Simultaneous removal of As(III) and As(V) by FMBO: Mechanism, Technology, and Engineering Application

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Developing novel adsorbents for simultaneous removal of As(III)/As(V); Illustrating interactions between As(III)/As(V) and FMBO and mechanisms involved in As(III)/As(V) removal; and developing novel technologies for simultaneous removal of As(III)/As(V) and successfully implementing these technologies in over 20 Demo. Engineering works.

Adsorbent design, preparation, and removal mechanism

Function Design for FMBO

Objectives → Materials capability → Materials components → But how to prepare?

Adsorbents for the simultaneous removal of both As(III) and As(V)

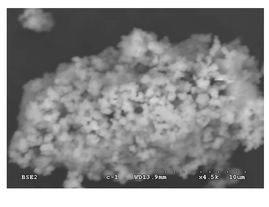
Interfacial reactions

- As(III) oxidation → Manganese oxides $MnO_2 \cdot xH_2O$
- As(V) adsorption → Ferric oxides $Fe_2O_3 \cdot yH_2O$

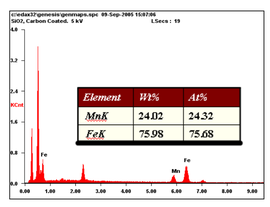
→ Ferric and manganese binary oxides (FMBO)

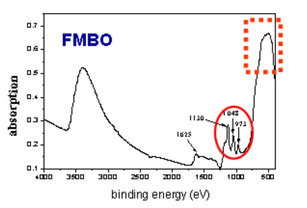
Characterization

Removal efficiency

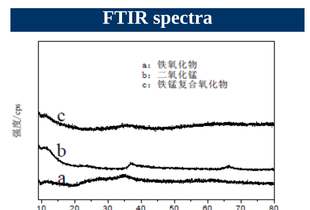


SEM images



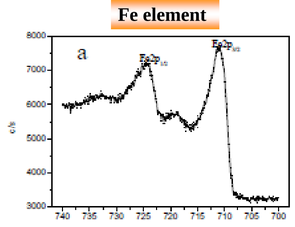


FTIR spectra

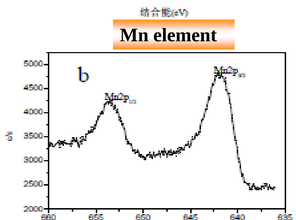


XRD spectra

Fe element



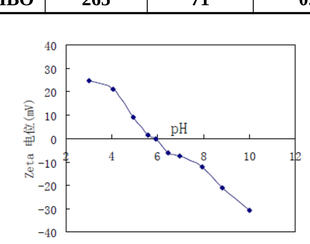
Mn element



XPS spectra

BET测定结果

Adsorbent	S_{BET} (m^2/g)	Pore diameter (A°)	Pore volume (cm^3/g)
FeOOH	247	40	0.25
MnO_2	121	103	0.33
FMBO	265	71	0.47

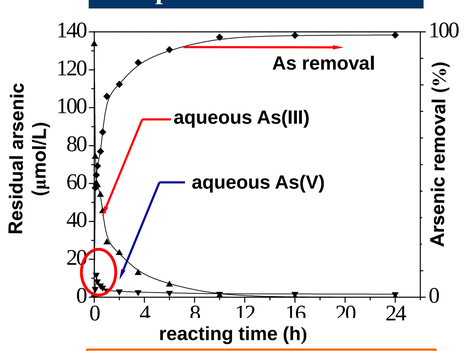


IEP = ~5.9

Removal efficiency comparison

adsorbents	Maximal adsorption potentional As(III)mmol/g	As(V)mmol/g	references
FMBO	1.77(pH4.8)	0.93(pH4.8)	*This study*
MnO_2	0.13	0.1	Lenoble *et al.*
Geothite	/	0.53(pH3.3)	Matis *ea al.*
$Al(OH)_3$/Fe(OH)3	0.12(pH6.6)	0.49(pH7.2)	Hlavay *et al.*
Fe(III)-loaded sponge	0.24(pH9.0)	1.83(pH4.5)	Munoz *et al.*
Fe-Mn-mineral	0.16(pH5.5)	0.09(pH5.5)	Deschamps *et al.*
TiO_2	0.43(pH7.0)	0.55(pH7.0)	Ban…

As species transformation



Initial As(III) 133μmol/L, adsorbents dosage 0.2g/L, pH=6.9±0.1

Mechanisms

Removal Mechanism of As(III) by FMBO

≡M-OH … ≡M-OH (FMBO surfaces)

1st Step: As(III) adsorption onto FMBO surfaces

$As(III)(aq) + (-S_{Fe\text{-}Mn}) \rightarrow As(III) - S_{Fe\text{-}Mn}$ (1)

