Environmental Nanotechnologies

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LEHIGH
University

Environmental Technologies *at the* **Nanoscale**

Nanotechnology could substantially enhance environmental quality and sustainability through pollution prevention, treatment, and remediation.

Iron Nanoparticles for Treatment of Toxic Wastes

Acknowledgments

In the 21st century we are faced with major environmental challenges …

Emissions of Airborne Gaseous and Particulate Matter

Oil and Chemical Spills

Pesticide and Fertilizer Runoff

Abandoned Industrial and Mining Sites

New approaches are required to maintain and improve soil, water, and air quality

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Enter Nanotechnology …

Pollution Prevention

Sensors

Treatment/ Remediation

- Improve environmental technologies (treatment, remediation, sensing, etc.)

- Improve manufacturing processes (efficiency, waste reduction, etc.)
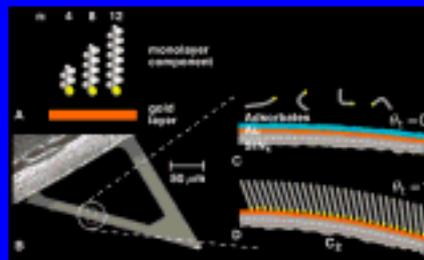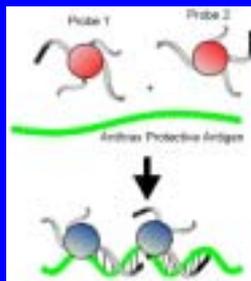
- Dematerialization

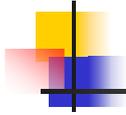# Nanoscale Technologies for Pollution Prevention

- Make a manufacturing process environmentally benign.

- Be an environmentally benign material.

- Be a manufactured product that replaces a toxic substance or minimizes use of raw materials.

Nanoscale Technologies for Sensing and Detection
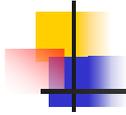
Biological pathogens, heavy metals, organics, etc.

IBM, Zurich

Treatment/Remediation

Iron Nanoparticles
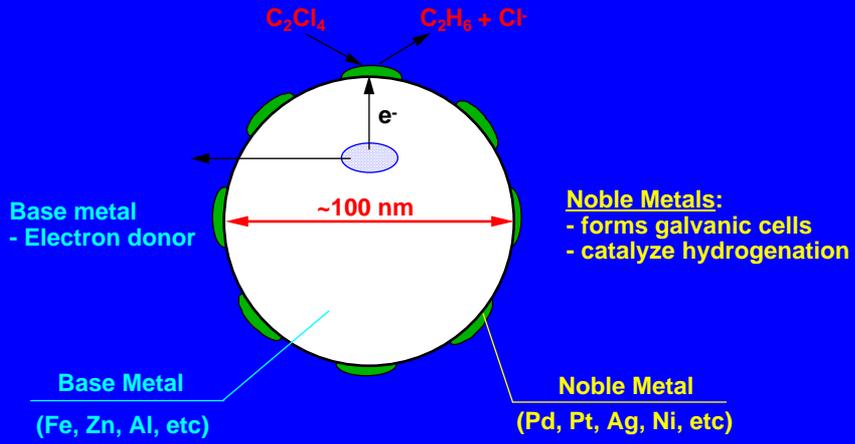## for Treatment of Toxic Wastes

Why Fe?

- A powerful reductant
- Effective for transformation of many contaminants
- Widely used in environ. proc.
- Accepted by regulatory agencies
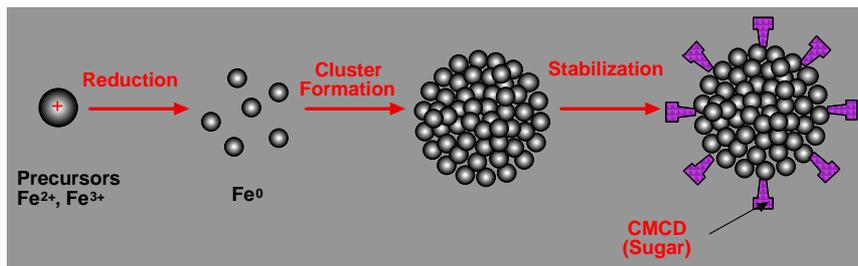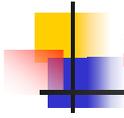- Nontoxic
- Cheap

Why Nanoparticles?

