UDEMM: Widespread environmental contamination from undersea munitions in the southwest Baltic Sea

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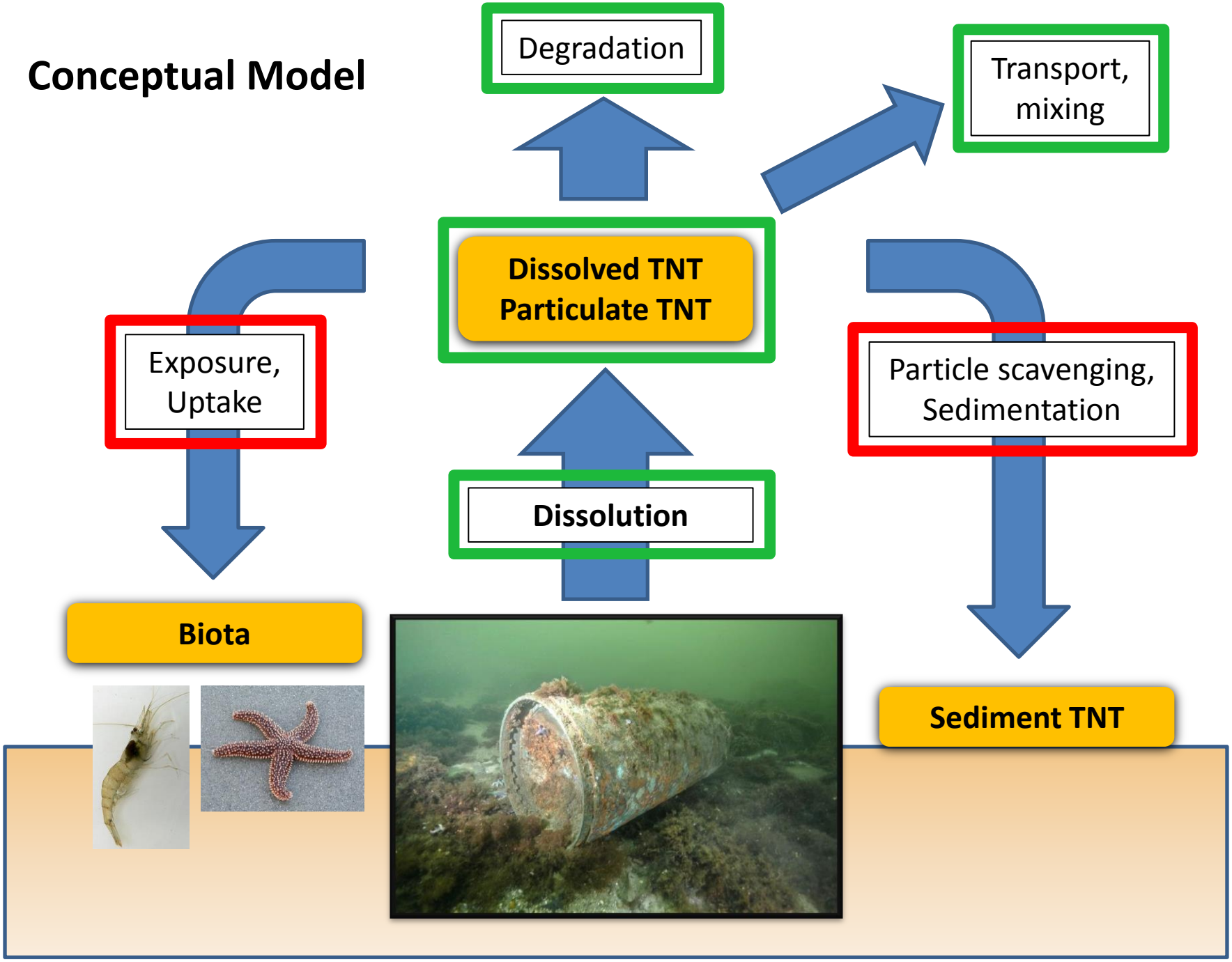
Zukunft Meer
sea our future

SH Schleswig-Holstein
Der echte Norden

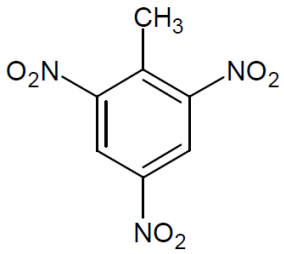
Conceptual Model



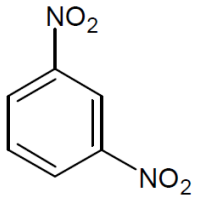
Detecting explosives in seawater

New method (Gledhill et al., submitted):

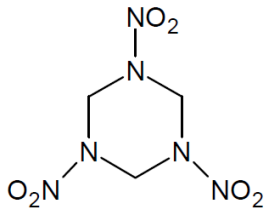
- Solid-phase extraction, analysis by ultra-high-performance liquid chromatography (UHPLC) and electrospray mass spectrometry (ESI-MS)
- Unequivocal compound identification
- Detection limits ~5 fg/L (femtogram per liter; 10^{-15} g/L)



2,4,6-Trinitrotoluene (TNT)



1,3-Dinitrobenzene (DNB)



