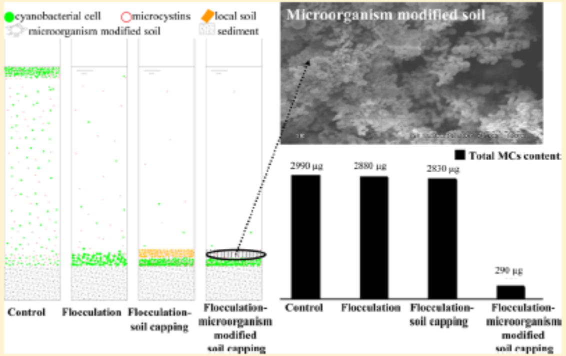
[‡]Institute of Biology, Guizhou Academy of Science, Guiyang 550009, China

Supporting Information

ABSTRACT: Cyanobacterial harmful algal blooms (cyano-HAB) and microcystins (MCs) can cause a potential threat to public health. Here, a method for simultaneous removal of cyano-HAB and MCs was developed using chitosan-modified local soil (MLS) flocculation plus microorganism-modified soil capping. The experiment was conducted in simulated columns containing algal water collected from Lake Taihu (China). More than 90% of algal cells and intracellular MCs were flocculated and removed from water using chitosan-MLS and the sunken flocs were treated by different capping materials including *Pseudomonas* sp. An18 modified local soil. During 40 days of incubation, dissolved MC-LR and MC-RR showed 10-fold increase in the flocculation-only system. The increase of MC-LR and MC-RR in water was reduced by 30 and 70% in soil capping treatments; however, the total content of MCs in the sediment−water column remained



Remediation of hypoxia in polluted sediment

Science of the Total Environment 637–638 (2018) 550–560

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Combating hypoxia/anoxia at sediment-water interfaces: A preliminary study of oxygen nanobubble modified clay materials

Honggang Zhang [a], Tao Lyu [b], Lei Bi [a], Grant Tempero [c], David P. Hamilton [c,d], Gang Pan [a,b,*]

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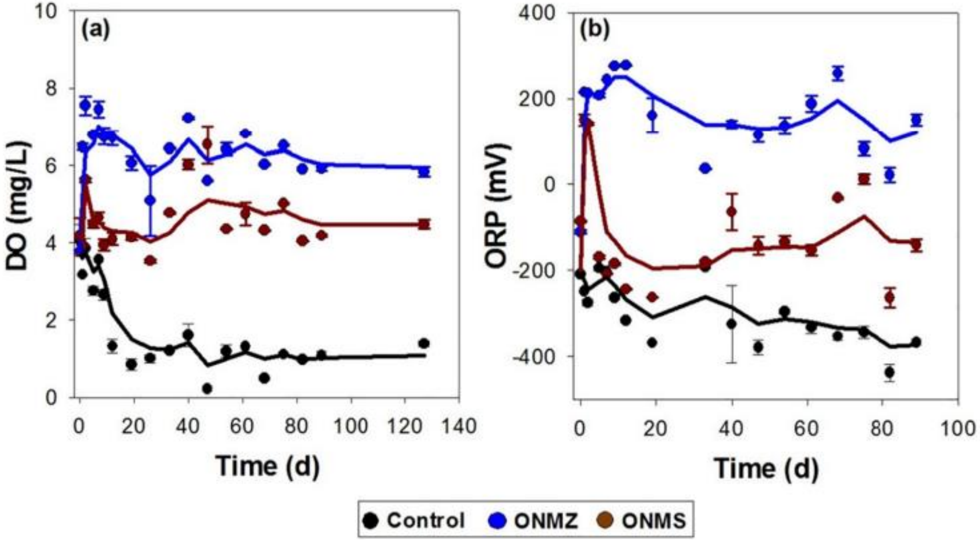
[d] Current Address: Australian Rivers Institute, Griffith University, 170 Kessels Road, Brisbane 4120, Australia

Fig. 7. The color change at sediment-water interfaces in the column experiment after 127 days. Treatment A and treatment B are ONMZ and ONMS, respectively. Th
was taken off for the picture.

H. Zhang et al. / Science of the Total Environment 637–638 (2018) 550–560



The O_2/ORP change can trigger many geochemical and microbial processes in the sediment, affecting P, N, C, S, metal cycling

Manipulation of N, P cycling

Chemical Engineering Journal 406 (2021) 127206

Contents lists available at ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Exploring a multifunctional geoengineering material for eutrophication remediation: Simultaneously control internal nutrient load and tackle hypoxia

Honggang Zhang[a,b,*], Tao Lyu[c,*], Lixuan Liu[d], Zhenyuan Hu[e], Jun Chen[a], Bensheng Su[d], Jianwei Yu[a], Gang Pan[f]

