Vertex Environmental Inc.

Sustainable Remediation:
At the Intersection of Current and Future Regulations

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SABCS

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Outline

- “Old School” Remediation
  - Examples of Non-Sustainable Approaches
- Regulation Discussion
  - Current Focus of Regs vs
  - What We May Need in Future Regs
- Sustainable Remediation
  - Examples
- Closing

Who Am I?

Bruce Tunnicliffe, M.A.Sc., P.Eng.

- Masters – U of Waterloo. Remediation
- Founder – Vertex Environmental Inc.
- Founder – SMART Remediation

Vertex Environmental Inc.

- Started July 2003
- Environmental Contractor

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“Old School” Remediation

- In the early days of remediation, there was an ideology to complete **remedial actions to the extent practicable**
- This usually involved disruptive action:
  - Excavation
  - Long-term energy-intensive pump and treat systems
  - Other engineering / aggressive approaches (e.g. Multi-phase extraction)

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Philosophical Question

Is it worth it to save the natural environment,
if the only way to save it,
is to destroy it?

Philosophical Thoughts, con’t

When we look at a clean-up,
do we only look at it in the context of that location?
…at the micro-scale?

The natural world is more complex than the absence or presence of a contaminant.

We Need to Consider **Sustainability**

How Did We Get Here?

From a 2019 Remediation Article:

- …the remediation industry in the United States was born in the 1970s following a steady stream of highly publicized discoveries…
- …of toxic chemicals in landfills, drinking water, and even neighborhoods.
- Environmental laws were passed at the state and national level, and industry and consultants kept pace by hiring staff, building programs, and initiating cleanups.
- The remediation industry was off at a sprint before it had learned to crawl.
- With the public demand for swift and sometimes immediate cleanups, responsible parties and the remediation industry invested heavily in energy intensive engineered projects,
- …such as groundwater pump-and-treat systems, soil excavation and off-site disposal, and incineration.
- **Now**: the remediation industry uses energy, consumes raw materials, and otherwise contributes to humankind's environmental footprint.
- **Now**: Is the public's perception changing, to see the large scale? Climate change.

Favara *et al*, 2019, "Ten years later: The progress and future of integrating sustainable principles, practices, and metrics into remediation projects"

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Are Our Current Remedial Practices Bad?

nature reviews earth & environment https://doi.org/10.1038/s43017-023-00404-1

Sustainable remediation and redevelopment of brownfield sites

2023 Article on Sustainable Remediation:

- Conventional remediation strategies…
- …such as dig and haul, or pump and treat…
- …ignore secondary environmental burdens and socio-economic impacts; and,
- over their life cycle, some strategies are **more detrimental** than taking no action

Hou *et al*, 2023, "Sustainable remediation and redevelopment of brownfield sites"

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Are We Truly at A Regulatory Intersection?

Current Regulations are strong for groundwater, soil, and soil vapour protection

But do our Regs consider other important factors, such as climate change, or social issues?

Sustainable Remediation

Triple Bottom Line

- Environment
- Economy
- Social Interests

Groups Involved in Remediation:

- Site Owners
- Regulatory Entities
- The Public
- Service Providers

The Problem?

- Everyone can not agree to a common framework

Favara *et al*, 2019, “Ten years later: The progress and future of integrating sustainable principles, practices, and metrics into remediation projects”

Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites

2008

"Green Remediation: The practice of considering all environmental effects of remedy implementation and incorporating options to maximize net environmental benefit of cleanup actions."

EPA, 2008

EPA Green Remediation Document

Table 3. Estimated CO_2 emissions from use of five types of cleanup technologies at NPL sites over 23 years are equivalent to operating two coal-fired power plants for one year. [26]

NPL = National Priorities List

Technology	Estimated CO_2 Emissions Annual Average (Metric Tons)	Total Estimated CO_2 Emissions in 2008-2030 (Metric Tons)
Pump & Treat	323,456	7,439,480
Thermal Desorption	57,756	1,328,389
Multi-Phase Extraction	12,000	276,004
Air Sparging	6,499	149,476
Soil Vapor Extraction	4,700	108,094
Technology Total	*404,411*	*9,301,443*

"consumption of fossil fuel energy at NPL sites during operation of these five technologies is anticipated to cost over $1.4 billion from 2008 through 2030."

EPA, 2008

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Examples of non-Sustainable Remediation Projects

Favara *et al*., 2019:

- Consider environmental risk vs remediation worker safety
- Env Exposure = incremental life-time cancer risk of 1 in 1 million
- Remediation Worker = risk of injury or fatality
- Based on actuarial figures
  - the risks associated with the actual cleanup
  - were potentially **more than**
  - human health exposure risks

Favara *et al*, 2019, “Ten years later: The progress and future of integrating sustainable principles, practices, and metrics into remediation projects”

Examples of non-Sustainable Remediation Projects

Environ. Sci. Policy article, 2014:

- Site in New Jersey
- Plan to complete dig and haul at a single brownfield site
- Estimate the work could emit 2.7 million tons of CO^2
- This equals 2% of the annual CO^2 emissions for the entire state

What Can We Do?

What Have Others Recommended?

Canada:

Soil Excavation:

- Reduce excavation and off-site disposal, where possible
- Consider use of on-site treatment rather than off-site treatment of soils
- Make beneficial reuse of excavated soils on-site, where possible

“Incorporating sustainability: federal contaminated sites decision-making framework”
https://www.canada.ca/en/environment-climate-change/services/federal-contaminated-sites/decision-making-framework/incorporating-sustainability.html

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What Have Others Recommended?

US EPA Green Remediation Document, 2008:

Consider Non-Traditional Remedial Approaches, such as:

- Enhanced Bioremediation
- Permeable Reactive Barriers (PRBs)
- Monitored Natural Attenuation

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EPA, 2008, “Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites”

What Have Others Recommended?

