Environmental Fate of Carbon Nanotubes

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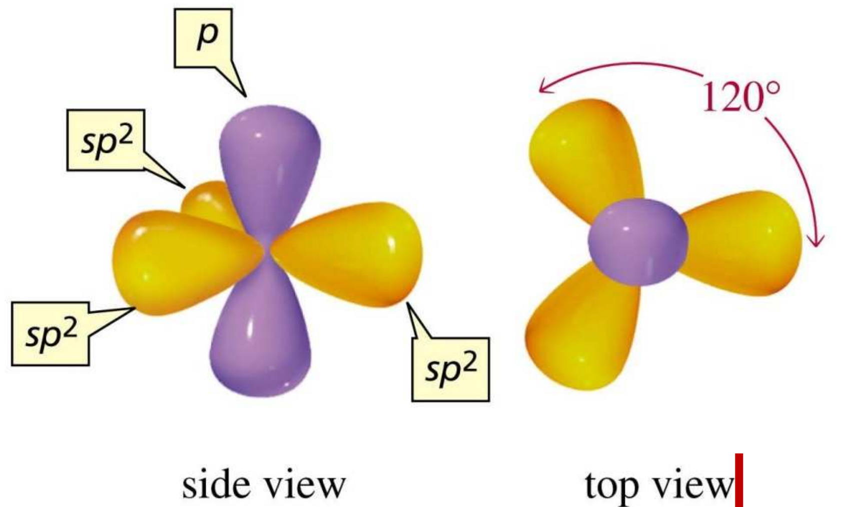
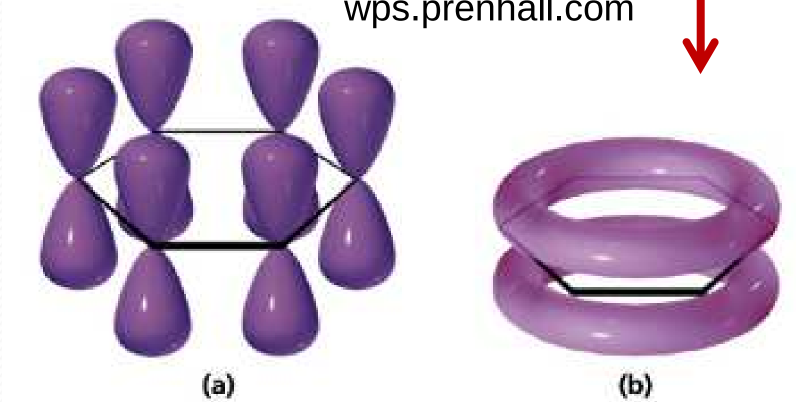
Presented 8/12/2013 at the University of Jyväskylä