2nd step: As(III) oxidation with manganese oxides

$2MnO_2 + H_3AsO_3 + H_2O \rightarrow 2MnOOH^* + H_2AsO_4^- + H^+$ (2)

$2MnOOH^* + H_3AsO_3 + 3H^+ \rightarrow 2Mn^{2+} + H_2AsO_4^- + 2H_2O$ (3)

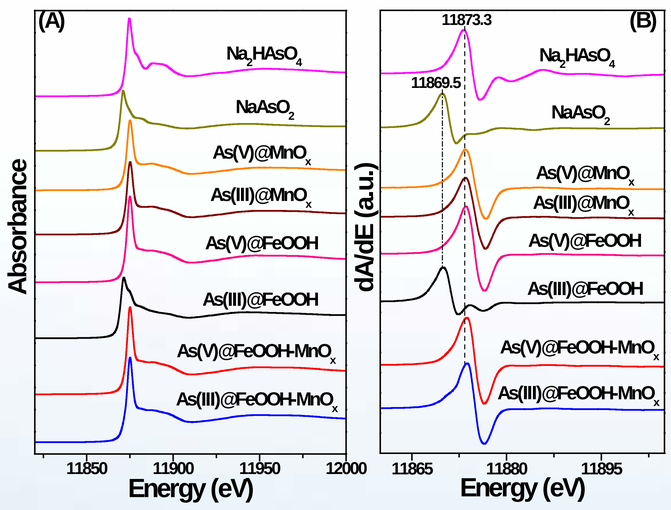
As(III) → Arsenic species transformation and Manganese dioxides reductive dissolution → As(V) + Mn^{2+}

3rd step: As(V) adsorbing onto ferric oxides sites

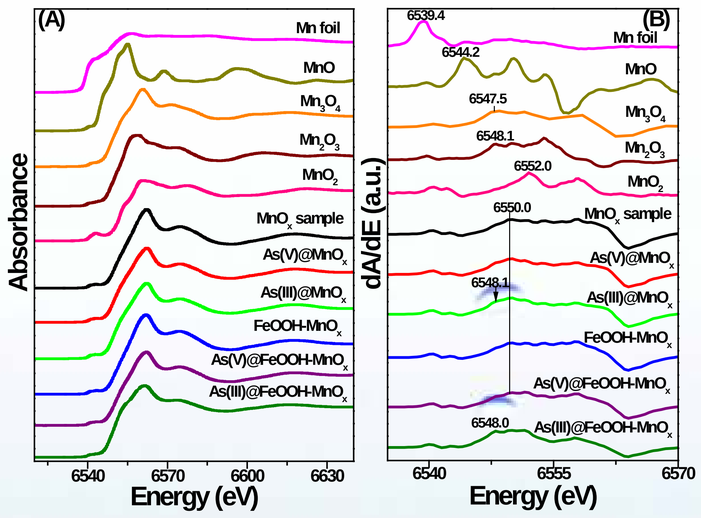
$As(III) - S_{Fe\text{-}Mn} + As(V)(aq) \rightarrow As(V) - S_{Fe\text{-}Mn} + As(III)(aq)$ (4)

The adsorbed As(III) quickly transform to As(V) after being adsorbed onto FMBO, and is then removed by FMBO. Mn(IV) oxidation plays an important for arsenic removal.