Hou et al., 2023:

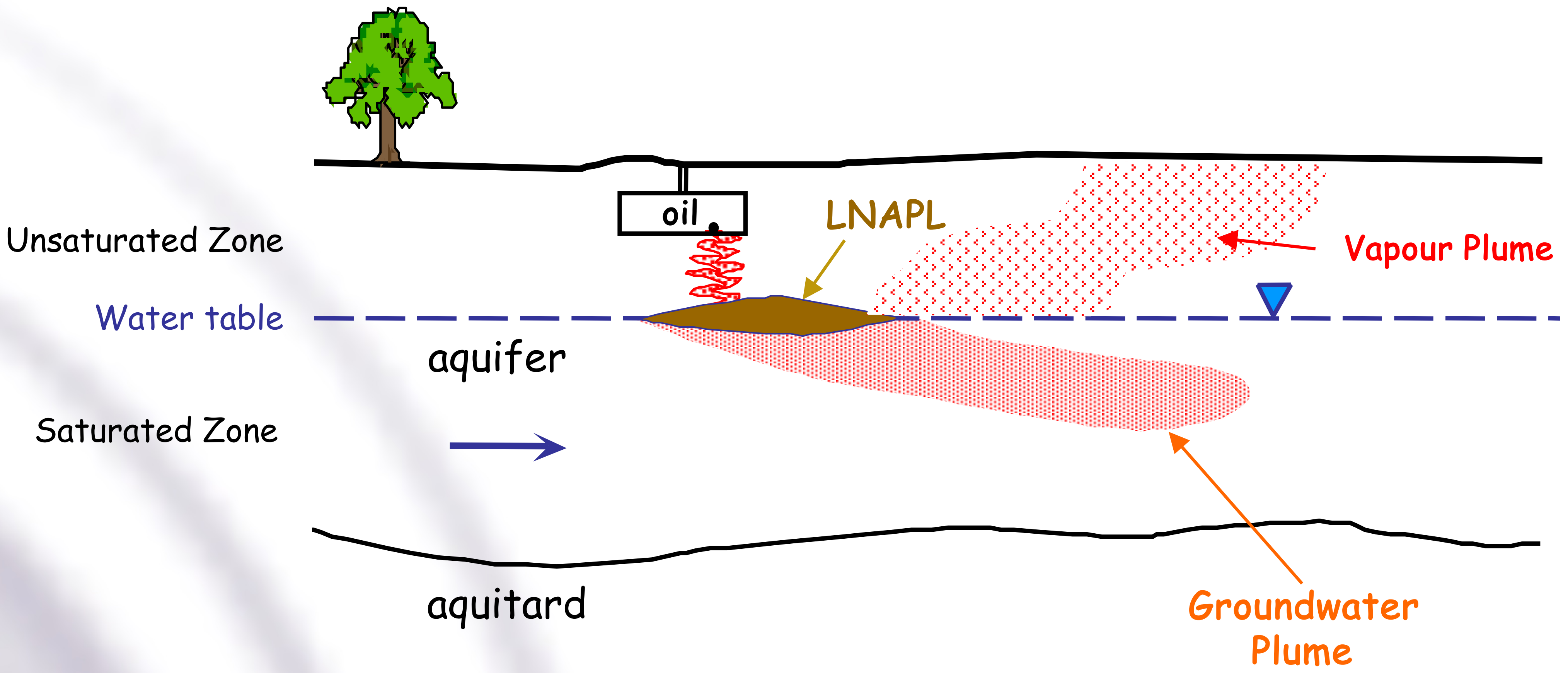
- Apply sustainable remediation technologies, such as:
  - Immobilization,
  - Bioremediation,
  - New forms of in-situ chemical treatment
  - Innovative passive barriers (PRBs)
- Compared with traditional methods:
  - One can typically reduce the life-cycle greenhouse gas emissions by ~50–80%.
- Could further consider sustainable energy systems to provide carbon sequestration or green energy

EPA, 2008, “Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites”

Let’s Look at Sustainable Solutions

But First, How Does the Subsurface Work?

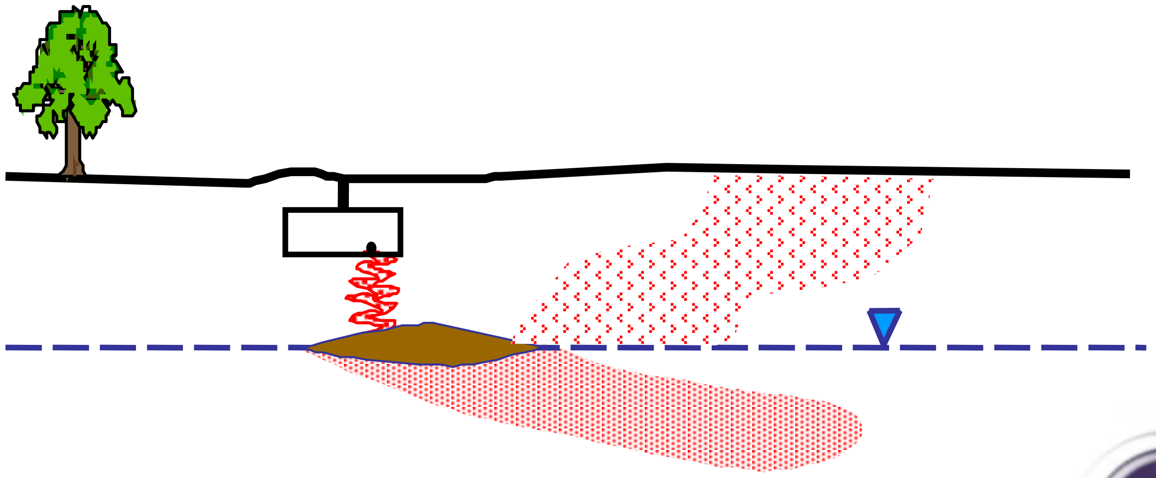
Contaminants in the Subsurface



Review of More Sustainable Remediation Approaches

Remedial Approaches:

- Bioremediation: Natural Source Zone Depletion (NSZD)
- Permeable Reactive Barriers (PRBs)
- In-Situ Remediation
  - using Mother Nature's processes
- On-Site Remediation
  - for soil
  - for groundwater
  - for LNAPL

