Bioengineering for Brownfields Redevelopment along the Harlem River

Bronx Council for Environmental Quality
Harlem River Brownfields Program
Manhattan College, 15 March 2005
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The Gaia Institute

Mission of The Gaia Institute

The work of the Gaia Institute couples ecological engineering and restoration with the integration of human communities in natural systems.

While much environmental engineering has the worthy aim of minimizing harm, the Gaia Institute explores, through research and development, design and construction, how human activities and waste products can be treated to increase ecological productivity, biodiversity, environmental quality, and economic well being.

The purpose of the Gaia Institute is to test through demonstration the means by which the ecological components of backyards, communities, towns and cities, as well as watersheds and estuaries, can be enhanced through integrated wastes-into-resources technologies.

Bioremediation Overview

- Make use of microbial biogeochemical processes to breakdown pollutants
  - Carried out through enzyme activity
- Similar principles that are used for biological treatment of municipal wastewater
- Oxidation-Reduction (redox) reactions carry out transformations
- Environmentally controlled – pilot studies used here

Benefits

- Low cost compared to traditional methods of remediation
- Process takes place *in situ*
  - site disturbance is minimized
  - contributes to low cost
- Less landfilling
- Material can be physically recovered

Constituents Addressed with Bioremediation

- Hydrocarbons – TPH, PAH
- PCBs
- Heavy metals
  - Chromium, Cadmium, Mercury, Lead, Nickel, Zinc, Cobalt, Copper
- Pesticides
- Excess nutrients
- Pathogens – remain experimental

Environmental Conditions Considered

- Soil Parameters:
  - pH, CEC, moisture, organic matter
  - Sand, silt, clay content
- Concentrations of:
  - C : N : P : K
  - Constituents of concern
- HYDROLOGY
  - Controls soil redox status

Biological Labor

- Bacteria
  - Redox transformation/degradation
- Fungi and Yeasts:
  - Accumulate and/or adsorb heavy metals
  - Metabolic processes transform/breakdown
- Algae
  - Bind aluminum, iron, mercury, anions/cations
  - Algae can be harvested and material recovered
- Higher plants
  - Hyperaccumulate metals

Constructed Treatment Wetlands: Landscape, Clay, Organics, and Native Plant Communities

East New York Command Bus Depot, Crescent St. Stormwater Capture Park
October 2003

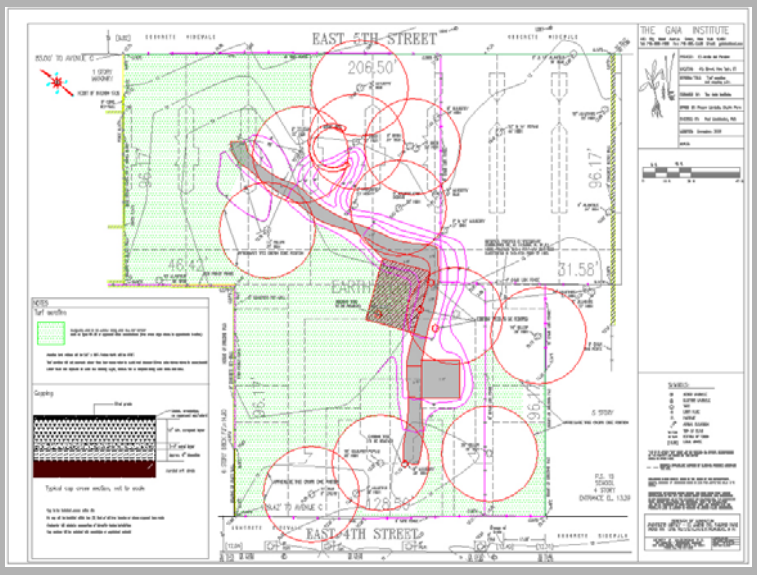
- Designed for stormwater capture and treatment with wetland plantings

Lafayette St. Corridor “Before”

Lafayette St. Corridor “After”

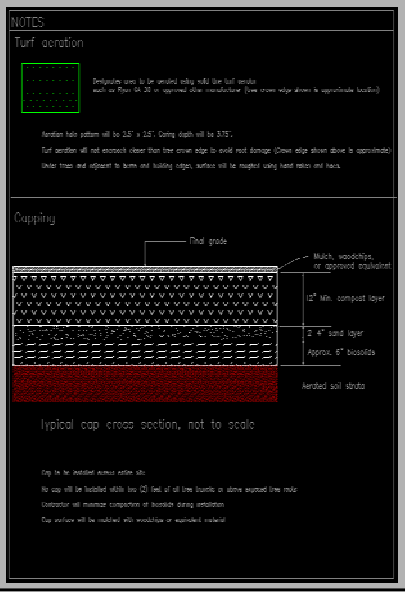
El Jardin del Paraiso

- View from 5th Street between Ave. C & D
- Model project, community – agency partnerships



Community Gardens, NYC Parks, NYC DEP, NYC DOS, Gaia Institute, Young Environmental Consulting

Lower East Side: El Jardin del Paraiso:
Stormwater capture and lead mitigation cap



- **Risk-based approach – eliminate contact with human and other biological receptors**
- **One foot of compost from NYC DOS and/or Green Thumb**
- **Two to several inches of clean sand or ground brick, concrete, & rock**
- **Several inches of composted NYC DEP biosolids**
- **Fill presently on site, left in place, unmodified**

Delivery of Biogeochemical Cap Material

- Delivery of 40 cubic yards of composted NYC Biosolids
- Compost contains ≈ 0.1 -1% Fe, P, and Mn

