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Removal and fate of silver nanoparticles in lab-scale vertical flow constructed wetland

S Bao[1], L Liang[1,2], J Huang[1,2], X Liu[1,2], W Tang[1], T Fang[1,2,*]（fangt@ihb.ac.cn）
[1] Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan 430072,China； [2] University of Chinese Academy of Sciences, Beijing 100049,China

Introduction

Silver nanoparticles (AgNPs) are intensively used in diverse products due to their excellent antimicrobial properties (Xiu et al., 2011). The increasing production, use and disposal of AgNPs will inevitably increase their concentrations in environments. However, limited researches were conducted concerning the removal of AgNPs from the aquatic environments. Although constructed wetlands (CWs) are used worldwide for controlling non-point and point source pollution, the application and underlying mechanism of CWs treated the municipal wastewater and landfill leachate that potentially contains AgNPs has received little attention to date (Button et al., 2016; Auvinen et al., 2017). To fill these knowledge gaps, lab-scale vertical flow CWs were constructed to investigate the interaction of CWs with AgNPs.. The removal rate, environmental fate and impact of AgNPs in the CWs system were determined.

Highlights

- ➢*The Reed-CWs effectively removed AgNPs from wastewater.*
- ➢*The presence of plants in CWs significantly increased the removal efficiency of AgNPs.*
- ➢*Ag removed by Reed-CWs were mainly accumulated in substrate.*
- ➢*The performance of Reed-CWs was little affected by Ag pollution.*

Materials and Methods

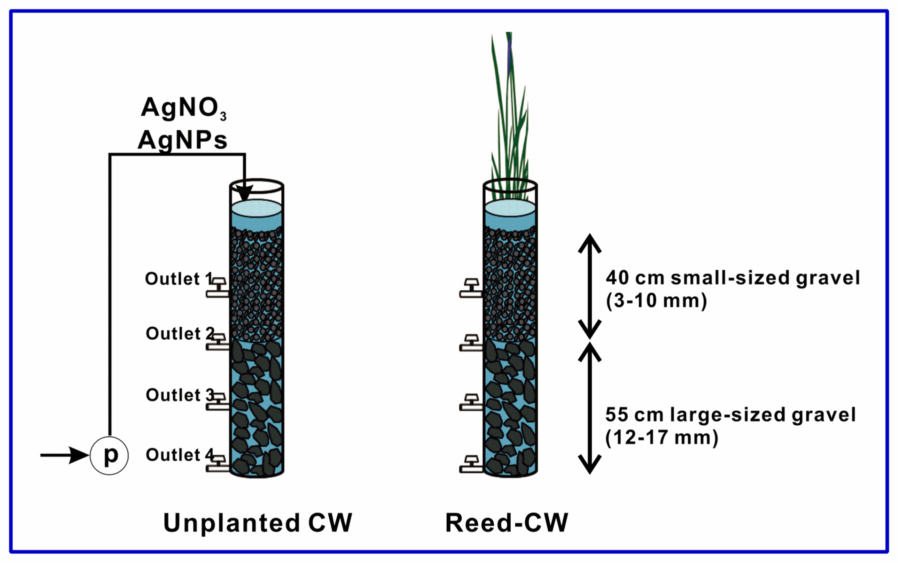

Fig. 1 Unplanted CWs and Reed-CWs

Lab-scale, cylindrical, vertical flow CW units, with inner diameter of 0.15 m and height of 1.00 m, were designed and constructed. The CWs were filled from bottom to top with large-sized gravels of 12–27 mm (55 cm depth) and small-sized gravels of 3-10 mm (40 cm depth). The CWs were planted with common reed (Reed-CWs), or were left unplanted (Unplanted CWs).The influence of hydraulic loading rates, wetland depth and presence of plants on AgNPs removal was studied by analyzing the Ag contents of the effluent. After running for 2 months, the plant biomass, biofilm biomass, substrate and Ag content were determined to reveal the distribution of AgNPs in CWs.

