Bioremediation: The Important Stuff in 15 Minutes

Eric Bueltel, P.E.
Technical Director

WWW.ETEC.BIO

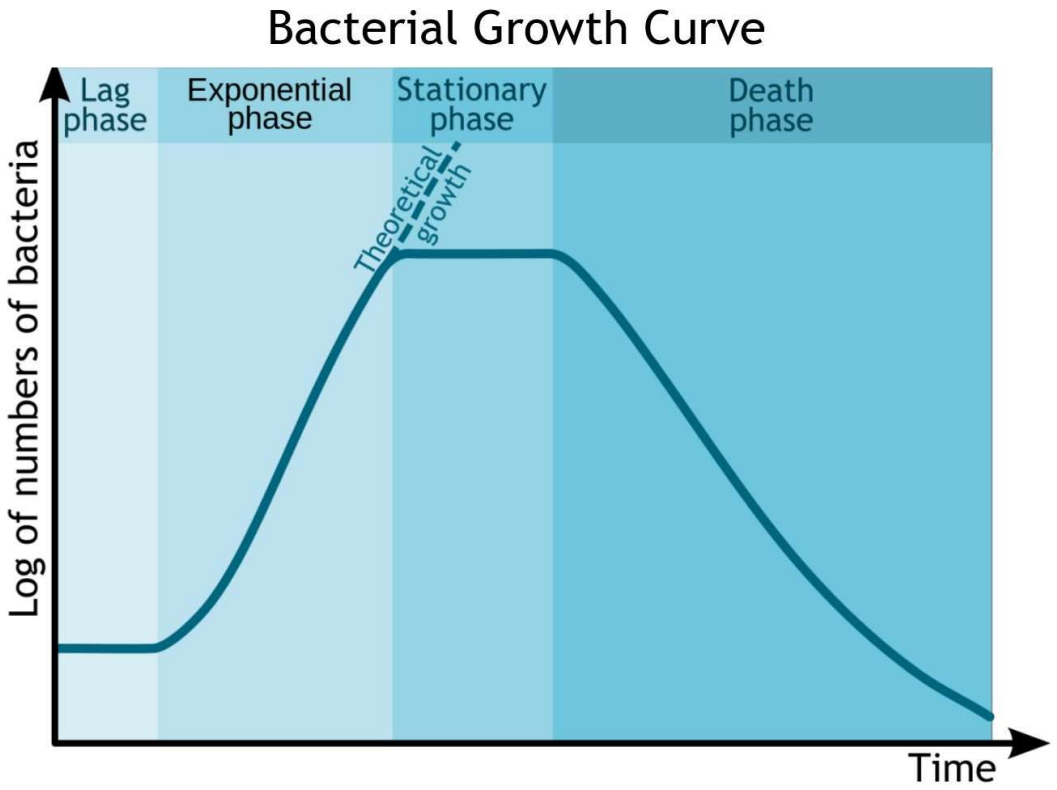
Today's Talk Track

ETEC ADVANCED BIOREMEDIATION SOLUTIONS

1. **Learn**: components for success
2. **Project Setup:** project planning
3. **Project Evaluation:** data analysis

