“Effect of Sediment Toxicity on Anaerobic Microbial Metabolism”

Environmental Toxicology and Chemistry

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Purposes of Experiment

- To study the effects of sediment on anaerobic bacteria metabolism of a known toxic waterway called the Arthur Kill estuary
- Located on the NY/NJ Harbor System

Background

- In coastal areas, sediments are often anoxic below a few millimeters of the water
- Estimated that more than 90% of total organic matter buried in ocean sediments lie under anoxic conditions

Background

- Introduction of toxic materials to these sediments not only affects microbial metabolism, but also higher organisms via the flow of energy through the entire ecosystem
- The health of microbial sediment communities directly impacts the overall health of a waterway

14C-benzoate

- Evidence of sediment toxicity was measured in terms of 14C-benzoate mineralization by anaerobic bacteria present in the sediment
- Benzoate used because it is easily degradable in the absence of O_2 and it is a key metabolite in the anaerobic degradation of larger aromatic contaminants, such as pesticides

14C-benzoate

- The measurement of differences in 14C-benzoate mineralization rates under various treatments was used used to show the effects of sediment toxicity on bacterial populations

Materials and Methods

- Sediment
  - collected from Arthur Kill estuary near a landfill and several petroleum loading docks
  - taken from the upper 0 to 60 cm of sediment located beneath approximately 30 meters of water

Sediment, cont'd

- Uncontaminated sediment was collected from Flax Pond in Stony Brook, NY
- This sediment was unimpacted by oil input or landfill runoff

Materials and Methods

- Sediment slurries and water were prepared by degassing with 70% N_2:30% CO_2
- pH 7
- Strict anaerobic conditions maintained throughout
- 14C-benzoate added to each bottle from a 100 milliCurie stock solution in toluene
- All experiments performed in triplicate plus sterile controls for each condition

Materials and Methods

- Mineralization of 14C-benzoate was monitored by the detection and quantification of $14CO_2$ and $14CH_4$ evolved into the headspace of each bottle by a gas chromatograph
- Gas headspace analysis was done by withdrawing a 1-ml headspace sample, which were then injected into the gas chromatograph

Materials and Methods

- Microtox bioassays were used to determine sediment toxicity
- This test measures the light emission by a test organism, *Vibrio fischeri*, when exposed to different dilutions of the sediment
- Reduced light emissions indicated greater toxicity
- Toxicity was reported as EC50 values, which is an estimate of the concentration, in mg/L, which reduced the light output of the organism by 50%

Materials and Methods

- Energy dispersive x-ray fluorescence spectrometry was used to determine the heavy metals concentrations in the sediment samples from the Arthur Kill and Flax Pond sites

Results

- The mineralization of 14C-benzoate in anoxic organisms with either 10 or 50% sediment:site water slurries is shown in Fig1
- No lag period
- Sterile controls and no substrate added controls had no detectable mineralization in their headspace

Results

- Mineralization rates were calculated using the equation: Rate = (14CO_2 produced/dry weight of sediment)/time.
- In samples with 10% sediment slurry, the initial rate is four times higher than that of the 50% slurry, even though five times greater bacterial population in 50% slurry

Results

- To make sure toxic components of Arthur Kill site were actually affecting metabolism, a dilution experiment was performed using Arthur Kill sediment and uncontaminated sediment of similar geochemistry (Flax Pond)
- Fig 2

Results

- As seen previously, increasing the ratio of Arthur Kill sediment in the environment resulted in an inhibitory effect on the rate of mineralization

Measurement of Sediment Toxicity

- Using the Microtox bioassay relative toxicity levels were measured
- EC50 values were at least five times lower in Arthur Kill sediments than Flax Pond sediment samples
- This means that Arthur Kill sediment is very toxic

Measurement of Sediment Toxicity

- By adding more Flax Pond sediment (uncontaminated) to the toxic Arthur Kill sediment EC50 values increased, which indicates increased light emissions by the test organism, which means a decrease in toxicity
- Table 3

Metals Analysis

- Values given are compared to Effects Range Low (ERL) and Effects Range Medium (ERM)
- Arthur Kill sediment exceeded ERL range for Cr, and ERM ranges for Cu, Pb, and Zn
- Fig 3

Discussion

- Lower benzoate mineralization rates observed in microcosms with 50% Arthur Kill sediment, despite the five times greater bacterial population expected, than in microcosms with 10% Arthur Kill sediment

Discussion

- Also, increasing the ratio of Arthur Kill sediment in the microcosms decreased the rate of 14C-benzoate mineralization

Conclusion

- Some components in the Arthur Kill sediment must have an inhibitory effect on anaerobic metabolism of benzoate specifically and perhaps anaerobic carbon turnover in general

Conclusion

- This inhibitory effect could be alleviated by adding uncontaminated sediment to the Arthur Kill sediment

Conclusion

- Since ERMs were exceeded for Cu, Zn, and Pb, these metals were at high enough levels to be a probable cause of biological effects
- These metals are at least partly responsible for the decrease in benzoate mineralization

Discussion

- Metabolic inhibition caused by heavy metals has been shown in other studies as well

Example 1

- Metals added to salt marsh sediments were shown to decrease the amount ot sulfate reduction and methanogenesis by resident bacterial populations

Example 2

- Two researchers concluded in their experiments that heavy metals, including Cu, Hg, Zn, Cd, and Cr, were more inhibitory to the biodegradation of organic chemicals than high concentrations of microbially toxic organics (phenol, toluene, n-butanol, benzene, acetone, methanol)

Applications

- The inhibitory effect caused by the Arthur Kill sediment could be alleviated through the addition of uncontaminated sediment dilutions, as was shown throughout this experiment

Applications

- Clean sediment dilutions could be applied to contaminated hot spots in an estuary
- This would promote a natural degradation activity

Questions?