THE EFFECT OF NANOPARTICLES ON SORPTION AND SUSPENSION STABILITY OF A MIXTURE OF RARE EARTH ELEMENTS IN SOIL/SAND SOLUTIONS

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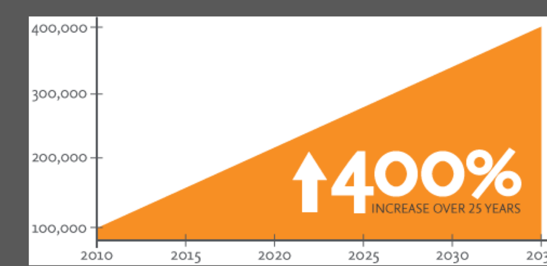
INTRODUCTION

As a consequence of their growing use in electronic and industrial products, increasing amounts of technology critical elements (TCEs) are being released to the environment. Currently little is known about their fate and potential environmental impact. Here we present results of an initial adsorption study of a major group of TCEs – rare earth elements (REEs) – on sand and soil. We investigate REE adsorption in the presence of selected nanoparticles (NPs), with and without humic acid (HA), to test the potential of colloids to stabilize REE suspensions and thus serve as vehicles for REE transport.

OVERALL OBJECTIVE

To test the potential of NPs to increase suspension stability of REEs in soil and sand solutions.

Global demand for rare earth elements is expected to grow by 400% by 2035 compared to 2010.



Common Products Rely on Rare Earth Elements

Source: https://www.elsevier.com/rd-solutions/industry-insights/other/a-look-inside-rare-earths

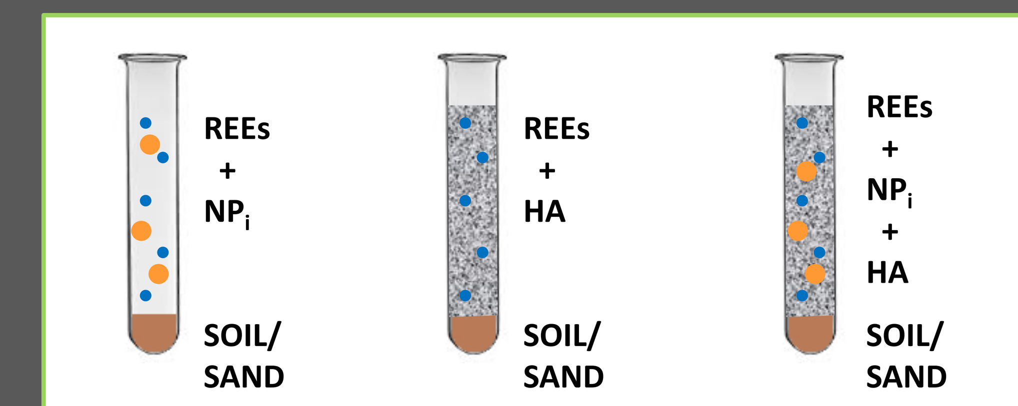
MATERIALS & METHODS

REE mixture: Ce, Dy, Er, Eu, Gd, Ho, La, Nd, Pr, Sc, Sm, Tb, Tm, Y, Yb + non-TCEs Lu and Th in 5% HNO_3

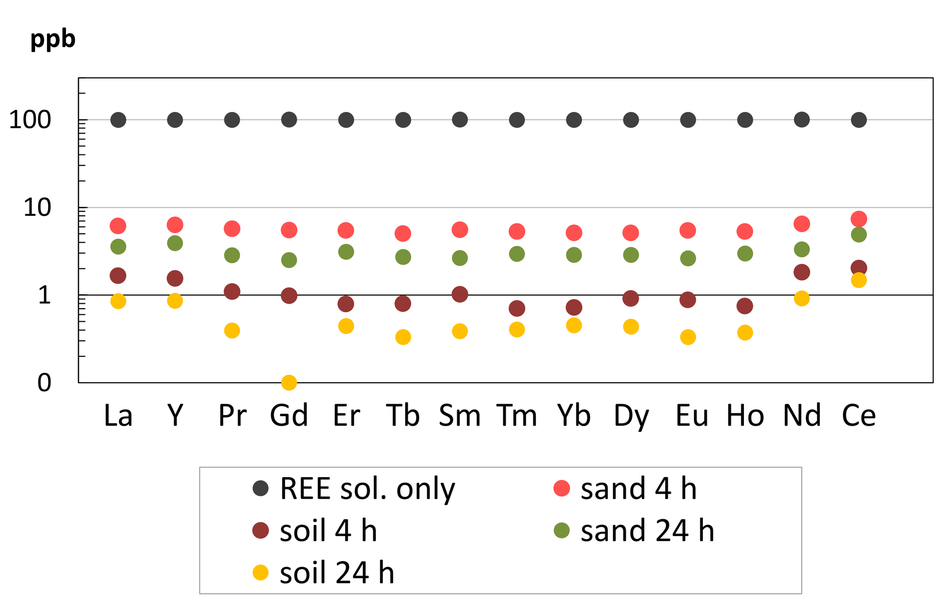
NPs examined: Al_2O_3, SiO_2, CeO_2, ZnO, Ag, Au, carbon dots and montmorillonite

