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SUPPLEMENTARY MATERIAL TO

Removal of Pb(II), Cd(II), and Zn(II) from landfill soil and leachate using a graphene oxide membrane

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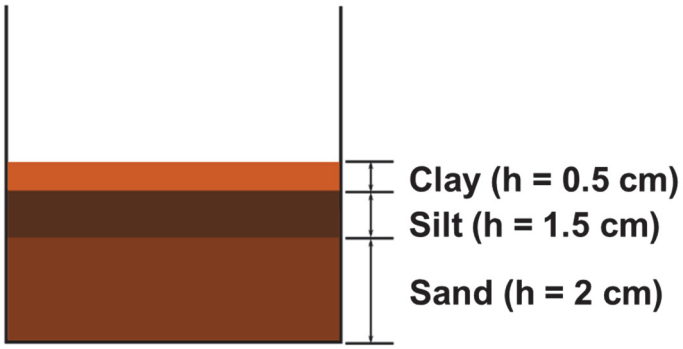

Figure S-1. Soil type was determined from the soil texture pyramid after sedimentation of 48 h. The soil fractions including clay on the top, silt in the middle and sand on the bottom were formed during the sedimentation process. The heights of each soil fraction are given in the figure.

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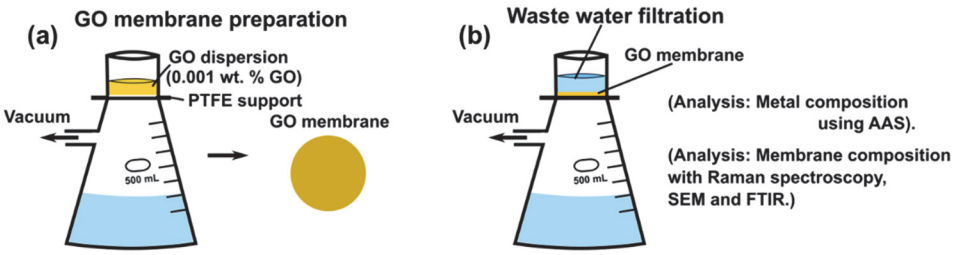

Figure S-2. Vacuum filtration. (a) Filtration of 10 mL of GO dispersion (0.001 wt. %) through polytetrafluoroethylene membrane at the vacuum of 8×10^4 Pa. (b) Filtration of washed off water through the GO membrane.

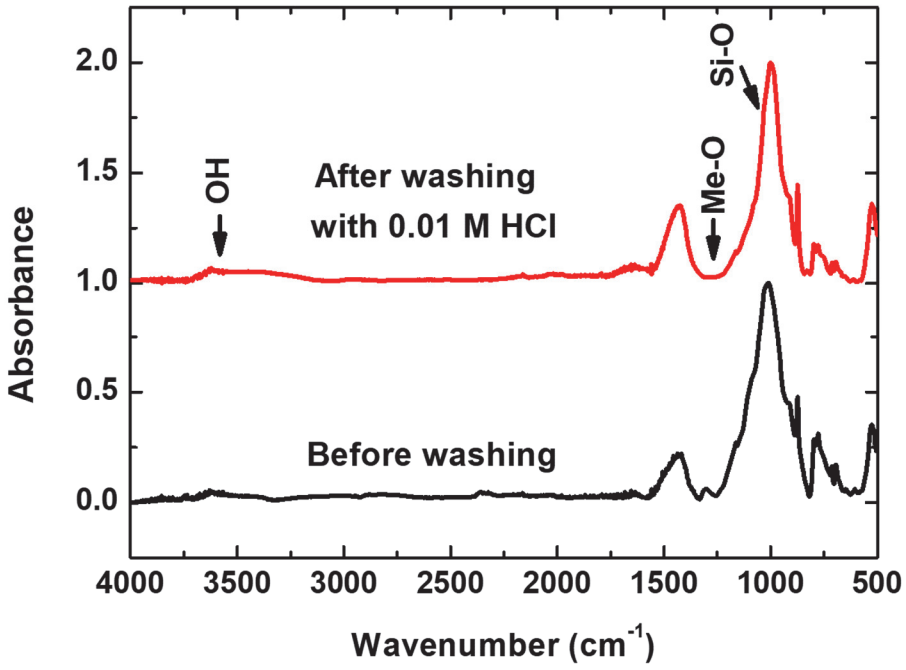

Figure S-3. FTIR spectra of the soil before and after washing with 0.01 M HCl for 60 min.