BACTERIA GROWTH CURVE

Bacteria population growth & death



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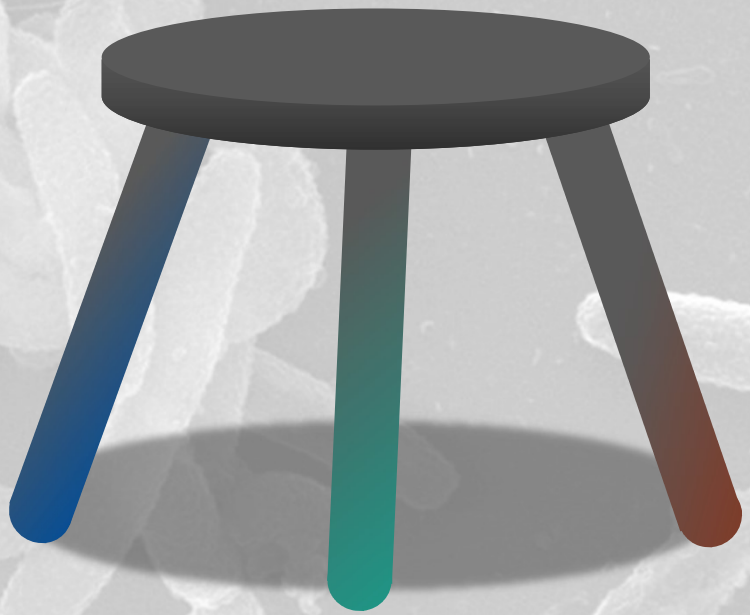
A healthy bacterial population requires three balanced elements

Contaminants provide one "leg". Effective bioremediation begins with balancing the other two.

FOOD SOURCE
(petroleum hydrocarbons)

RESPIRATION SOURCE
(oxygen, nitrate, etc.)



NUTRIENTS
(nitrogen, phosphorous, etc.)

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RESPIRATION SOURCE: Electron Acceptors