Sand: Industrial quartz, 212-300 µm
Soil: Red Mediterranean soil (4% clay, 96% sand, <250 µm), from Weizmann Institute campus

Suspension stability of each TCE solution was examined in presence of each NP on its own, HA on its own, and with mixture of a NP and humic acid. Measurements were conducted separately for soil and sand solutions. TCE concentrations were measured by ICP-MS.
Initial concentrations in all experiments: REEs – 100 ppb, NPs – 10 ppm, HA – 50 ppm.



SORPTION OF REEs ON SOIL AND SAND

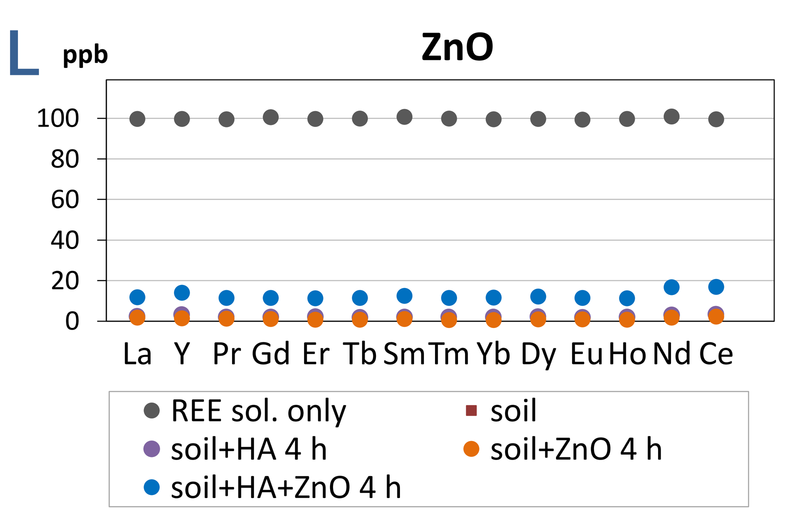


All REEs adsorb ~100% on soil and ~ 95% on sand.

There is no significant difference in REE concentration in solute after 4 h or 24 h settling, while recovery of REEs without presence of porous media is 100% in both cases.

SUSPENSION IN SOIL AND SAND SOLUTIONS

SOIL

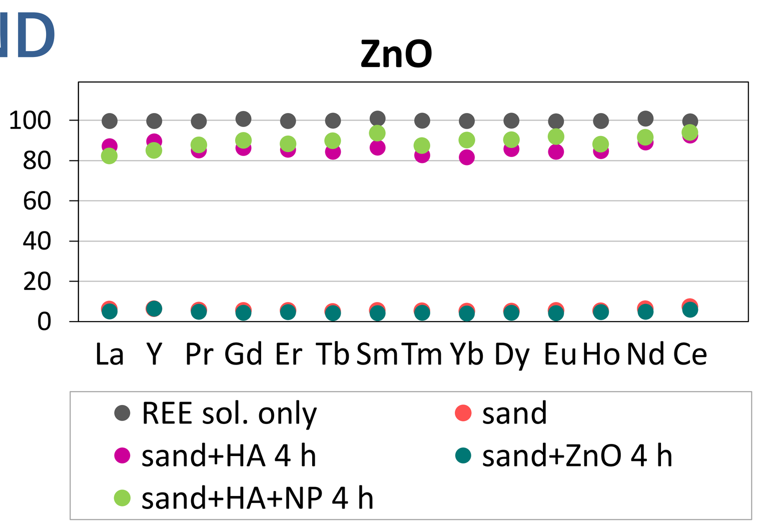


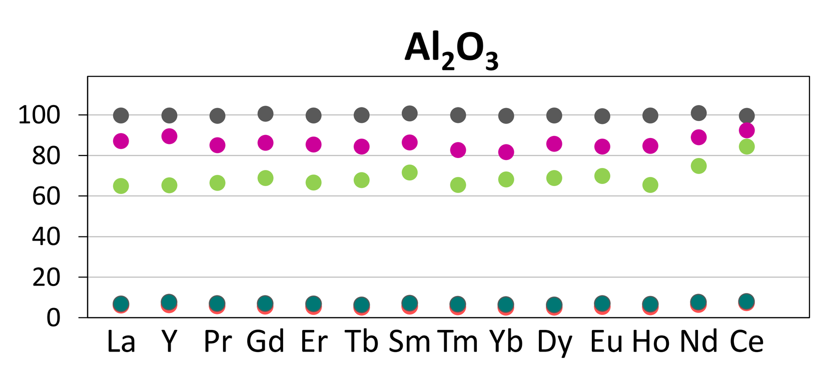
For all NPs, the concentration of REEs in the NP + HA experiment is between 10 and 20 ppb; recovery with ZnO is shown here as an example.