Carbon Nanotubes

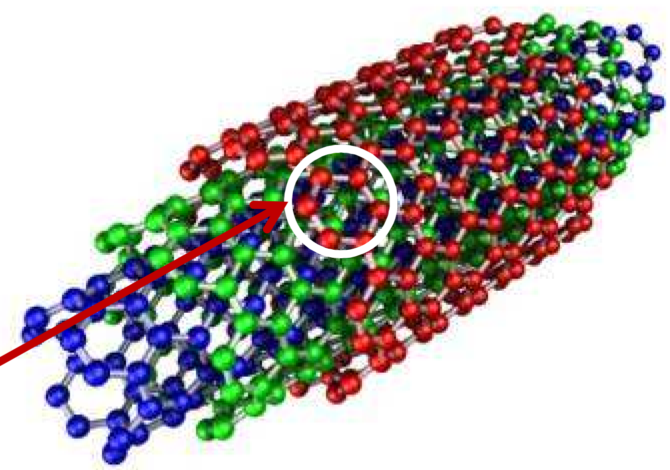
- Aromatic rings
- Inert
- →Persistent



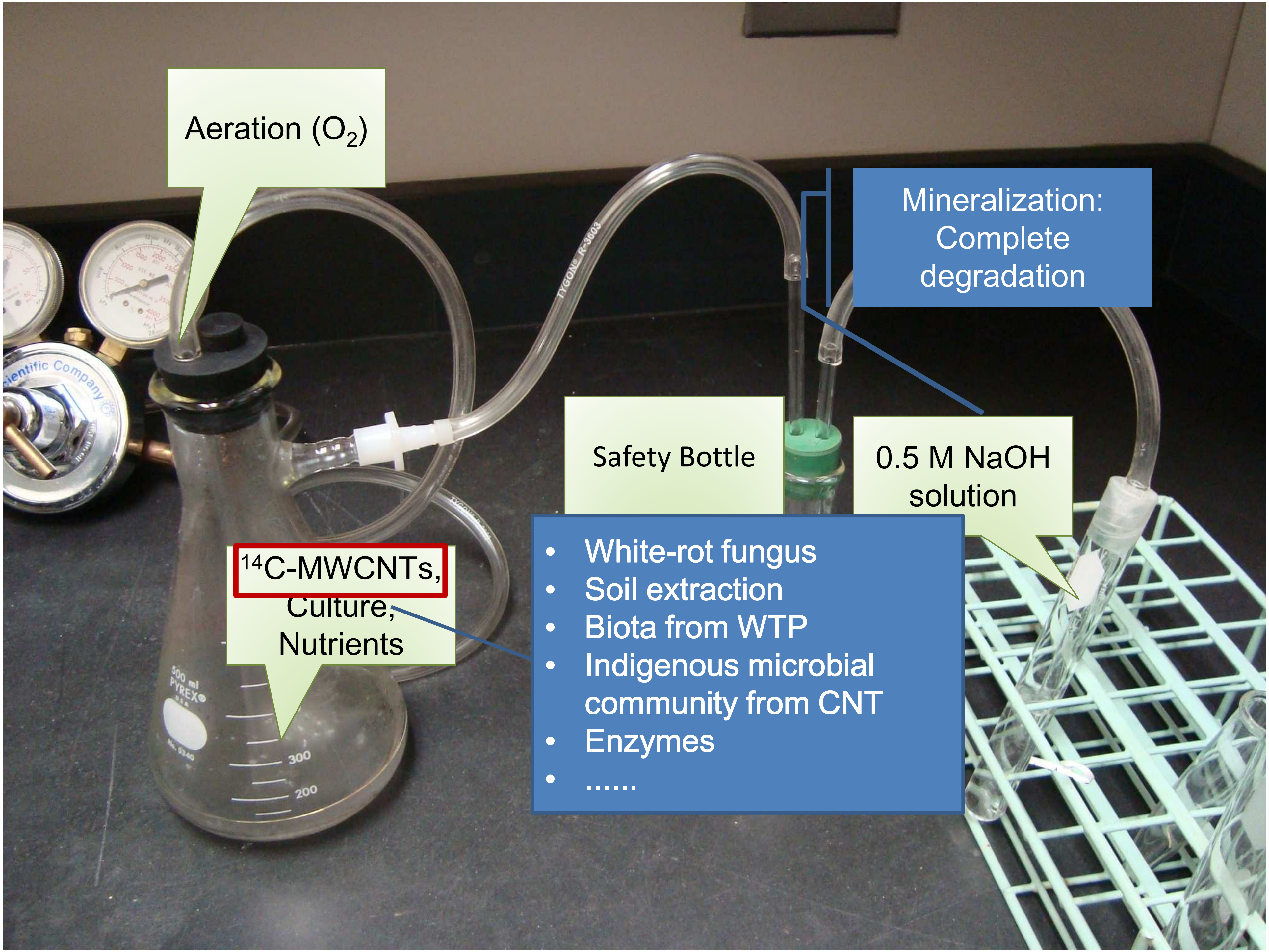
sp^2 orbital
wps.prenhall.com



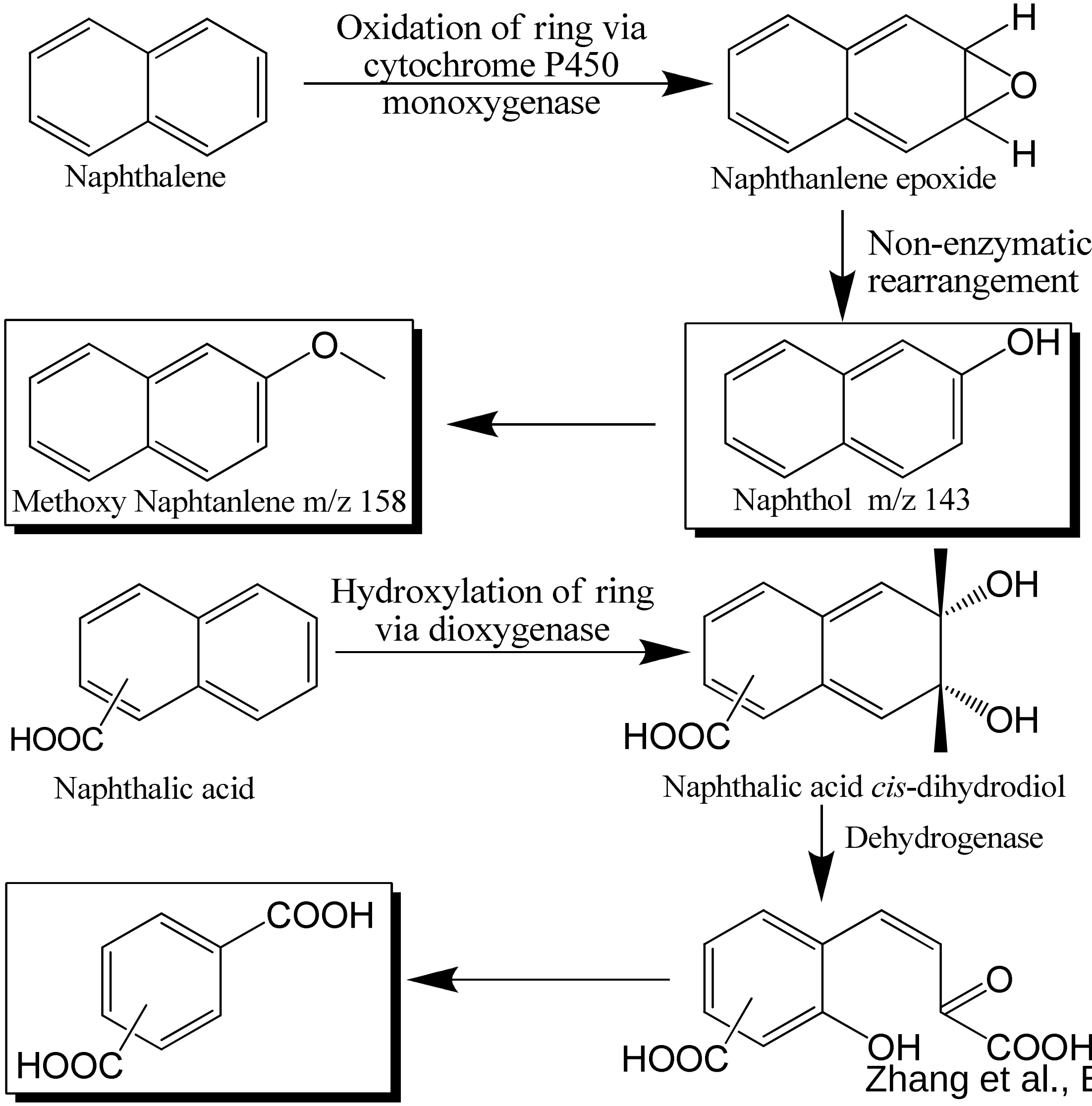
Benzene
teenbiotechchallenge.ucdavis.edu/

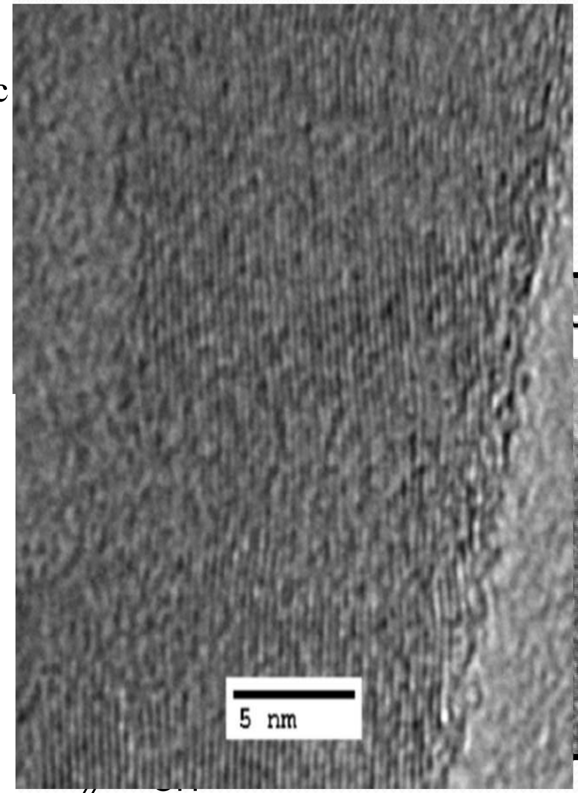


MWCNT
wapedia.com


Aeration (O_2)
Mineralization: Complete degradation
Safety Bottle
0.5 M NaOH solution
^{14}C-MWCNTs, Culture, Nutrients
• White-rot fungus
• Soil extraction
• Biota from WTP
• Indigenous microbial community from CNT
• Enzymes
• ......

Degradation Pathway





Zhang et al., Environ. Poll. 2013, 181, pages 335-339

Carbon Nanotube Reactivity

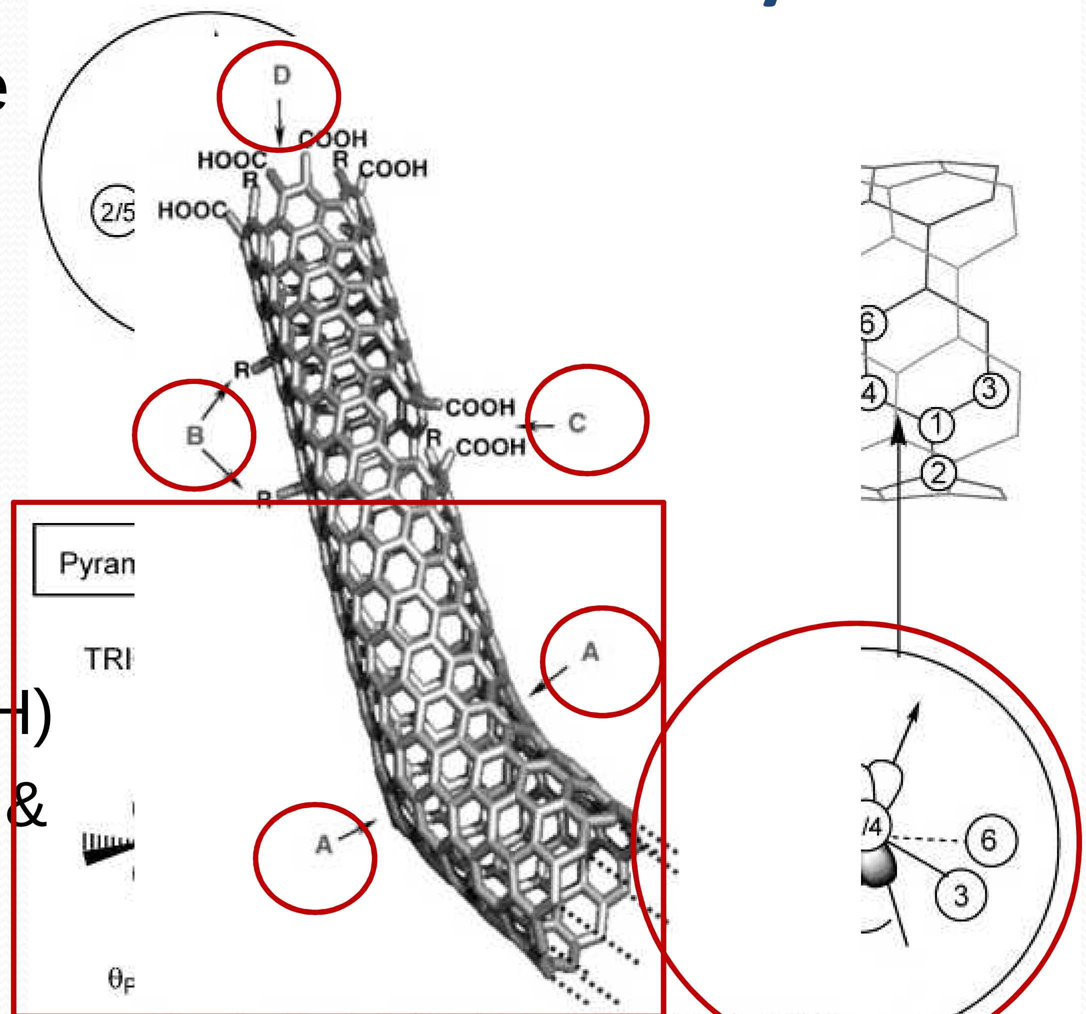
- Backbone: Curvature
  - Pyramidalization
  - Misalignment
- Structural Defects