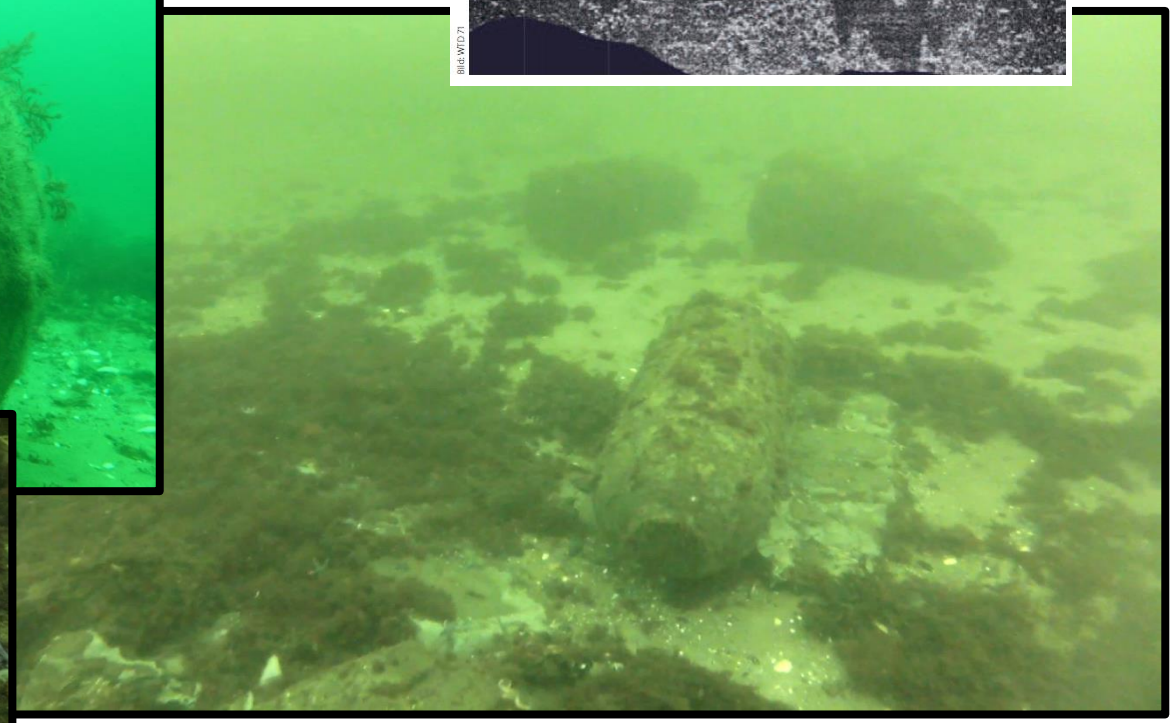
Cyclotrimethylenetrinitramine (RDX)

Primary study site: Kolberger Heide

- Munitions dumpsite
- Contains intact and corroded munitions and exposed explosive pieces

„Mine mound“

Frenz, 2014

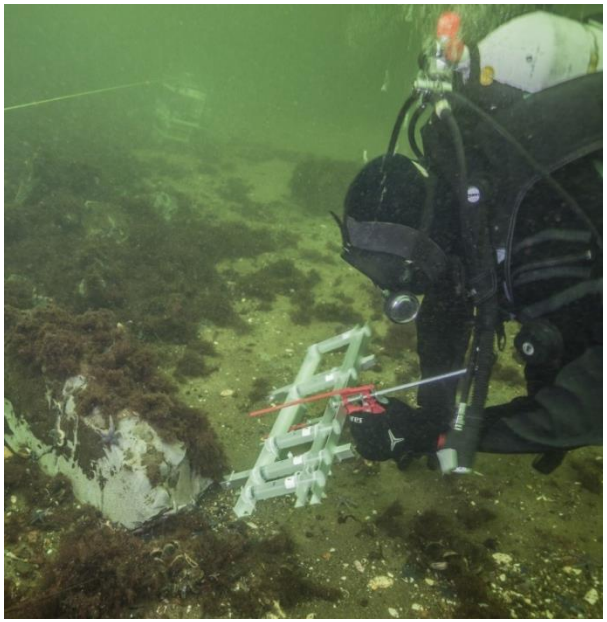


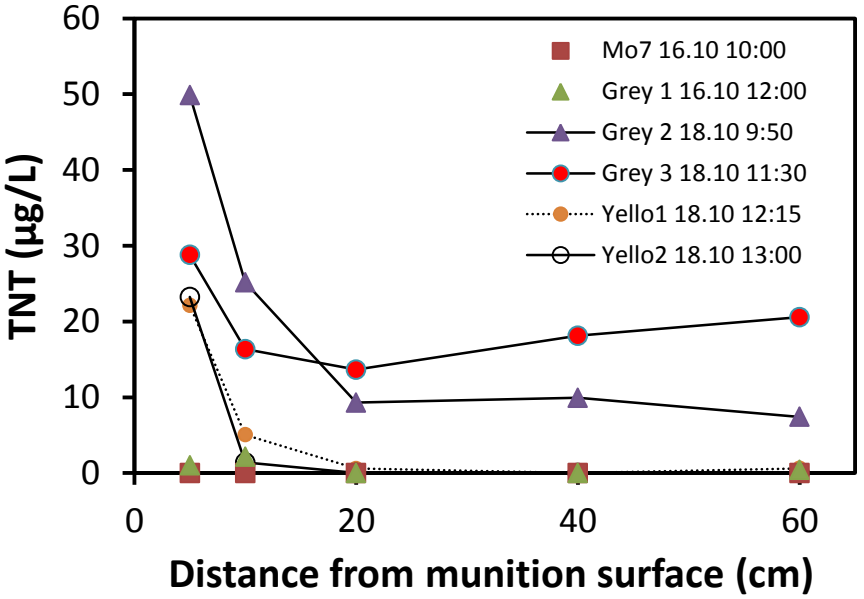
„Craters“

In situ dissolution rates: Profile method

- Simultaneous sampling near explosive surface
- At steady state, flux from surface equal to dissolution of surface

$$J_{dissol} = J_x = -D_e \frac{dC}{dx}$$



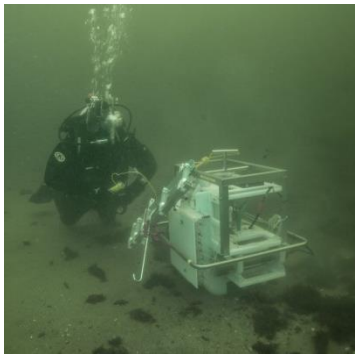


J_{dissol} = 100 -1000 µg/cm²/d

- In situ dissolution rates MUCH lower than most literature reports – slow water stirring rates in situ?
- High degree of heterogeneity, even within 0.5 m of open explosive surface

