Two Birds With One Stone: Artificially Enhanced Olivine Weathering for Sediment Management and CO_2 Sequestration in the Port of Rotterdam

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Background

Millions of tons of sediment are dredged every year by the Port of Rotterdam (PoR). These sediments are either redeposited at sea or contained in a confined disposal facility. Whilst these sediments could be useful in building ecological engineering projects, there are concerns about the release of greenhouse gases and toxic metals.

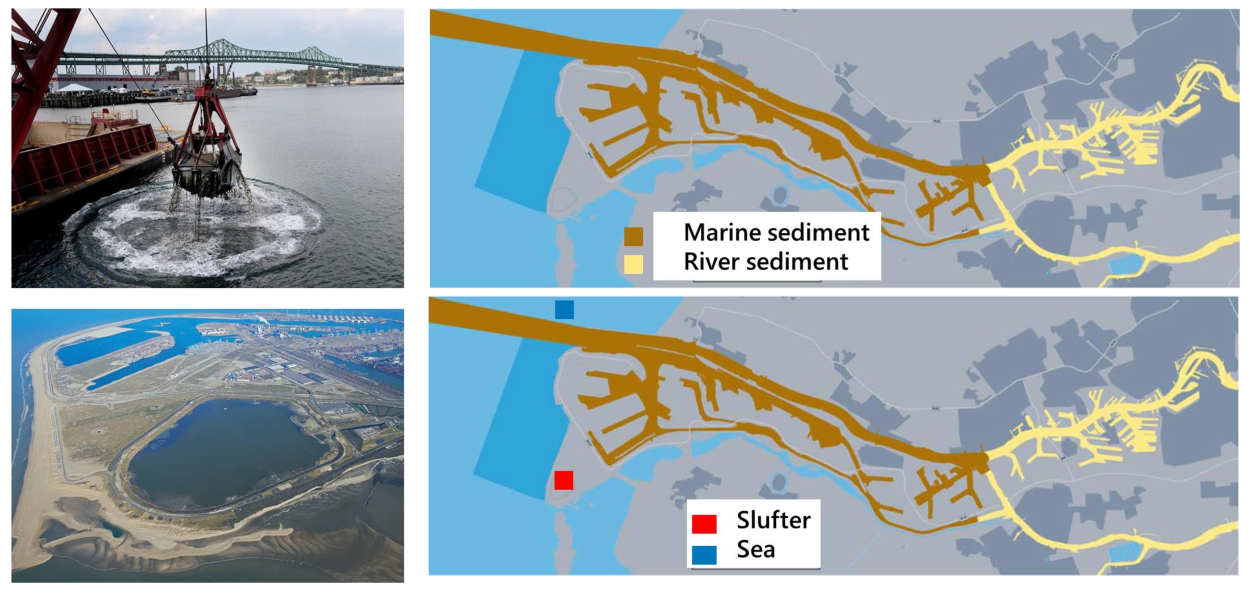


Figure 1: Port of Rotterdam. About 10-14 million m^3 of sediments are dredged per year, ~10% stored underwater in a confined site 'The Slufter', and the rest to sea[1].

The idea of spreading ground olivine in terrestrial and coastal environments to capture CO_2 is becoming increasingly popular due to the urgency to combat climate change. This technique (termed Artificially Enhanced Olivine Weathering, EOW) capitalizes on the natural process of olivine weathering that encourages gaseous CO_2 to transform into dissolved bicarbonate ions (HCO_3^-)[2]. In addition, the dissolution of olivine increases soil water pH and allows precipitation of secondary minerals (e.g., Fe oxyhydroxides) that can immobilize toxic metals through adsorption and co-precipitation mechanisms[3]. As a result, EOW could be a promising geo-engineering solution for sediment management at PoR and reduce the negative environmental impacts associated with dredging.

Research Objective

Through laboratory experiments and field trials, we aim to investigate whether the addition of olivine can transform the dredged material from the PoR into a sustainable resource.