A. Pentagons or Heptagons

B. sp^3-hybridized defects (R = H or OH)

C. Functional Groups & Holes

D. Open Ends



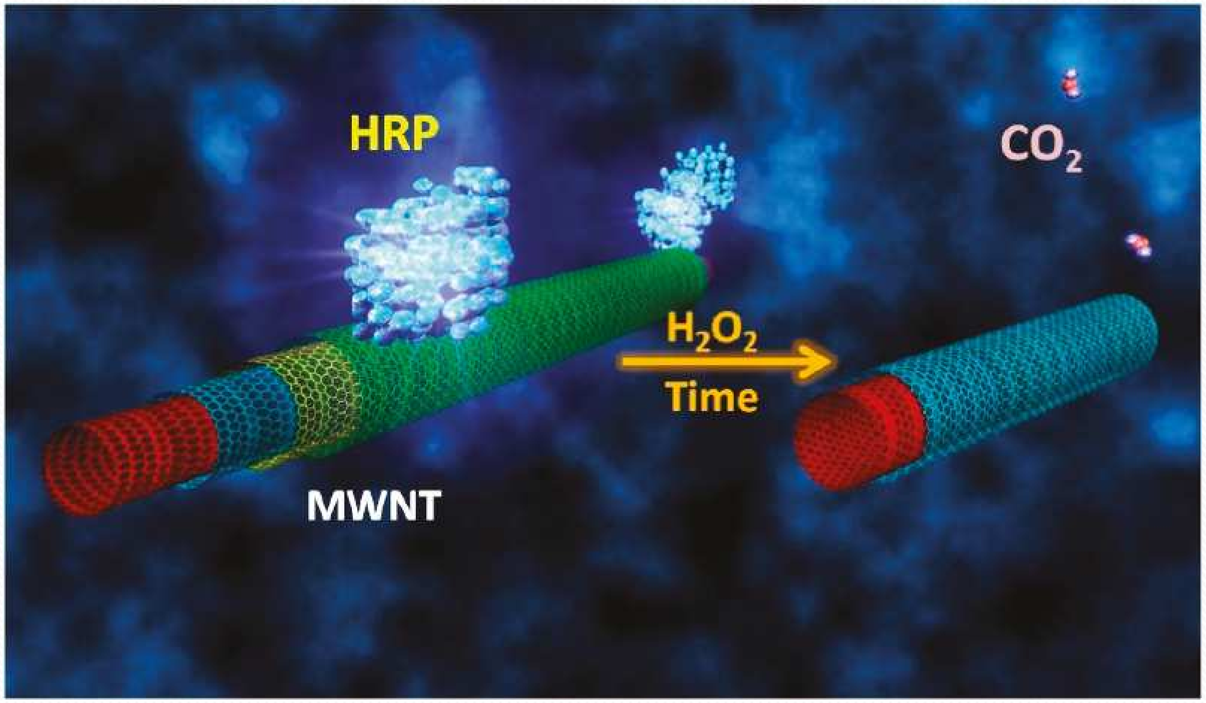
Banerjee, S.; et al. *Adv. Mater.* **2005**, 17 (1), 17-29.

Niyogi, ... -1113.

Chop, peel, or both?

