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The long tail of Leachate Management

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MSW Leachate

… water-based solution with four groups of pollutants:

1. Dissolved organic matter
   (e.g., TOC, COD, BOD, volatile fatty acids, fulvic and humic-like compounds)
2. Inorganic macro components
   (e.g., ammonia, sulfate, sodium, chloride, iron)
3. Heavy metals
   (e.g., lead, nickel, copper, mercury, chromium)
4. Xenobiotic organic compounds
   (e.g., aromatic hydrocarbons, phenols, pesticides, chlorinated aliphatics, plasticizers)

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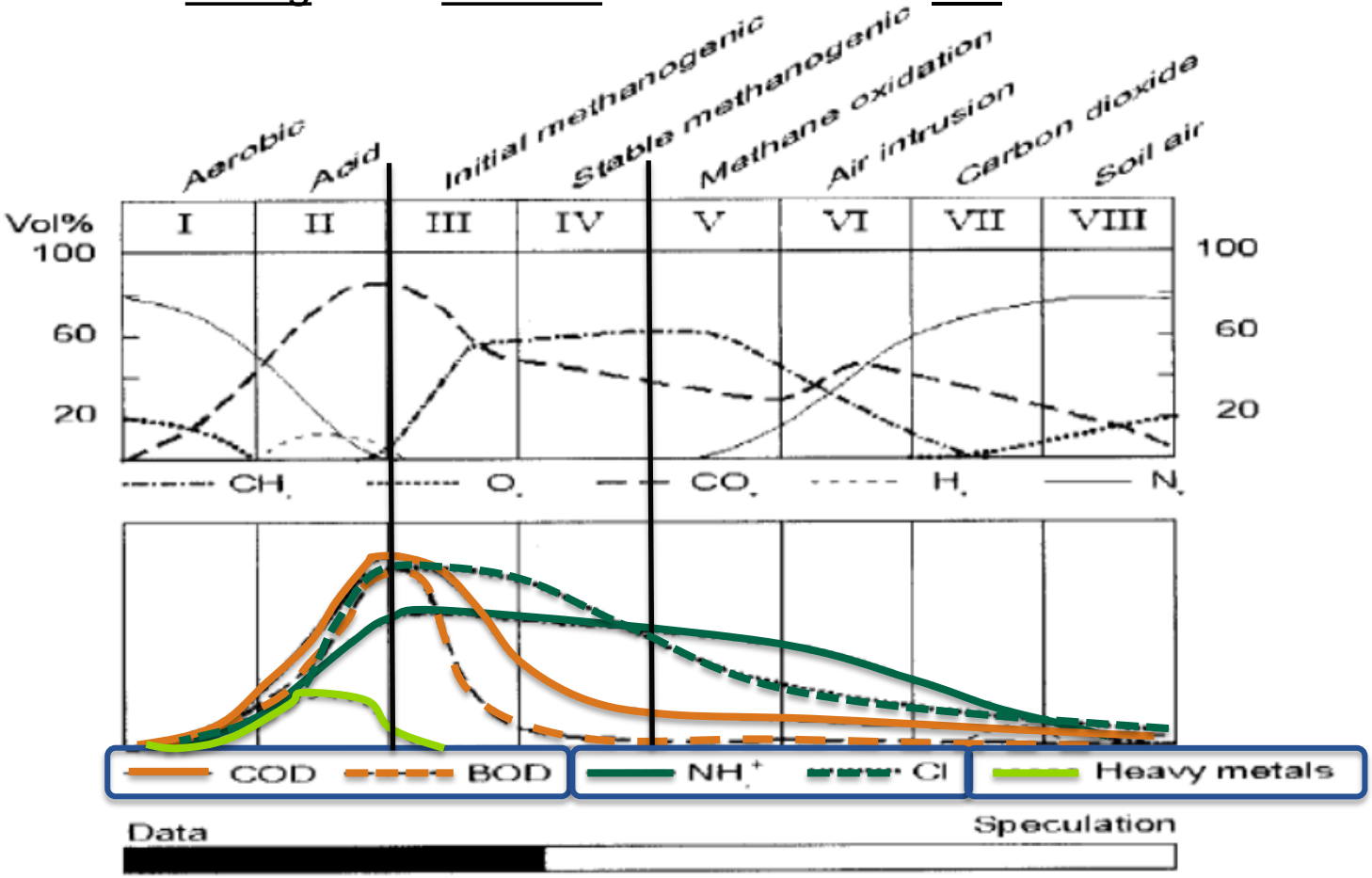
Evolution of Leachate (qualitative)