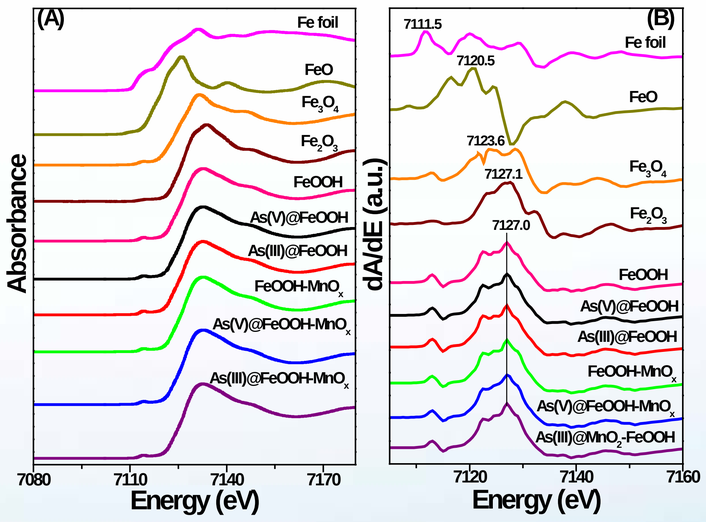
XANES and EXAFs spectra of As K-edge

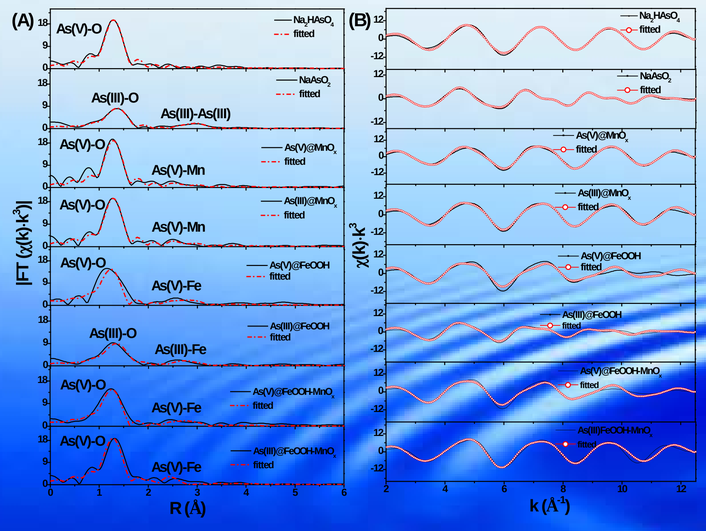


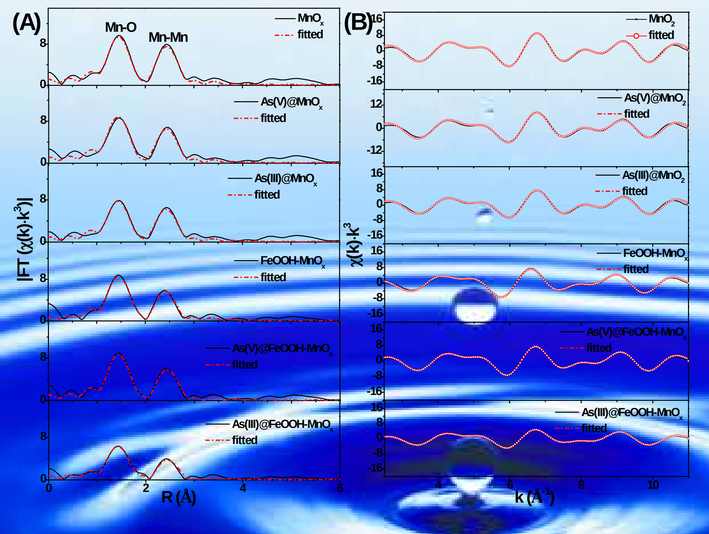
XANES and EXAFs spectra of Mn K-edge

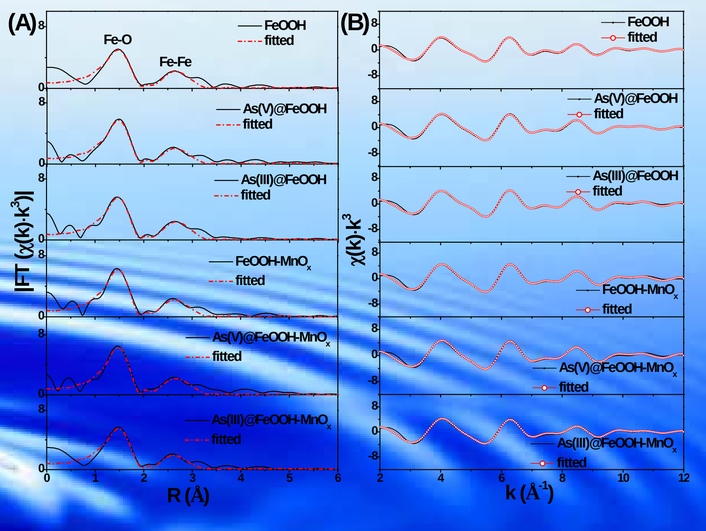


XANES and EXAFs spectra of Fe K-edge







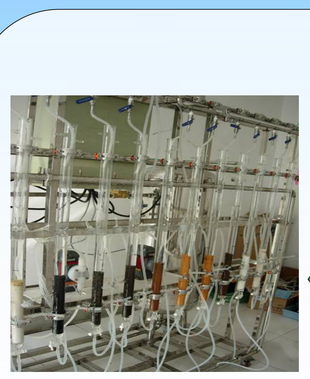


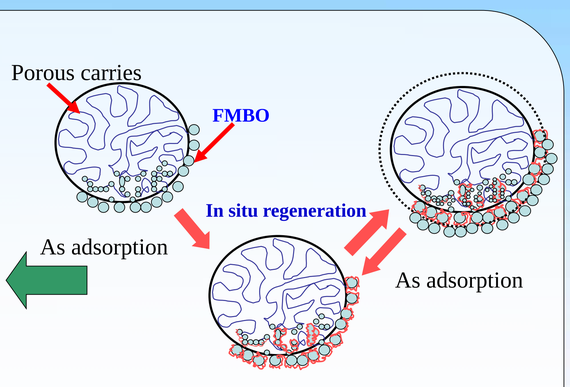
- **Mn(IV) within FMBO oxidizes As(III) to As(V), and Mn(IV) itself transforms to Mn(II) by reductive dissolution;**
- **Fe(III) within FMBO provides sorbing sites for As adsorption, and the chemical valence variation rarely occurs during arsenic adsorption;**
- **The synergism between Fe(III) oxide and Mn(IV) oxide within FMBO enables its significantly high removal efficiency towards arsenic and achieves the simultaneous removal of As(III) and As(V).**

Simultaneous removal of As(III) and As(V): Mechanism, Technology, and Engineering Application

On the basis of FMBO, we have developed technologies and treatment facilities for arsenic removal in small-scale drinking water stations, large-scale drinking water treatment plants, and for the remediation of arsenic-polluted water environments such as rivers and lakes. After that, we have successfully implemented these technologies in over 20 Demo. Engineering.