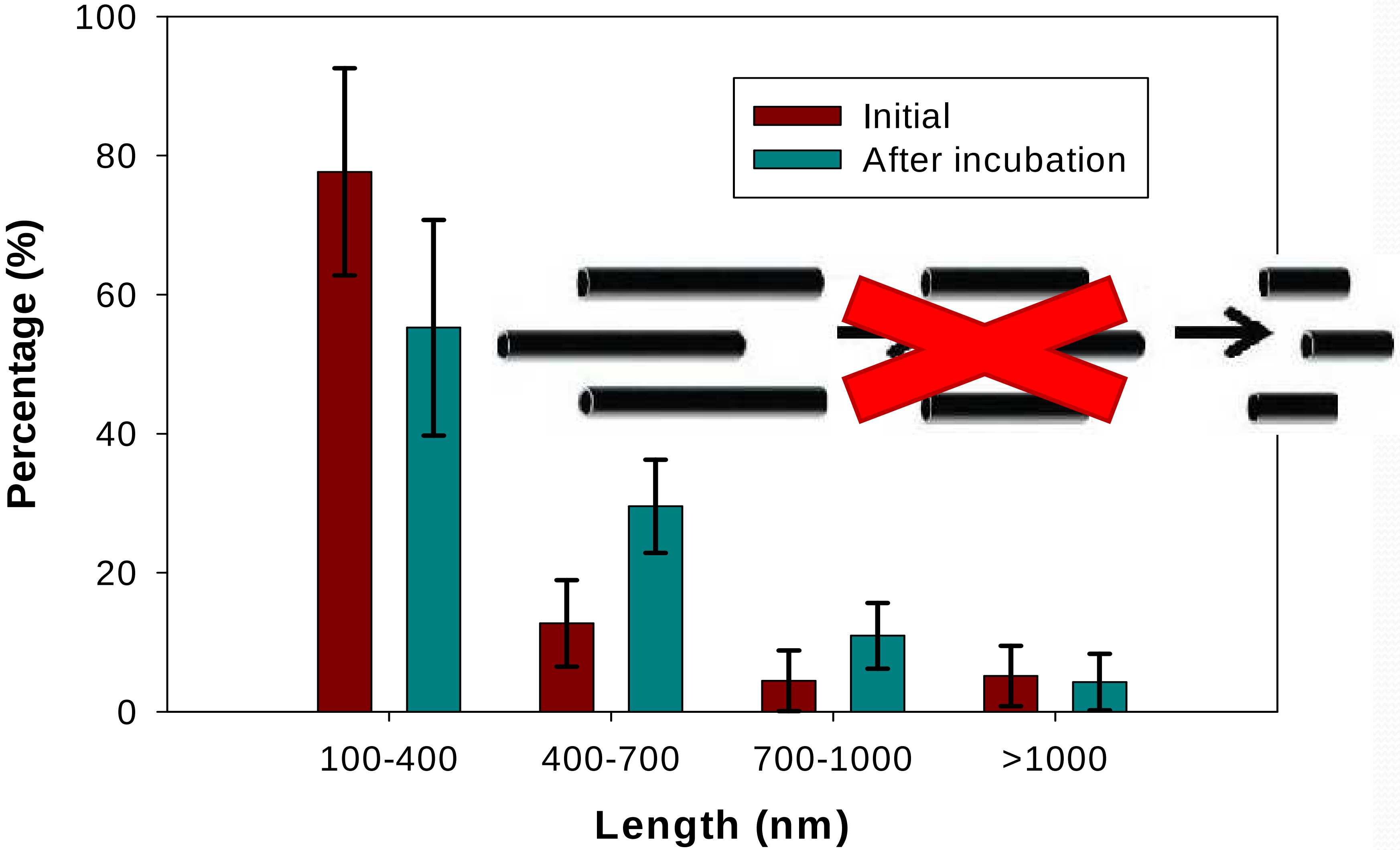
- Chop:
  - Shortening length

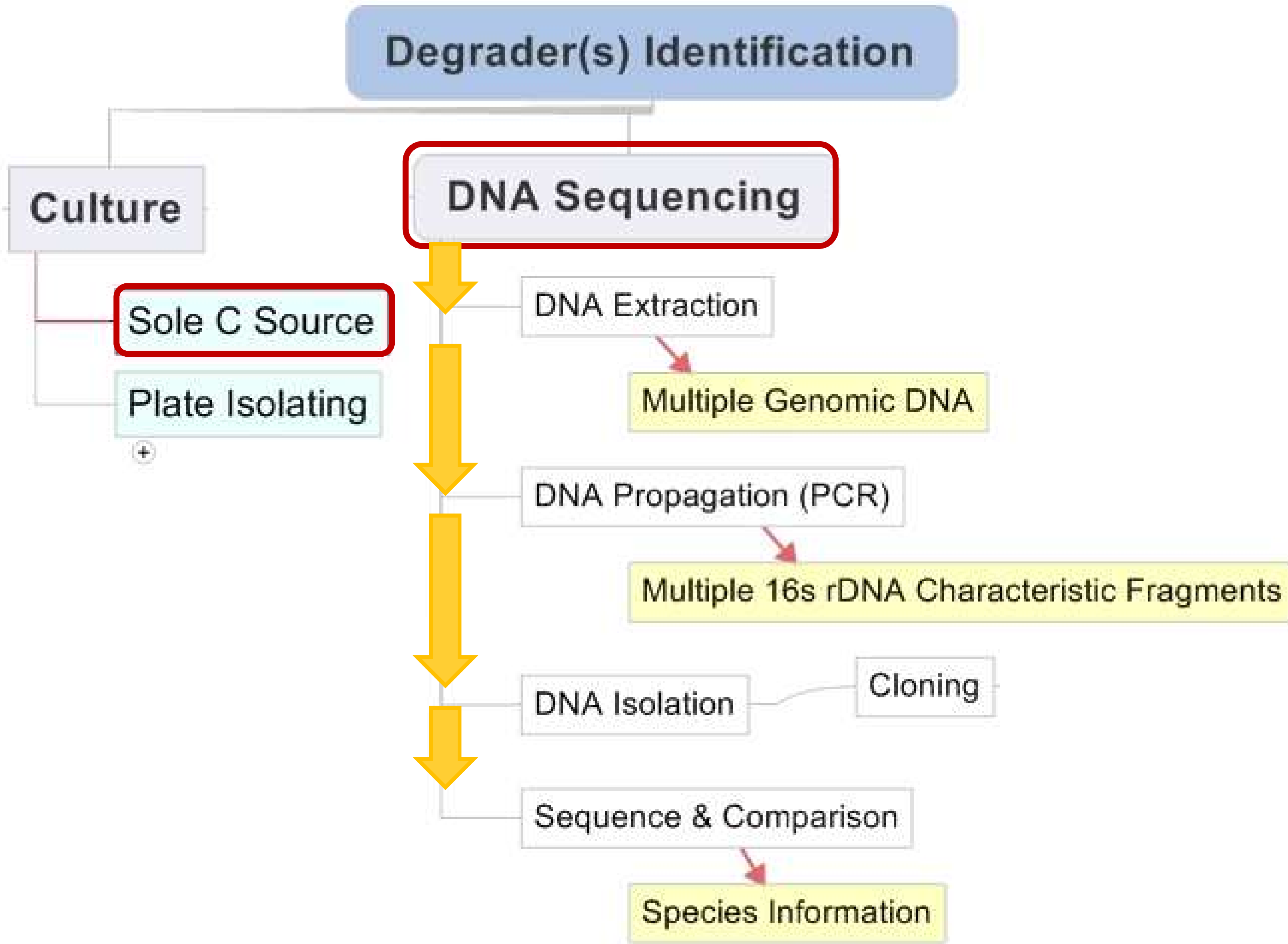
- Peel: Decreasing diameter



Zhao, Y., Allen, B.L., Star, A., *J. Phys. Chem. A* . 2011

Individual length: SEM images




Degrader(s) Identification
Culture
Sole C Source
Plate Isolating
DNA Sequencing
DNA Extraction
Multiple Genomic DNA
DNA Propagation (PCR)
Multiple 16s rDNA Characteristic Fragments
DNA Isolation
Cloning
Sequence & Comparison
Species Information

Sequence Results

Proteobacteria

- Beta Proteobacteria
  - burkholderiales
    - Burkholderiaceae
      - 1 Burkholderia
    - Comamonadaceae
      - 2 Delftia
- Gamma Proteobacteria
  - Xanthomonadales
    - Xanthomonadaceae
      - 3 Stenotrophomonas