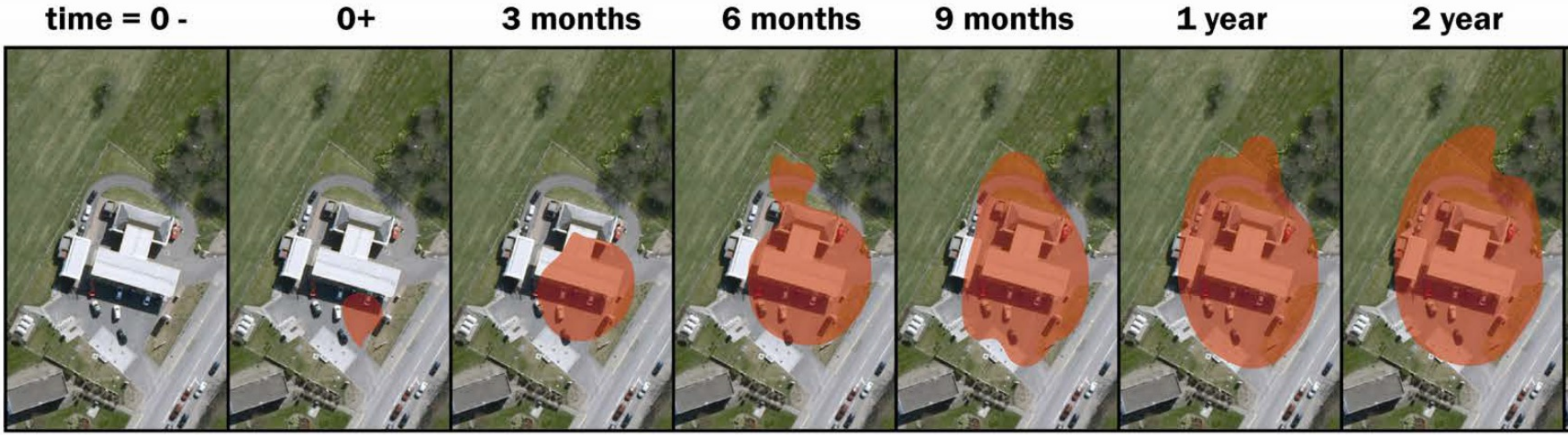


Natural Source Zone Depletion (NSZD)

This is LNAPL bioremediation!

Thank you to Matt Rousseau, GHD

Regarding LNAPL Migration



LNAPL Stabilization:

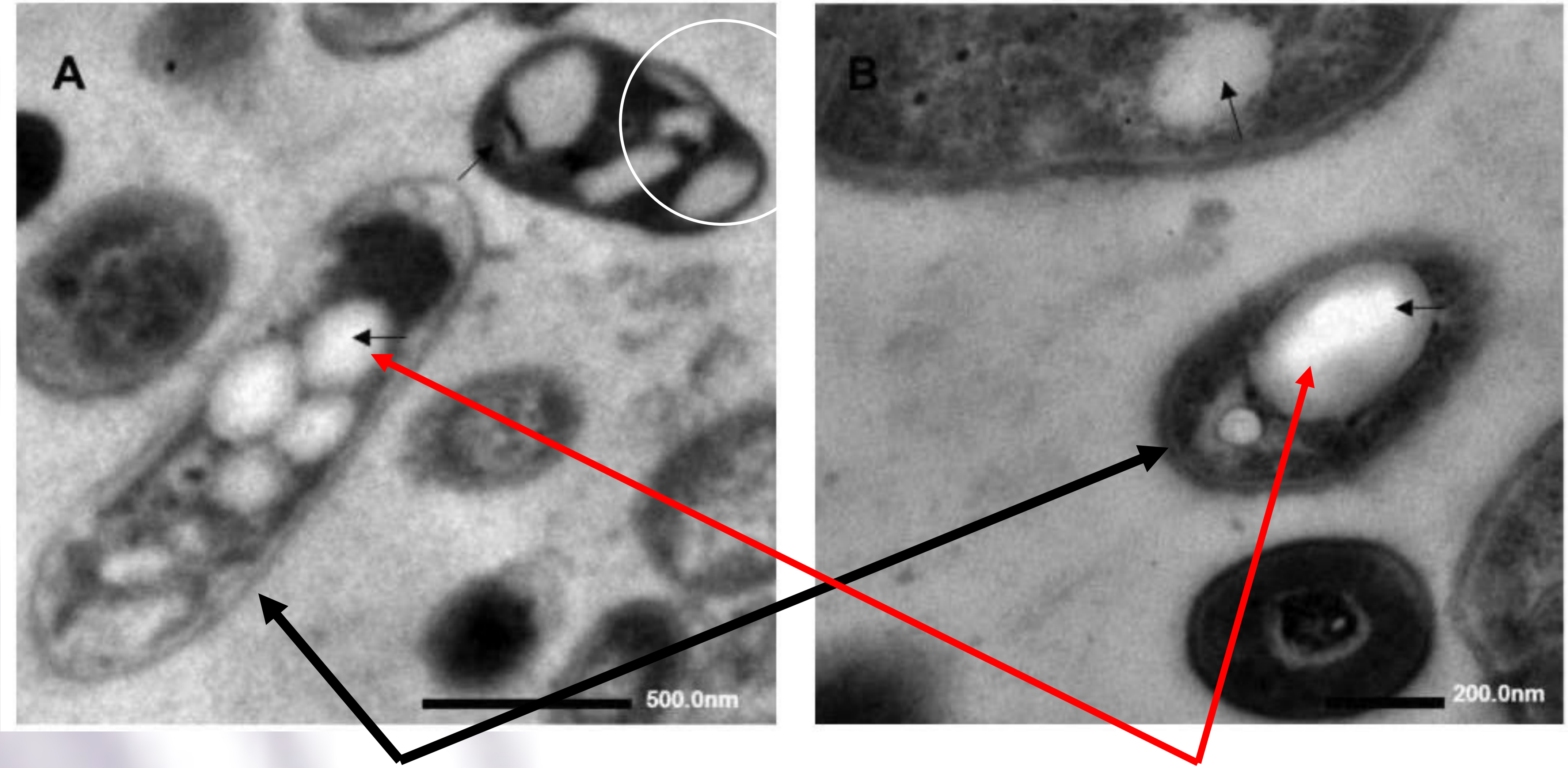
- low viscosity LNAPL (gasoline / diesel) = **weeks to months**
- more viscous LNAPL (heating oil) = months to years

Old Remediation Thought: Remove LNAPL to the extent practicable. Why? We thought LNAPL was not stable, and it would never biodegrade, ever.