Figure 2: Marker Wadden[4]

Methods and Materials

Step 1: Port of Rotterdam: Sampling and Characterizations

Guangnan et al. (in prep)

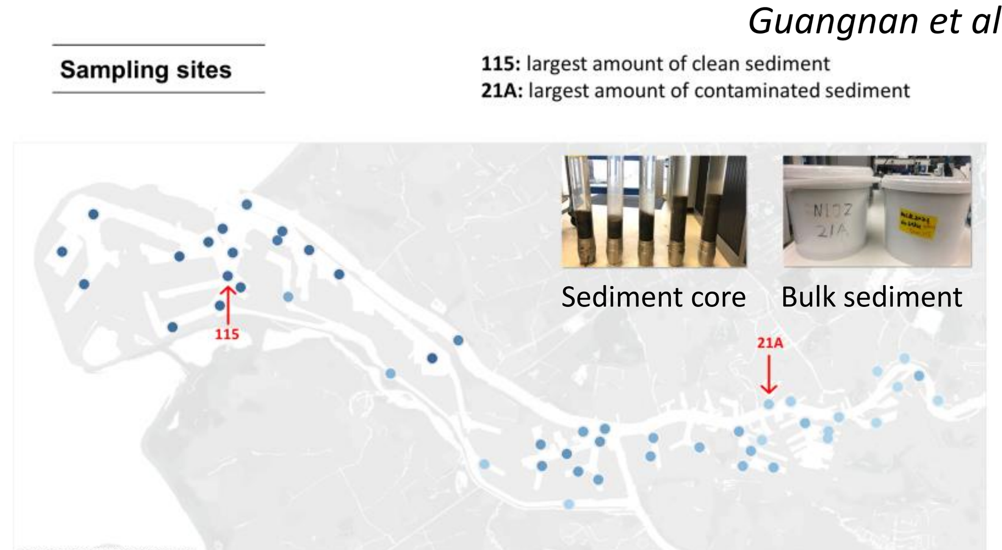


Figure 3: Sampling sites at the PoR: Stat 115 (marine site) and Stat 21A (riverine site)

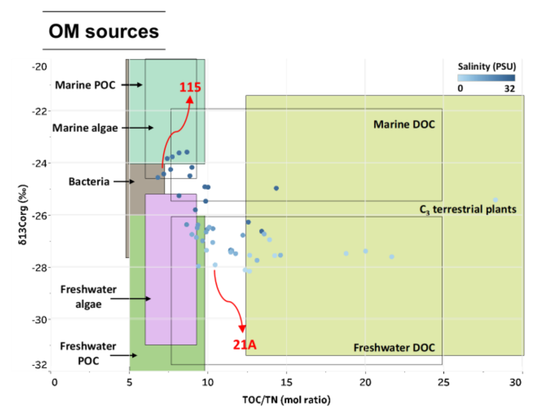


Figure 4: Organic matter sources along the salinity gradient of the sampling sites

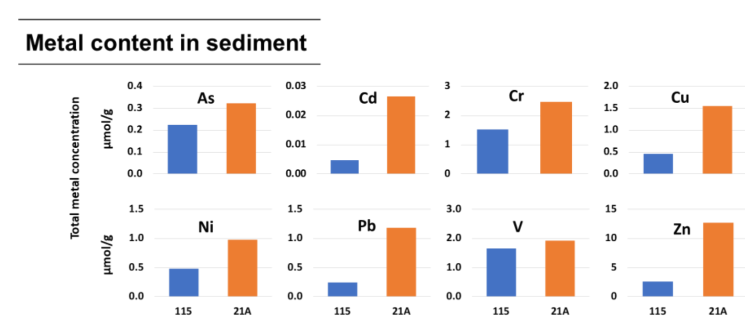
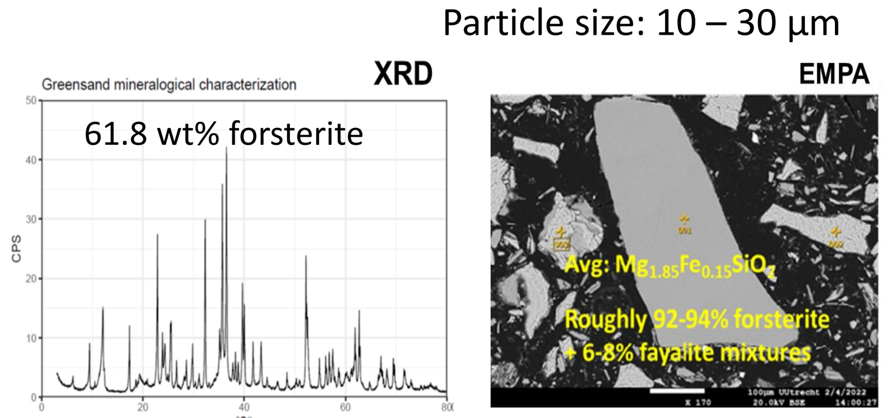