Soil rhizospheres
Groundwater
Surface water

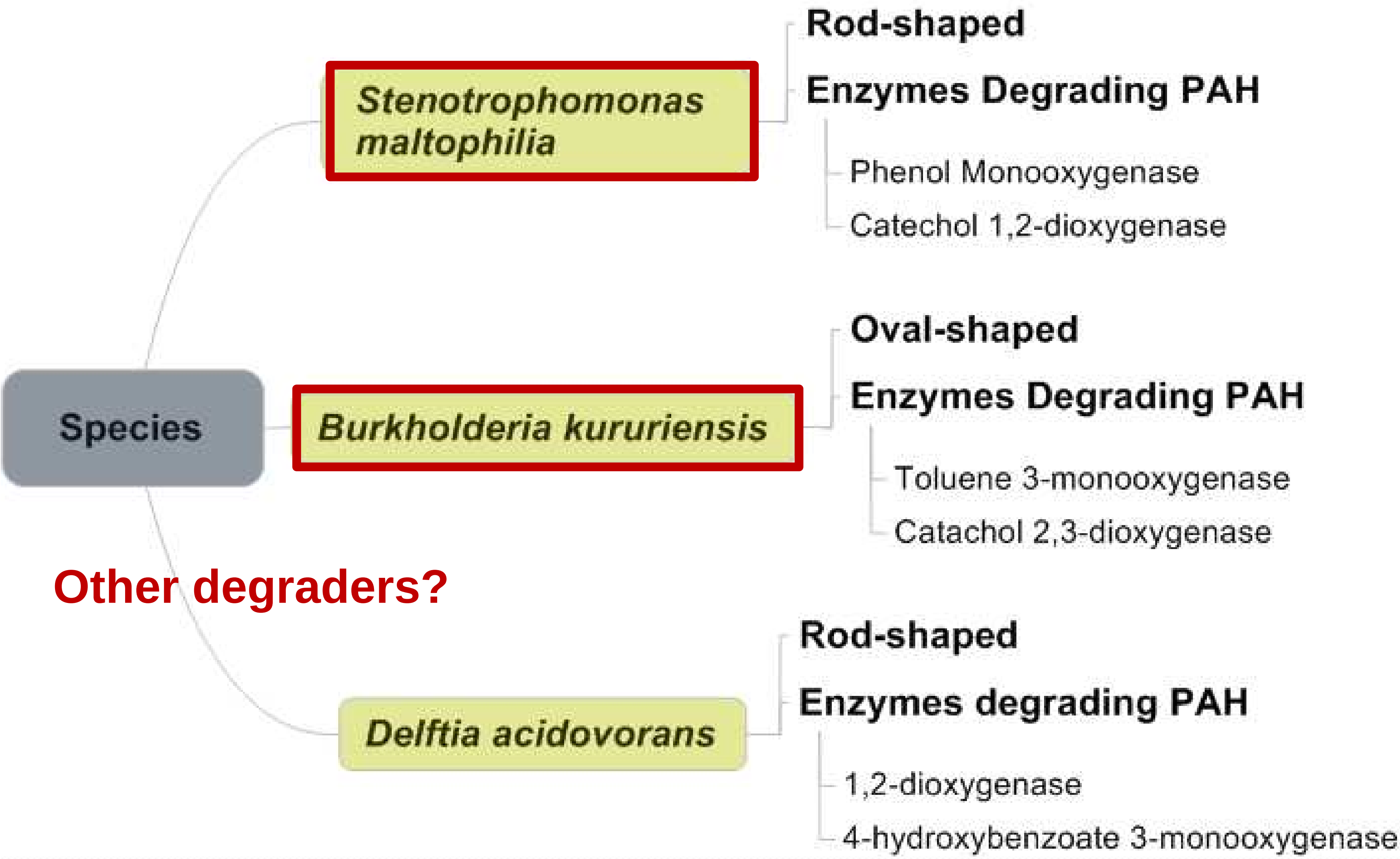
Gram-negative

Aerobic

Degrade Aromatic Compounds

- Individual/Consortium
- Co-metabolic Systems

Degraders identification



Other degraders?

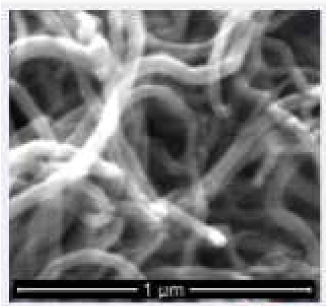
Outline

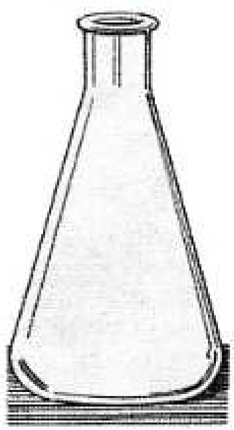
0. Background
1. Biotransformation
2. Phase distribution
3. Accumulation & toxicity
4. Conclusions & acknowledgement