Now We Know: Active LNAPL recovery efforts can lead to **significant detrimental effects** – e.g. diminished air quality, climate change

Thank you to Matt Rousseau, GHD

Regarding LNAPL Biodegradation – What We Have Recently Learned



Bacteria munching on microdroplets of petroleum hydrocarbon

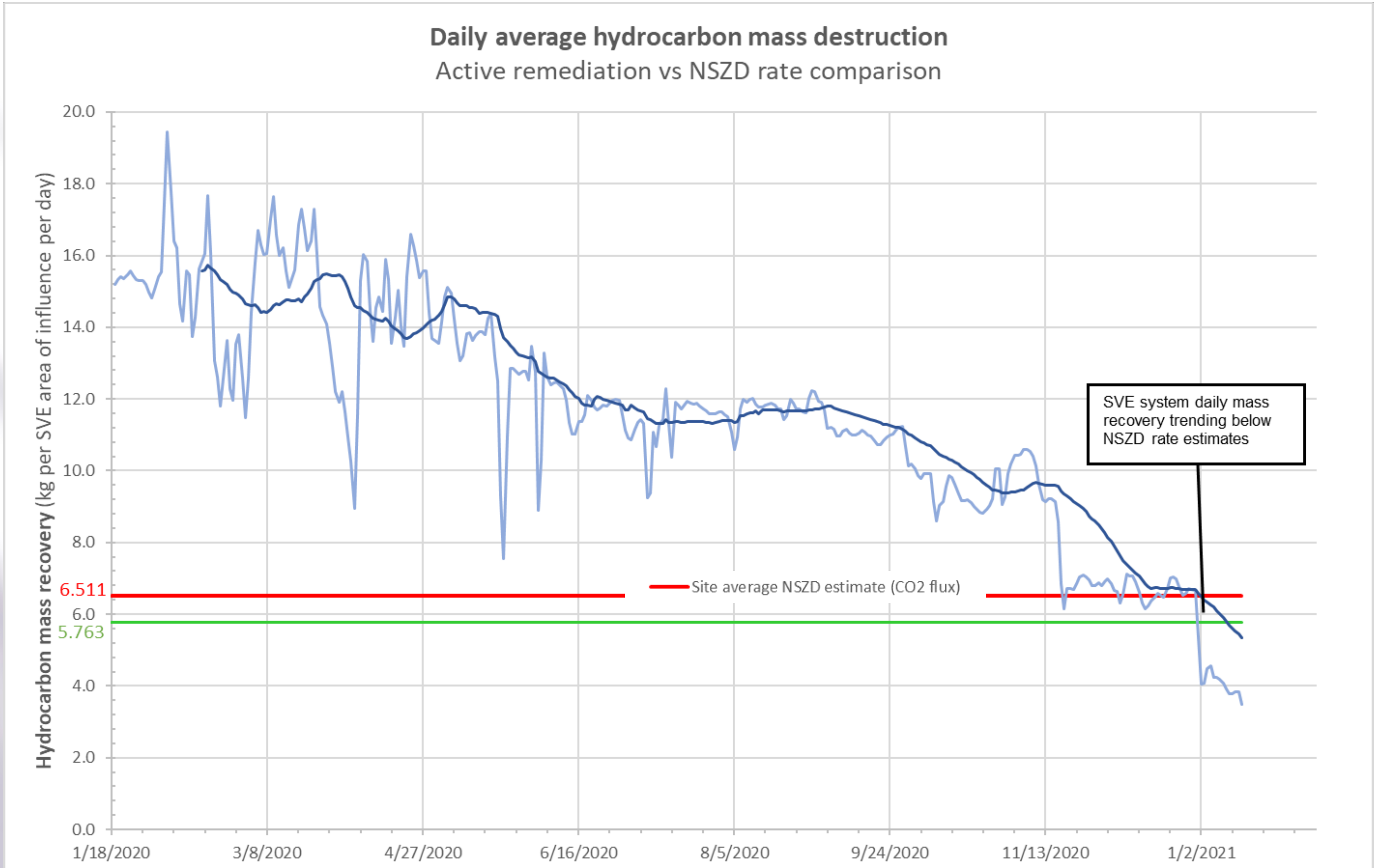
LNAPL microdroplet within cell walls

Thank you to Matt Rousseau, GHD

(see Ng et al, 2014, doi: 10.1016/j.jconhyd.2014.04.006)


Bubbles are the product of direct outgassing of CO_2, CH_4 from pore space adjacent to LNAPL
Thank you to Matt Rousseau, GHD
courtesy of Julio Zimbron/E-Flux LLC

