The Evolution of Remediation

Going towards Nature Based Solutions

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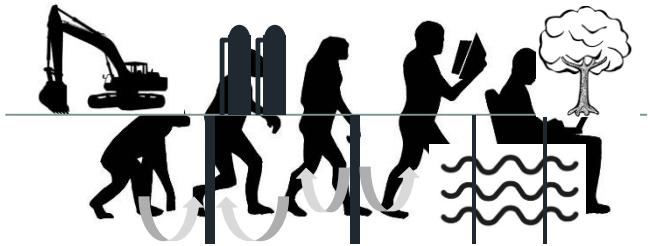
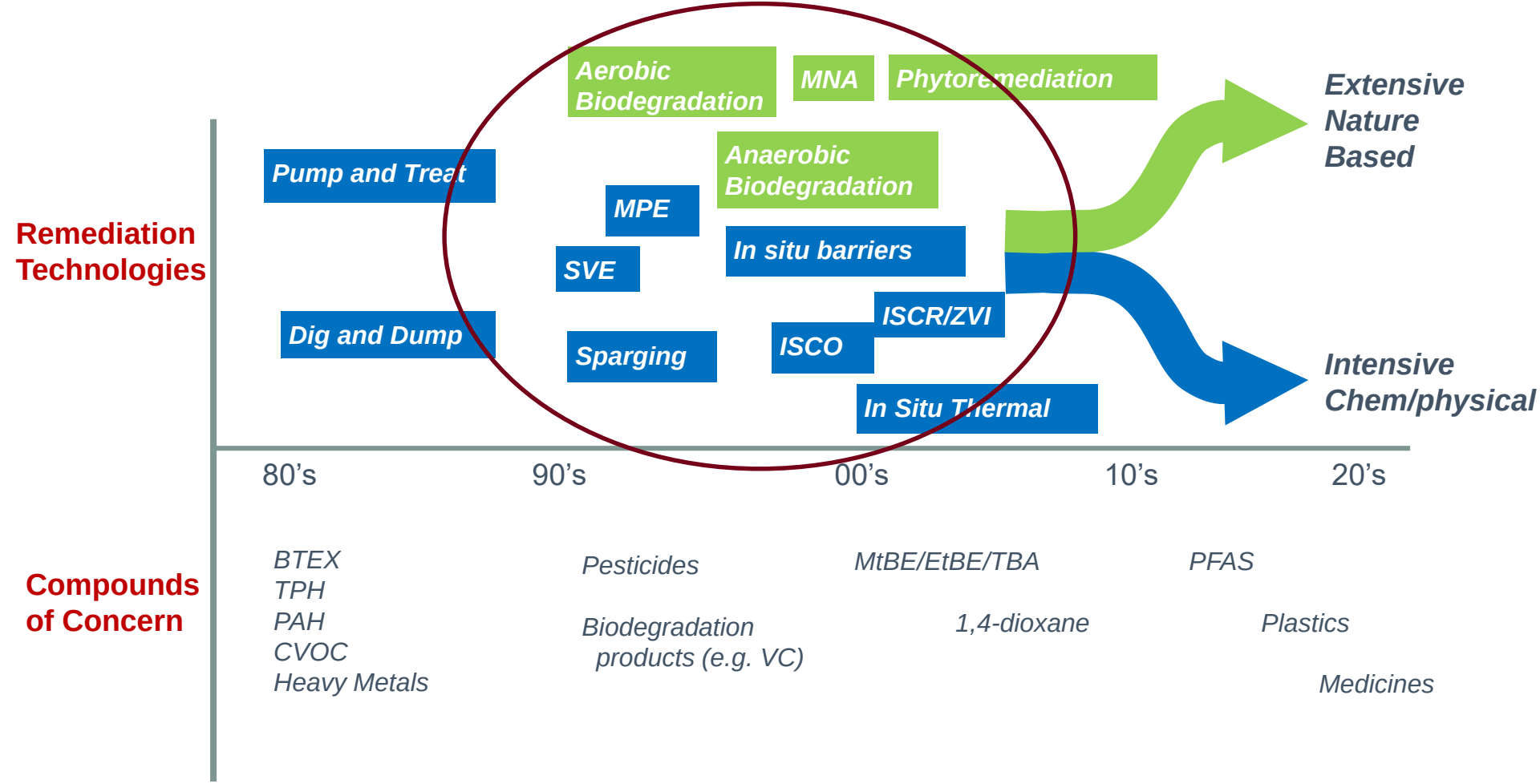
EVOLUTION