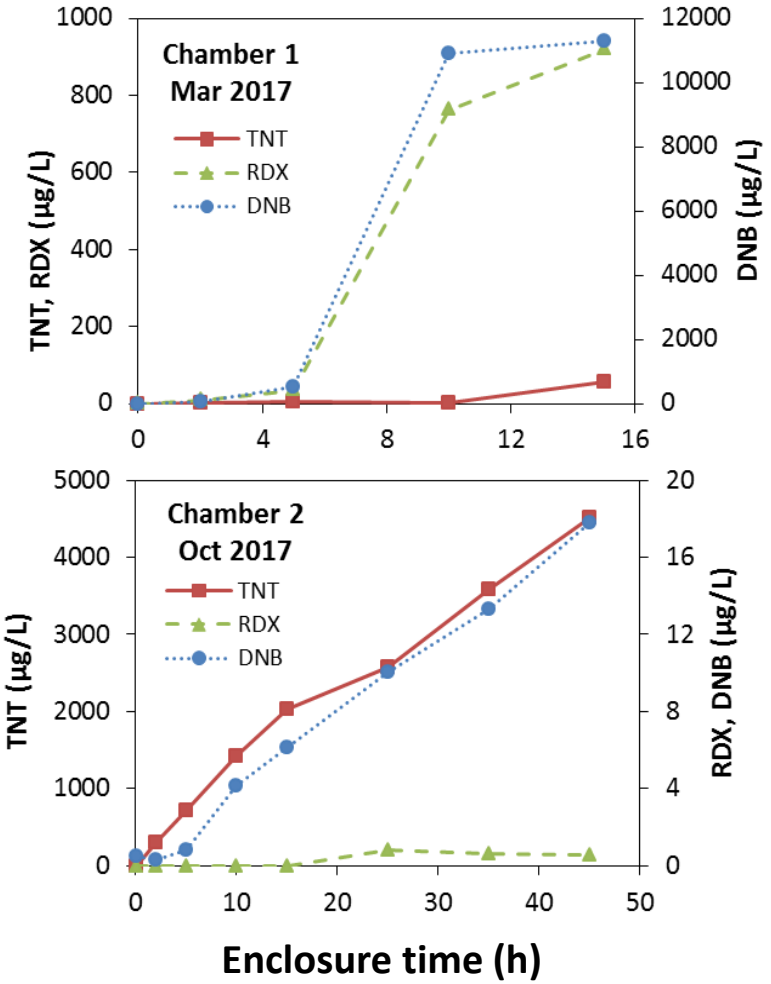
In situ dissolution rates: Benthic chamber method

- Deployed Mar 2017, Oct 2017
- Different explosives composition?

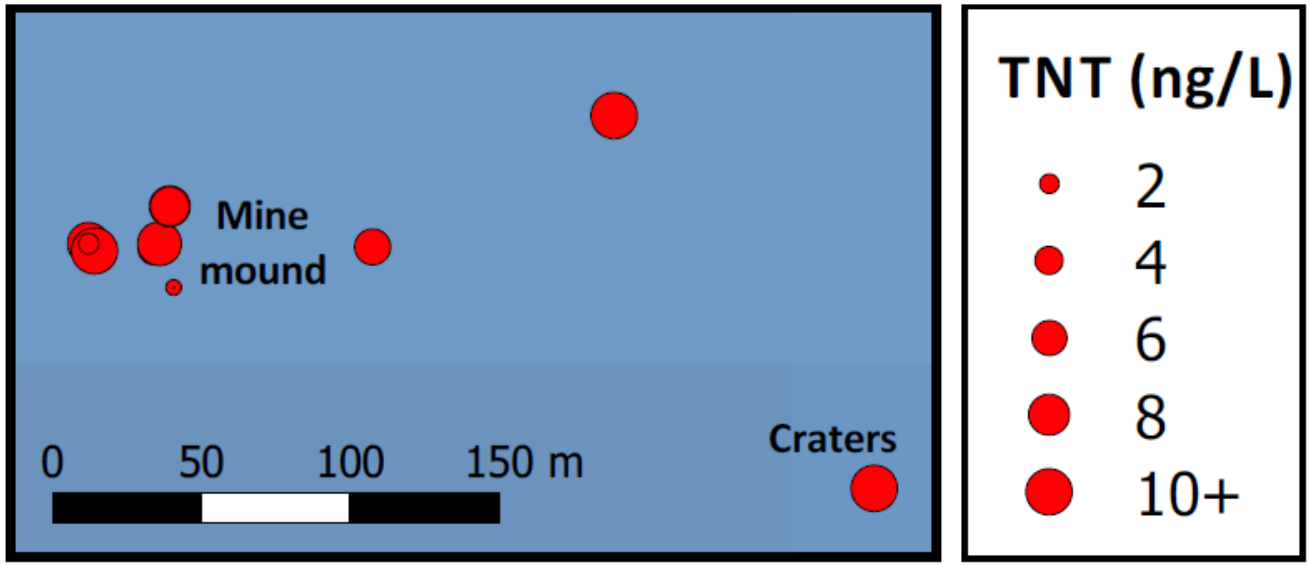


J_{dissol} = 10 -1000 µg/cm²/d

- Dissolution rates similar to Profile Method —lower than literature reports
- Variability depends on explosives composition!