Intelligently Use Active Remediation then NSZD



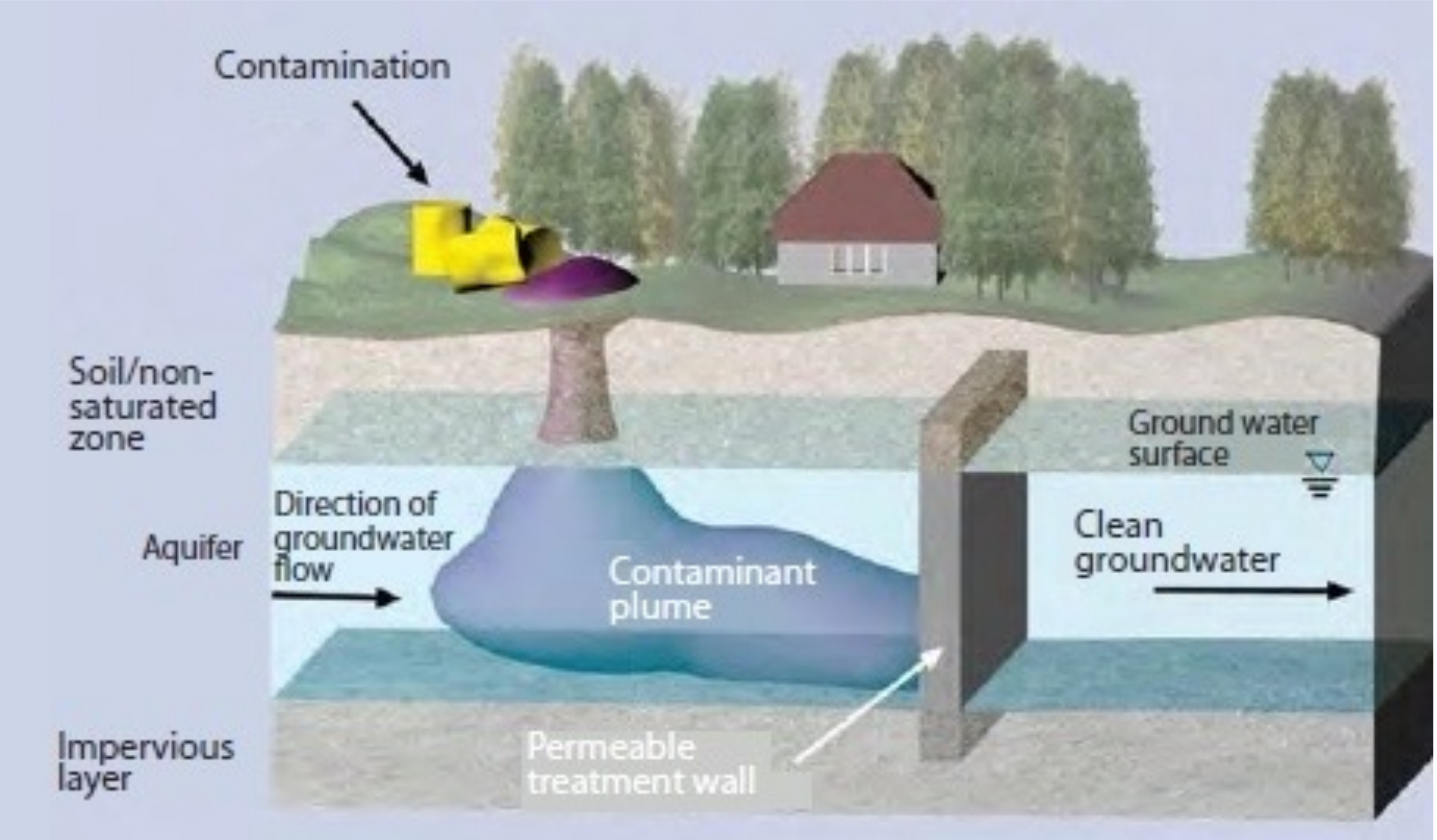
Not Being Intelligent with Active Remediation

MPE system @ Superfund site in Michigan	
Total LNAPL recovered	394 litres 356 kg
Average LNAPL recovery rate	0.2 kg/hour
Cost	>$1M >$2,500/litre LNAPL >$2,800/kg LNAPL
GHG emissions – CO_2, CH_4, N_2O (based on electrical power consumption, USEPA eGRID emission factors)	>150,000 kg >100 kg/hour
Environmental Footprint (based on USEPA SEFA spreadsheets, power consumption, manufacturing of materials, groundwater extraction, etc.)	143,000 kg CO_2e 7,300 kg NO_x+SO_x+PM 20 kg HAPs

Thank you to Matt Rousseau, GHD

Permeable Reactive Barrier

Permeable Reactive Barrier (PRB)

