Environmental Science Nano

ROYAL SOCIETY OF CHEMISTRY

PAPER

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Cite this: *Environ. Sci.: Nano*, 2022, **9**, 1519

When chicken manure compost meets iron nanoparticles: an implication for the remediation of chlorophenothane-polluted riverine sediment†

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Received 17th November 2021, Accepted 10th February 2022

DOI: 10.1039/d1en01056e

rsc.li/es-nano

The remediation of contaminated sediment is an intractable problem as both the remediation efficiency and the ecological environmental impact should be carefully considered. In this study, nanoscale zero-valent iron (nZVI) was applied to assist the remediation of chlorophenothane (DDT)-polluted sediment by chicken manure compost. The response of sediment bacterial communities to the remediation treatments was evaluated a month later after two strategies of adding the remediation materials (simultaneous and phased) were implemented. Using nZVI could enhance the degradation efficiency for chlorophenothane with the compost. Compared with the simultaneous addition of chicken manure compost and nZVI at the beginning of remediation, using nZVI as a forerunner followed by adding the compost a week later further enhanced *p,p*′-DDT degradation but increased the $\sum$DDT residual amount. The used chicken manure compost increased the richness, evenness, and diversity of sediment bacterial communities. According to β-diversity analysis, the compost made a greater difference in the bacterial communities than nZVI at 0.25 wt%, 0.5 wt%, and 1.0 wt%. Using 0.5 wt% nZVI could help to activate the bacterial metabolism in the compost-remediated sediment and increase functional abundance for DDT degradation. This study contributes to the improvement of sediment remediation technologies and the understanding of bacterial community variations in chlorophenothane-contaminated sediment remediated with chicken manure compost and nZVI.

Environmental significance

Riverine sediment is susceptible to pesticide pollution due to frequent agricultural activities in the river basin. Using compost for the sediment remediation can help to establish an abundant microbial population quickly for degrading organic pesticides, but it is subject to variable weather conditions and a long remediation period. This work suggests that using nanoscale zero-valent iron (nZVI) as an adjuvant additive can enhance the degradation efficiency for chlorophenothane (DDT) in sediment using chicken manure compost. Using nZVI as a forerunner followed by adding the compost a week later further enhanced *p,p*′-DDT degradation but increased the $\sum$DDT residual amount compared with the simultaneous addition of the two materials. These findings promote the understanding of the regulating effects of nZVI on DDT degradation and sediment bacterial communities.

1. Introduction

Riverine sediment is susceptible to pesticide pollution due to frequent agricultural activities in the river basin. During the application of pesticides, only a very small proportion (less than 5%) of the pesticides can reach the targets, and the majority of pesticides are released to the surrounding environment.[1] A considerable amount of pesticides can enter nearby rivers through agricultural effluent discharge, rain wash, and surface runoff, and gradually accumulate in the sediment. The long-term heavy use of pesticides has caused their occurrence in many riverine sediments, with the concentration level varying from ng kg^{-1} to mg kg^{-1}.[2,3] The pesticides in

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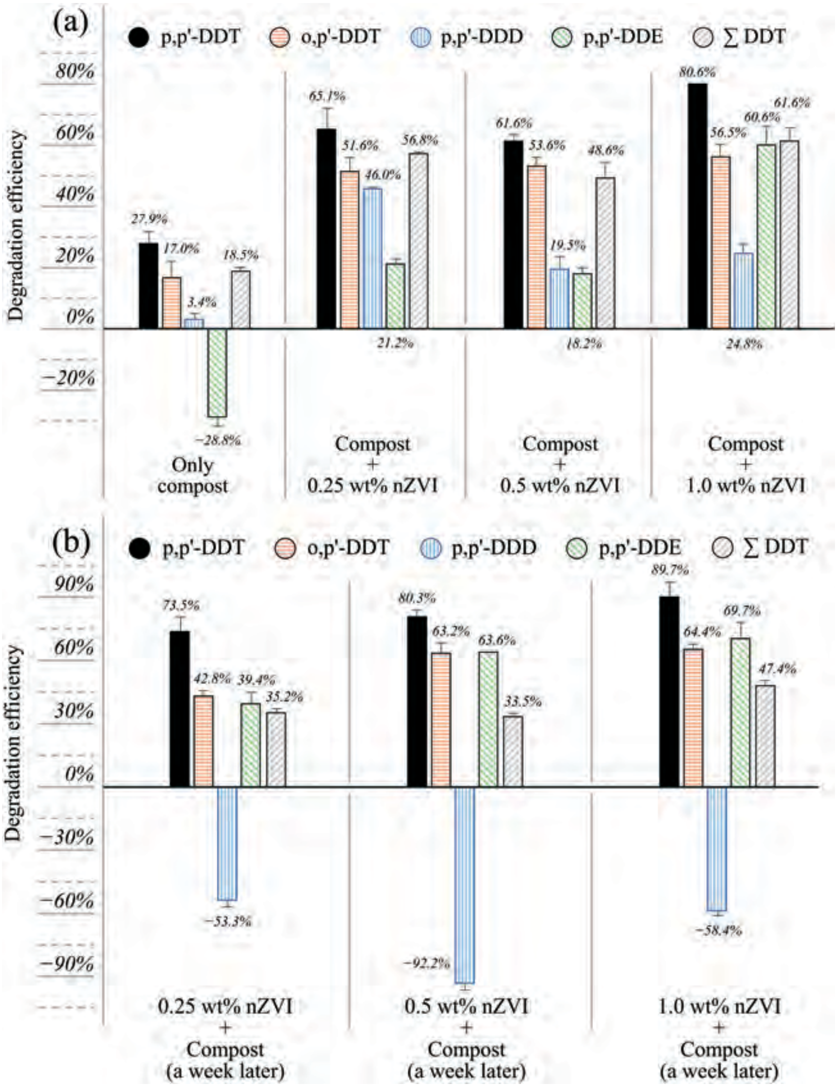