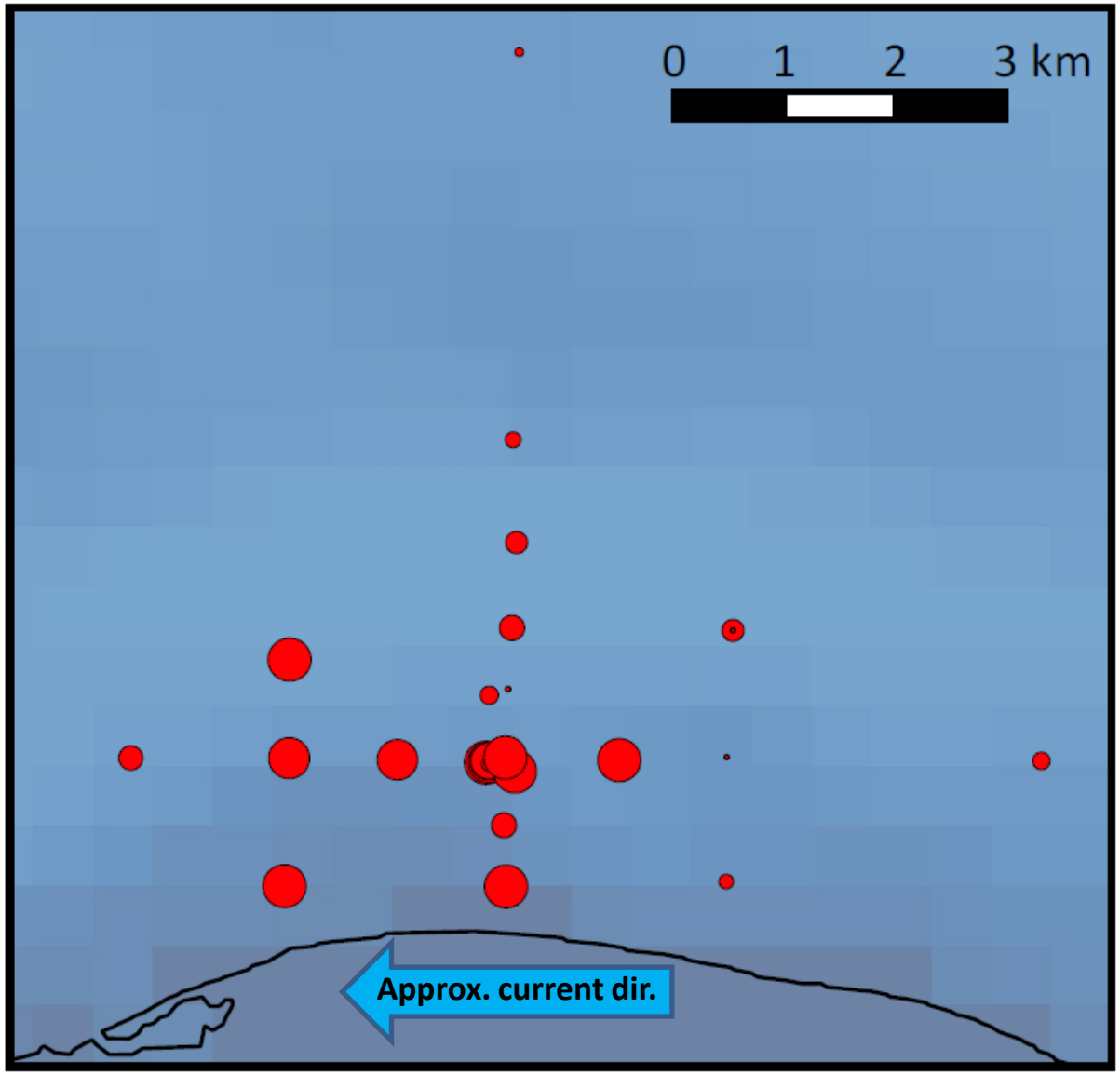


Munitions compounds in water column at Kolberger Heide site



- Concentrations approximately 1-100 ng/L
- Heterogeneous distribution seasonally and over small (km) spatial scales

Munitions compounds in water column at Kolberger Heide site



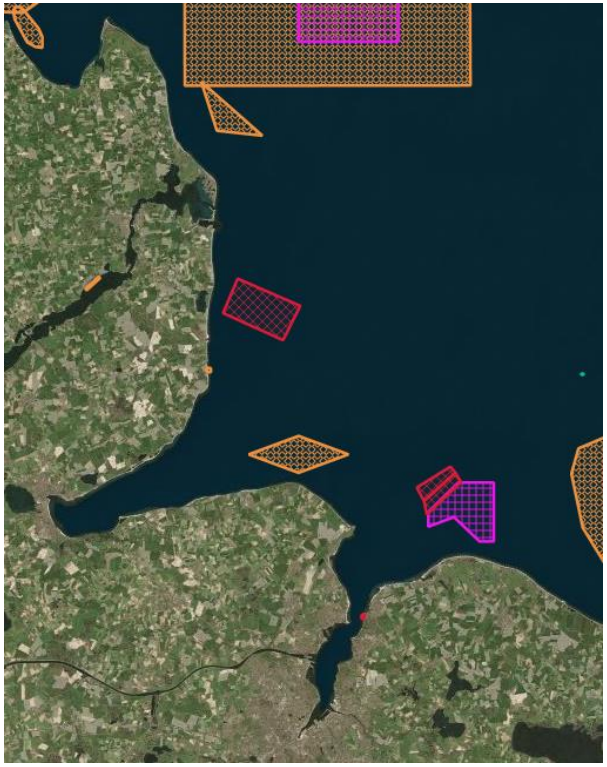
TNT (ng/L)