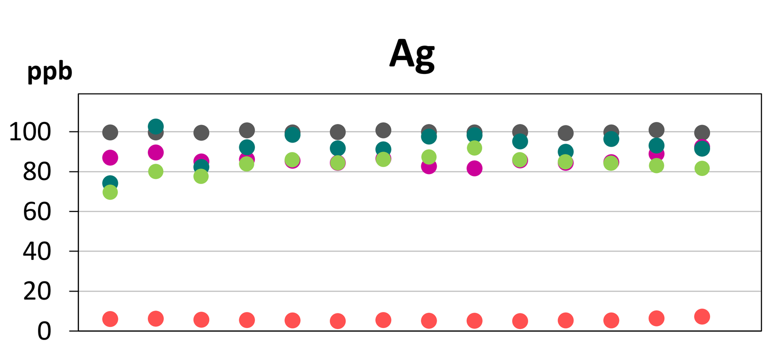
All NPs together with HA increase suspension stability of REEs.

No NP on its own or HA on its own increases REE suspension stability.

SAND





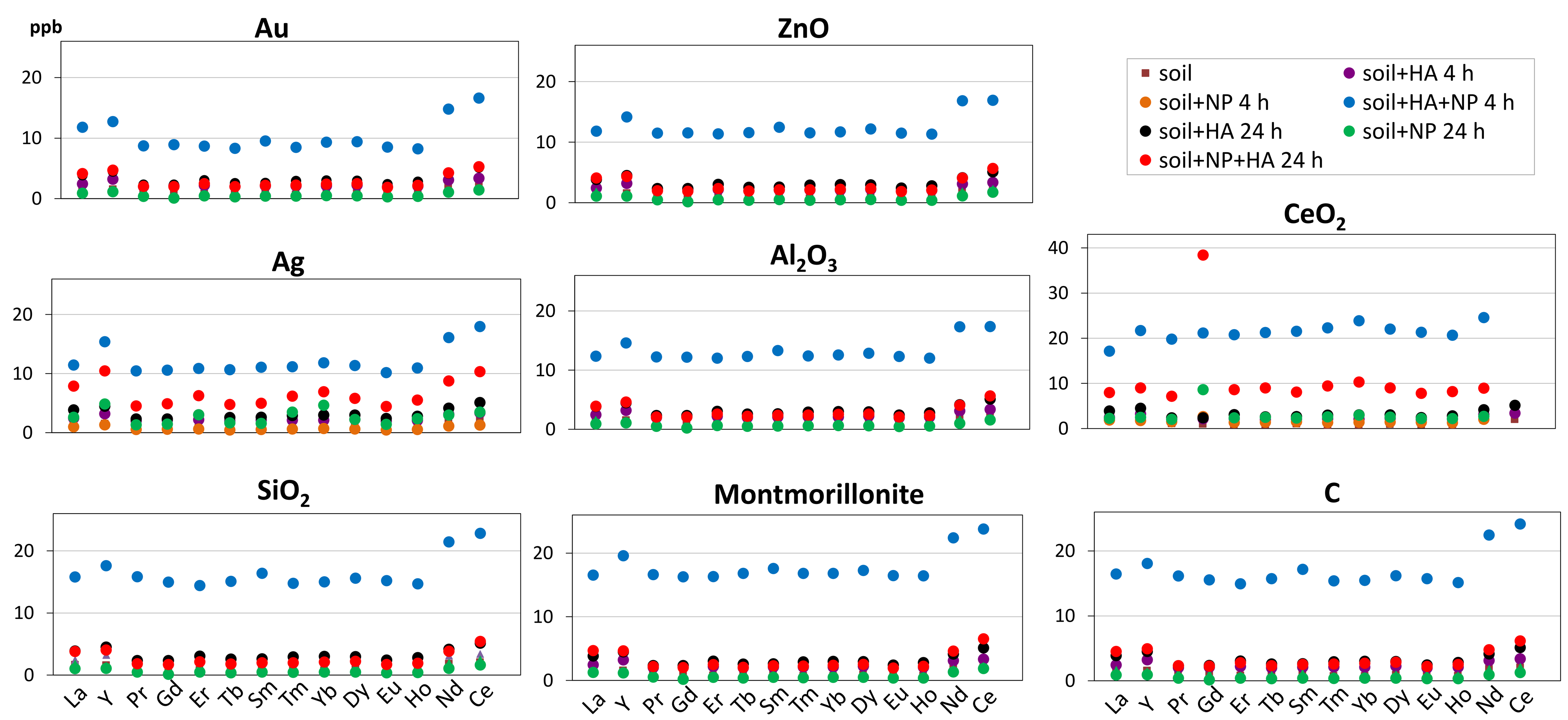


HA alone suspends REEs as efficiently as HA+NP. Al_2O_3 is the only NP for which HA + NP suspends REEs less efficiently than HA alone.