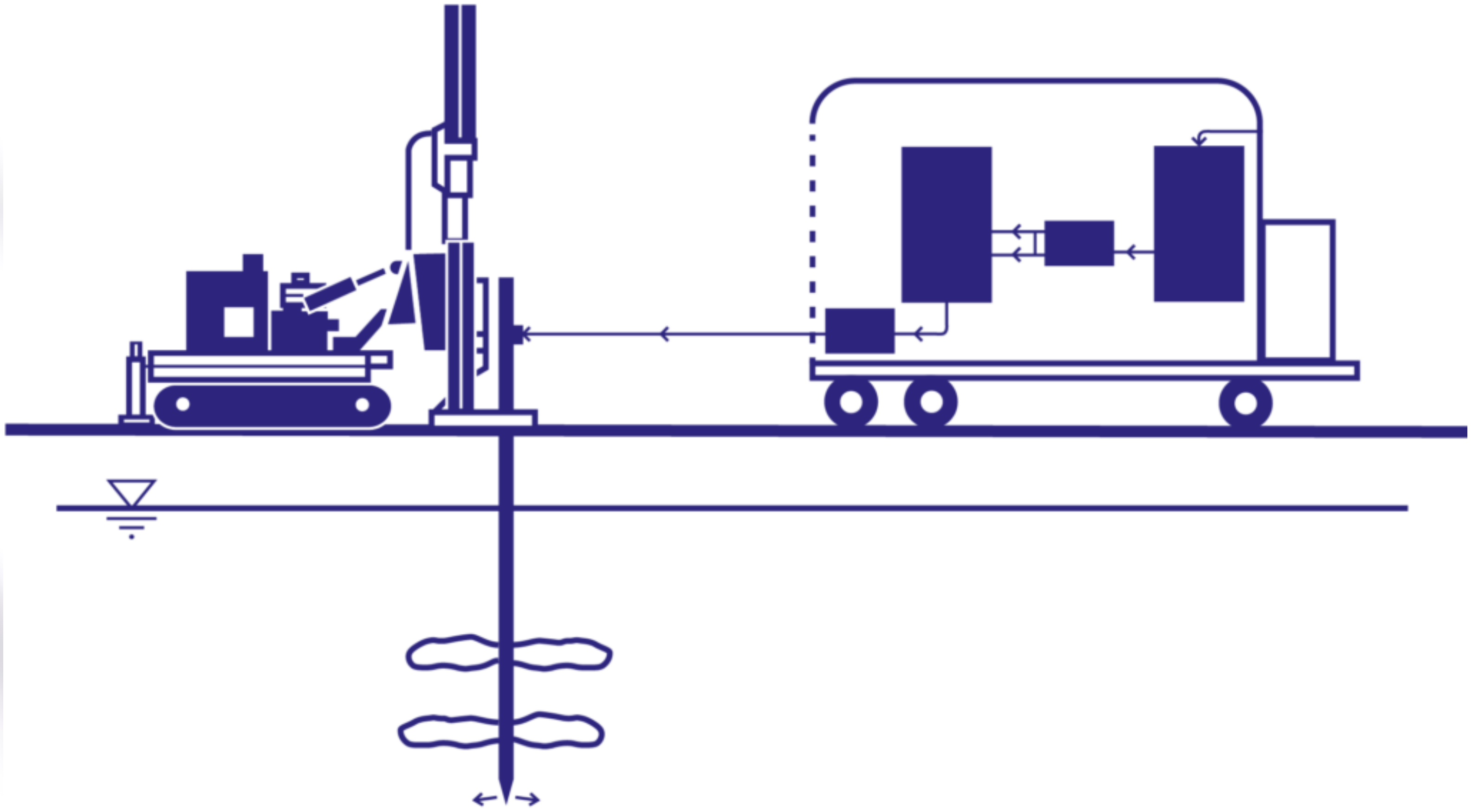


Permeable Reactive Barrier

Permeable Reactive Barrier

In-Situ Remediation

In-Situ Remediation



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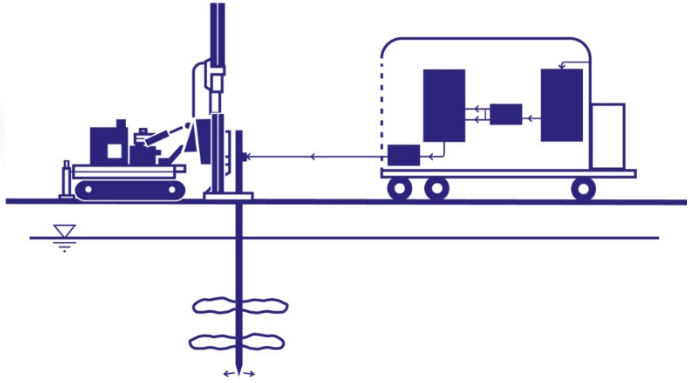
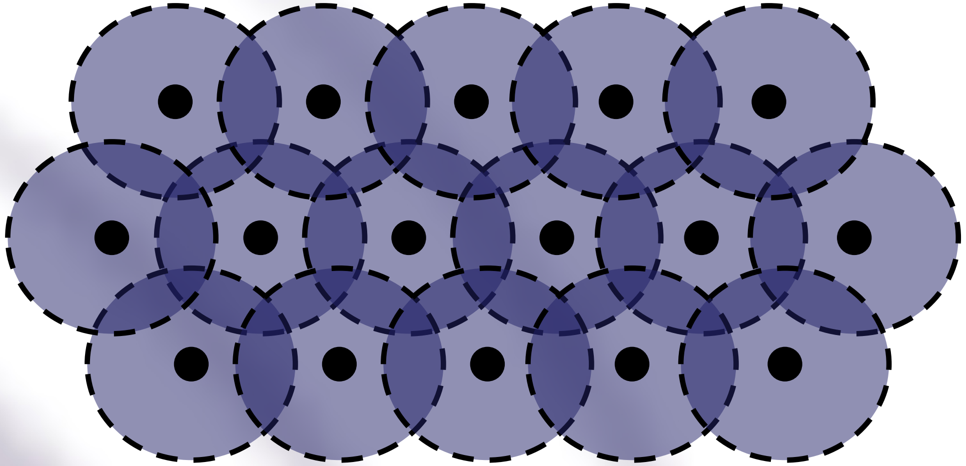
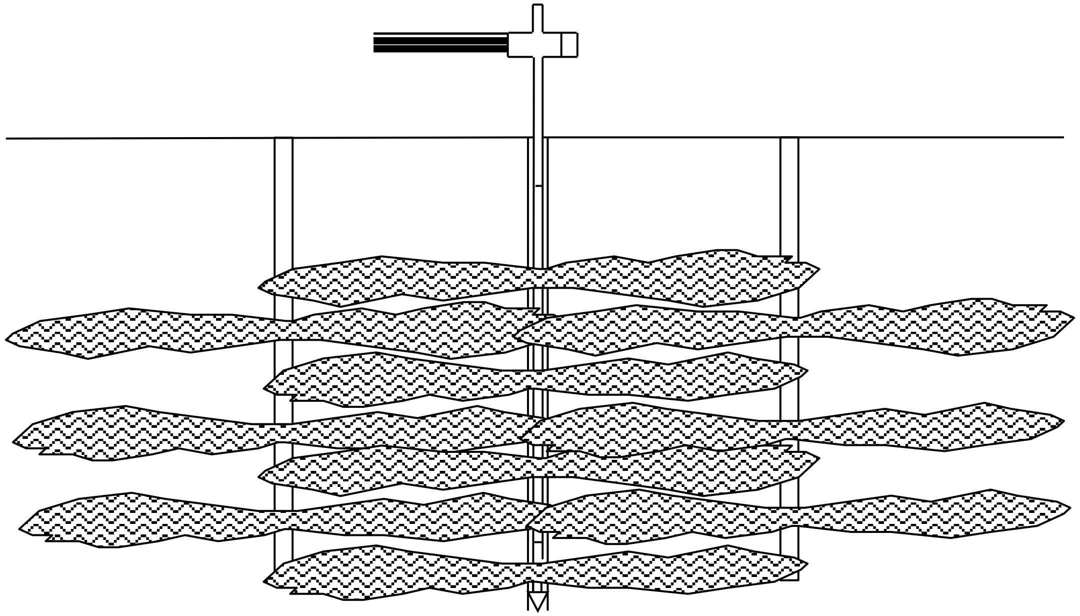
In-Situ Remediation Approach