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[b] Yangtze River Delta Branch, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Yiwu 322000, China
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[e] Administration Office of the Summer Palace, Beijing 100091, China
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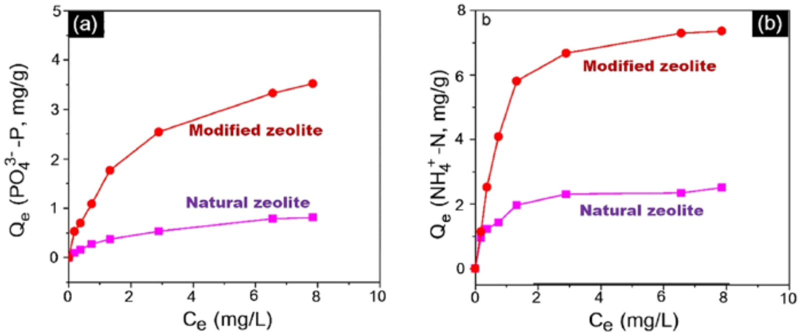
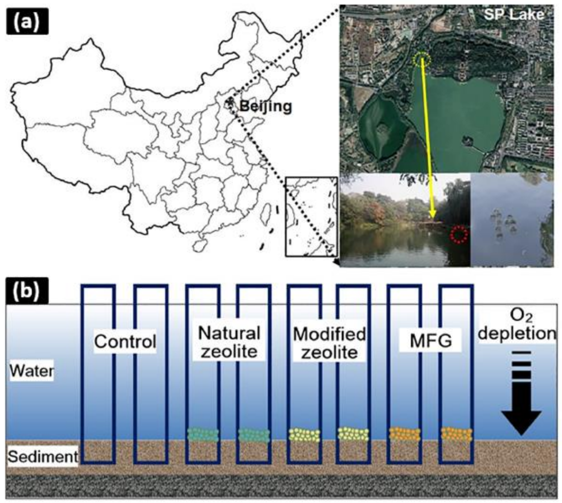
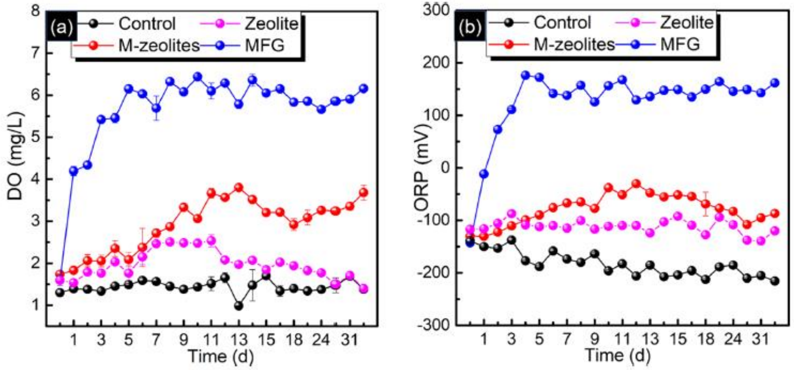
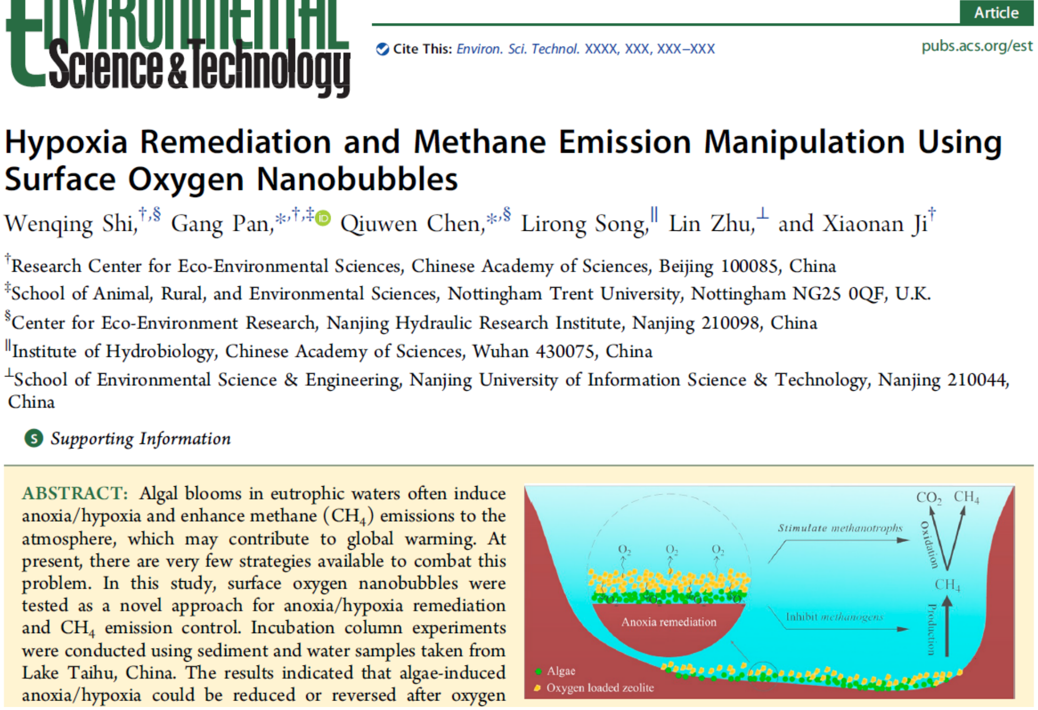






Manipulation of C cycling

Environ. Sci. Technol., **2018**, *52*, 8712


Environmental Science & Technology
Article
Cite This: Environ. Sci. Technol. XXXX, XXX, XXX−XXX
pubs.acs.org/est

Hypoxia Remediation and Methane Emission Manipulation Using Surface Oxygen Nanobubbles

Wenqing Shi,[†,§] Gang Pan,[*,†,‡] Qiuwen Chen,[*,§] Lirong Song,[∥] Lin Zhu,[⊥] and Xiaonan Ji[†]

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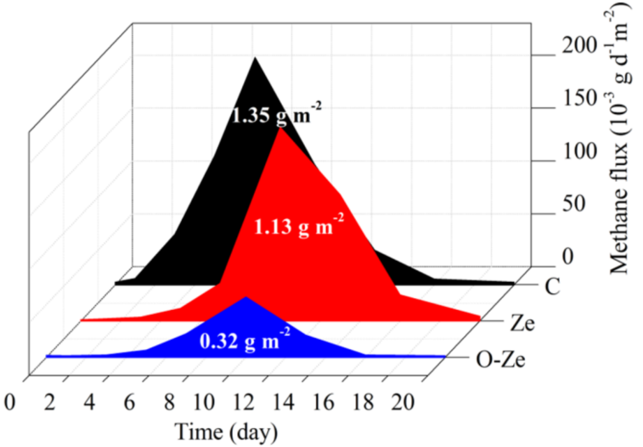
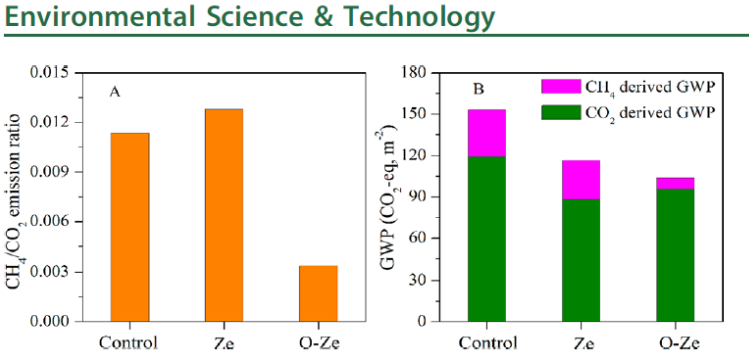
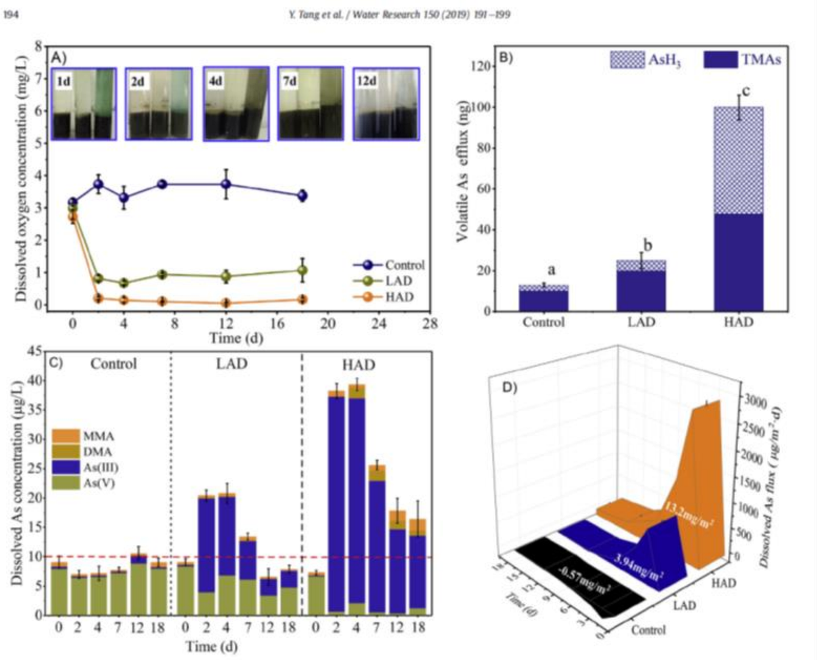
Supporting Information