Technology principals



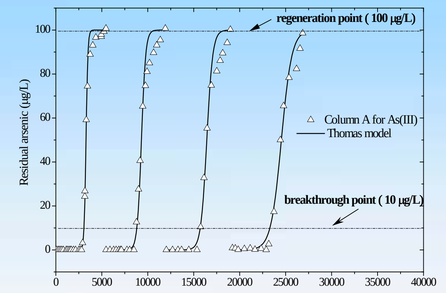


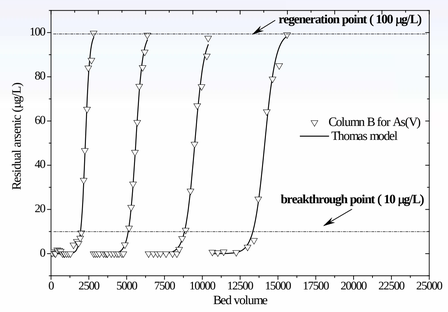
Small-scale field tests for technologies optimization

Adsorbents preparation and regeneration

Strategy for FMBO application in engineering

In situ coated FMBO





$[As]_0$ =100 μg/L, pH= 7.0, EBCT=5 min

Continuous tests

Pilot-scale field investigation

Technology application for As removal from drinking water and water environments remediation

400 m^3/d, Regeneration cycle=6 months

5000 m^3/d

2000 m^3/d

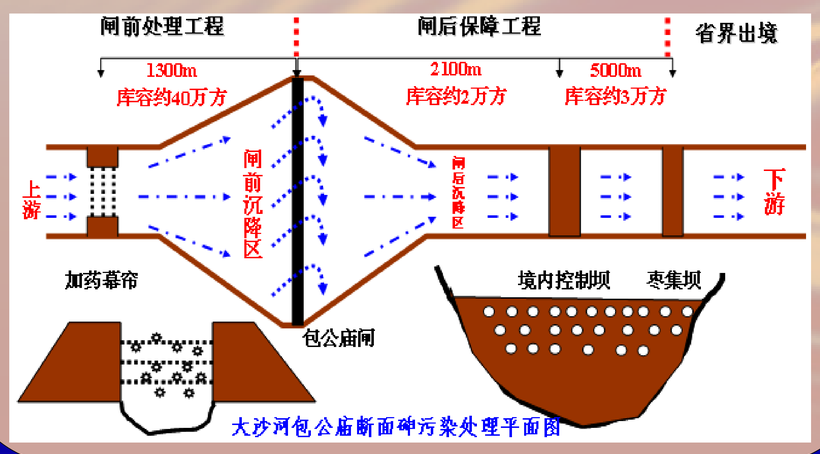
200,000 m^3/d

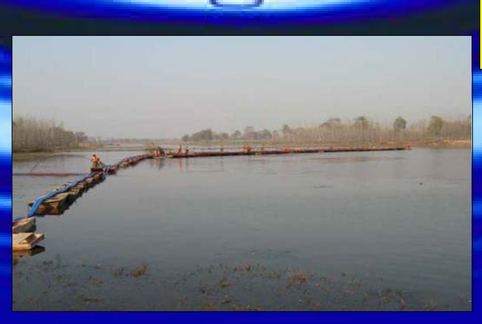
Demo. Engineering for As removal in small systems available in rural villages

Demo. Engineering for As available in towns and urban cities

Demo. Engineering for As removal in large scale drinking water treatment plants available in urban cities

Technology Strategy for the remediation of arsenic–polluted water environments in emergent As pollution accidents in China





Totally over 18 million tons of high-As river water has been successfully treated, and the residual As concentrations are below 0.03 mg/L