Supporting Information for

# Facile Oriented Immobilization and Purification of His-Tagged Organophosphohydrolase on Virus-like Mesoporous Silica Nanoparticles for Organophosphate Bioremediation

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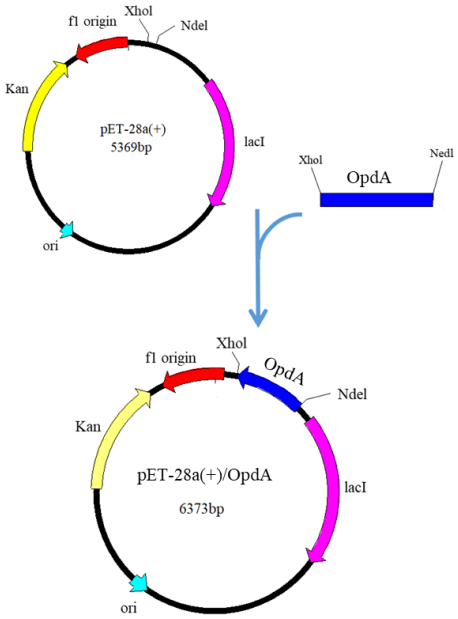
**Application and reusability of OpdA@Ni-NTA-VMSN in decontamination of methyl parathion on fruits or vegetables**

Fresh grapes (12.35 g) or cucumbers (10.03 g) were contaminated with 380 nmol methyl parathion. After 30 min, fruits or vegetables were submerged in a solution of tap water (25 mL, pH 7.4) supplied with 10 mg of OpdA@Ni-NTA-VMSN. The solution was stirred for 1 h at 25 °C. Then, the OpdA@Ni-NTA-VMSN was recovered by centrifugation and rinsed three times with Tris-HCl buffer before the next washing batch. The degradation was determined by monitoring p-nitrophenol production at 410 nm.




Scheme S1. The engineered plasmid pET-28a (+)/OpdA

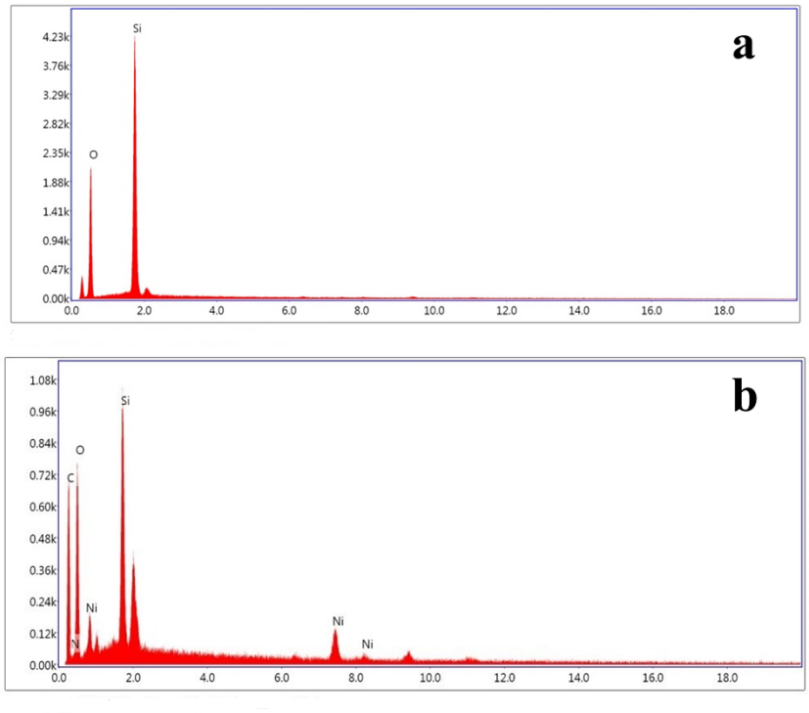



Figure S1 EDX analysis of (a) VMSN and (b) Ni-NTA-VMSN

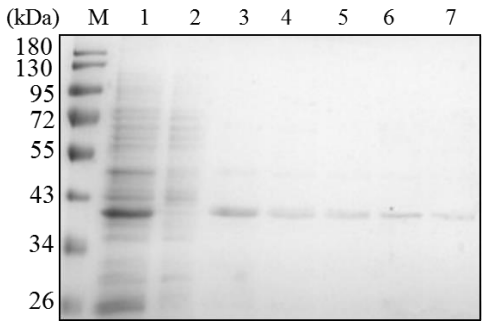



Figure S2 SDS-PAGE analysis. Lane M: protein marker; lane 1: cell lysates; lane 2: supernatant after mixing with Ni-NTA-VMSN; lane 3-7: eluted protein of 1st to 5th runs (reusability).