Biogeochemical Cap Under Construction

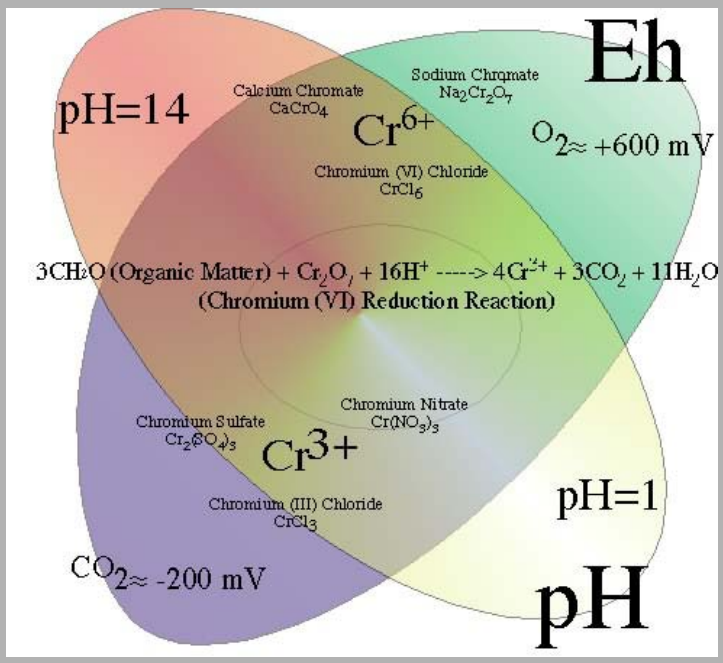
- Humus, phosphorus, iron, and manganese rich compost is spread about a foot deep over subsoil
- Bind at least 3x the total lead in the top 30 cm of subsoil

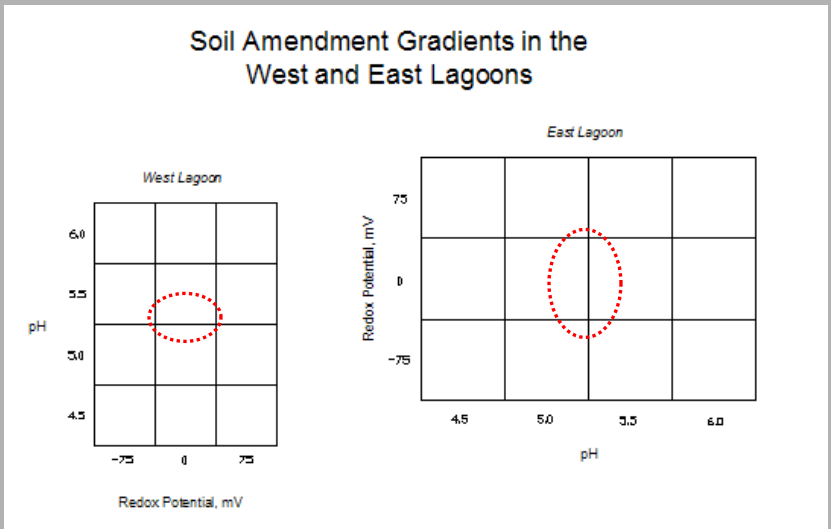
Phytoremediation

- Plants take up nutrients and metals for growth and development
- Hyperaccumulator Plants
  - Sunflower, Indian Mustard, Alfalfa, Soybean, Wheat, Cattail, Duckweed
  - Members of Brassicaceae and Legume families
- Ability to translocate material from soil through roots and into stems and leaves which are harvested
- Redox status is controlled to promote desired reactions and metal bioavailability

Chromium Phytoremediation in Newburgh, NY

- Proposed design
- Contamination from electroplating wastes
- High levels of chromium, copper, nickel, lead, and zinc in soils – above DEC action levels


Eh
pH=14
Calcium Chromate
$CaCrO_4$
Sodium Chromate
$Na_2Cr_2O_7$
Cr^{6+}
$O_2 \approx +600$ mV
Chromium (VI) Chloride
$CrCl_6$
$3CH_2O$ (Organic Matter) + Cr_2O_7 + $16H^+$ ----> $4Cr^{3+}$ + $3CO_2$ + $11H_2O$
(Chromium (VI) Reduction Reaction)
Chromium Nitrate
$Cr(NO_3)_3$
Chromium Sulfate
$Cr_2(SO_4)_3$
Cr^{3+}
Chromium (III) Chloride
$CrCl_3$
pH=1
$CO_2 \approx -200$ mV
pH


Soil Amendment Gradients in the
West and East Lagoons
West Lagoon
6.0
5.5
5.0
4.5
pH
-75
0
75
Redox Potential, mV
East Lagoon
75
0
-75
Redox Potential, mV
4.5
5.0
5.5
6.0
pH

Chromium Removal: Phytoextraction

Biomass Harvest Rate- **10 tons/acre/yr**

Site Area- **2 acre**

Total Biomass Harvest- **20 tons/yr**

Mass of Cr to be Removed- **0.97 tons**

Average Plant Removal Rate- **1.70%**

Soybean- **2.90%**

Sunflower- **1.50%**

Alfalfa- **0.80%**

Cr removed- **0.34 tons/yr**

Harvesting Period- **2.9 Years**

Standard Farming Techniques for Biomass Harvest

Cost Comparison

- Excavation and removal = $1,900,000
- Impermeable barrier = $400,000
- Permeable barrier = $250,000
- Phytoremediation = $160,000
- No action = $40,000 (monitoring)

Opportunities along the Harlem River

- Implementing low cost bioremediation techniques along the Harlem River Corridor during the redevelopment process will ensure the protection of public health and enhance ecological components of the region

Commitment to Sustainable Development

- These solutions address sustainable development from both environmental and economic perspectives