ABSTRACT: Algal blooms in eutrophic waters often induce anoxia/hypoxia and enhance methane (CH_4) emissions to the atmosphere, which may contribute to global warming. At present, there are very few strategies available to combat this problem. In this study, surface oxygen nanobubbles were tested as a novel approach for anoxia/hypoxia remediation and CH_4 emission control. Incubation column experiments were conducted using sediment and water samples taken from Lake Taihu, China. The results indicated that algae-induced anoxia/hypoxia could be reduced or reversed after oxygen





Arsenic exposure in eutrophic waters



Water Research 150 (2019) 191–199

Contents lists available at ScienceDirect

Water Research

journal homepage: www.elsevier.com/locate/watres

Impact of eutrophication on arsenic cycling in freshwaters

Ying Tang [a, c], Meiyi Zhang [a, *], Guoxin Sun [a], Gang Pan [a, b, *]

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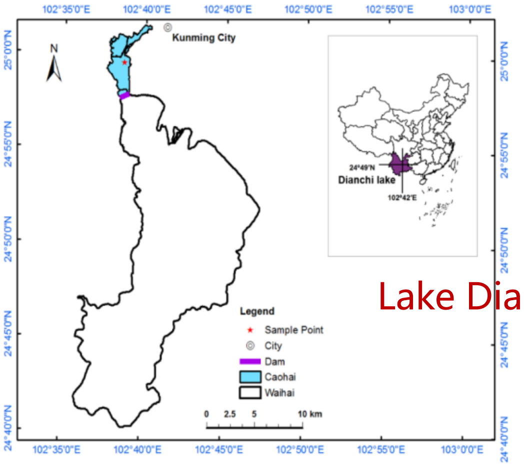

Lake Dianchi

Water Research 205 (2021) 117657

Contents lists available at ScienceDirect

Water Research

journal homepage: www.elsevier.com/locate/watres

Reducing arsenic toxicity using the interfacial oxygen nanobubble technology for sediment remediation

Ying Tang [a,b], Meiyi Zhang [b], Jing Zhang [b], Tao Lyu [c], Mick Cooper [d], Gang Pan [b,d,*]

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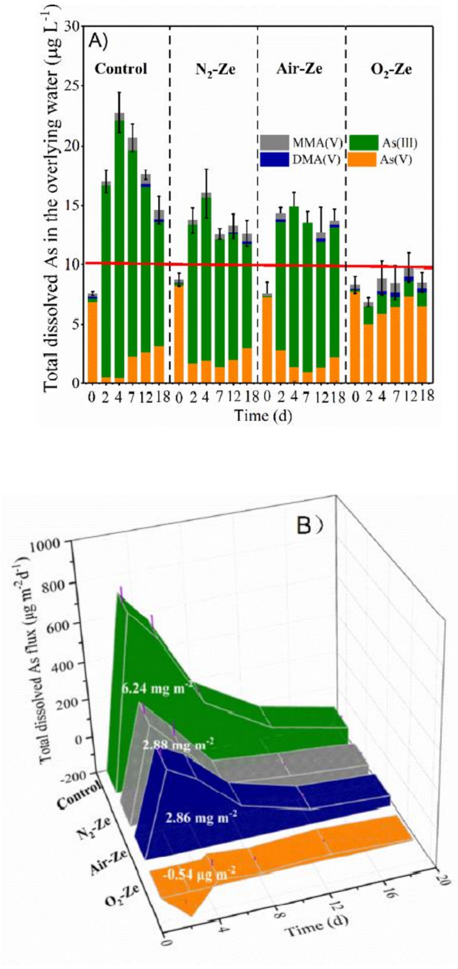
[b] Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, PR China

[c] Cranfield Water Science Institute, Cranfield University, College Road, Cranfield, Bedfordshire MK43 0AL, United Kingdom

[d] Integrated Water-Energy-Food Facility (iWEF), School of Animal, Rural, and Environmental Sciences, Nottingham Trent University, Nottinghamshire NG25 0QF, United Kingdom



Remediation of sediment mercury pollution

Water Research 173 (2020) 115563

Contents lists available at ScienceDirect

Water Research

journal homepage: www.elsevier.com/locate/watres

Mitigation of methylmercury production in eutrophic waters by interfacial oxygen nanobubbles

Xiaonan Ji [a, b], Chengbin Liu [a, c], Meiyi Zhang [a, **], Yongguang Yin [a], Gang Pan [a, b, d, e, *]

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[c] State Key Laboratory of Pollution Control and Resource Reuse, College of Environmental Science and Engineering, Tongji University, 1239 Siping Road, Shanghai, 200092, PR China
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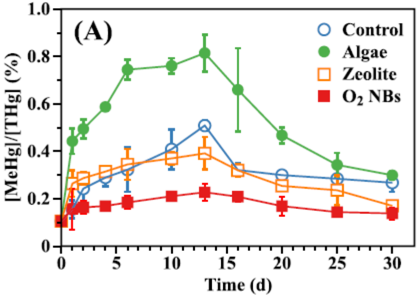
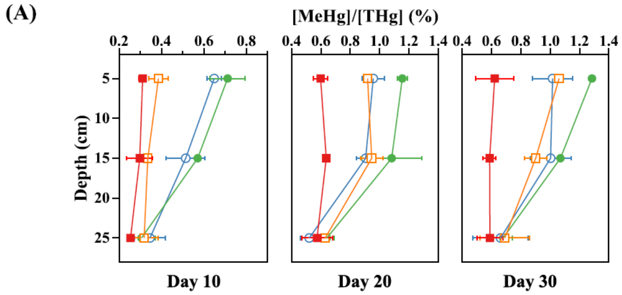




Shallow water ecological restoration

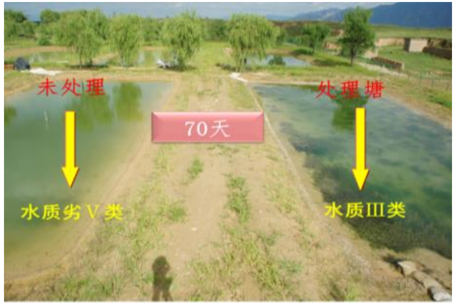
Control

MLS Treatment
(70 days)

1.5 m, submerged macrophytes restoration

Three-year monitoring of ecological and water quality

control



1st year

3rd year

2nd year

Water, 2019, 11, 1123

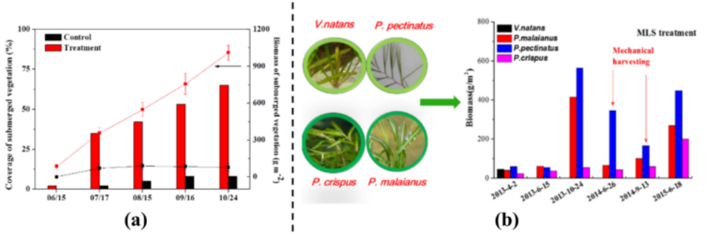


Figure 12. (**a**) The coverage and biomass of submerged vegetation in the control and treatment ponds after 4 months and (**b**) a 3-year monitoring result on submerged vegetation restoration in the treated pond.