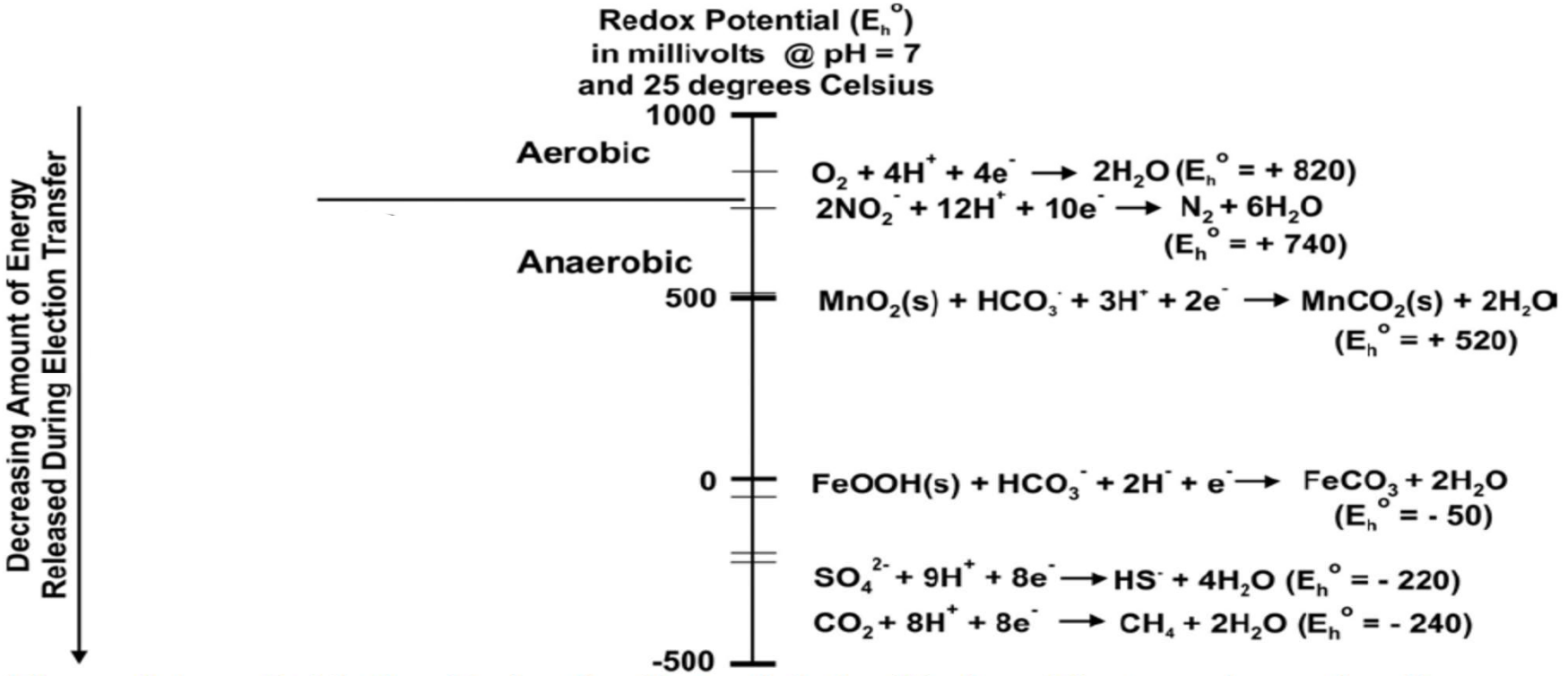
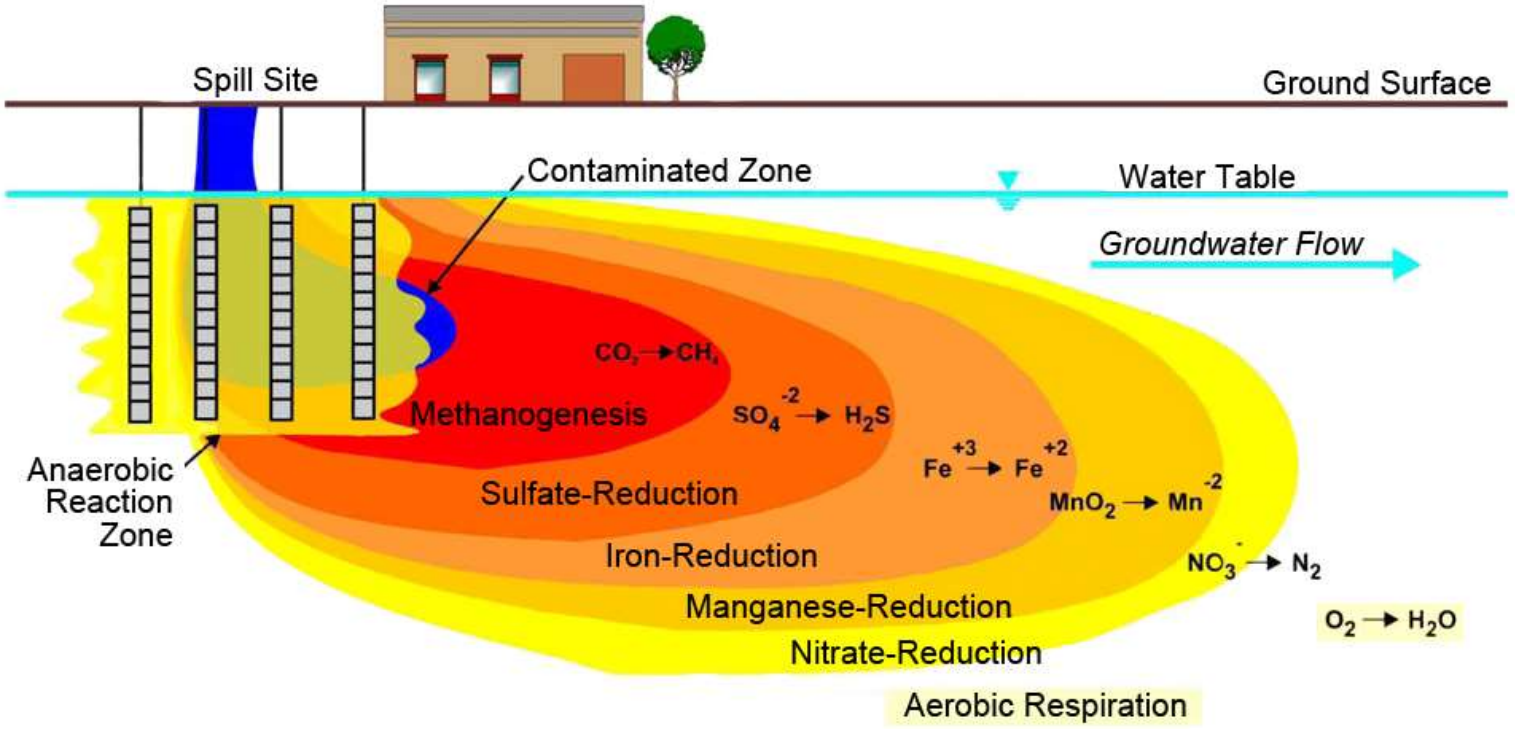