Results

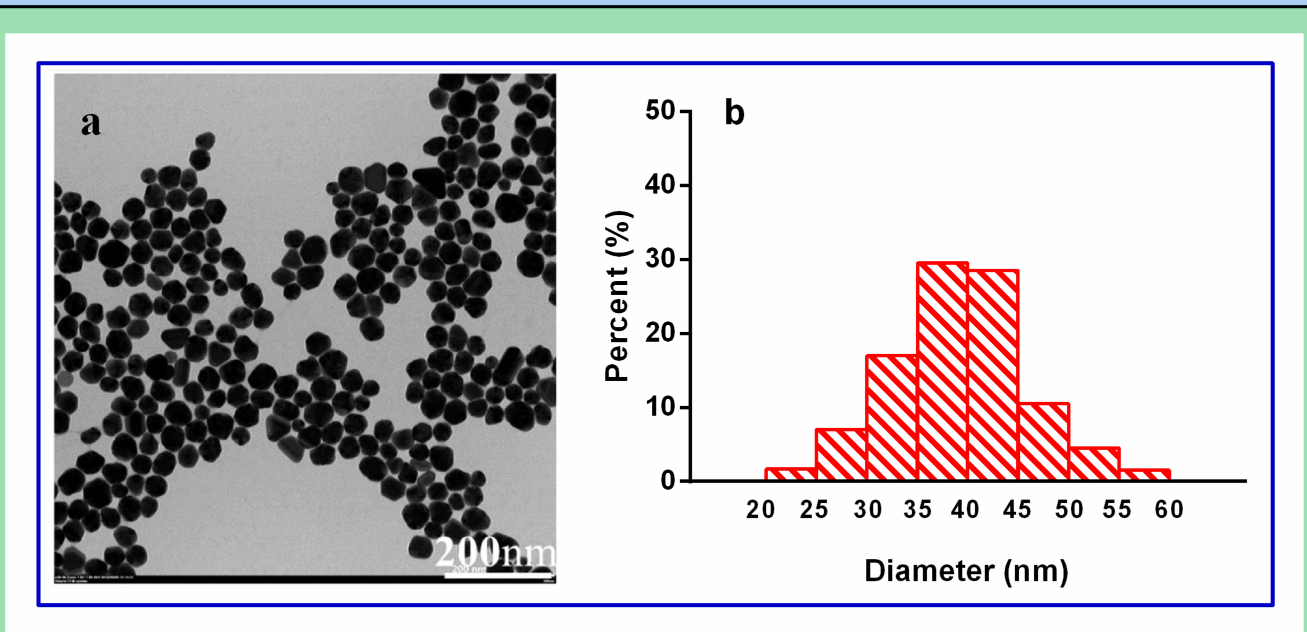

Fig. 2 (a) TEM image of AgNPs used in this work; (b) The size distribution histogram of AgNPs.

Table 1 Distribution of Ag in AgNPs and $AgNO_3$ treated Reed-CWs

	Substrate		Plant			
	Acid-exchangeable form	Stable form	root	stem	leaf	Biofilm
$AgNO_3$ treated Reed-CWs	25.91%	71.86%	2.03%	0.16%	0.02%	0.02%
AgNPs treated Reed-CWs	32.32%	65.73%	1.56%	0.20%	0.12%	0.06%