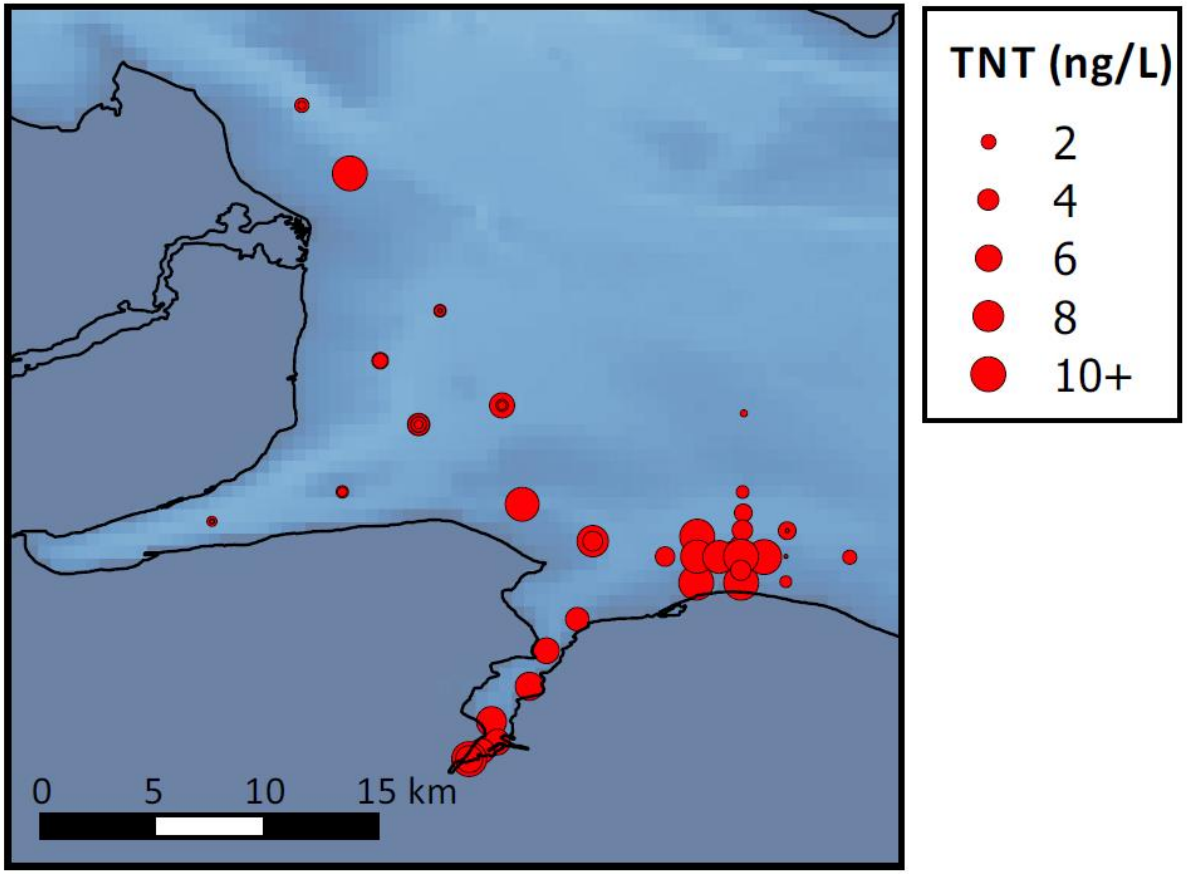
- 2
- 4
- 6
- 8
- 10+

- Wider-scale patterns show highest concentrations near munitions dumpsite, and downstream

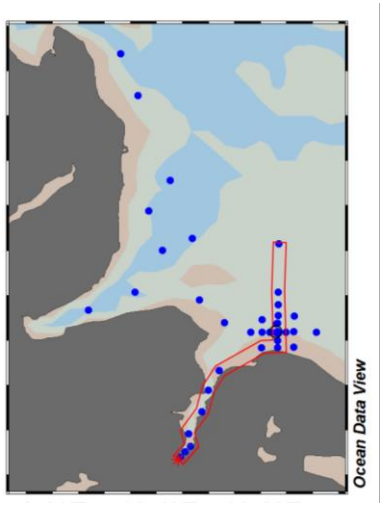
Munitions compounds in water column: Regional trends

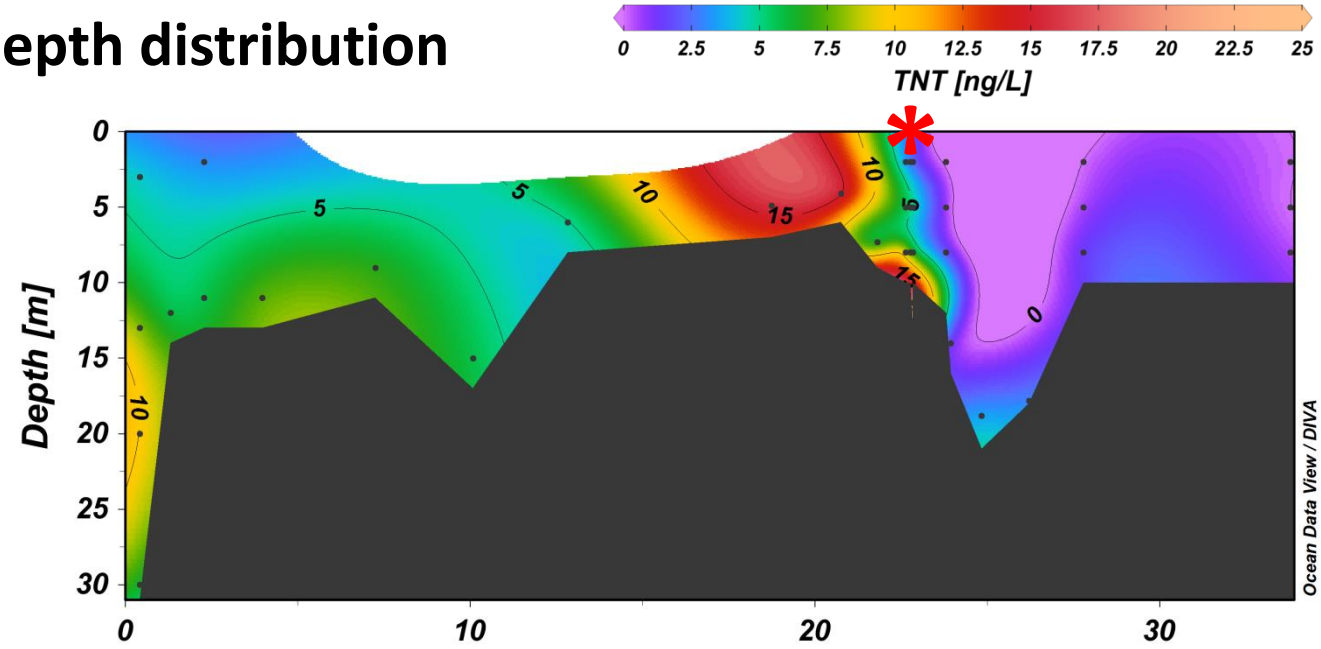
Munitions contaminated regions (AmuCad.org)