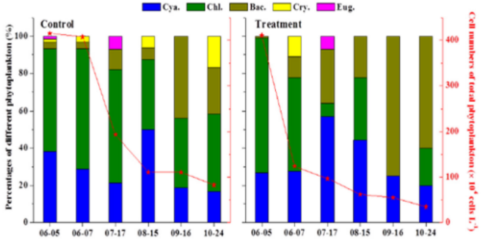


Figure 13. Changes of the dominant phytoplankton composition in the control and treatment ponds.

Turning microalgae to macrophytes through MLS

Environmental Science & Technology

Article

Cite This: *Environ. Sci. Technol.* 2018, 52, 11778–11785

pubs.acs.org/est

Switching Harmful Algal Blooms to Submerged Macrophytes in Shallow Waters Using Geo-engineering Methods: Evidence from a ^{15}N Tracing Study

Honggang Zhang,[†] Yuanyuan Shang,[†] Tao lyu,[‡,§] Jun Chen,[†] and Gang Pan*[,†,‡,§]

[†]Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China

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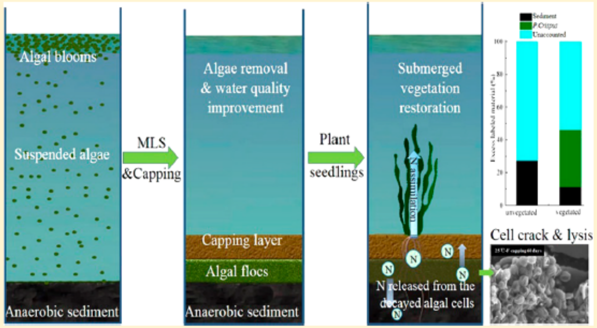
Supporting Information

ABSTRACT: Switching the dominance from algae to macrophytes is crucial for lake management of human-induced eutrophication. Nutrients from algal sources can be utilized in the process of transition from algal blooms to macrophytes, thereby mitigating eutrophication. However, this process rarely occurs in algal bloom dominated waters. Here, we examined the hypothesis that the transition of algal blooms to macrophytes and the transfer of nutrients from algae at different temperatures (8 and 25 °C) can be facilitated by using a geo-engineering method. The results showed that the combination of flocculation and capping treatment could not only remove *Microcystis aeruginosa* blooms from eutrophic waters but also facilitate algal decomposition and incorporation into a sub-



5 field pilot studies and overview of MLS

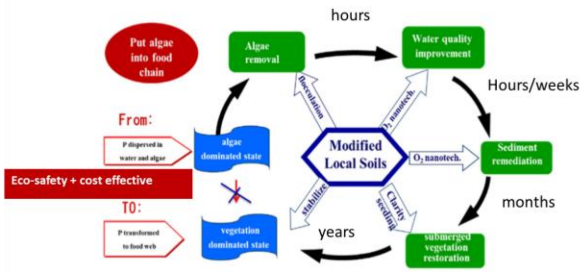


Figure 1. Multi-disciplinary principle of Modified Local Soil (MLS) technology.

ES&T, 2006, 40:1377; ES&T, 2012, 46, 5077; ES&T, 2013, 47, 4555; ES&T, 2013, 47, 9685; ES&T, 2014, 48, 9977; ES&T, 2015, 49, 426; ; ES&T, 2017, 51, 3418; ES&T, 2018, 52, 11778; ES&T, 2018, 52, 8712; ES&T, 2019, 53 (10), 6103; ; ES&T, 2019, 53(13):7175; Environ. Pollut. 2006, 141, 195; Environ. Pollut. 2006, 141, 201; Environ. Pollut. 2006, 141, 206; Ecol. Eng., 2009, 35, 1599; Ecol. Eng., 2011, 37, 302; Harmful Algae, 2011, 10, 381; J. Applied Phycology, 2012, 24, 1183; J. Applied Phycology, 2015; J. Microbiol. Method., 2014, 96, 73; Inland Water, 2014,4, 349; Water Res., 2016, 101:25; Water Res., 2016, 97,11; Water Res., 2016, 97, 133; Water Res., 2016, 97, 19; Water Res., 2019, 165,115005; Water Res., 2019, 150, 191; Water, 2019, 11, 1123; Langmuir, 2016, 32, 11133; Langmuir, 2016, 2016, 32, 11147; Scientific Reports, 2017, 7, 15477; Chemical Society Reviews, 2019, 48, 3740

water Water, 2019, 11, 1123 MDPI

Article

Modified Local Soil (MLS) Technology for Harmful Algal Bloom Control, Sediment Remediation, and Ecological Restoration

Gang Pan [1,2,3,4,5,6,*], Xiaojun Miao [1,2], Lei Bi [1], Honggang Zhang [1], Lei Wang [1], Lijing Wang [1,5], Zhibin Wang [1,5], Jun Chen [1,2], Jafar Ali [1,2], Minmin Pan [1,6,7], Jing Zhang [1], Bin Yue [3,4,8] and Tao Lyu [3,4,*]

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Chem Soc Rev, 2019, 48:3740-3770 (IF 60.615)

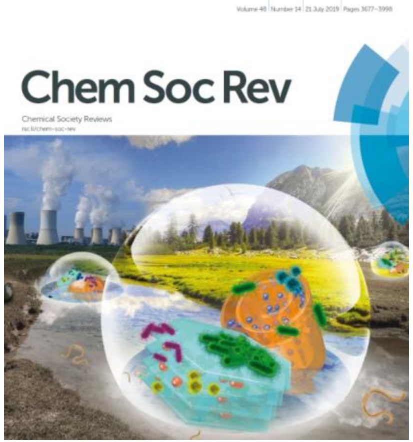
Chem Soc Rev

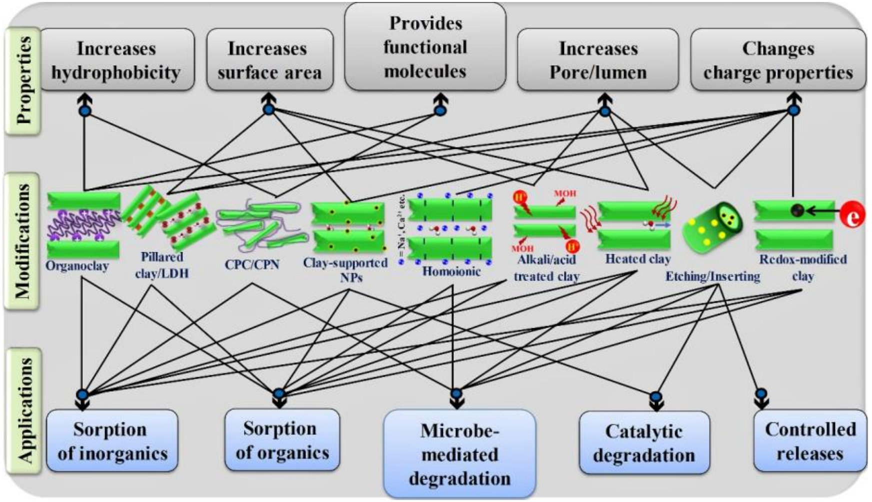
REVIEW ARTICLE

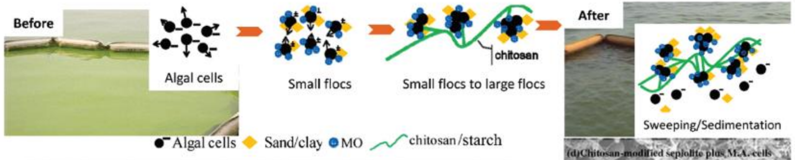
Biocompatible functionalisation of nanoclays for improved environmental remediation