Figure 2.1 Oxidation-Reduction Potentials for Various Electron-Accepting Processes (modified from Bouwer, 1994)

RESPIRATION SOURCE: Electron Acceptors

Electron acceptor usage prior to bioremediation effort



Redox zones of a typical contaminant plume (Source: Parsons 2004).

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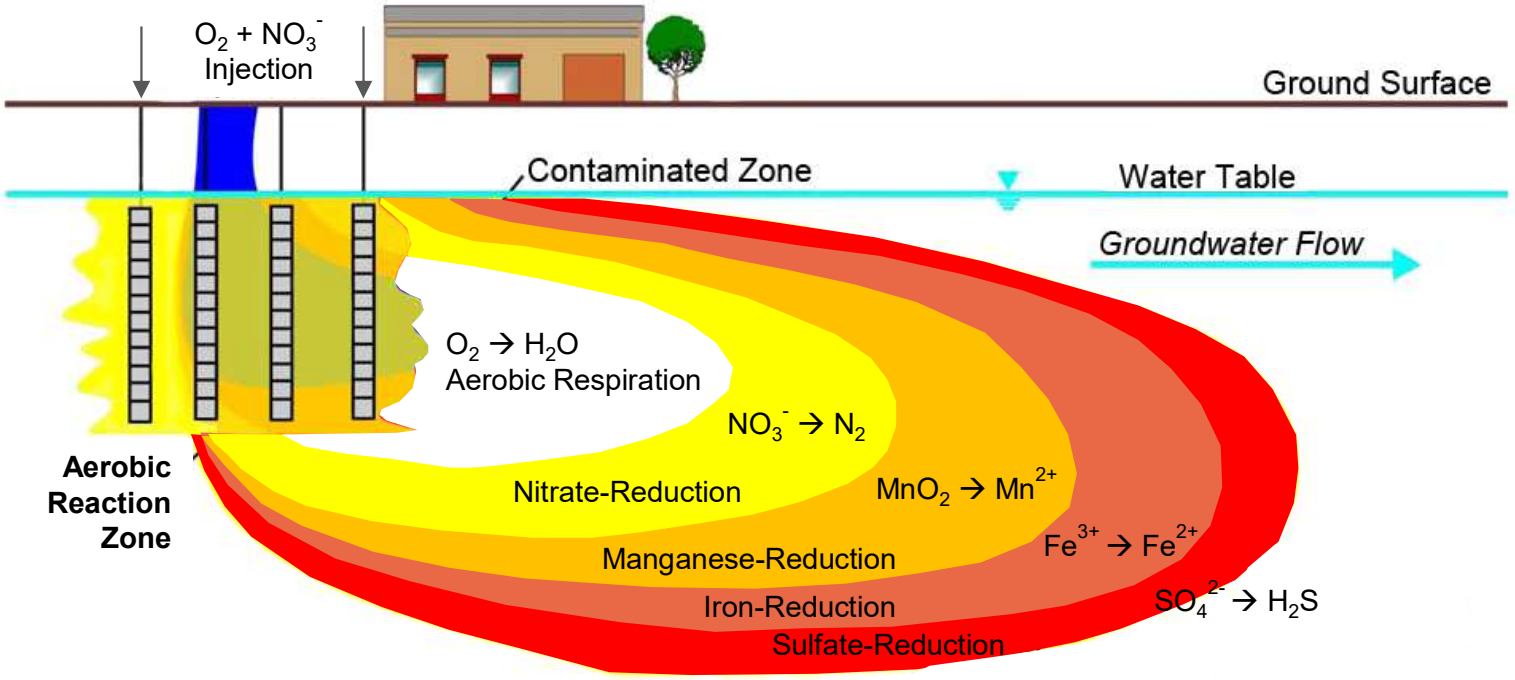
RESPIRATION SOURCE: Electron Acceptors