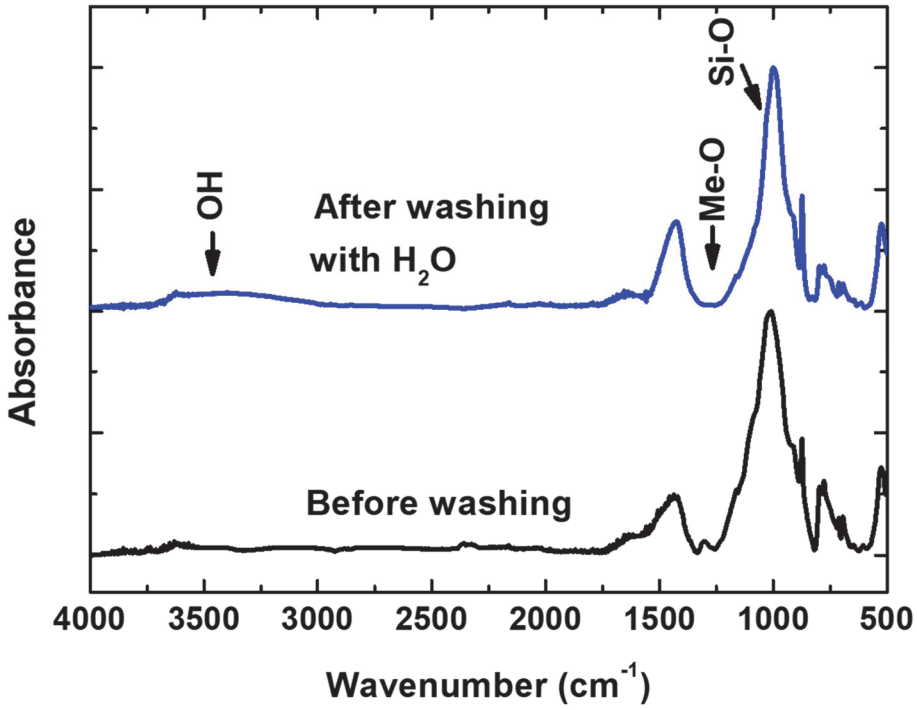

Figure S-4. FTIR spectra of the soil before and after washing with H_2O for 60 min.

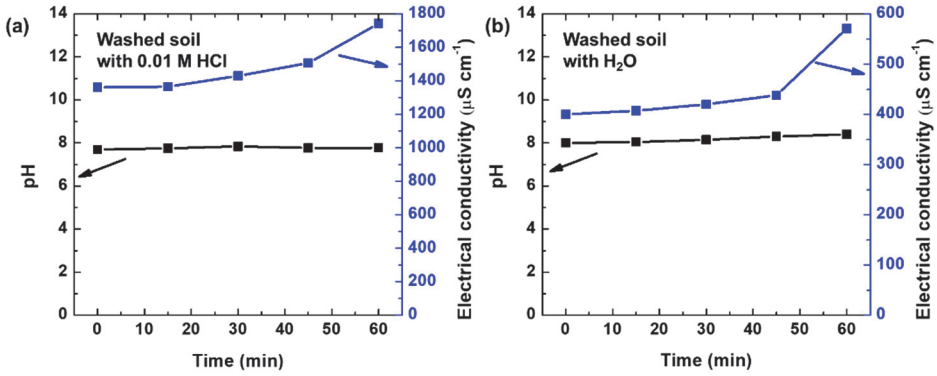

Figure S-5. pH and electrical conductivity of the landfill leachate. (a) The soil washed with 0.01 M HCl. (b) The soil washed with H_2O. The washing time of soil was 60 min.

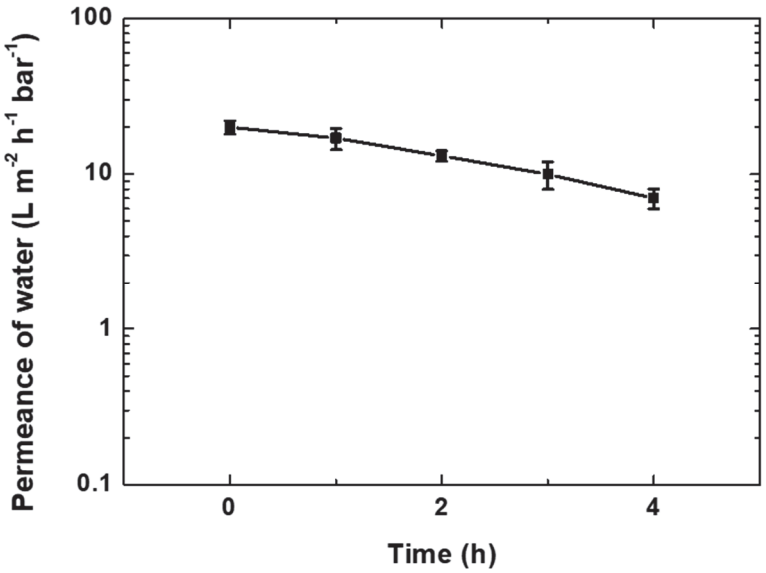

Figure S-6. Permeance of landfill soil wastewater against time.