Cite this: DOI: 10.1039/c8cs01019f

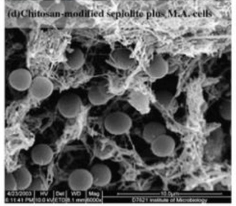
Bhabananda Biswas, *[ab] Laurence N. Warr,[c] Emily F. Hilder,[a] Nirmal Goswami,[d] Mohammad M. Rahman,[be] Jock G. Churchman,[f] Krasimir Vasilev,[d] Gang Pan[g] and Ravi Naidu *[be]





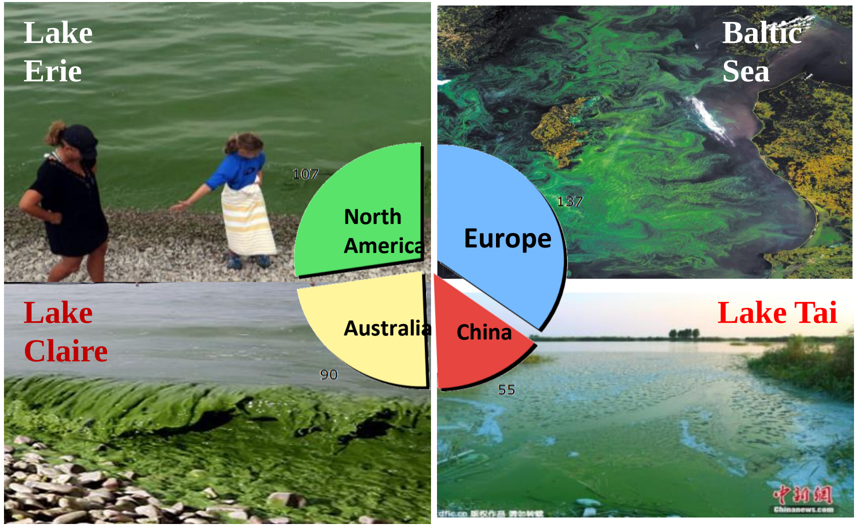


Test endpoint	Concertation required to kill/damage 50% of organisms (mg/L)				
	Chitosan	Chitosan@modified soil*	Cationic starch	Starch@modified soil*	Soil*
72-h algae yield inhibition	3.5	110.2	1.8	113.2	>500
48-h daphnia immobilization	2.2	102.0	0.9	90.2	>500
96-h tubificidae immobilization	6.9	323.2	3.7	248.7	>1000
96-h fish mortality	3.0	165.7	1.4	173.1	>1000



iWEF: integrated Water-Energy-Food Study: ex-situ approach

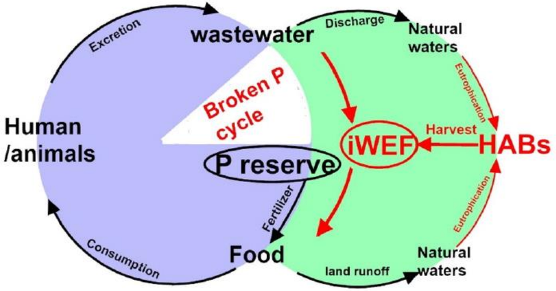
Harmful algal blooms (HABs) ← **Food & energy security**



Pan et al， 2018

Comment: Closing phosphorus cycle from natural waters: re-capturing phosphorus through an integrated water-energy-food strategy

JOURNAL OF ENVIRONMENTAL SCIENCES 65 (2018) 375–376



HAB harvesting: flocculation-flotation

Algal Research 55 (2021) 102268

Contents lists available at ScienceDirect

Algal Research

journal homepage: www.elsevier.com/locate/algal

Short communication

Enhanced chitosan flocculation for microalgae harvesting using electrolysis

Lin Zhu [a], Gang Pan [b,f], Hui Xu [c], Lingwei Kong [d], Weijie Guo [e], Jianghua Yu [a], Robert J. G. Mortimer [f,g], Wenqing Shi [a,*]

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Bioresource Technology 233 (2017) 127–133

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Synergy of flocculation and flotation for microalgae harvesting using aluminium electrolysis

Wenqing Shi [a,1], Lin Zhu [b,1], Qiuwen Chen [a,*], Ji Lu [c], Gang Pan [d], Liuming Hu [a], Qitao Yi [a]

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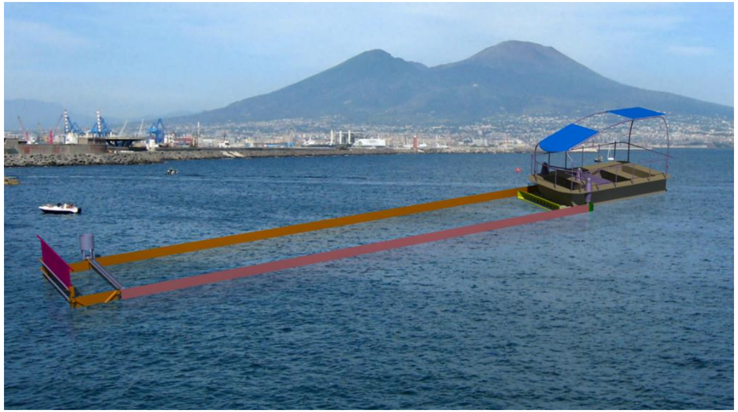

Utilization: wastewater treatment

Water Research 190 (2021) 116735

Contents lists available at ScienceDirect

Water Research

journal homepage: www.elsevier.com/locate/watres

Mitigating antibiotic pollution using cyanobacteria: Removal efficiency, pathways and metabolism

Minmin Pan[a,b,c], Tao Lyu[d,*], Lumeng Zhan[a,b], Victor Matamoros[e], Irini Angelidaki[c], Mick Cooper[f], Gang Pan[a,b,f,*]

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[c] Department of Environmental Engineering, Technical University of Denmark, DK-2899 Lyngby, Denmark
[d] Cranfield Water Science Institute, Cranfield University, College Road, Cranfield, Bedfordshire MK43 0AL, UK
[e] Department of Environmental Chemistry, IDAEA-CSIC, Jordi Girona, 18-26, E-08034 Barcelona, Spain
[f] School of Animal, Rural and Environmental Sciences, Nottingham Trent University, Brackenhurst Campus, NG25 0QF, UK

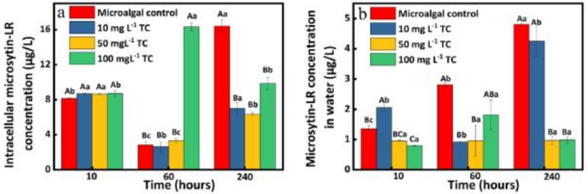

Fig. 5. Microcystin-LR concentrations of (a) intracellular *M. aeruginosa*, and (b) released into water from *M. aeruginosa*. Different uppercase letters above the error bars in each figure represent significant difference ($p < 0.05$) among different treatment groups at the same sampling time. Different lowercase letters above error bars in each figure represent significant difference ($p < 0.05$) of the same treatment group over different sampling times.