Electron acceptor usage following a bioremediation treatment



Redox zones of a typical contaminant plume (Source: Parsons 2004). Modified by ETEC

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RESPIRATION SOURCE: Electron Acceptors

In sites with **petroleum hydrocarbons**, the bacteria respire with:

- ✓ **Oxygen**
  - Highest energy
  - 3 lbs. oxygen : 1 lb. hydrocarbon
  - Hardest to apply large masses
  - Used very rapidly
- ✓ **Methods of application**
  - Water infused with 40-ppm dissolved oxygen
  - Air sparging / oxygen sparging
  - Oxygen releasing chemicals (direct push, pit application)
- ✓ **Mass need for a 500 gallon release**
  - 3,500 lbs. of TPH
  - 10,500 lbs. of dissolved oxygen

RESPIRATION SOURCE: Electron Acceptors

In sites with **petroleum hydrocarbons**, the bacteria respire with:

- ✓ **Nitrate**
  - 92% energy of aerobic respiration
  - 5 lbs. nitrate : 1 lb. hydrocarbon
  - Easy to apply large masses
  - Soluble & transports with groundwater
- ✓ **Methods of application**
  - Injection through wells, trenches
  - Direct push
  - Pit application
- ✓ **Mass need for a 500 gallon release**
  - 3,500 lbs. of TPH
  - 17,500 lbs. of nitrate

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RESPIRATION SOURCE: Electron Acceptors

In sites with **petroleum hydrocarbons**, the bacteria respire with:

- ✓ **Manganese**
  - Naturally occurring
  - Insoluble Mn^{4+} to soluble Mn^{2+}
  - Appears black when re-oxidized
  - Typical concentrations in plume are 1-10 mg/L
- ✓ **Iron**
  - Naturally occurring
  - Insoluble Fe^{3+} to soluble Fe^{2+}
  - Appears orange-red when re-oxidized
  - Typical concentrations in plume are 10-100+ mg/L

Thank Mn- and Fe-reducing bacteria the next time you clean your air stripper trays!

RESPIRATION SOURCE: Electron Acceptors

In sites with **petroleum hydrocarbons**, the bacteria respire with:

- ✓ **Sulfate**
  - 6% energy of aerobic respiration
  - 5 lbs. sulfate : 1 lb. hydrocarbon
  - Easy to apply large masses
  - Soluble & transports with groundwater
- ✓ **Methods of application**
  - Injection through wells, trenches
  - Direct push
  - Pit application
- ✓ **Mass need for a 500 gallon release**
  - 3,500 lbs. of TPH
  - 17,500 lbs. of sulfate