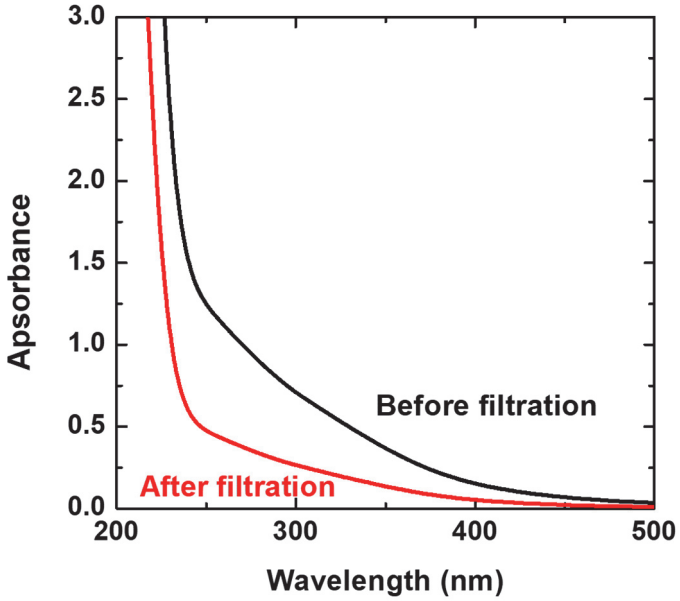

Figure S-7. UV-vis spectra of the soil suspension before and after filtration through GO membrane.

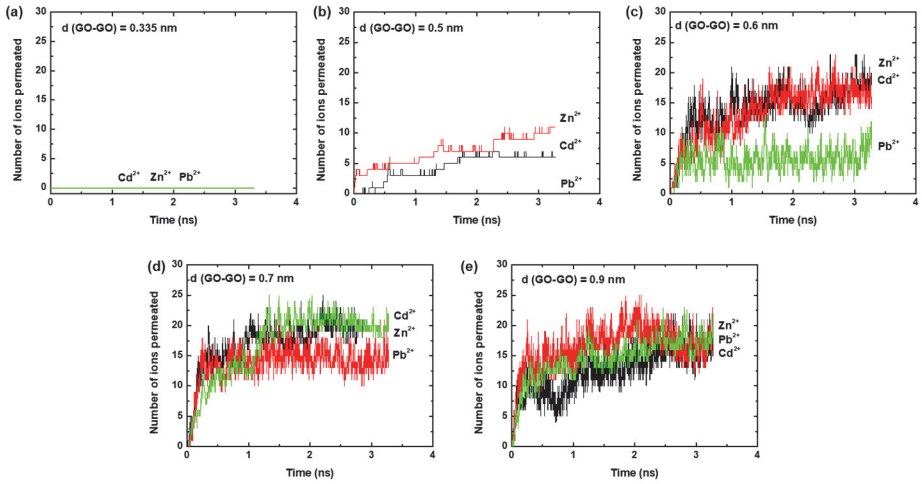

Figure S-8. Number of permeated ions through the GO membrane against simulation time. (a – e) The interlayer distance was increased from the completely stacked GO layers of 0.335 to 0.90 nm. Zn^{2+} ions are in red, Cd^{2+} ions in black, and Pb^{2+} ions in green color.

Table S-I. Force field parameters including atomic weights, charges, and Lennard-Jones(LJ) σ and ϵ parameters for MD simulations of metal ion permeance through the GO membrane.

Molecule	Mass (1.66×10^{-27} kg)	Charge (e)	LJ σ (nm)	LJ ϵ (K)	References
C (-C=)	12.011	0	0.336	28	(1)
C (C-O-H)	12.011	0.15	0.355	35.2	
O (C-O-H)	15.9994	-0.585	0.307	85.5	
H (C-O-H)	1.00794	0.435	0	0	
C (C-O-C)	12.011	0.25	0.38	35.2	
O (C-O-C)	15.9994	-0.5	0.3	59.5	
C (C-H)	12.011	-0.115	0.355	35.2	
H (C-H)	1.00794	0.115	0.242	15.1	
Pb	207.2	2	3.829	0.662	(2, 3)
Zn	65.38	2	2.763	0.124	
Cd	112.411	2	2.537	0.228	
Cl	35.453	-1	4.4	0.1	

Table S-II. The efficiency of toxic metals removal by washing from soil and from leachate by GO membrane separation.

Metal cations content in washing medium			Water filtration by GO membrane	
Metals	Washed with H_2O (%)	Washed with 0.01 M HCl (%)	Rejection after washing with H_2O (%)	Rejection after washing with 0.01 M HCl (%)
Zn	0.21	0.52	43.80	44.00
Cd	0.10	7.58	95.20	96.15
Pb	0.10	1.14	99.05	99.80

REFERENCES

1. H. Khanmohammadi, B. Bayati, J. Rahbar-Shahrouzi, A.-A. Babaluo, A. Ghorbani, *J. Environ. Chem. Eng.* **7** (2019) 103040 (https://doi.org/10.1016/j.jece.2019.103040).
2. F. Vallejos-Burgos, F.-X. Coudert, K. Kaneko, *Nat. Commun.* **9** (2018) 1812 (https://doi.org/10.1038/s41467-018-04224-6).
3. Y. Zheng, A. Zaoui, *Solid State Ion.* **203** (2011) 80 (https://doi.org/10.1016/j.ssi.2011.09.020).