- **Small size for easy subsurface injection**
- **Extremely high reaction rate**
- **Low temperature reaction**
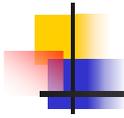- **Added Catalytic functions**
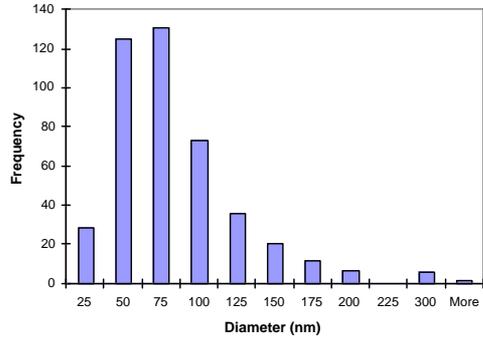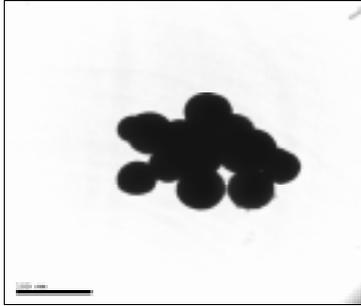
Nanoscale Bimetallic Particles

C_2Cl_4 → C_2H_6 + Cl^-
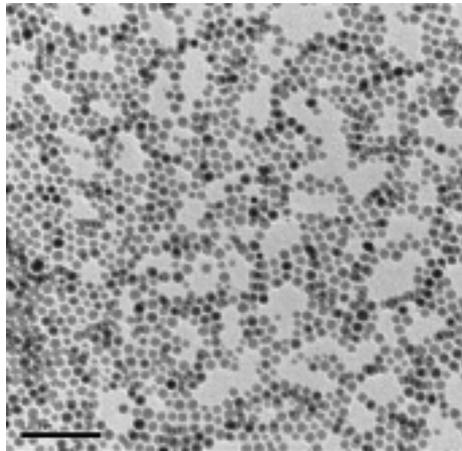
e^-

~100 nm

Base metal
- Electron donor

Noble Metals:
- forms galvanic cells
- catalyze hydrogenation

Base Metal

(Fe, Zn, Al, etc)

Noble Metal

(Pd, Pt, Ag, Ni, etc)

Methods of Synthesis

Reduction   **Cluster Formation**   **Stabilization**

Precursors
Fe^{2+}, Fe^{3+}

Fe^0

CMCD
(Sugar)

Size (50-60 nm)

Iron particles (3-5 nm)
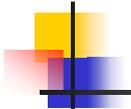
Surface Area

Fe	SSA (m^2/g)
1 mm (existing method)	0.0012
Aldrich, ~10 µm	~1.0
Lehigh (60 nm)	25-35
Lehigh (2-5 nm)	142
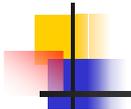
COSTS