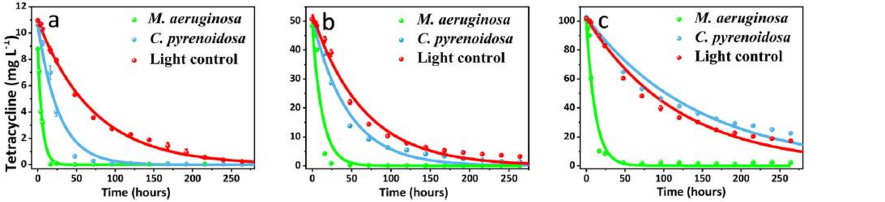

Fig. 1. The dynamics of tetracycline concentration in blank control groups, and treatment groups of *M. aeruginosa* and *C. pyrenoidosa* at initial concentrations of 10 mg L^{-1} (a), 50 mg L^{-1} (b), and 100 mg L^{-1} (c). The solid lines are simulated pseudo-first-order kinetic degradation models.

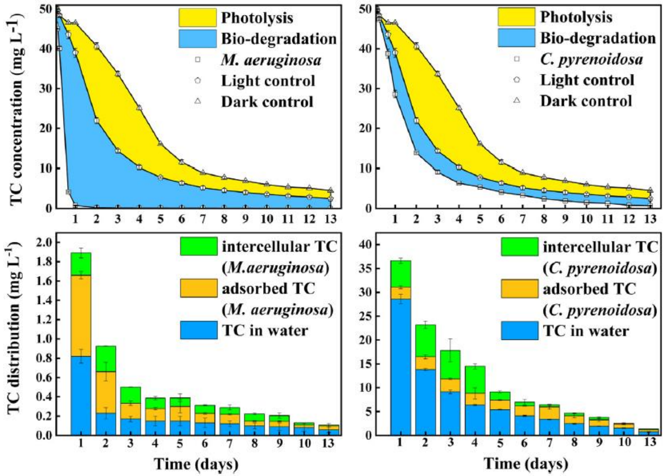

Fig. 2. Theoretically different contributions (photolysis, hydrolysis & cation-binding and bio-remediation) towards tetracycline removal in (a) *M. aeruginosa*, and (b) *C. pyrenoidosa* treatment groups, and distribution (in water, adsorption by microalgae and bio-accumulation into microalgal cells) of residual tetracycline in (c) *M. aeruginosa*, and (d) *C. pyrenoidosa* treatment groups.

Biofuel production from wastewater

Zhang *et al. Biotechnol Biofuels* _####################_
https://doi.org/10.1186/s13068-019-1407-x

Biotechnology for Biofuels

RESEARCH Open Access

Check for updates

Comprehensive evaluation of a cost-effective method of culturing *Chlorella pyrenoidosa* with unsterilized piggery wastewater for biofuel production

Weiguo Zhang[1,2], Jiangye Li[1], Zhenhua Zhang[1], Guangping Fan[1], Yuchun Ai[1], Yan Gao[1,2*] and Gang Pan[3*]

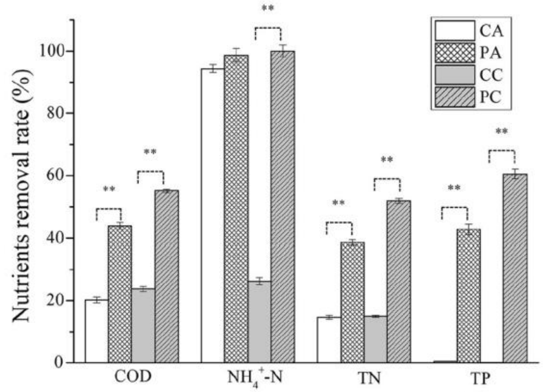

Fig. 2 Chemical oxygen demand (COD), ammonium (NH_4^+-N), total nitrogen (TN) and total phosphate (TP) removal rates. CA means

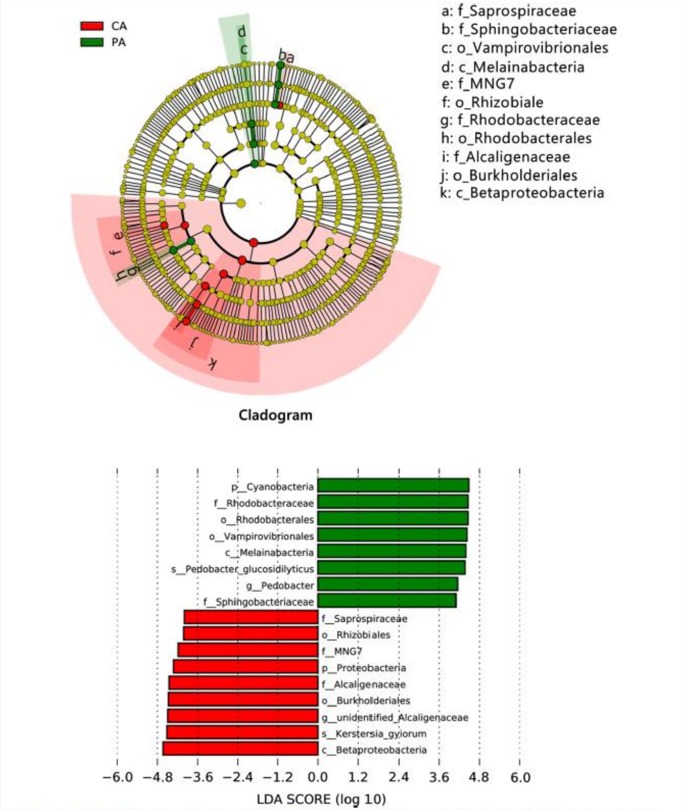

Fig. 5 LEfSe analysis identified the most differentially abundant taxa between CA and PA. The taxonomic cladogram was obtained from LEfSe analysis of 16S rRNA sequences; only taxa meeting an LDA significance threshold of 4.0 are shown. Small circles and shading with different colors in the diagram represent the abundance of those taxa in the respective group. Yellow circles represent nonsignificant differences in abundance between CA and PA for that particular taxonomic group. The brightness of each dot is proportional to its effect size. Taxa enriched in PA are shown with a positive LDA score (green) and taxa enriched in CA have a negative score (red). CA means sparging air; PA means culturing *C. pyrenoidosa* with sparging air

Protein production from food industrial wastewater

Bioresource Technology 326 (2021) 124761

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Integrated valorization system for simultaneous high strength organic wastewater treatment and astaxanthin production from *Haematococcus pluvialis*

Minmin Pan [a,b,c], Xinyu Zhu [a,d,*], Gang Pan [b,c,e], Irini Angelidak [a,d]

[a] *Department of Environmental Engineering, Technical University of Denmark, DK-2800 Lyngby, Denmark*
[b] *Sino-Danish College of University of Chinese Academy of Sciences, Beijing 100049, China*
[c] *Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China*
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[e] *Centre of Integrated Water-Energy-Food Studies (iWEF), School of Animal, Rural and Environmental Sciences, Nottingham Trent University, Brackenhurst Campus, NG25 0QF, UK*