Figure 5: Metal concentrations at Stat 115 (marine site) and Stat 21A (riverine site)

Step 2: Olivine-rich Mineral Mixtures From Norway (Greensand)

Particle size: 10 – 30 µm



Oxide/Element	Amount in	Greensand
MgO	%	44,16
SiO_2	%	41,84
Fe_2O_3	%	6,58
Al_2O_3	%	0,92
CaO	%	0,43
MnO	%	0,10
TiO2	%	0,01
Cr	ppm	2011
Ni	ppm	1785
Zn	ppm	90

Figure 6: Characterizations (XRD, EMPA, and XRF) of the Greensand olivine

Step 3: Laboratory Batch Experiments with Artificial Seawater

Temp 12°C

1. Greensand Olivine (GS) + Artificial Seawater (AS)
2. Greensand Olivine (GS) + PoR Sediment (PoR) + Artificial Seawater (AS)

Open system

Triplicates

Periodic fluid sampling (pH, Alk, DIC, Elements)

Results and Discussion

1. Greensand Olivine (5, 10, and 20g) + Artificial Seawater (200 ml)

The Carbonate System *Pokharel et al. (in prep)*

Elemental Analysis

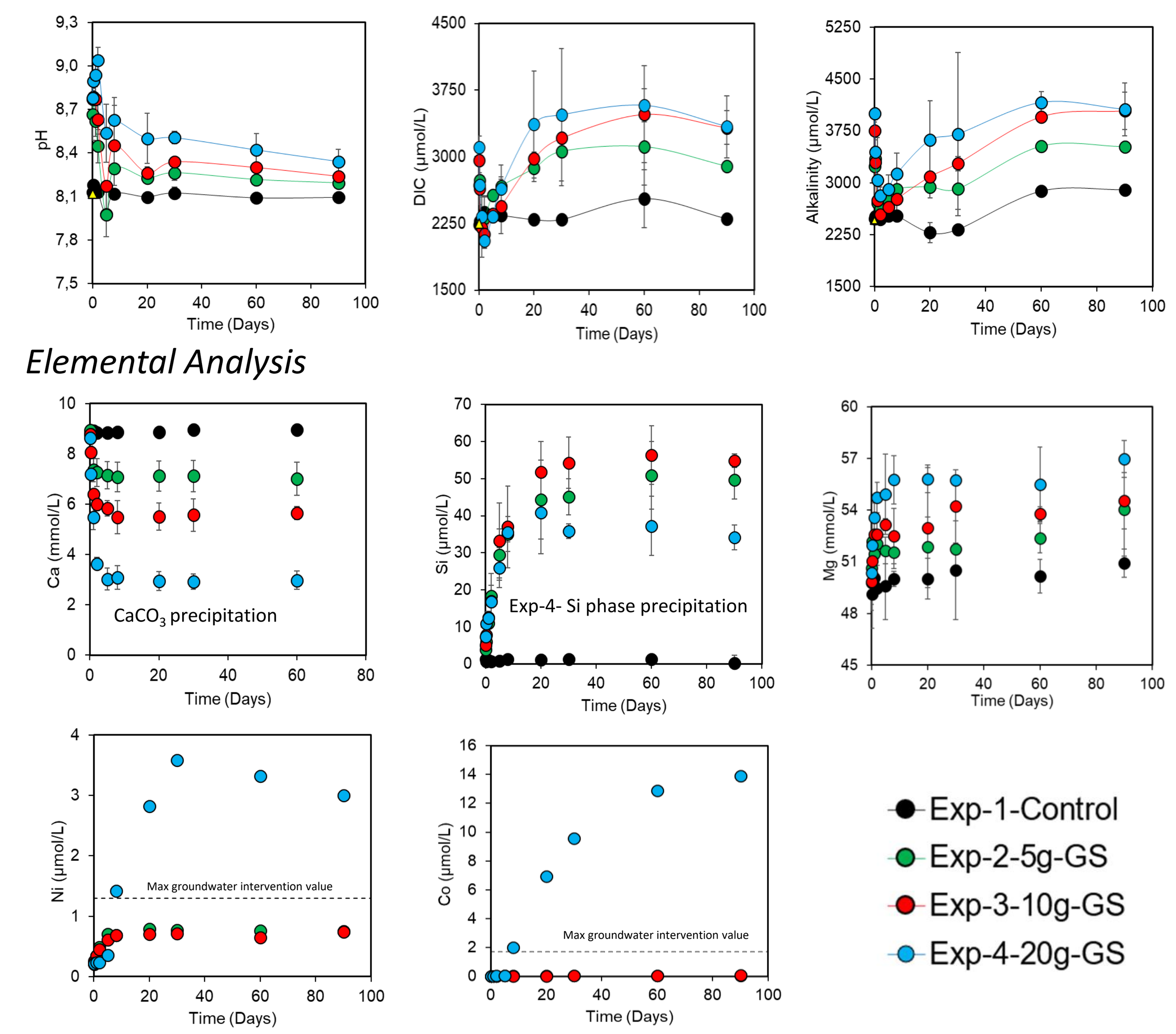


Figure 7: Temporal evolution of pH, DIC, alkalinity, and metals (Ca, Si, Mg, Ni, and Co) during the batch experiments. Cr and Zn concentrations were below the ICP-MS detection limit in all samples.

SEM/EDS Analysis

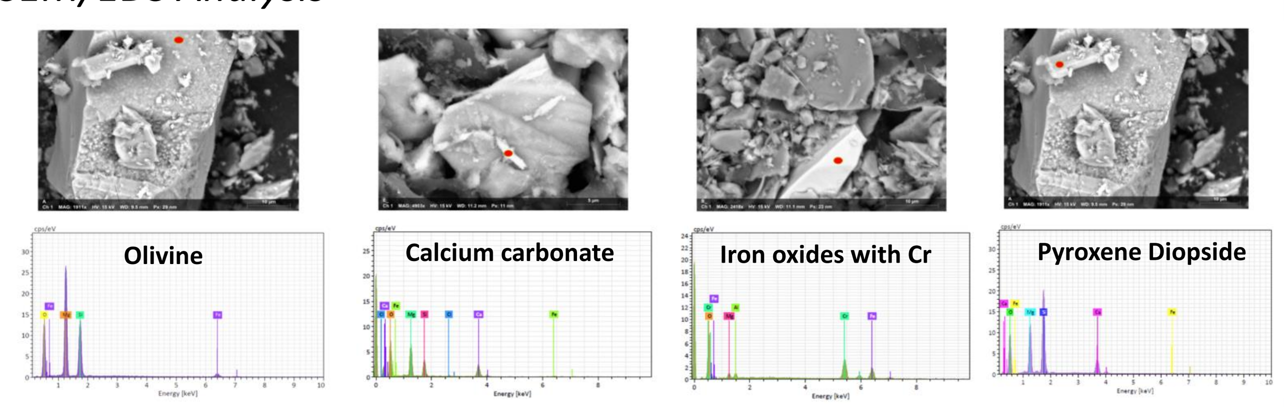


Figure 8: SEM/EDS analysis of reacted and unreacted solid samples

Observations & Conclusions :

- Greensand olivine buffers seawater pH and generates alkalinity.
- $CaCO_3$ and Si-phase precipitated ($SiO_{2\,(am)}$ or Mg-silicates).
- Toxic metals (Ni, Co, Cr, Zn, etc.) concentrations were below environmental standards in most of the experiments except for experiments with the highest solid/liquid ratio.
- Greensand olivine: Viable for EOW application from the environmental geochemical point-of-view.