Fig. 1 Degradation of chlorophenothane in remediation treatments: Set I (a) and Set II (b). Experimental conditions of Set I: simultaneously adding chicken manure compost and nZVI at the beginning of remediation, using an amount of the compost = 5.0 wt%, and treatment time = 30 days. Experimental conditions of Set II: using nZVI as a forerunner followed by adding the compost a week later, using an amount of the compost = 5.0 wt%, and treatment time = 30 days.

in this case. When the contaminated sediment was remediated with only nZVI, the degradation efficiency for chlorophenothane was higher than that with both compost and nZVI in some cases (Fig. S2†). The best performance for ∑DDT degradation was observed with 0.5 wt% nZVI alone, showing a degradation efficiency of 63.0%. These results indicate the negative effect of chicken manure compost on the nZVI reactivity, which is closely related to the changes of nZVI properties during the remediation process.[32] Xu *et al.*[33] investigated the effects of the particle properties of nZVI on its reactivity to chlorinated organic compounds and found that the Fe^0 content and the reactivity of nZVI decreased with time as a result of oxidation. This result supports the high degradation capacity of nZVI to *p,p′*-DDT in Set II. Adding nZVI with a high Fe^0 content at the beginning of remediation showed excellent reactivity to *p,p′*-DDT degradation. However, using only nZVI for the remediation had a significant negative impact on the sediment bacterial communities and the incorporation of compost could mitigate it. This point will be described and discussed below. Considering the pros and cons of both sides, proper combination of nZVI and compost is necessary to ensure that the benefits outweigh the ecological risks when using them for the remediation of chlorophenothane-polluted riverine sediment.

3.2. Response of the bacterial community structure

According to the taxonomy of 1652 OTUs, the sediment bacterial communities involve at least 24 bacterial phyla, and the relative abundance of them in various treatments is displayed in Fig. 2. *Proteobacteria* is the most abundant bacterial phylum and its relative abundance ranges from 41.4% to 52.8%, followed by 14.1–27.2% for *Bacteroidetes*, 6.5–11.5% for simultaneous addition of chicken manure compost and nZVI at the beginning of remediation, using nZVI as a forerunner followed by adding the compost a week later further enhanced *p*,*p*′-DDT degradation but increased ∑DDT residual amount. The used chicken manure compost contributed to a more diversified structure of the bacterial communities and increased the bacterial α-diversity after remediation treatment. Analyzing the β-diversity of the sediment bacterial communities for the different treatment groups suggested that the compost caused a greater difference in the bacterial communities than nZVI at 0.25 wt%, 0.5 wt%, and 1.0 wt%. *Actinomadura*, *Luteimonas*, *Lysobacter*, *Ramlibacter*, and *Microvirga* in response to the addition of chicken manure compost and nZVI were identified. Using 0.5 wt% nZVI could help to activate the metabolic function of bacterial communities in the compost-remediated sediment and increase the functional abundance for DDT degradation. This study investigated the community level variations of chlorophenothane-contaminated sediment before and after remediation based on the bacterial community structure. Further research is needed to reveal the actual response of the metabolic function and correlate it with the degradation efficiency for chlorophenothane.

Author contributions

Biao Song: conceptualization, funding acquisition, investigation, methodology, and writing – original draft. Zhuo Yin: investigation, methodology, and writing – original draft. Eydhah Almatrafi: investigation, methodology, and writing – original draft. Fan Sang: investigation, formal analysis, and validation. Maocai Shen: visualization, formal analysis, and validation. Weiping Xiong: formal Analysis and writing – review & editing. Chengyun Zhou: visualization and writing – review & editing. Yang Liu: funding acquisition, validation, and writing – review & editing. Guangming Zeng: funding acquisition, project administration, resources, and writing – review & editing. Jilai Gong: resources, supervision, and writing – review & editing.

Conflicts of interest

There are no conflicts of interest to declare.

Acknowledgements

This work was supported by the National Natural Science Foundation of China (U20A20323, 52100180, 51521006, and 51909085), the China National Postdoctoral Program for Innovative Talents (BX20200119), the Project funded by China Postdoctoral Science Foundation (2021M690961), and the Hunan Provincial Natural Science Foundation of China (2021JJ40087).

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