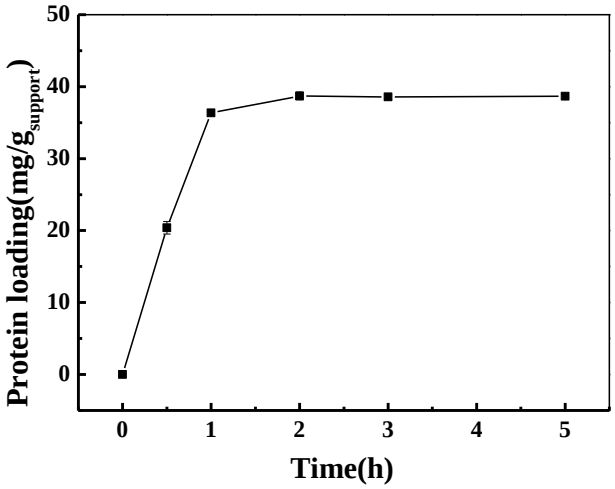



Figure S3 Protein loading of His-OpdA under different adsorption time at 5:1 ratio (w/w) of Ni-NTA-VMSN to total protein.

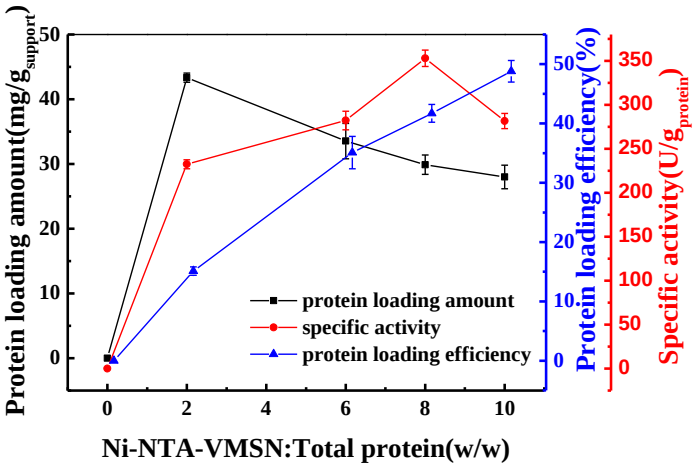



Figure S4 Protein loading amount, protein loading efficiency and specific activity of OpdA@Ni-NTA-VMSN at different ratio (w/w) of Ni-NTA-VMSN to total protein.

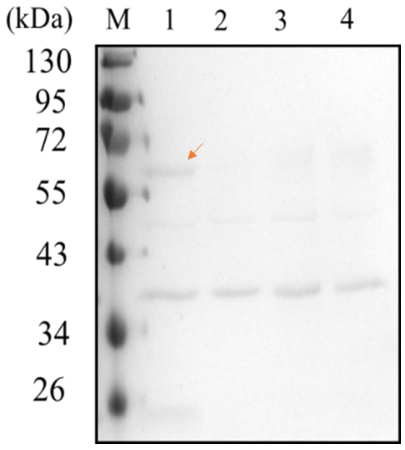



Figure S5 SDS-PAGE analysis. Lane M: protein marker; lane 1-4: eluted protein from OpdA@Ni-NTA-VMSN at different mass ratio (w/w) of Ni-NTA-VMSN to total protein (10:1, 8:1, 6:1, 2:1).