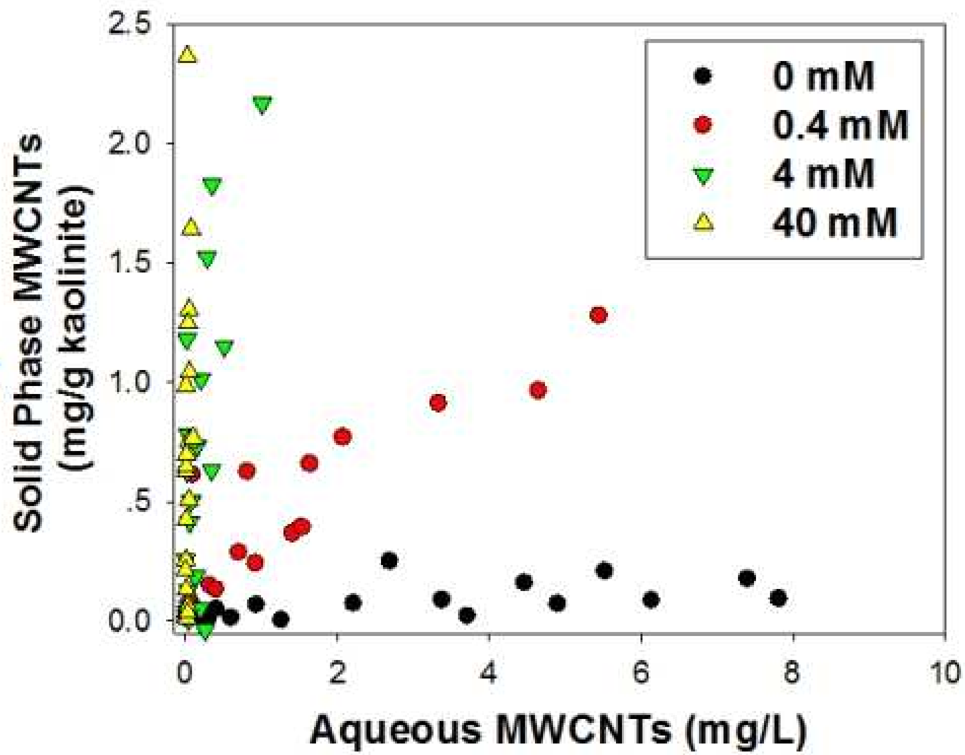
Phase Distribution

multiwall carbon nanotubes

soil minerals

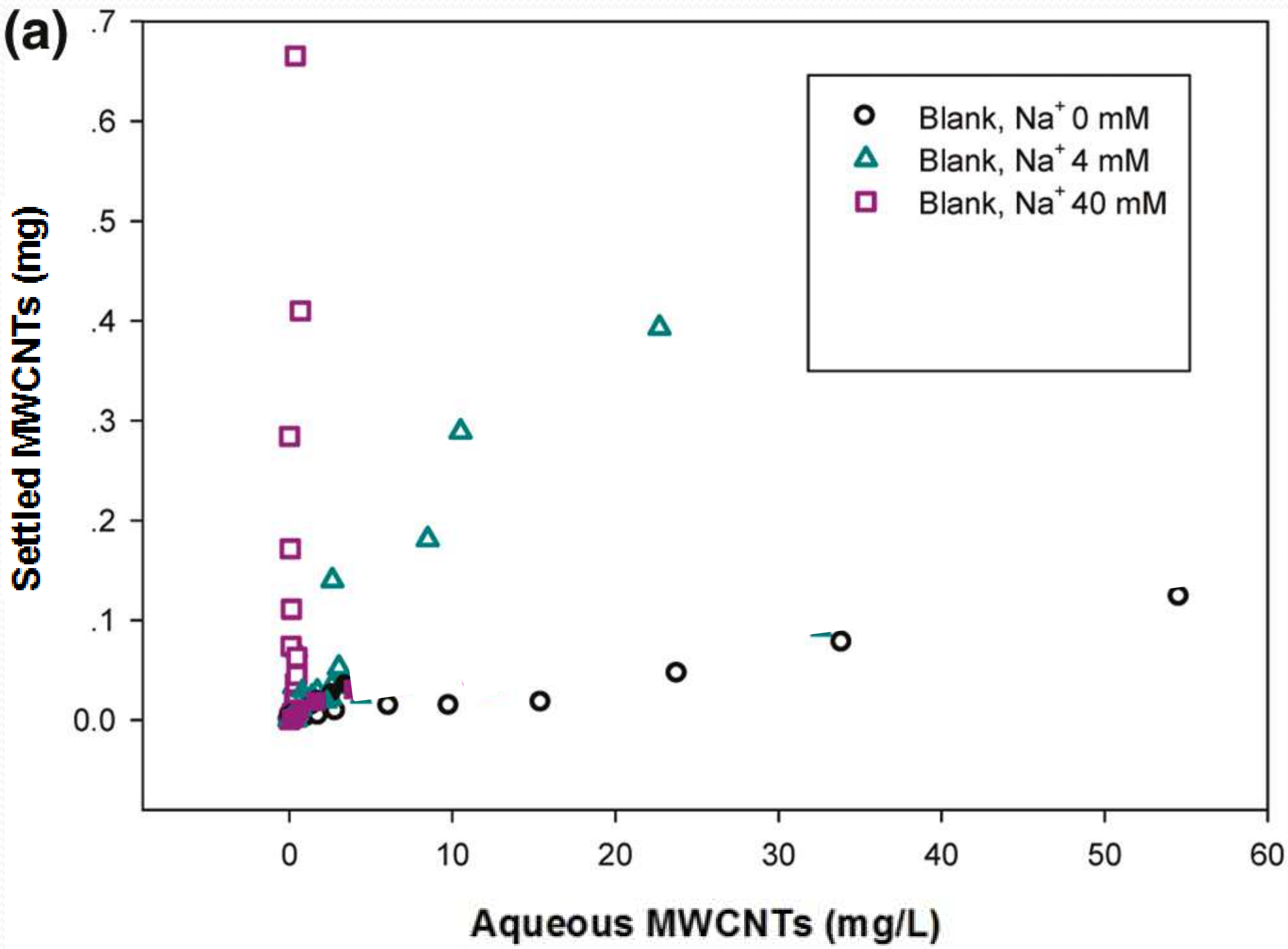






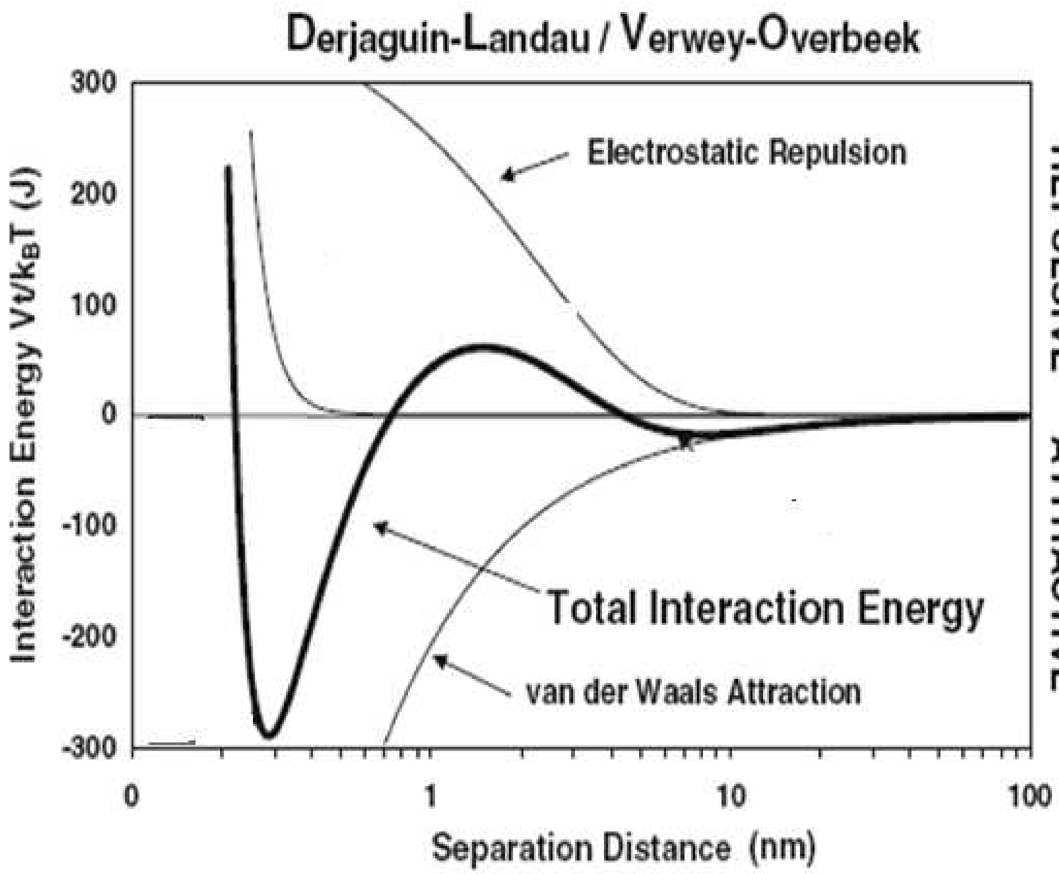
Zhang et al., Environ. Sci. Tech. 2011, 181, pages 1356-1362

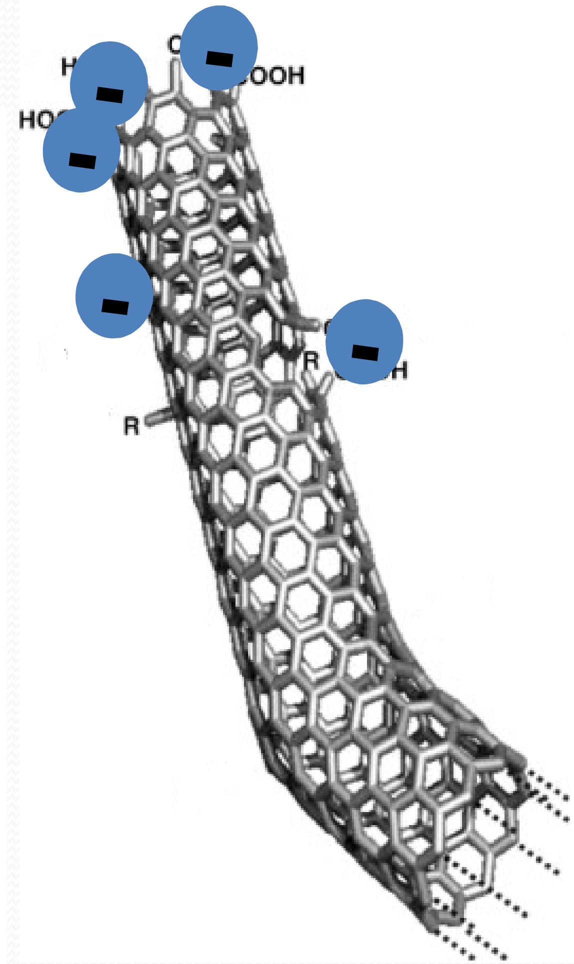
Governing Process: Settling



Settle or not, it's a problem…

- Surface functional groups





Settling and Sorption

Aqueous conditions

- Ionic strength
- pH
- Dissolved organic matters (DOM)