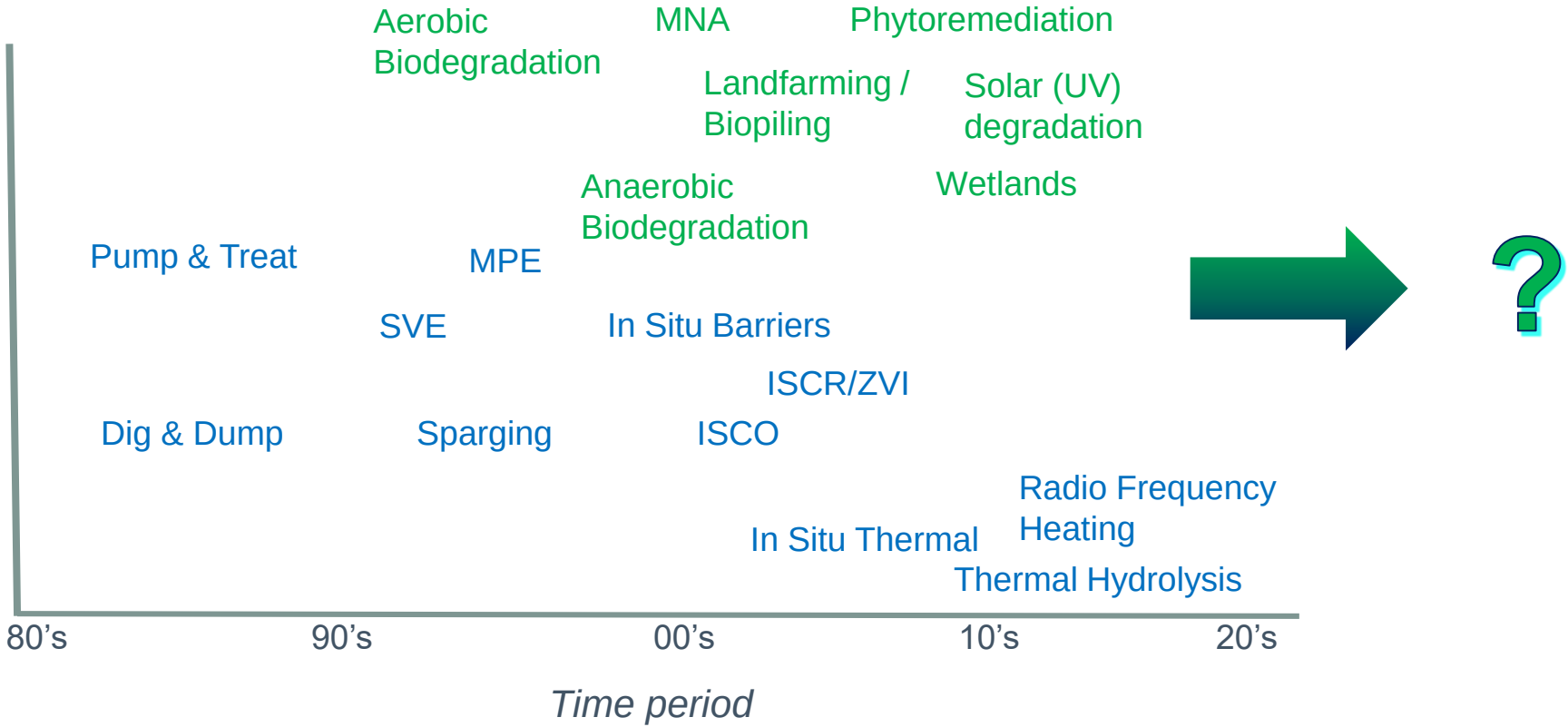
- Remediation over the last 30 years has made a major leap from very “primitive” remediation technology to very “sophisticated” technologies



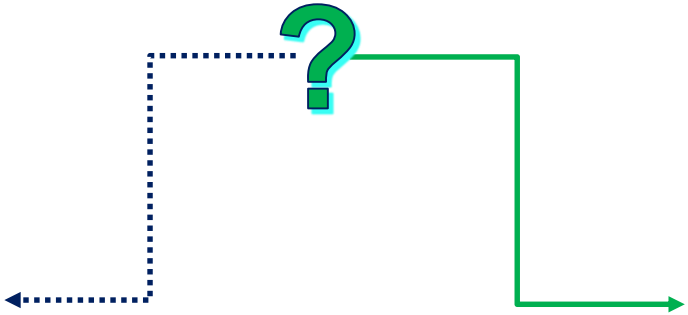
- Remediation has evolved from excavations and pump & treat to in situ injections of various materials, thermal and phyto enhanced remediation systems.
- Emerging contaminants pose new challenges


Remediation Technologies
Aerobic Biodegradation
MNA
Phytoremediation
Pump and Treat
Anaerobic Biodegradation
MPE
In situ barriers
SVE
ISCR/ZVI
Dig and Dump
ISCO
Sparging
In Situ Thermal
Extensive Nature Based
Intensive Chem/physical
80's
90's
00's
10's
20's
Compounds of Concern
BTEX
TPH
PAH
CVOC
Heavy Metals
Pesticides
Biodegradation products (e.g. VC)
MtBE/EtBE/TBA
1,4-dioxane
PFAS
Plastics
Medicines

Remediation Implementation



WHERE TO FROM HERE



Intensive Chemical / Physical Solutions

Extensive Nature Based Solutions

Nature Based Remediation Solution unless ….