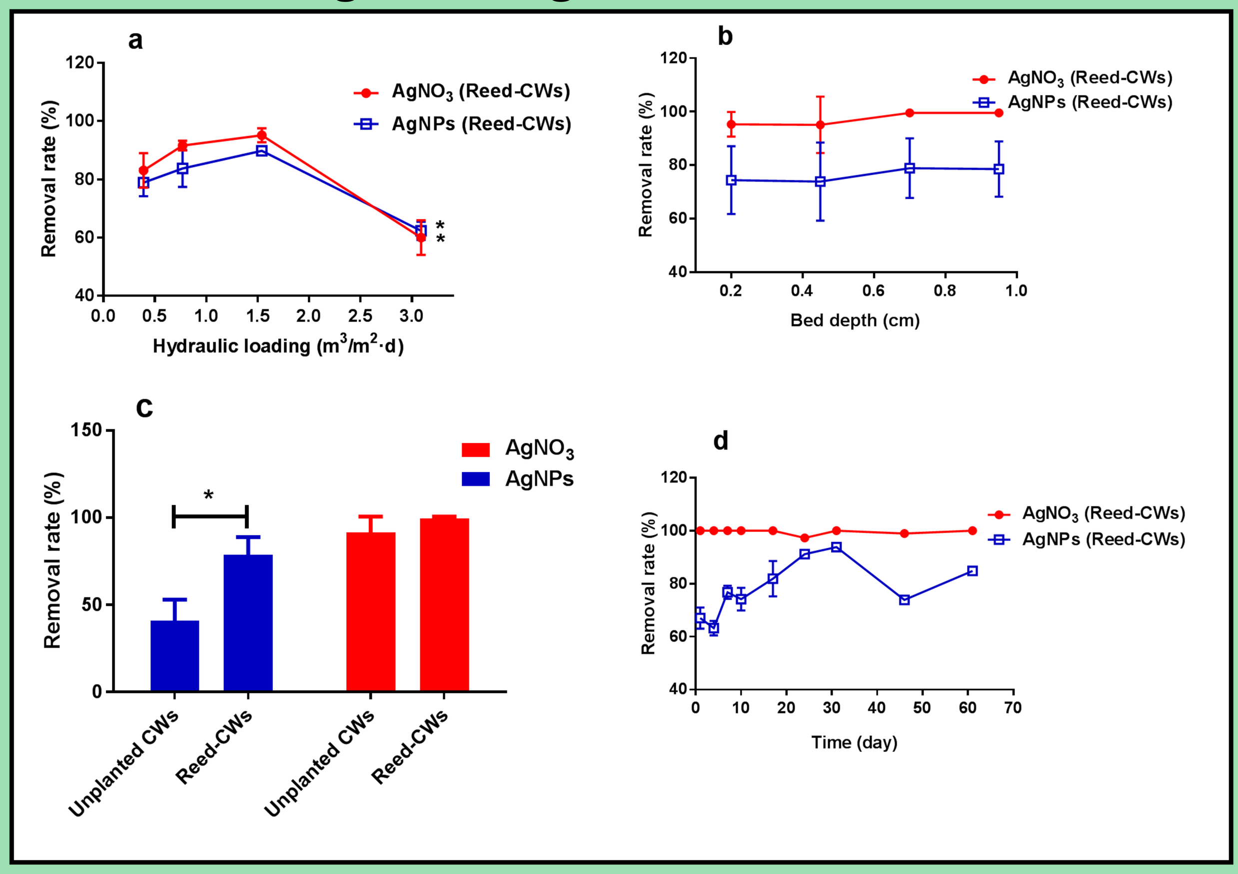

Fig. 3 The influences of different design parameters on removal efficiency of AgNPs and $AgNO_3$ in CWs: (a) Hydraulic loading; **(b)** Bed depth; **(c)** Plant. **(d)** Variations of Ag removal rates in Reed-CWs during a 2-month running.