Soil/Sediment

- Soil organic matters (SOM)
  - Peat
  - Shale

Three Treatments

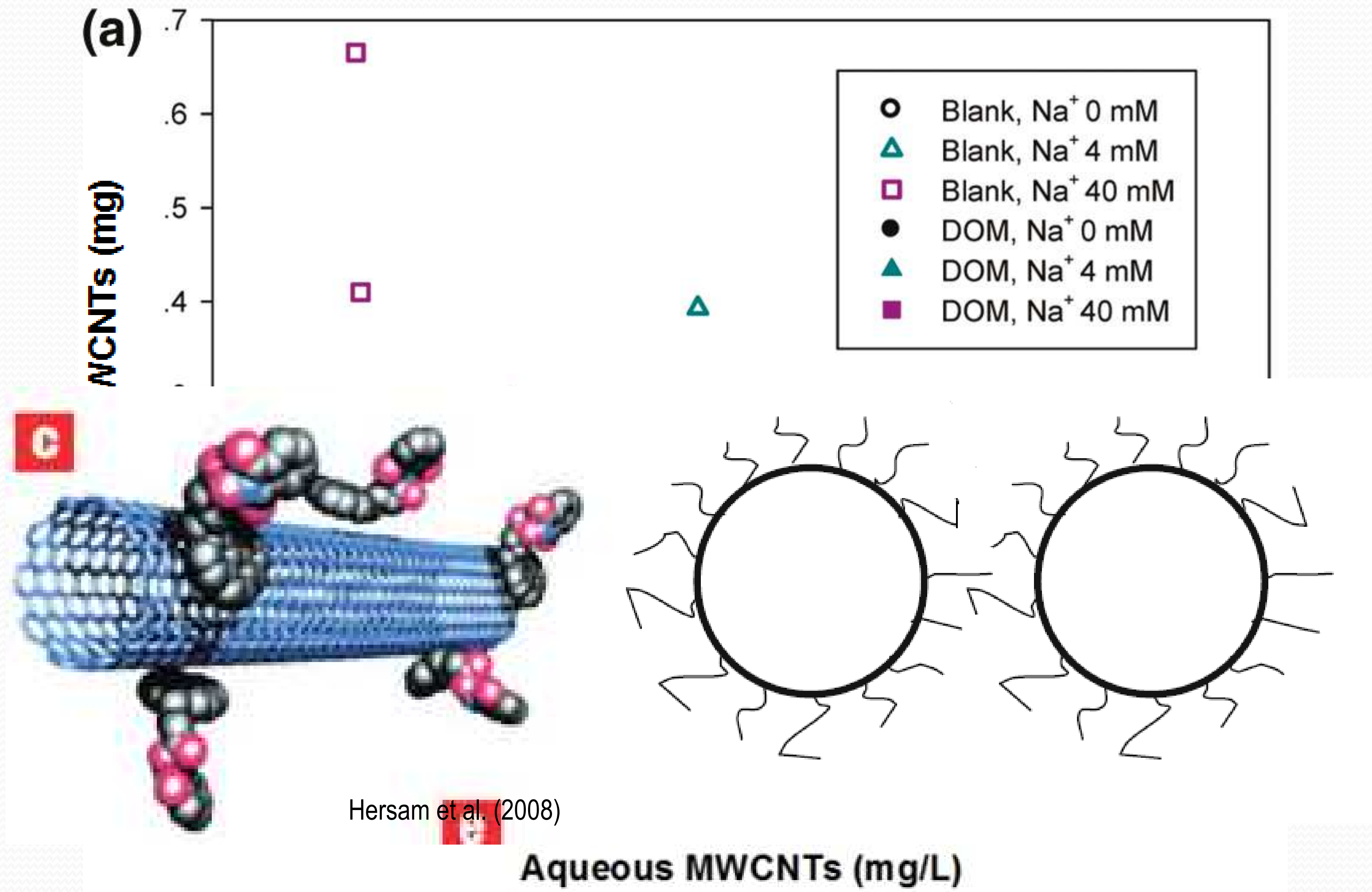
Treatment 1: H_2O + CNTs

Treatment 2: Peat DOM + CNTs

Treatment 3: Peat + CNTs

Settling: Effect of DOM

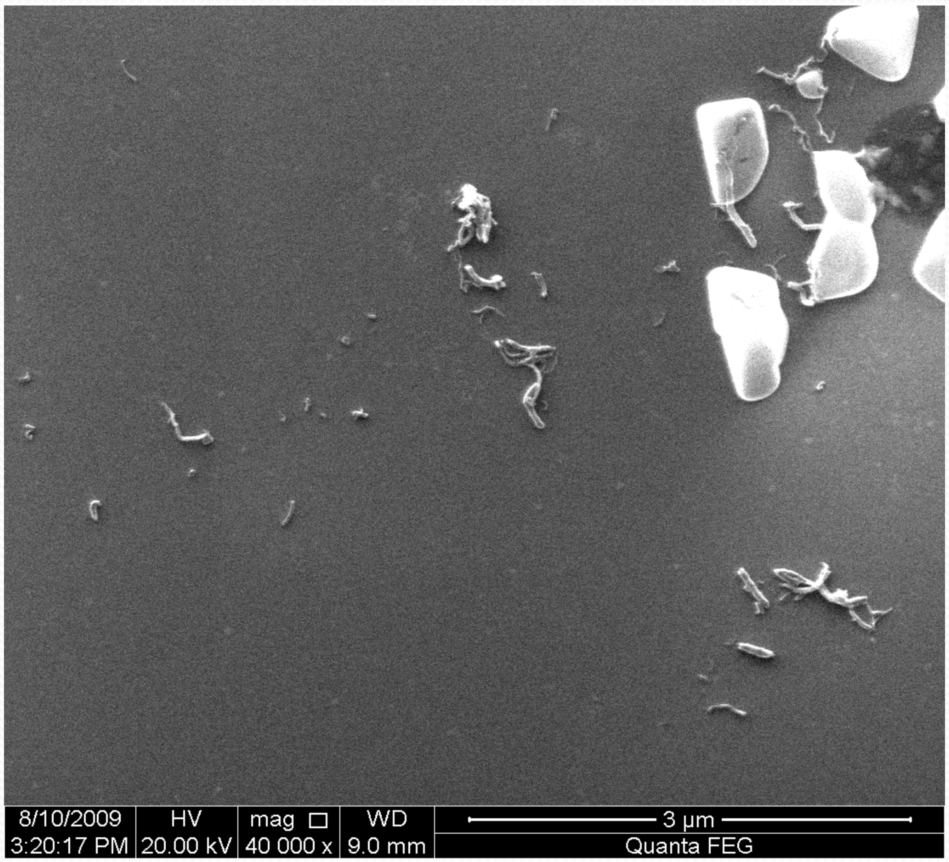
- DOM help disperse MWCNTs



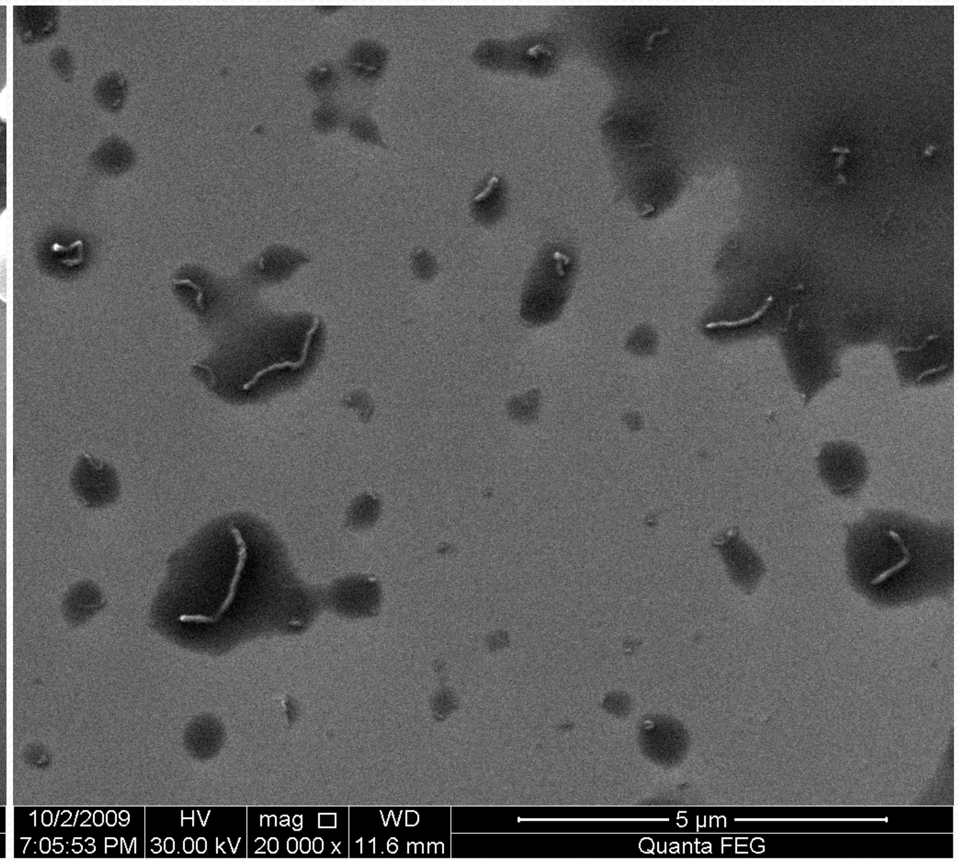
Hersam et al. (2008)