Change of coarse (in progress)

- Move to Nature Based Remediation where feasible
  - Supports Dow's Valuing Nature Goal
  - Identify and incorporate ecosystem services
  - Reduce Remediation Cost
  - Reduce use of Hazardous materials
  - Reduce the CO_2 footprint for remediation

Valuing Nature
Dow applies a business decision process that values nature, which will deliver business value and natural capital value through projects that are good for the company and better for ecosystems.

- Dow has set up a Nature Based Remediation Task Force
  - Assess current available Natural Remediation solutions
  - Identify which projects are currently already "Nature Based"
  - Assess which current projects can potentially be transformed to a Nature Based solution
  - Define a research agenda for finding Nature Based Remediation solutions

Nature Based Remediation

- When is a project Nature Based…?
  - When 50% or more of the Contaminant Mass is removed by Natural Processes
    - ✓ Biodegradation, UV Sunlight, bioprecipitation (metal sulphides), Phyto
  - Doesn't mean more than 50% of the budget is spent on Nature Based Remediation

- In-Scope
  - Natural solutions, including flora, bacteria, fungi, wind, sunlight, bioreactors, engineered natural technologies, etc.
  - Natural attenuation where mass removal can be demonstrated
  - Using conventional systems to assist natural remedy:
    - ✓ Advanced oxidation to reduce to a compound that can be naturally degraded
    - ✓ Pumping groundwater to expose to sunlight for degradation

Hot Springs Limestone Natural Zinc Sorption Channel

The Grey Area – Out of Scope ?

- What is a Natural system exactly?
  - Application of Solar Energy for heating or power generation?
  - Natural sorption materials for heavy metals?
  - Natural attenuation processes (sorption, dilution, diffusion)?
- Metrics (mass removal, CO2 footprint, waste generation, multicriteria analysis) : Keep it Simple !

Hot Springs Limestone Natural Zinc Sorption Channel

1,4-Dioxane Remediation

- 1,4-Dioxane characteristics
  - Completely miscible in water
  - Not volatile
  - In 2012 considered not biological degradable
  - Has a half life of 4-6 hours under UV

- What to do with a plume with Dioxane?
- Most likely solution was Pump & Treat with an UVOX for treatment

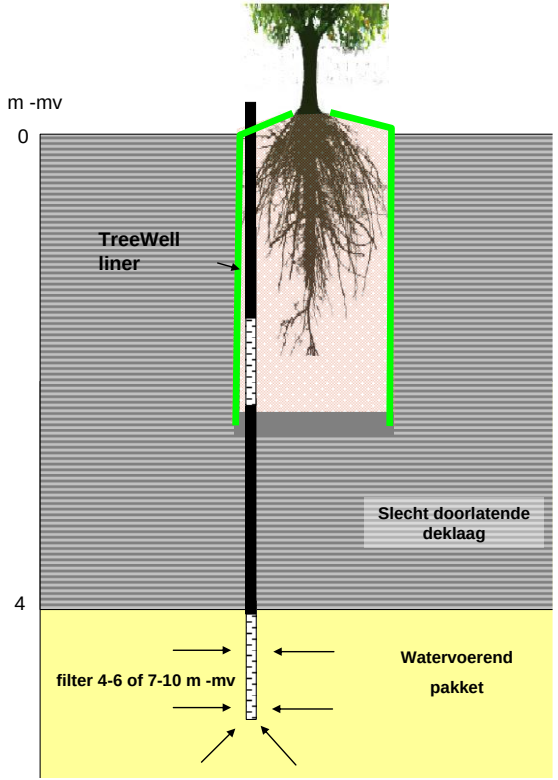
- What if you could bring the groundwater in contact with sunlight..

1,4-Dioxane Remediation, *cont'd*

- Tested 1,4-Dioxane on trees (Poplar) for toxicity
- Adapted TreeWell® technology for deeper groundwater
- Groundwater from -8m bgl taken up by Poplar. 1,4-Dioxane exposed to sunlight on the leave and degraded
- Installed 240 male poplar trees

- CO_2 footprint of remediation:
  - Conventional -> 969 MT CO_2
  - Phytoremediation -> -205 MT CO_2 (incl Carbon Capture)

- Phytoremediation ~ 50% cheaper than conventional remediation



POSSIBILITIES - CHALLENGE THE OBVIOUS

- Biodegradable?
  - 1,4-Dioxane was supposed to be non-biodegradable (literature)
    - ✓ Mass Balance and Root Zone investigation
      - – Found various bacteria species which are metabolizing 1,4-Dioxane
    - ✓ 1,4-Dioxane is biodegradable!
  - 2,6-Dimethylmorpholine (DMM) is supposed to be not biodegradable (literature)
    - ✓ Recent investigations of a P&T sand filter showed bacteria degrading DMM
    - ✓ DMM is biodegradable
- Knowledge on ecosystem services and capacities continues to evolve
- ***Key Message : natural systems can adapt to a changing environment !***

When Nature Based Remediation of a certain compound seems not possible?

Change the circumstances and parameters and keep an open mind.

"When you can't change the direction of the wind, adjust your sails."
H. Jackson Brown Jr.

Thank you for your attention

Seek

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