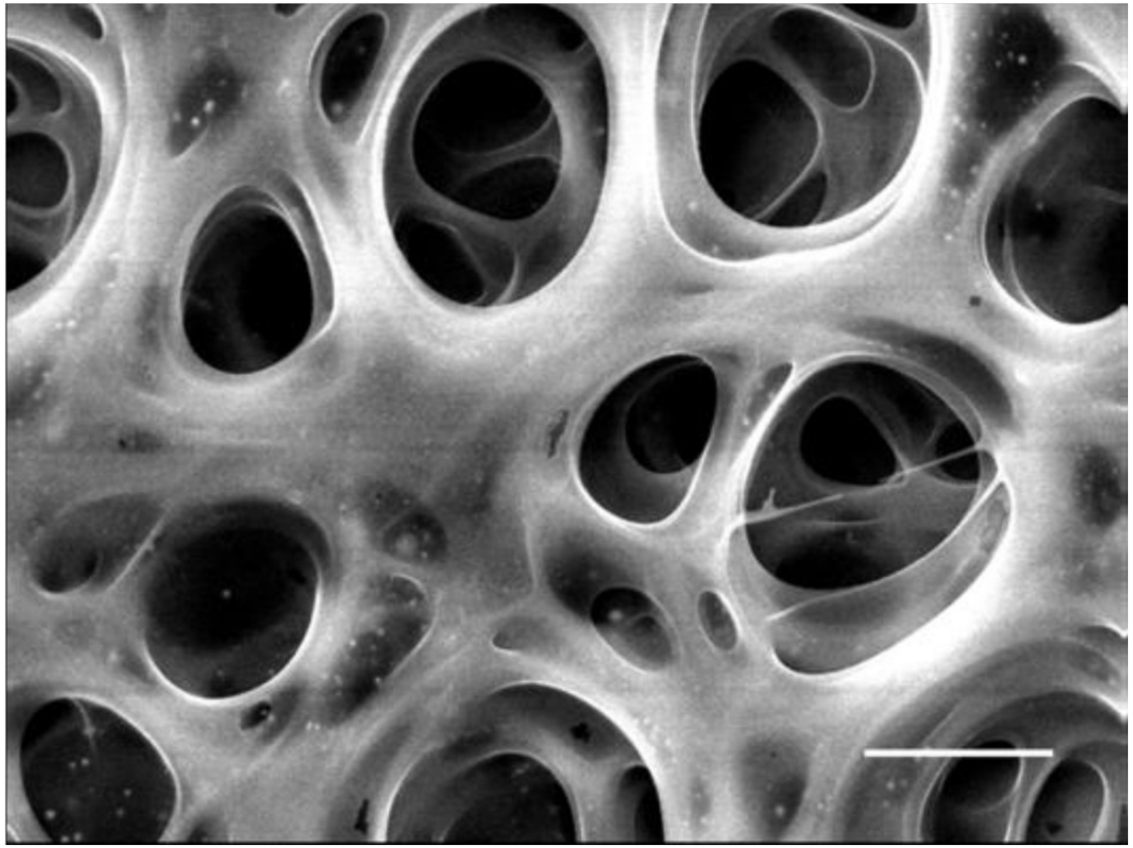


Plan View



Profile View

Activated Carbon – Give Mother Nature a Media to Enjoy



AC is produced from carbonaceous source materials
(coconut husk, wood, coal, etc)