- **Iron Filing (~mm)**
  - $0.5/kg
  - 5 m^2/kg
  - < 10 m^2/dollar

- **Nano Iron (50 nm)**
  - $20-50/kg
  - 25,000 m^2/kg
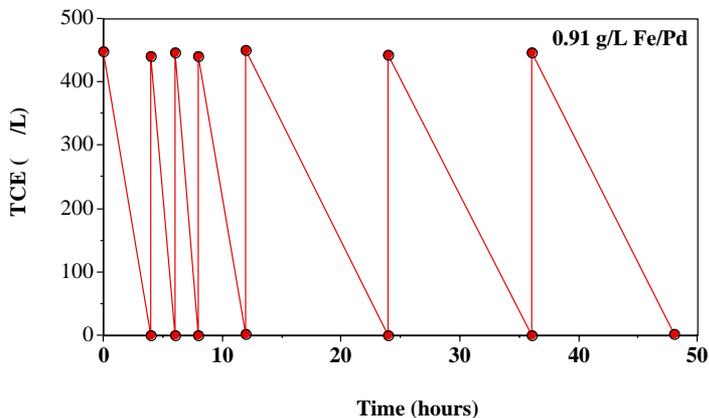 - > 1,000 m^2/dollar

Environmental Chemistry

Organic: **Inorganic:**

Chlorinated Methanes   **Cr(VI)**
Chlorinated Ethenes   **Pb(II)**
Chlorinated Ethanes   **Ni(II)**
Chlorinated Benzenes   **Cu(II)**
PCBs   **Perchlorate**
Lindane (HCHs)   **As**

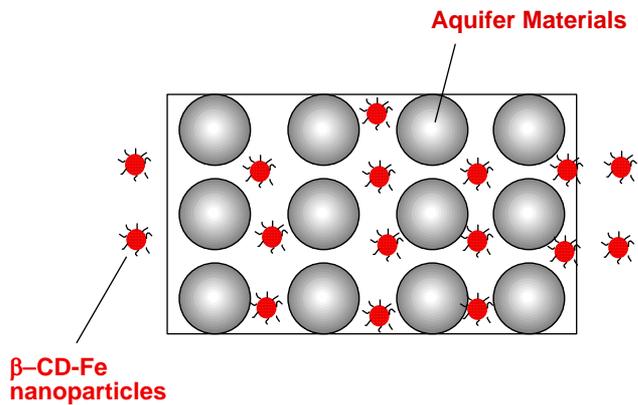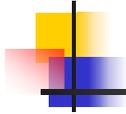**~60 compounds tested at Lehigh**

TCE Reduction (C_2HCl_3) - # 1 Contaminant in Groundwater
(Samples from a site in NJ)

Lindane (HCH) - A Pesticide
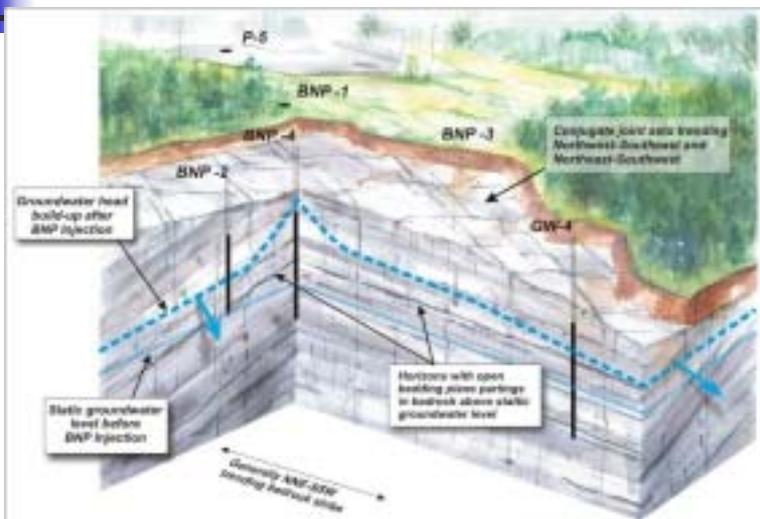**(Sample from Jacksonville, FL)**
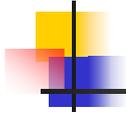
Transport In Porous Media
(Little has been reported)

Aquifer Materials

β–CD-Fe
nanoparticles

Conceptual Geologic/Hydrogeologic Model

Conceptual Model

Test Set-up

The Nano Fe Slurry

Field Test
(Nano Fe 10 kg)