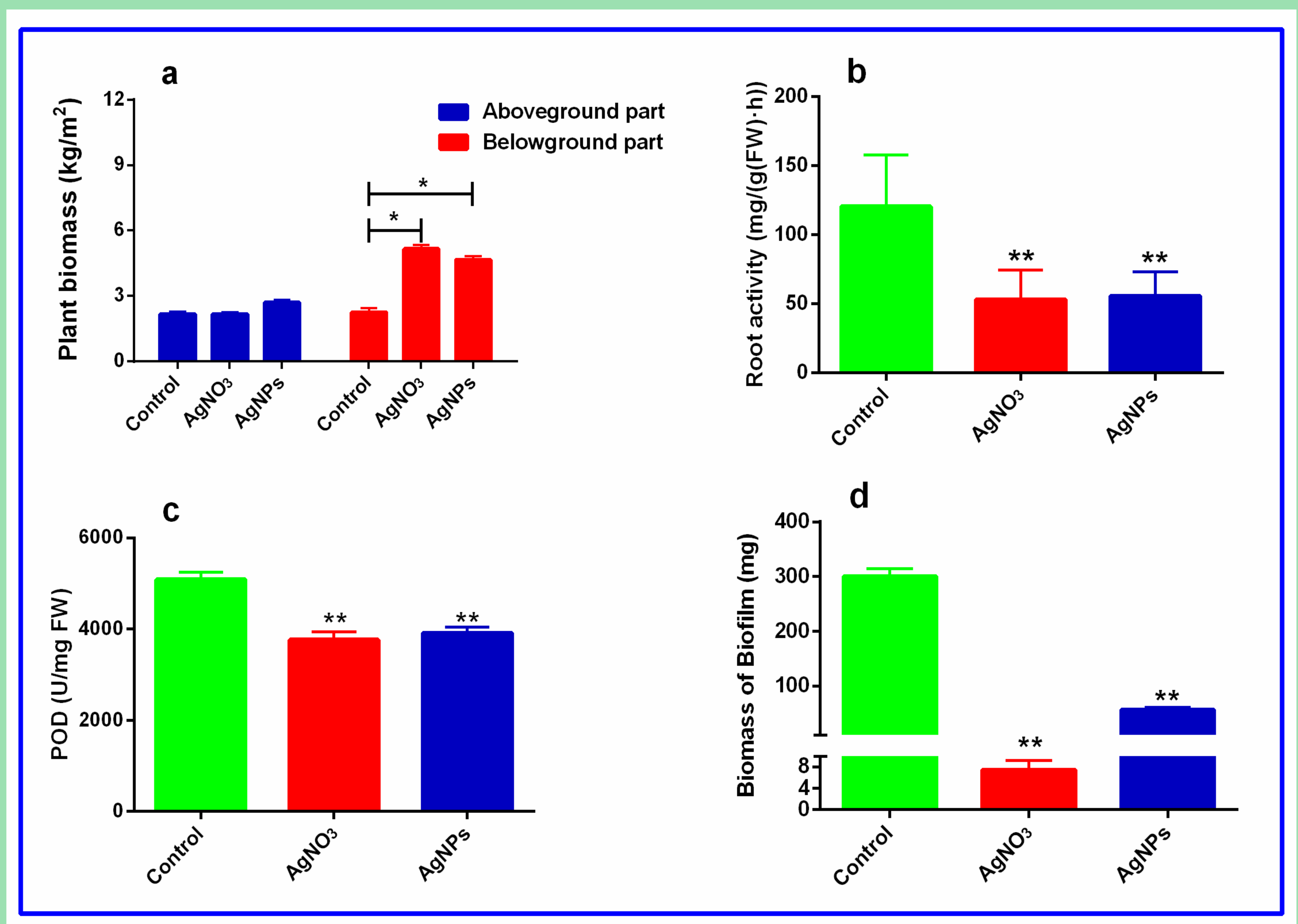

Fig. 4 The impacts of long-term exposures to AgNPs and $AgNO_3$ on different parts of Reed-CWs: (a) Plant biomass; **(b)** Root activity; **(c)** POD activity in leaf; **(d)** Biofilm biomass.