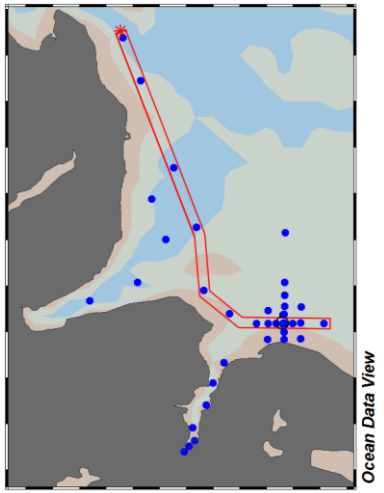


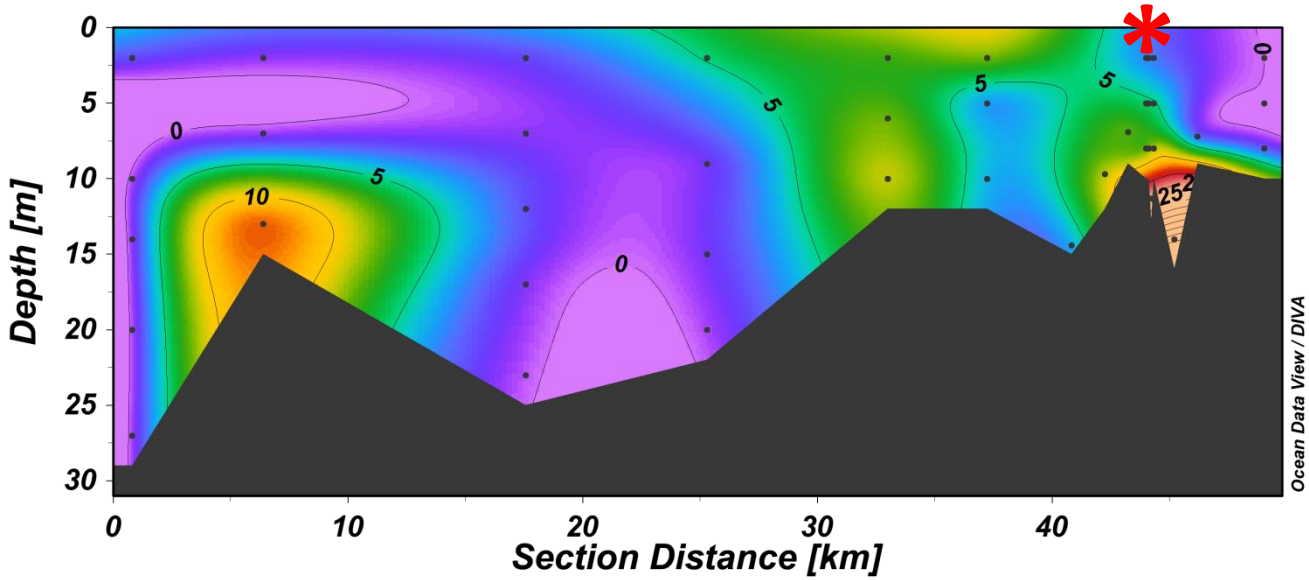


Munitions compounds in water column: Depth distribution



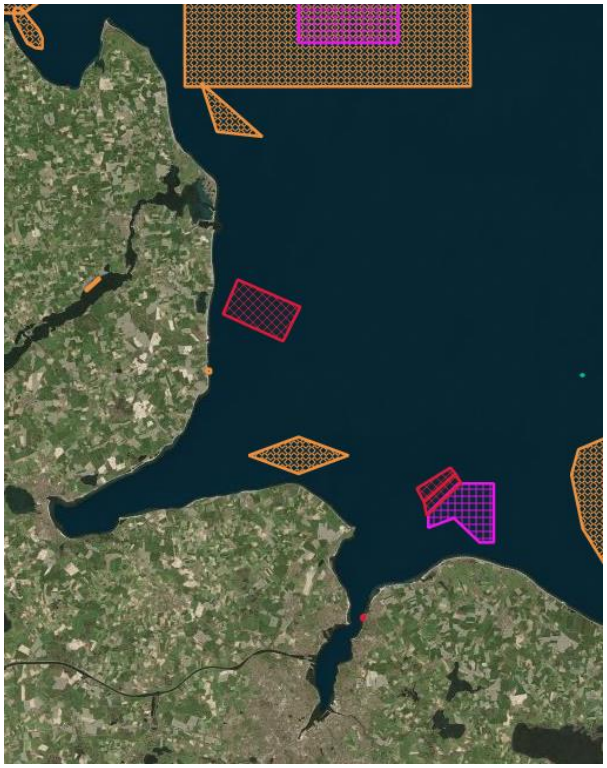


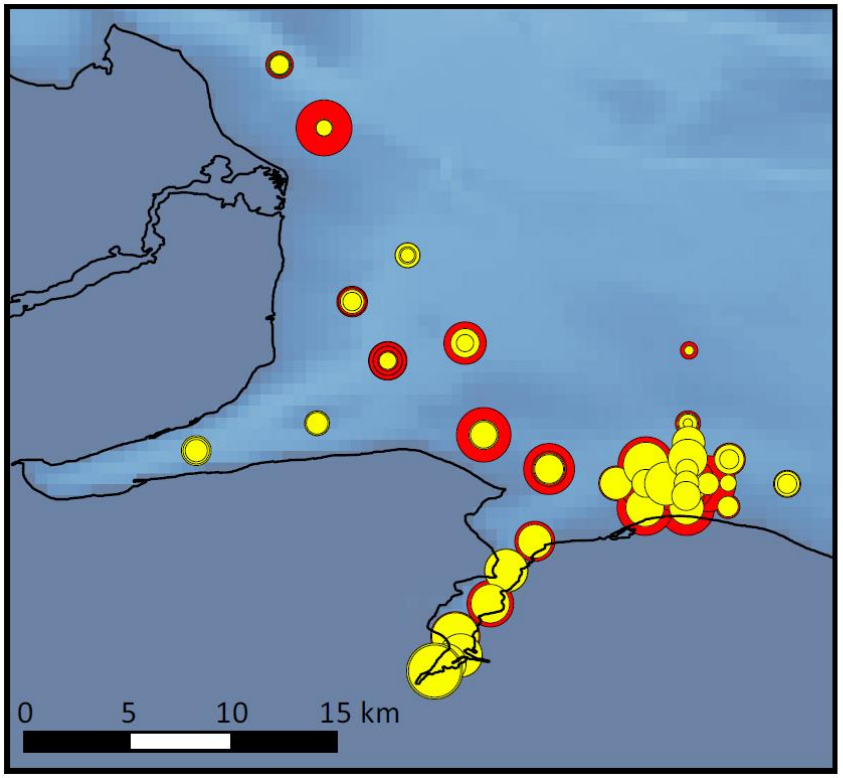




Munitions compounds in water column: Do differences in distribution reflect sources?