Resources, Conservation & Recycling 168 (2021) 105441

Contents lists available at ScienceDirect

Resources, Conservation & Recycling

journal homepage: www.elsevier.com/locate/resconrec

Bioelectrochemically assisted sustainable conversion of industrial organic wastewater and clean production of microalgal protein

Minmin Pan [a,b,c], Yanyan Su [d], Xinyu Zhu [a], Gang Pan [b,c,e,*], Yifeng Zhang [a,*], Irini Angelidaki [a]

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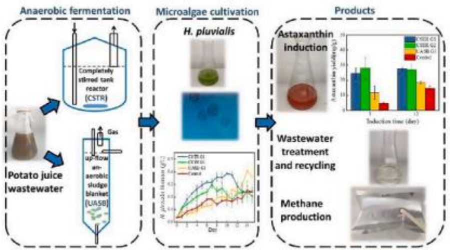
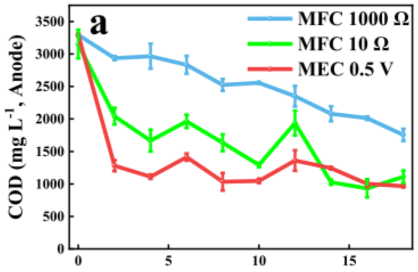
[e] *School of Animal, Rural and Environmental Sciences, Nottingham Trent University, Brackenhurst Campus, NG25 0QF UK*

HIGHLIGHTS

- Integrated bacterial and microalgal approach for potato juice wastewater treatment.
- Higher astaxanthin yield from potato juice wastewater than from standard medium.
- Acidification effluent significantly shortened astaxanthin induction.
- The integrated system is economically attractive for high-strength wastewater.

GRAPHICAL ABSTRACT





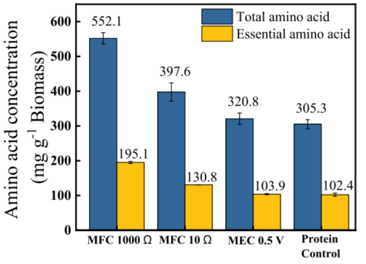


Fig. 7. Total and essential amino acid content of *C. vulgaris* in different groups at day 18.

Recovery of silver and generation of electricity– microbial/algal fuel cell

Chemical Engineering Journal 384 (2020) 123335

Contents lists available at ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

FeS@rGO nanocomposites as electrocatalysts for enhanced chromium removal and clean energy generation by microbial fuel cell

Jafar Ali[a,b], Lei Wang[a,*], Hassan Waseem[c], Ridha Djellabi[d], N.A. Oladoja[a], Gang Pan[a,b,e,*]

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Journal of Cleaner Production 235 (2019) 1425–1437

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Bioelectrochemical recovery of silver from wastewater with sustainable power generation and its reuse for biofouling mitigation

Jafar Ali[a, b, c], Lei Wang[a, b, c, *], Hassan Waseem[d], Hafiz Muhammad Adeel Sharif[e], Ridha Djellabi[f], Changbo Zhang[g], Gang Pan[a, b, c, h, *]

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energies

Energies, 2018, 7, 1-30

MDPI

Review

Electro-Microbiology as a Promising Approach Towards Renewable Energy and Environmental Sustainability

Jafar Ali [1,2], Aaqib Sohail [3], Lei Wang [1,*], Muhammad Rizwan Haider [2,4], Shahi Mulk [1,2] and Gang Pan [1,5,*]

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Environmental Pollution 266 (2020) 115373

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Turning harmful algal biomass to electricity by microbial fuel cell: A sustainable approach for waste management☆

Jafar Ali[a, b, c, d], Lei Wang[a], Hassan Waseem[d], Bo Song[a, b], Ridha Djellabi[e], Gang Pan[a, f, *]

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Production of algal bio-hydrochar materials

Journal of Materials Chemistry A

COMMUNICATION

Facile and green fabrication of multiple magnetite nano-cores@void@porous shell microspheres for delivery vehicles†

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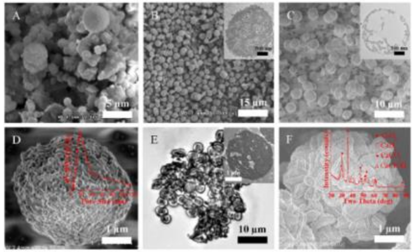
DOI: 10.1039/c3ta15020h

www.rsc.org/MaterialsA

Lei Bi and Gang Pan*

Multiple magnetite nano-cores@void@porous shell microspheres



SCIENTIFIC REPORTS

OPEN

From harmful Microcystis blooms to multi-functional core-double-shell microsphere bio-hydrochar materials

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Accepted: 1 November 2017
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Lei Bi[1] & Gang Pan[1,2]

Harmful algal blooms (HABs) induced by eutrophication is becoming a serious global environmental problem affecting public health and aquatic ecological sustainability. A novel strategy for the utilization

Chemical Engineering Journal 395 (2020) 125073

Contents lists available at ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Microalgae-derived cellulose/inorganic nanocomposite rattle-type microspheres as an advanced sensor for pollutant detection

Lei Bi[a], Yi-Ping Chen[b,c,*], Chen Wang[a], Jing Su[a], Gang Pan[a,d,e,*]

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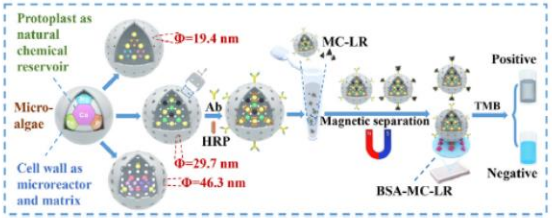
HIGHLIGHTS

- Rattle-type microspheres are fabricated using microalgae as single-source precursor.
- Microalgae act as natural chemical reservoir, microreactor and matrix.
- Microspheres with simultaneous adjustable pore-size shell and composite nano cores.
- Microspheres are an ideal signal multiplier for highly sensitive immunoassay.
- Enhancement of sensitivity is due to the tunable compositions and morphology.