Landfill Age — Young — Medium — Old

Landfill Gas

Leachate



Source: Kjeldsen P et al., Present and Long-term Composition of MSW Landfill Leachate: A Review, Crit Rev in Env Science and Tech, 32(4):297-336 (2002)

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Long-term stabilization processes

- Long-term behavior and characteristics of landfills and leachate: from 30-year to about 100 years post closure
- Speculation!
- Diminishing relevance of dissimilar waste age
- Stabilization of degradable components
- Leachate fate is closely linked to O_2 availability
- CH_4 generation affected
  - Residual organic carbon
  - Cover properties
  - LFG extraction
  - Landfill design

Phases V and VI: Methane Oxidation & Air Intrusion

- Decrease in CH_4 generation
- Air intrusion
  1. Landfills with active LFG systems
     - Air intrusion due to over-extraction
  2. Landfills with passive LFG venting
     - Internal positive LFG pressure
     - Air intrusion result of barometric pressure changes
- Initially localized effects, limited to intrusion zones:
  - CH_4 oxidation
  - CO_2 production
- Radii of influence increase with declining CH_4 generation

Phase VII: Carbon Dioxide

- Factors governing air exchange:
  - Diffusion, driven by cover permeability
  - Temperature-driven convection
  - Wind-induced exchange
  - Barometric pumping
- O_2 intrusion will create aerobic zones
- Decomposition of lingo-cellulosic substrate
- Essentially no CH_4 production
- Dominant gaseous components: CO_2, N_2, and O_2
- CH_4 and residual organic material oxidation

Phase V – Methane Oxidation

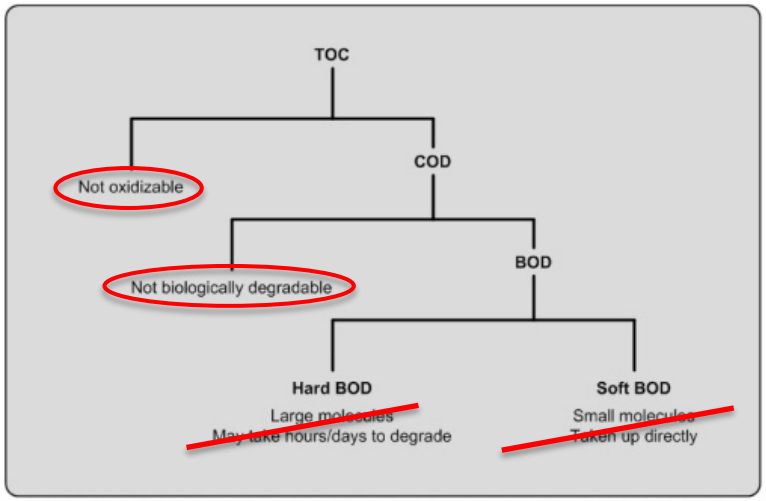
- Decreasing pH due to CO_2 formation
- Reduction of inorganic species due to downward extension of low pH zones
  (e.g., sulfur, nitrogen, and iron-containing species)
- Possible metal carbonate precipitation and pH buffering
- Duration (model estimates):
  - ~100 years (unsaturated, uncovered landfill)
  - >500,000 years (intact cover, low water content)