Munitions contaminated regions (AmuCad.org)





TNT (ng/L)

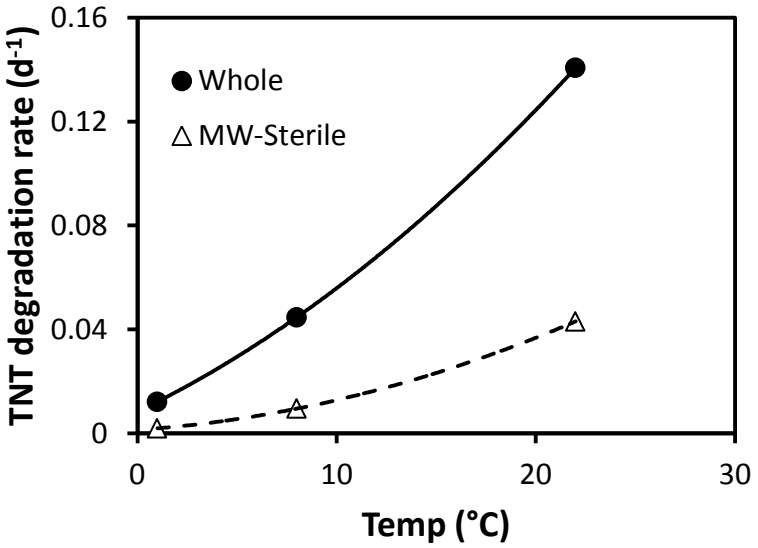
2
4
6
8
10

RDX (ng/L)

1
2
3
4
5

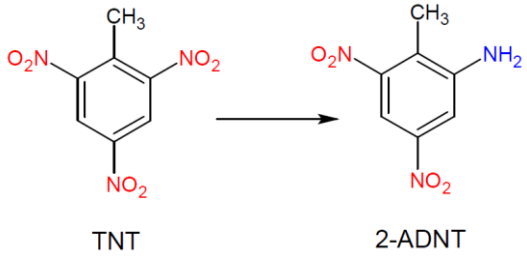
Degradation/particle sorption

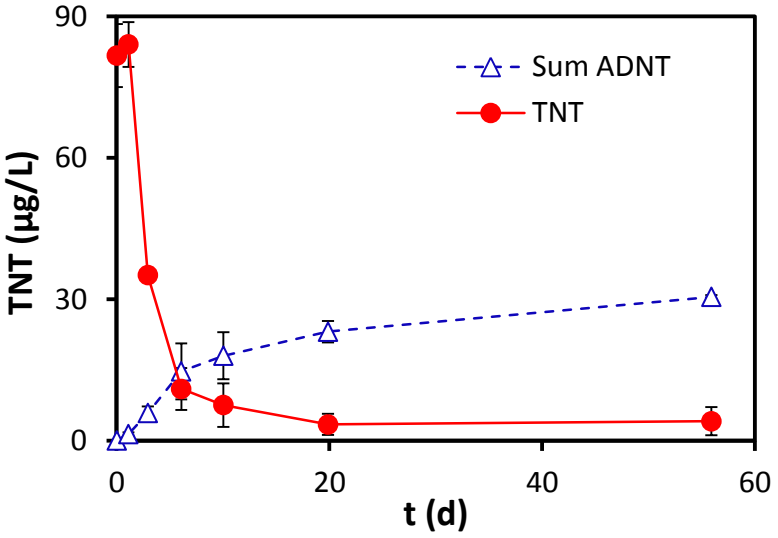
- Whole water, microwave sterilized, and filter sterilized (0.2µm)