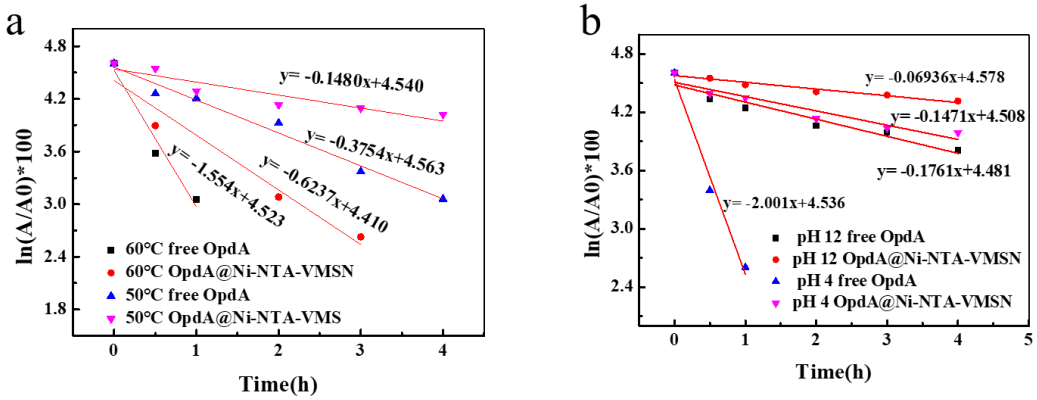



Figure S6 (a) Thermal inactivation kinetic of free OpdA and OpdA@Ni-NTA-VMSN at 50 °C and 60 °C. (b) pH deactivation kinetic of free OpdA and OpdA@Ni-NTA-VMSN at 4.0 and 12.0.

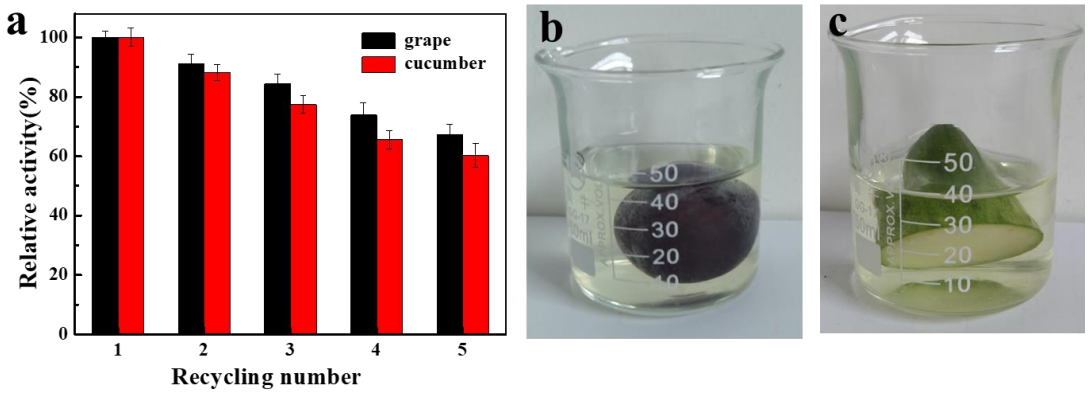



Figure S7 (a) Reusability of OpdA@Ni-NTA-VMSN. The Degradation of 380 nmol methyl parathion from contaminated grapes (b, 12.35 g) and cucumbers (c, 10.03 g) in 25 mL tap water using 10 mg OpdA@Ni-NTA-VMSN.

Table S1 Thermal deactivation kinetic parameters

| Thermal deactivation kinetic parameters | 50 °C | | 60 °C | |
|---|---|---|---|---|
| | $k_d(h^{-1})$ | $t_{1/2}(h)$ | $k_d(h^{-1})$ | $t_{1/2}(h)$ |
| free OpdA | 0.3754 | 1.846 | 1.554 | 0.4451 |
| OpdA@Ni-NTA-VMSN | 0.1480 | 4.682 | 0.6237 | 1.111 |

Table S2 pH deactivation kinetic parameters

| pH deactivation kinetic parameters | pH 4.0 | | pH 12.0 | |
|---|---|---|---|---|
| | $k_d(h^{-1})$ | $t_{1/2}(h)$ | $k_d(h^{-1})$ | $t_{1/2}(h)$ |
| free OpdA | 2.001 | 0.3463 | 0.1761 | 3.935 |
| OpdA@Ni-NTA-VMSN | 0.1471 | 4.711 | 0.06936 | 9.991 |