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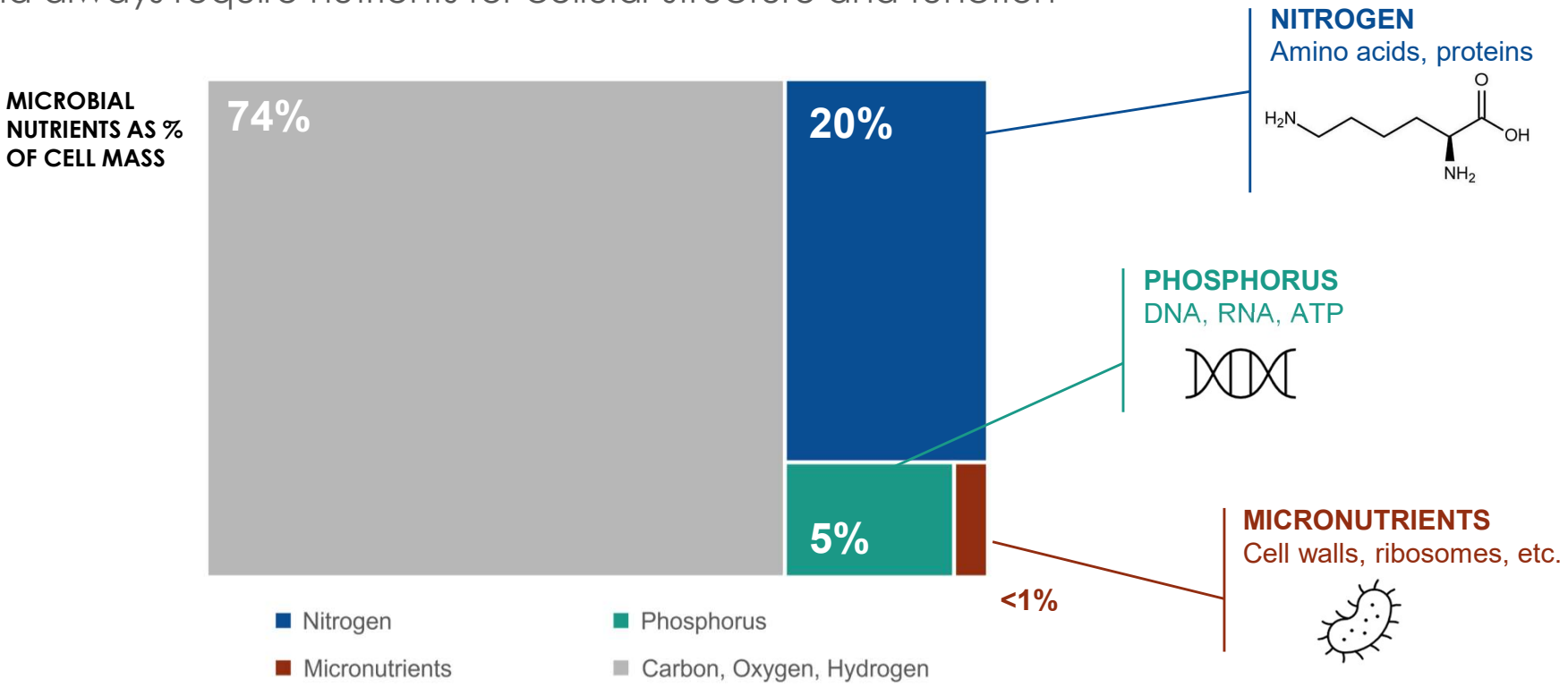
NUTRIENTS

Bacteria always require nutrients for cellular structure and function



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NUTRIENTS

Bacteria require the following nutrients

- ✓ **Nitrogen & Phosphorus**
  - Mass needed for a 500 gallon release
  - 3,500 lbs. of TPH
  - 700 lbs. of nitrogen
  - 175 lbs. of phosphorus
  - Increases microbial activity by orders of magnitude
- ✓ **Micronutrients**
  - Bacteria require <1% by weight
    - Potassium
    - Sulfur
    - Magnesium
    - Calcium
    - Iron
    - Many others

Only applying electron acceptors, even tons, is not enough!