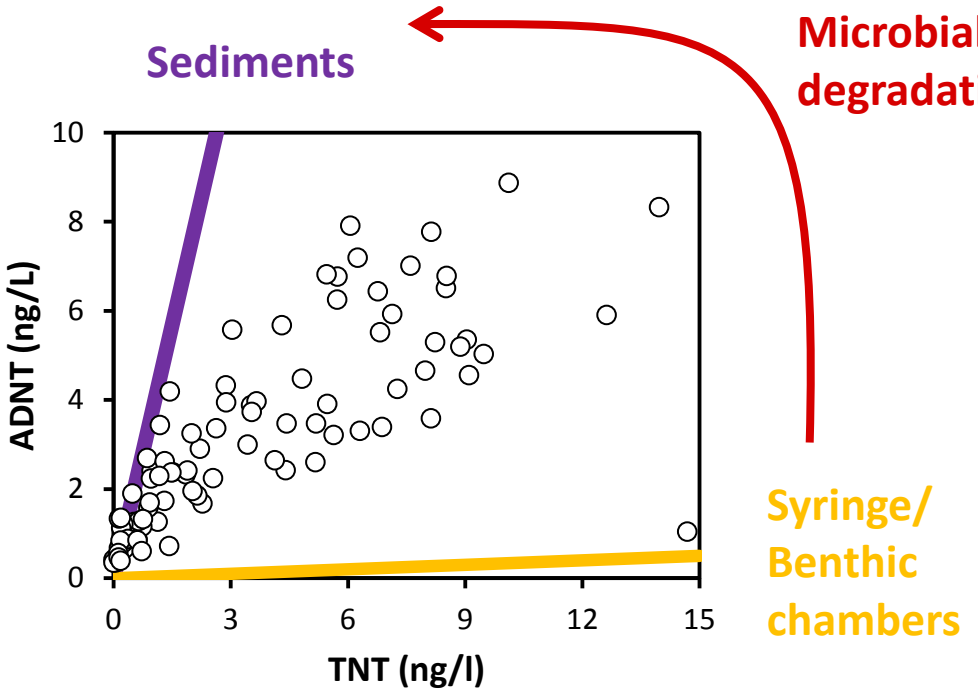
- Half-life ~10 d
- Water residence time in Fehmarn Belt 40-150 d (Gustafsson, 2000)

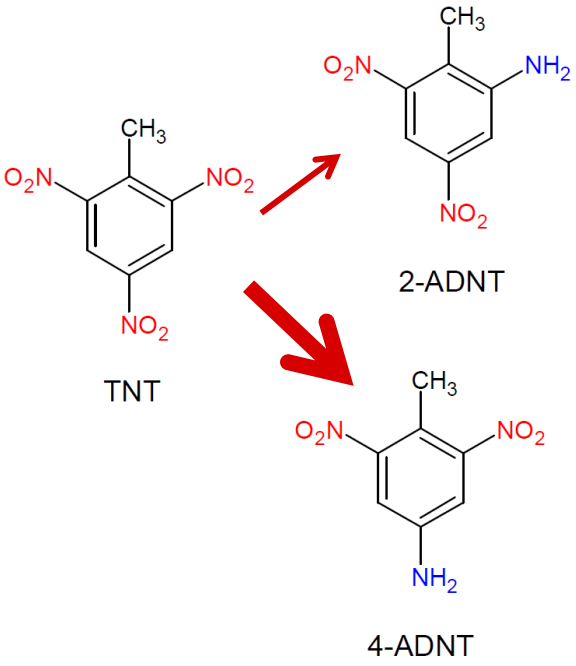
Microbial Degradation/Transformation

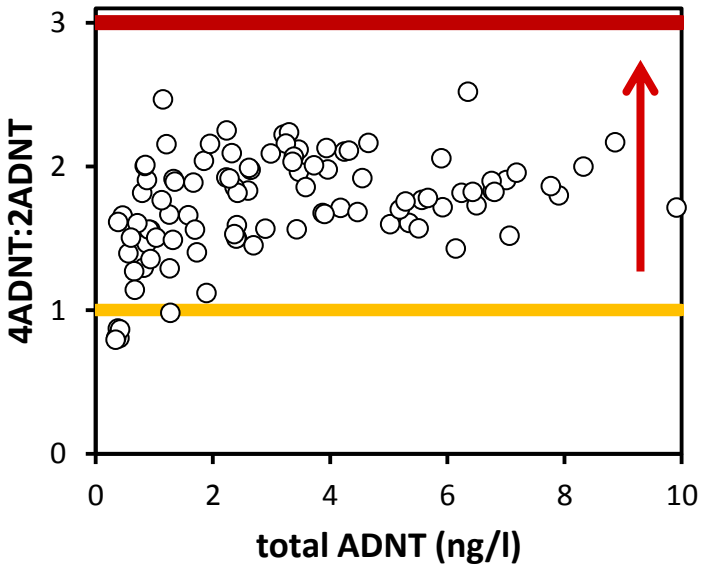




Degradation processes and products: Water column samples







Conclusions

- Analytical sensitivity critical for studying munitions compounds in seawater
- Low, but measurable MC concentrations detected throughout southwest Baltic Sea
- Dissolution rates relatively slow, likely controlled by water stirring energy
- TNT degradation half-life on the order of weeks, degradation products in water and sediments indicate microbial control

See UDEMM posters for more information, and munitions compounds in sediments and biota

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