Suspension by NP + HA in sand solutions is ~9 times greater than in soil solutions.

Only Ag and Au sustain REEs in the solution without presence of HA. Ag alone recovers ~90% REE concentration, whereas Au yields ~10%.

REE SUSPENSION STABILITY OVER TIME



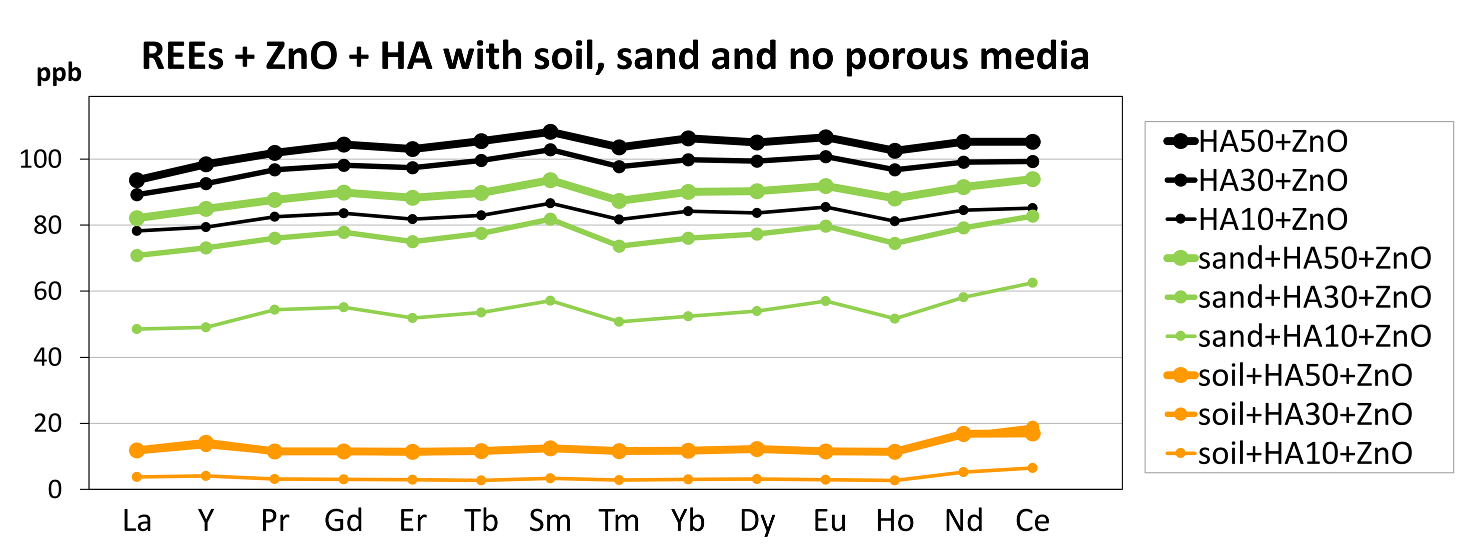
REE concentrations in soil solutions in the presence of NP alone, HA alone, and NP together with HA. This experiment was conducted twice – allowing samples to settle for 4 h and 24 h before extracting solute.

After 24 h settling, all NPs + HA except Ag and CeO_2 recover <5% REE concentration.

After 4 h settling, all NPs + HA recover 10-25% of REE concentration, depending on the NP, and the recovery is significantly higher than by NP alone or HA alone (< 5%).

Thus, NP + HA combination increases REE suspension stability, but the suspended colloids settle with time.

DEPENDENCE ON HA CONCENTRATION



HA 50 – 50 ppm humic acid

REE suspension efficiency with HA and HA + NPs is dependent on humic acid concentration. This holds true for solutions with no porous media, suggesting that the larger the HA concentration, the longer it takes for colloids with REEs to settle.

CONCLUSIONS

- NPs together with HA increase suspension stability of REEs for all NPs tested.
- In soil solutions, only NP + HA stabilizes REEs in solution, not NP alone or HA alone.
- In sand solutions, recovery by HA alone is similar to recovery by NP + HA and it is around nine times more efficient than in soil solutions.
- Ag and Au are the only NPs that increase suspension stability of REEs in absence of HA.
- Al_2O_3 is the only NP which together with HA suspends REEs less efficiently than HA alone.

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