Long-term Leachate Composition

- Leachate composition through Phases V – VII
- Based on theory and lab data
- Shortage of field data
- Considered leachate components:
  1. Dissolved Organic Carbon (DOC) and Inorganic Macro-components
  2. Heavy Metals
  3. Xenobiotic Organic Compounds

DOC and Inorganic Macro-components

- BOD, COD: Slow decreasing trend
- BOD/COD ratio << 0.1
- BOD trending towards 0 (zero)
- Residual COD composed of recalcitrant humic matter
- Nitrification
- Stagnating NO_3



Source: Davis P S, The Biological Basis of Wastewater Treatment, Strathkelvin Instruments, Ltd, 2005

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Heavy Metals

- Low metal concentrations during long, stable methanogenic phase
- Metal release not considered problematic with majority of MSW leachate meeting Drinking Water Standards
- Less than 0.02% of landfilled metals leach after 30 years (sorption and sulfide precipitation are likely significant mechanisms for metals immobilization)
- Significant fraction of metals not present in reactive forms, i.e., metals are immobilized (e.g., plastics)
- Metals are usually associated with colloidal fractions of humic material

Mobility of Heavy Metals

- Multiple, competing processes affect metal mobilization during oxidation
- Remobilization of heavy metals is not expected to occur for many centuries

Increase Metal Availability	Decrease Metal Availability
• Dissolution at low pH • Sulfide precipitates oxidize to metal sulfates • Higher solubility of sulfates results in increased metal mobilization • Mobility of some metals will increase as redox potential increases (e.g., Pb, Zn, Mn, and Fe)	• Waste CEC increases availability of carboxylic functional groups (chelators) • Metals absorbed by iron hydroxides and oxyhydrates formed during oxidation

Heavy Metals, Summary

- Number of complex factors influence metal mobility (e.g., pH, E_h, functional groups, CEC)
- Complex system with high uncertainty
- Diverging research results
- Lab data and models favor no increase in metal mobilization
- Field data not expected to be available for quite some time

Xenobiotic Organic Compounds

- Long term fate of XOC involves two mobile phases (solid phase is reservoir of XOCs)

Gaseous Phase	Liquid Phase
Volatilization	Degradation
Diffusion	Leachate

- Majority of XOC will volatilize, escape to atmosphere within a few decades
- Strongly sorbing compounds will be released over several decades with leachate (e.g., naphthalene)
- Degradation is a significant factor for liquid phase XOCs
- Environmental conditions and degradation kinetics drive partitioning and release of specific compounds

Leachate Toxicity

- Chemical analyses provide limited information on effect of leachate on the environment
- Toxicity assays characterize integrative biological consequences, including direct synergistic, antagonistic, and additive effects
- Bioassays generally performed on fish, crustaceans, and luminescent bacteria
- NH_3 found to be the primary cause of acute toxicity
- XOC toxicity likely masked by presence of sample matrix toxicity (e.g., NH_3, ALK, TDS)