Total volume injected = 1,600 gallons (6,056 L)
Nano Fe concentration = 1.9 g/l
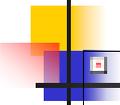Average injection rate = 0.6 gpm

Injection Well B-4
Monitoring Wells
    B-3: 20 feet north of B-4
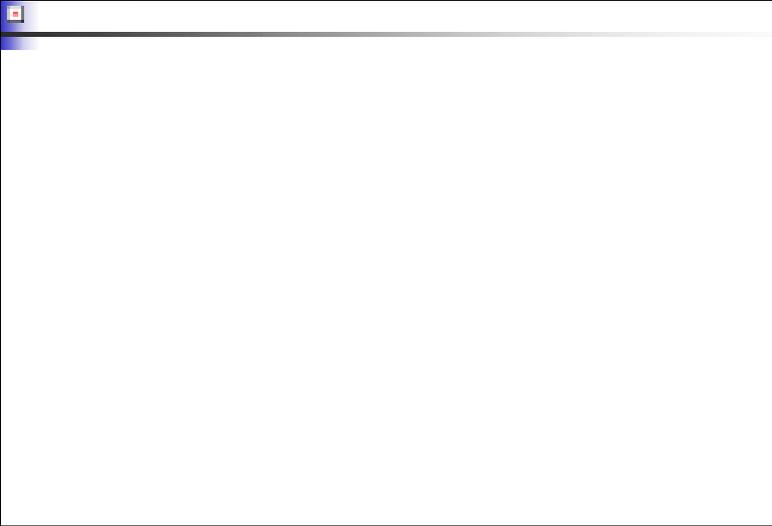   B-2: 40 feet northeast of B-4
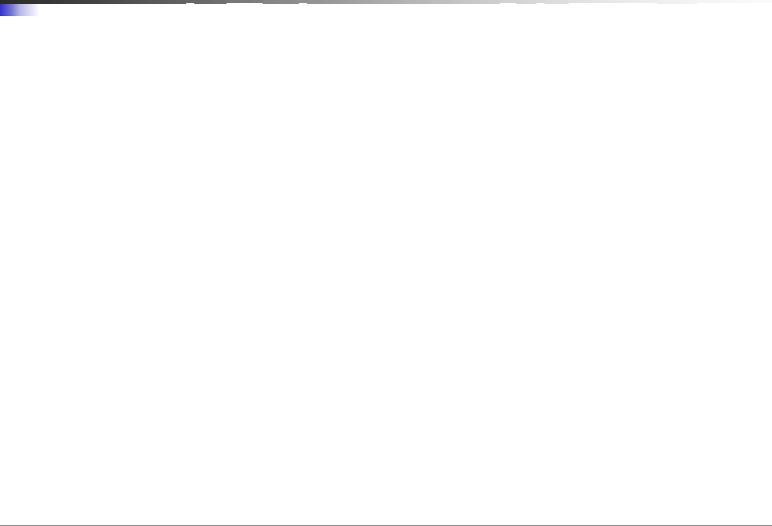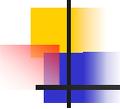   GW-4: 63 feet north-northeast of B-4
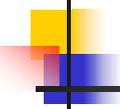
Monitoring

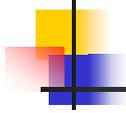# Injection Well

20 Feet Down Gradient

Summary

- Reactive Fe nanoparticles for direct injection into aquifers

- Enhanced reactivity (10-1,000X)

- Faster cleanup time & lower costs

12 Projects

- American Std
- BASF
- Boeing
- FMC
- GlaxoSmithKline
- GTE
- Honeywell
- IBM
- US Navy

- **Environgen**
- **Golder**
- **Geosyntec**
- **URS**
- **Tetra Tech**
- **Acadis**

10-20 tons of nanoparticles in 2004 (est.)

Keep in mind that …

Nanotechnology also has the potential for harm to human health and the environment …

Thanks