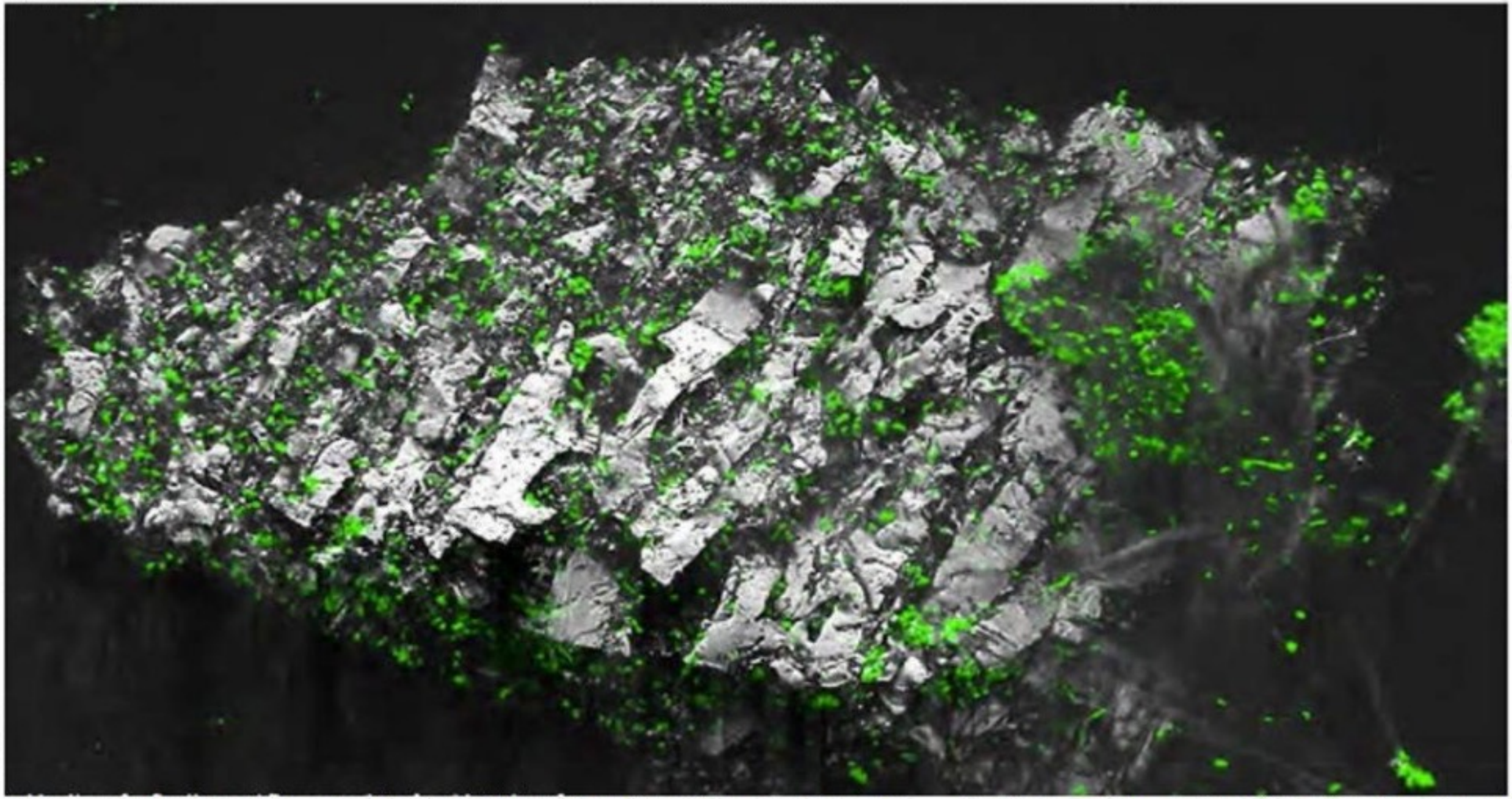
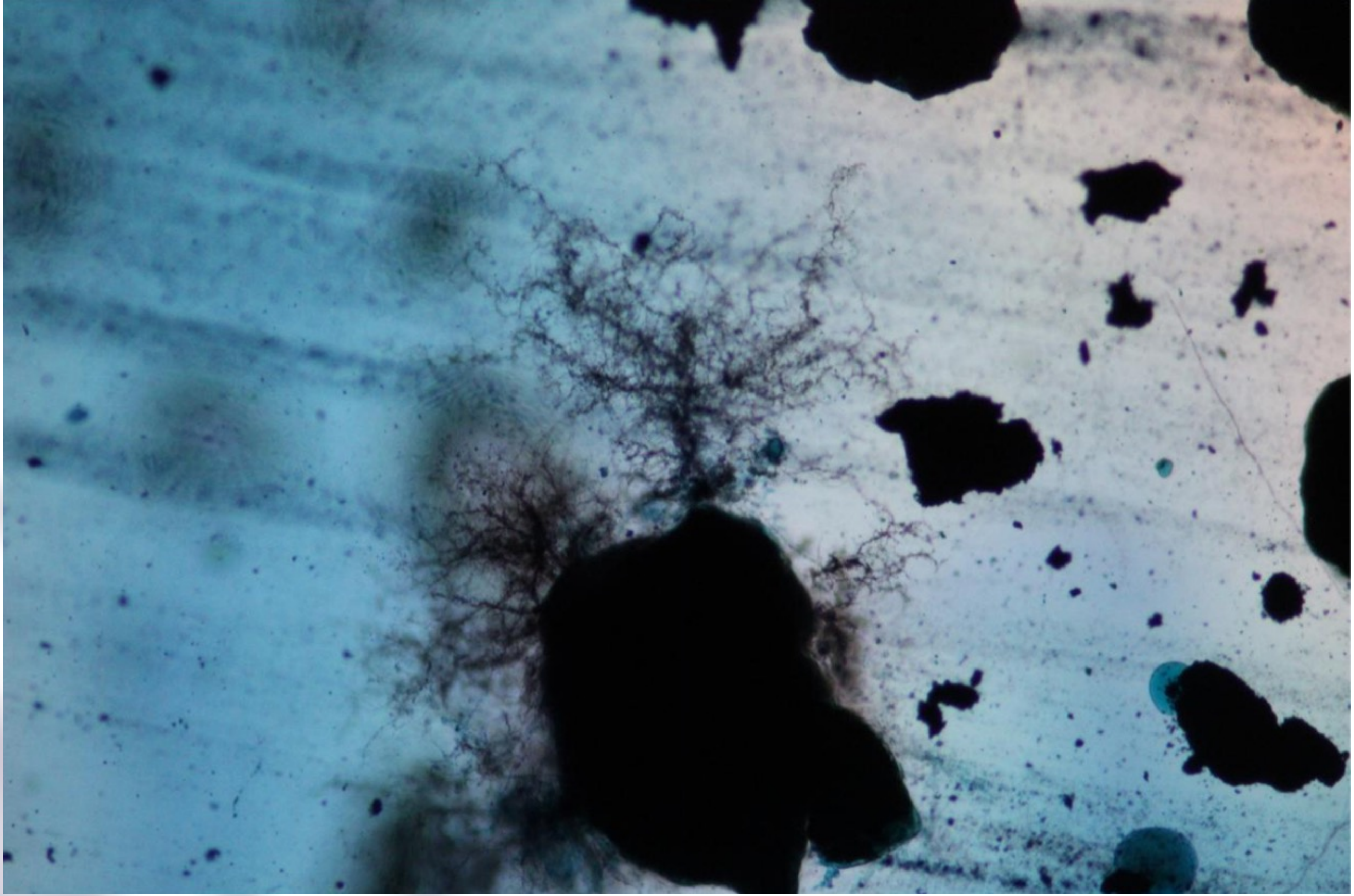


Figure 10. The image shows DF1 biofilm formed on the surface of an activated carbon particle.



Bacteria is growing off the activated carbon. Created a “bush” of bacteria. AC is better for growth than soil.

On-Site Treatment

Ex-Situ Remediation

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Ex-Situ Treatment: Biodegradation (Biopiles)


CAT
CAT

On-Site Treatment
Direct Soil Mixing – Plumes

Direct Soil Mixing – Not “Dig and Dump”, just a little Dig

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On-Site Treatment
Direct Soil Mixing – Free Product (LNAPL)

LNAPL Immobilization – Block & Adsorb Technology

LNAPL Immobilization – Block & Adsorb Technology

GAC addition and soil mixing

PC addition and soil mixing

LNAPL Immobilization – Block & Adsorb Technology

Groundwater Samples Collected: Control Plot vs Test Plot

Test Pit Excavated: Treated and Untreated

Closing Thoughts

Sustainable Remediation

- Consider the Bigger Picture
  - Environment, Economy, Social Interests
- Minimize use of Traditional remedial approaches
  - Dig and Dump
  - Pump and Treat
- Make use of more Innovative remedial approaches
  - Natural Source Zone Depletion
  - Permeable Reactive Barriers (PRBs)
  - In-Situ approaches
  - On-Site treatment (bio, soil mixing)

In the end, we should be kind to Mother Nature

Upcoming Regulations should reflect this kindness

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Questions?

Thank You for Your Time

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