PRODUCT SUPPLY PLANNING

Determining the correct product dosing requires a combination of technical calculations and real-world application planning

THEORETICAL CALCULATIONS

1. Estimate TPH mass present
2. Estimate soil-bound TPH mass using soil & groundwater data
3. Estimate electron acceptor needs
4. Estimate nitrogen & phosphorus needs

PRACTICAL CONSIDERATIONS

1. Ensure adequate distribution
2. Calculate injection rates
3. Consider onsite time available vs required

STEP 1: TPH MASS ESTIMATION

You don't know what you need until you know what you have

- ✓ **Best: Recent soil borings**
  - Using TPH in soil, it is easiest to estimate total TPH mass
  - C_{soil} * impacted soil mass = TPH mass
- ✓ **Next Best: TPH in groundwater**
  - $C_{gw} * K_{oc} * F_{oc} = C_{soil}$
  - K_{oc} for weathered gasoline & diesel is not easy to determine
  - F_{oc} must be collected with soil borings
  - Multiply C_{soil} * impacted smear zone volume
- ✓ **Not Great: COCs in groundwater**
  - BTEX is 5-25% in gasoline and diesel
  - BTEX * 4 (or 20) = TPH C_{gw}
- ✓ **Never: Only use GW mass**
  - GW TPH mass is <1% of total mass

STEP 2: ELECTRON ACCEPTOR & NUTRIENT ESTIMATION

You know what you have, now how much do you need

- ✓ **Electron acceptors**
  - TPH mass * electron acceptor ratio = mass of electron acceptors needed
  - TPH mass * 3 for oxygen TPH mass * 5 for nitrate & sulfate
  - Mass of electron acceptors / % electron acceptors in product = mass of product
- ✓ **Nutrients**
  - TPH mass * % nutrient needed = mass of nutrients needed
  - TPH mass * 20% for nitrogen TPH mass * 5% for phosphorus
  - Mass of nutrients / % nutrient in product = mass of product

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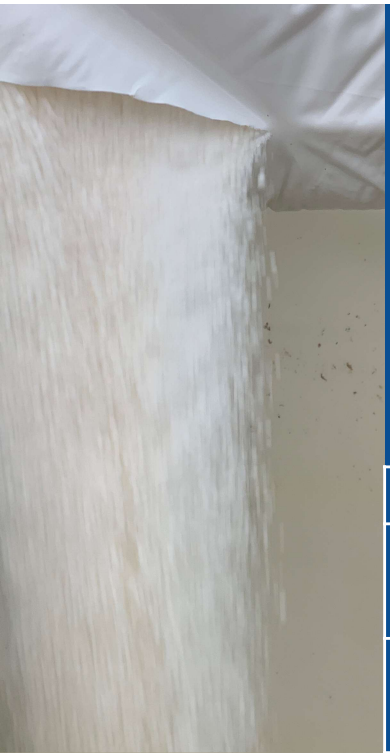
STEP 3: EVERYTHING ELSE

Sorry out of time!

- ✓ **Check environmental factors**
  - pH – adjust if necessary
  - Comingled plumes
  - Check for boring logs for peat, high organic soil
- ✓ **Application**
  - Check boring logs for permeable soil
  - Determine the best application method
  - Perform injection tests prior to going full-scale
  - Using flow rates, determine onsite time needed

MONITORING PROGRESS

Being proactive is the key to success



✓ **Check electron acceptor availability**

- Regularly check dissolved oxygen, ORP especially
- Sample for nitrate, soluble iron, soluble manganese, & sulfate
- Ideal nitrate concentration is 10 mg/L to 100+ mg/L

✓ **Check nutrient availability**

- Sample for ammonia-nitrogen & phosphorus
- Ideal ammonia-nitrogen concentration is 10+ mg/L
- Any detection of phosphorus is ideal

	Oxygen	Nitrate	Manganese	Iron	Sulfate
Increasing or high concentration	EA Abundance	EA Abundance	EA Depletion	EA Depletion	EA Abundance
Decreasing or low concentration	EA Depletion	EA Depletion	EA Abundance	EA Abundance	EA Depletion

CONTACT US

Jeff Jordan
Northwest Regional Manager
jeff@etec.bio
971.222.3616 x 102

Eric Bueltel, PE
Technical Director
eric@etec.bio
971.222.3616 x 104