GRAPHICAL ABSTRACT



Soil improvers for food safety: mitigation of As and Cd contamination

Chemical Engineering Journal 391 (2020) 123623

Contents lists available at ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Superior arsenate adsorption and comprehensive investigation of adsorption mechanism on novel Mn-doped $La_2O_2CO_3$ composites

Jing Su[a,b], Tao Lyu[c,d], Hao Yi[e], Lei Bi[a,*], Gang Pan[a,b,c,d,*]

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Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Efficient arsenic removal by a bifunctional heterogeneous catalyst through simultaneous hydrogen peroxide (H_2O_2) catalytic oxidation and adsorption

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Journal of Hazardous Materials 384 (2020) 121461

Contents lists available at ScienceDirect

Journal of Hazardous Materials

journal homepage: www.elsevier.com/locate/jhazmat

Highly efficient and irreversible removal of cadmium through the formation of a solid solution

Chen Wang[a,d], Hui Yin[e], Lei Bi[a,*], Jing Su[a,d], Meiyi Zhang[a], Tao Lyu[b,c], Mick Cooper[b,c], Gang Pan[a,b,c,f,*]

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Journal of Colloid and Interface Science 556 (2019) 606–615

Contents lists available at ScienceDirect

Journal of Colloid and Interface Science

journal homepage: www.elsevier.com/locate/jcis

Enhancement of cadmium removal by oxygen-doped carbon nitride with molybdenum and sulphur hybridization

Check for updates

Jing Su[a,d], Lei Bi[a,*], Chen Wang[a,d,e], Tao Lyu[b,c], Gang Pan[a,b,c,d,e,*]

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Algal bio-hydrochar fertilizer

Science of the Total Environment 717 (2020) 137127

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Microalgae-derived hydrochar application on rice paddy soil: Higher rice yield but increased gaseous nitrogen loss

Qingnan Chu [a,g], Lihong Xue [a,d], Yueqin Cheng [b], Yang Liu [c], Yanfang Feng [a,d,e,*], Shan Yu [a], Lin Meng [f], Gang Pan [g], Pengfu Hou [a], Jingjing Duan [a,d], Linzhang Yang [a]

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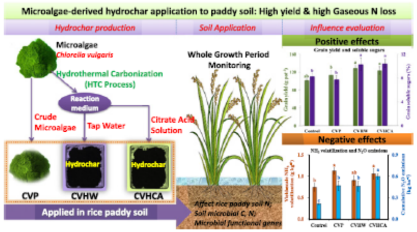
HIGHLIGHTS

- *Chlorella vulgaris* hydrochars (CVH) were fabricated by hydrothermal carbonization.
- CVH addition improved N use efficiency, sugar content, and grain yield of rice.
- CVH addition stimulated NH_3 volatilization and N_2O emission from paddy soil.
- Compared to direct addition of CV, CVH addition inhibited NH_3 volatilization.
- Increasing gaseous N loss results from physiochemical and microbiological factors.

GRAPHICAL ABSTRACT



Journal of Cleaner Production xxx (xxxx) xxx

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Hydrothermal carbonization of microalgae for phosphorus recycling from wastewater to crop-soil systems as slow-release fertilizers

Qingnan Chu [a,b], Tao Lyu [b,c], Lihong Xue [a,d,**,1], Linzhang Yang [a], Yanfang Feng [a,d], Zhimin Sha [e], Bin Yue [f], Robert J.G. Mortimer [b], Mick Cooper [b], Gang Pan [b,*,1]

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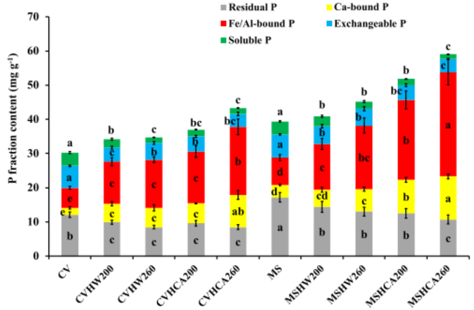

Fig. 2. Fractionation of P in sequential extracts of raw microalgae and microalgae-derived hydrochars.

JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY

Article

Cite This: J. Agric. Food Chem. 2019, 67, 10823−10831

pubs.acs.org/JAFC

Enhancement of Tomato Plant Growth and Productivity in Organic Farming by Agri-Nanotechnology Using Nanobubble Oxygation

Yuncheng Wu,[∇,†,‡,§,∥] Tao Lyu,[∇,§,∥] Bin Yue,[§,∥,⊥] Elisa Tonoli,[#] Elisabetta A. M. Verderio,[#,¶] Yan Ma,[*,†] and Gang Pan[*,§,∥]

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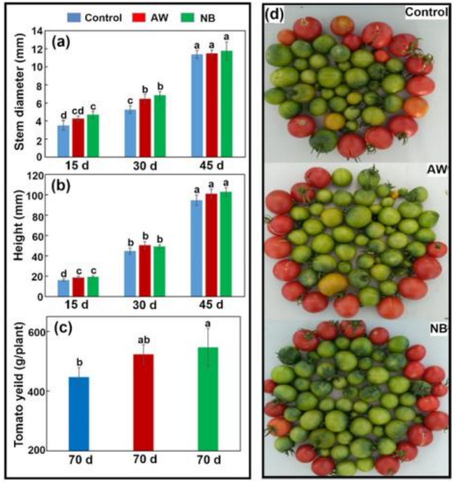
[¶]BiGeA, University of Bologna, 40126 Bologna, Italy



Chemosphere 245 (2020) 125558

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Sewage sludge-derived hydrochar that inhibits ammonia volatilization, improves soil nitrogen retention and rice nitrogen utilization

Qingnan Chu [a, b], Lihong Xue [a, e], Bhupinder Pal Singh [f, g], Shan Yu [a], Karin Müller [h], Hailong Wang [i, j], Yanfang Feng [a, d, e, *], Gang Pan [b], Xuebo Zheng [c], Linzhang Yang [a]

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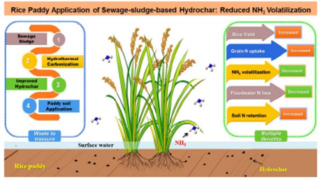
HIGHLIGHTS

- Sewage sludge was valorized through hydrothermal carbonization (HTC).
- Mg-citrate and H_2SO_4 solution as medium in HTC modified sludge-hydrochar (SSHMS).
- SSHMS improved surface porous volume and carboxyl group abundance, and reduced pH.
- SSHMS treatment inhibited rice paddy NH_3 volatilization and nitrogen runoff.
- SSHMS treatment increased paddy soil N retention, rice N uptake and rice yield.

GRAPHICAL ABSTRACT



iWEF technical framework for sustainable environmental circular economy

https://www.ntu.ac.uk/research/groups-and-centres/centres/integrated-water,-energy-and-food-iwef-centre

Target & resource	technology	products	references
Natural water eutrophication	Flocculation-flotation Algal biotechnique	Re-captured P Wastewater treatment	J. Environmental Sciences, 2018, 65, 375 Algal Research, 2021, 55, 102268 Bioresource technology, 2017, 233, 127 Resources, Conservation and Recycling, 2021, 168, 105441 Bioresource Technology, 2021, 326, 124761 Water Research, 2021, 190, 116735
+			
Wastewater	Nanomaterials	Algae Bio-char Soil improvers	Chemical Engineering Journal, 2020, 395, 125073 J. hazardous materials, 2020, 384, 121461 J. colloid and interface science, 2019, 556, 606 Scientific reports, 2017, 7, 1
+	Algal Biofuel cell	Electricity Bio-fuel	Environmental Pollution, 2020, 266, 115373 Chemical Engineering Journal, 2020, 384, 123335 Biotechnology for biofuels, 2019, 12,1 J. Cleaner Production, 2019, 235, 1425
Polluted soils	Nanobubble-algal technology	Organic farm Fertilisers	J. Cleaner Production, 2021, 283, 124627 Chemosphere, 2020, 245, 125558 J. Agricultural Food Chemistry, 2019, 67 , 10823

Thank you for your attention!