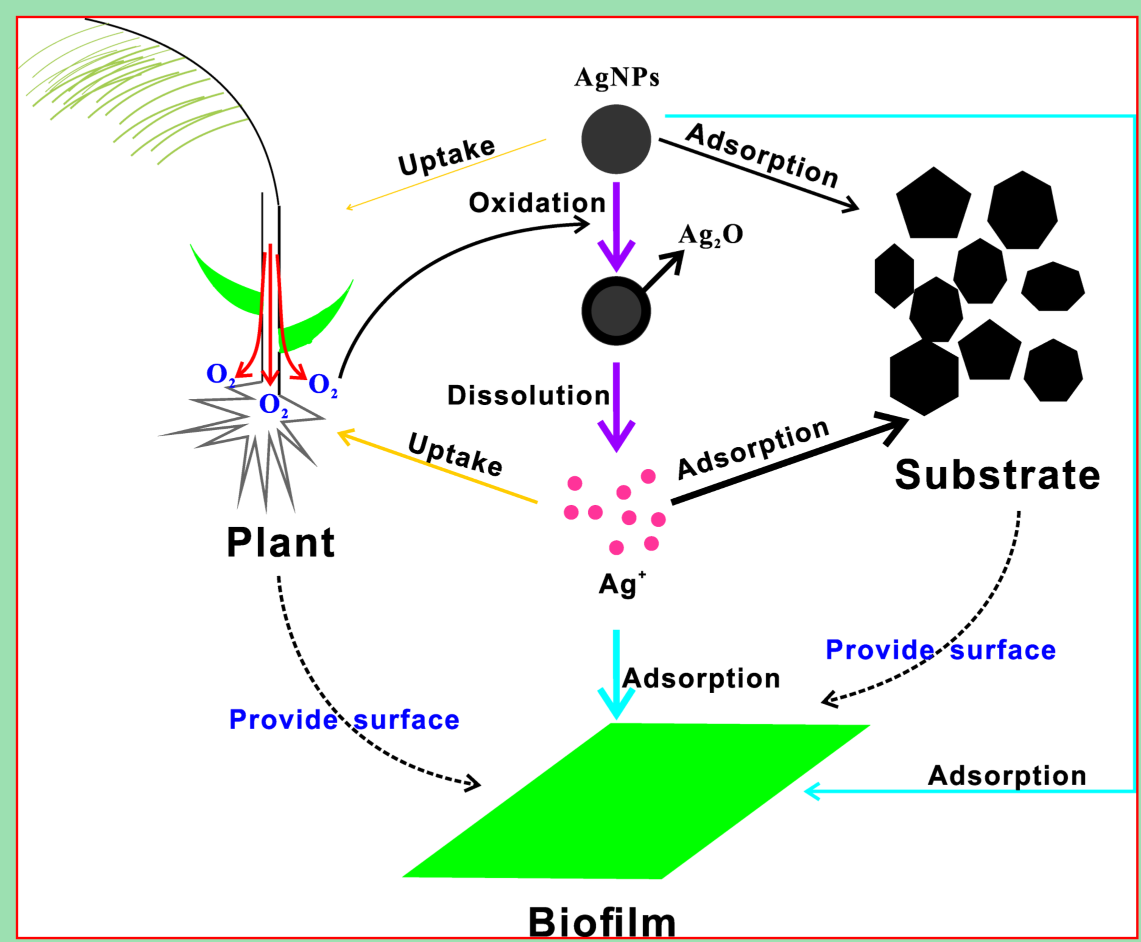

Fig. 5 The possible removal mechanism of AgNPs in CWs. The presence of plant in CWs could provide more surface for biofilm, which is adept in adsorbing AgNPs. The radial oxygen loss from roots of plant would promote the formation of Ag^+, which is more prone to be absorbed by substrate or biofilm and be assimilated by plant compared with AgNPs.

Conclusions

1. Plant biomass, root activity, POD activity of leaves and biofilm biomass in Reed-CWs were significantly altered following AgNPs exposure.
2. AgNPs removal efficiencies in Reed-CWs showed dependence on hydraulic loading but not on bed depth. Plant in CWs played a significant role in removing AgNPs.
3. AgNPs stopped in CWs were mainly resided in the substrate, and less Ag were found in plants and biofilm.

References

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