SEM Images after Treatments

Counterion (Na^+) treatment



DOM treatment



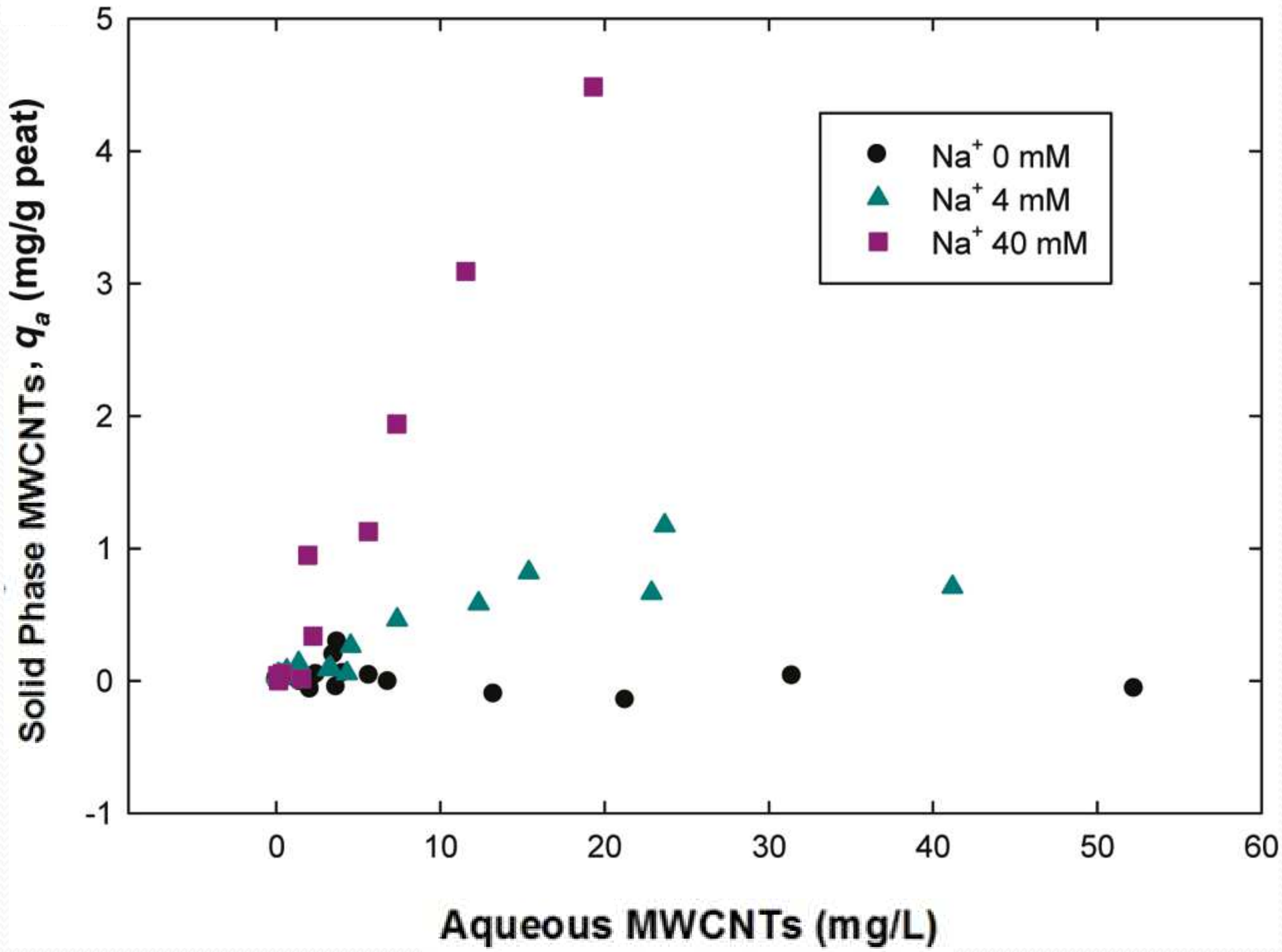
Three Treatments

Treatment 1: H_2O + CNTs

Treatment 2: Peat DOM + CNTs

Treatment 3: Peat + CNTs

Solid Peat Sorb MWCNTs



Environmental Conditions

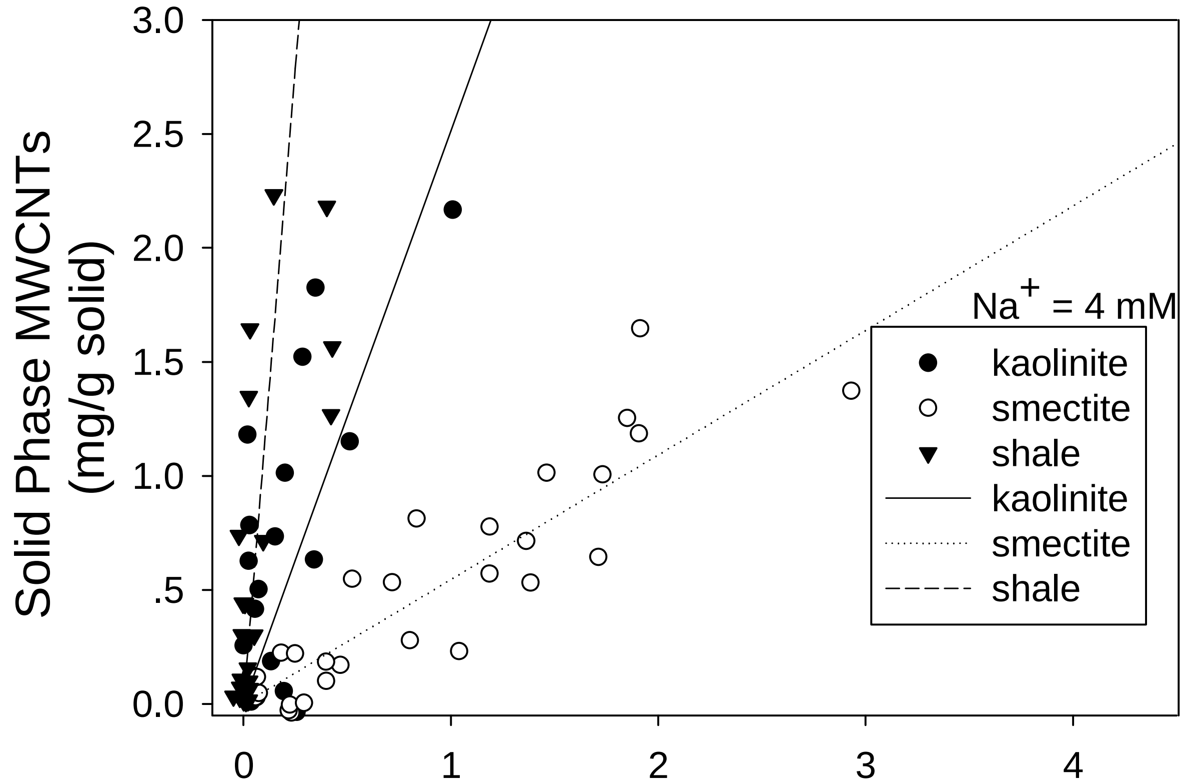
Aqueous

- Ionic strength
- pH
- Dissolved organic matters (DOM)

Soil/Sediment

- Soil organic matters (SOM)
  - Peat
  - Shale
- Clay minerals
  - Kaolinite (1:1)
  - Smectite (2:1)

Phase Distribution: Clay & Shale



- Electrostatic interaction
- Insoluble SOM → strong sorption

Zhang et al., Environ. Poll. 2013, 181, pages 335-339

Table 3
Electrophoretic mobility values of clay particles and MWCNTs (μm cm/Vs).

Sodium conc. (mM)	Kaolinite	Smectite	Shale	MWCNTs
0	−2.17 (0.03)	−2.78 (0.29)	−3.18 (0.57)	−1.51 (0.02)
0.4	−1.32 (0.02)	−2.14 (0.06)	−3.60 (0.73)	−1.10 (0.08)
4	−0.52 (0.02)	−1.18 (0.01)	−3.69 (0.61)	−0.95 (0.14)
40	0.01 (0.37)	−0.65 (0.08)	−3.11 (1.29)	−0.94 (0.06)

Extended-DLVO Modeling