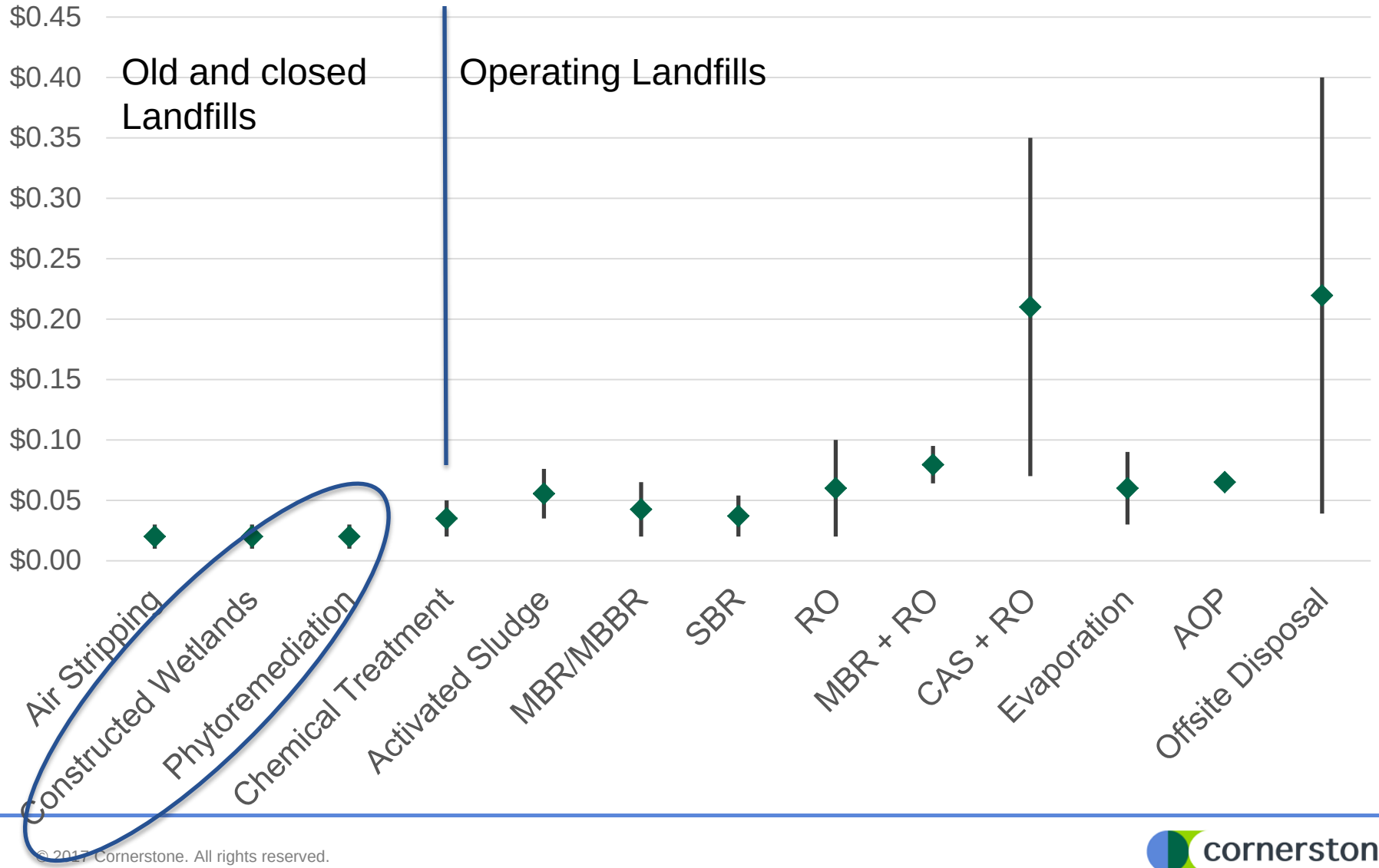
Summary I

- MSW Leachate is one of the major environmental (and financial) impacts related to solid waste disposal
- Leachate composition is strongly correlated to the waste degradation phase and environmental conditions
- Short- to- midterm leachate quality is dominated by dissolved organic matter and inorganic macro-components
- NH_3 is the most persistent inorganic macro-components affecting management options
- Only during the Aerobic Phase is NH_3 hypothesized to convert to NO_3, approx. 100 years post closure

Summary II

- Heavy metals concentrations peak early into the life cycle, but are low and remain depressed
- Research indicates that metals are unlikely to peak in the later, aerobic stages
- Leachate metal behavior is complex, with limited data and some contradictory research results
- Toxicity assays can complement conventional chemical analyses.
- Assays provide more comprehensive information for leachate management options in the long term

Leachate Disposal Cost (Cap & Op Ex)



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Questions? Comments?

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