Results and Discussion

2. Greensand Olivine + Sediment + Artificial Seawater (ongoing…)

Table 1: Greensand olivine content in the sediment-olivine mixture batch experiments

Experiment ID	% of Greensand	Mass of Greensand (Dried; g)	Mass of Sediment (g)
Cont-1-only-SW	0	0	0
Exp-1-only-RS	0	0	20
Exp-2-10%-GS	10	2	18
Exp-3-20%-GS	20	4	16
Exp-4-30%-GS	30	6	14
Exp-5-40%-GS	40	8	12
Exp-6-50%-GS	50	10	10

Stat 21A Riverine Site

The Carbonate System

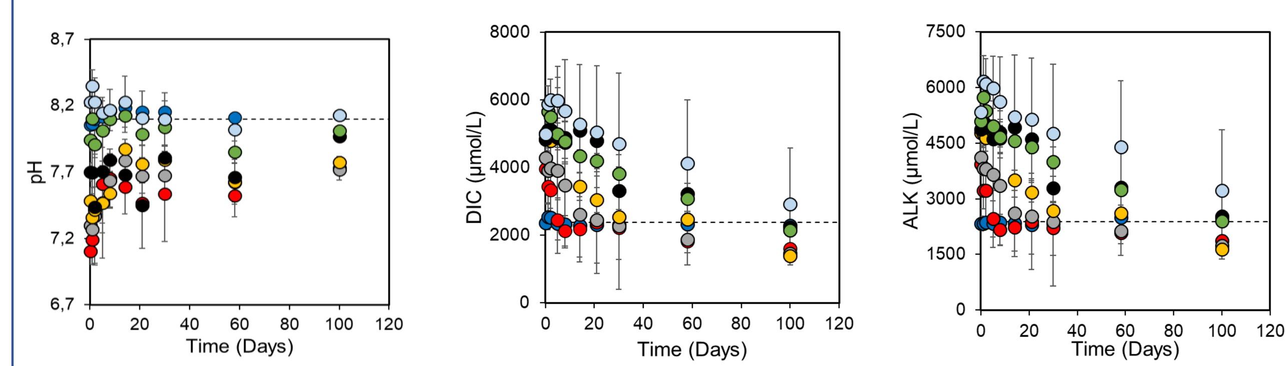
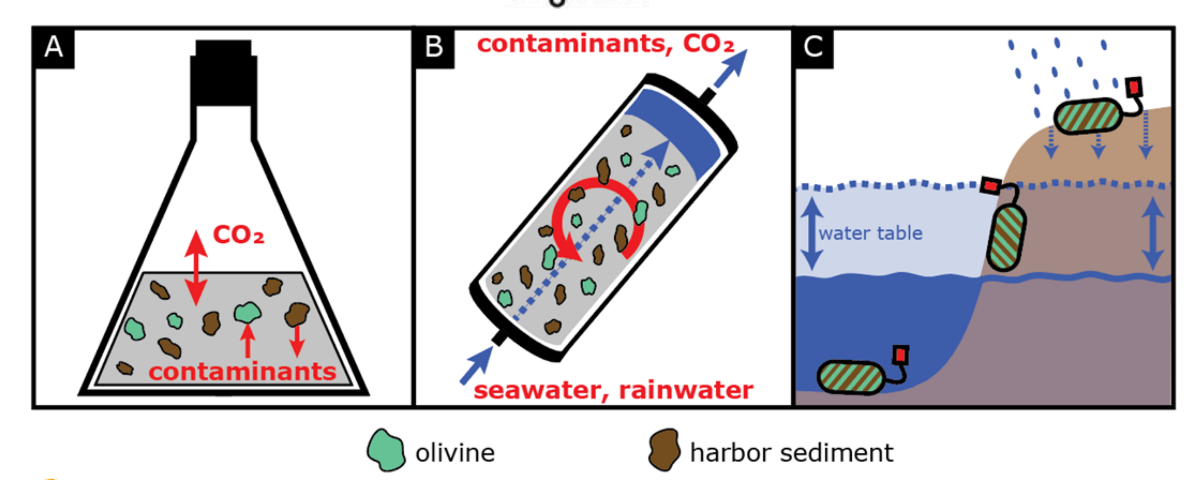


Figure 9: Temporal evolution of the carbonate system (pH, DIC, and alkalinity) during the batch experiment

Elemental Analysis and SEM/EDS data to follow

Future Experiments

Stat 115 Marine Site



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