Monitored natural attenuation (MNA) as a long-term management technique for contaminated sites

Application and experience

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Scope of presentation

- The processes
- Evaluating MNA
- A quick case summary – petroleum hydrocarbon spill
- The range of MNA applicability
- Conclusions

Natural attenuation (NA)

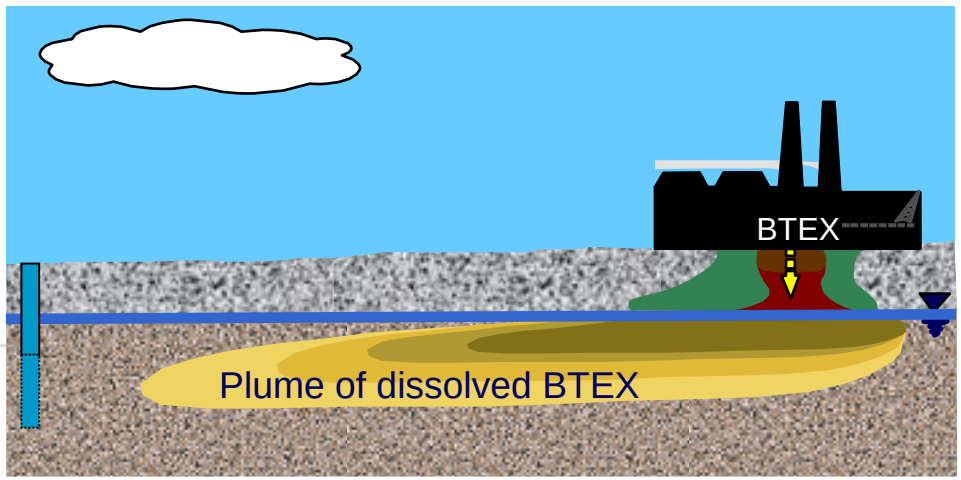
The effect of naturally occurring physical, chemical and biological processes, or any combination of these processes to reduce the load, concentration, flux or toxicity of polluting substances in groundwater. For natural attenuation to be effective as a remedial action, the rate at which these processes occur must be sufficient to prevent polluting substances entering identified receptors and to minimise expansion of pollutant plumes into currently unpolluted groundwater. Dilution within a receptor, such as a river or borehole, is not natural attenuation.

Environment Agency R&D P95

Monitored natural attenuation (MNA)

Monitoring of groundwater to confirm whether NA processes are acting at a sufficient rate to ensure that the wider environment is unaffected and that remedial objectives will be achieved within a reasonable timescale; this will typically be less than one generation or 30 years.

Environment Agency R&D P95



Contributing processes

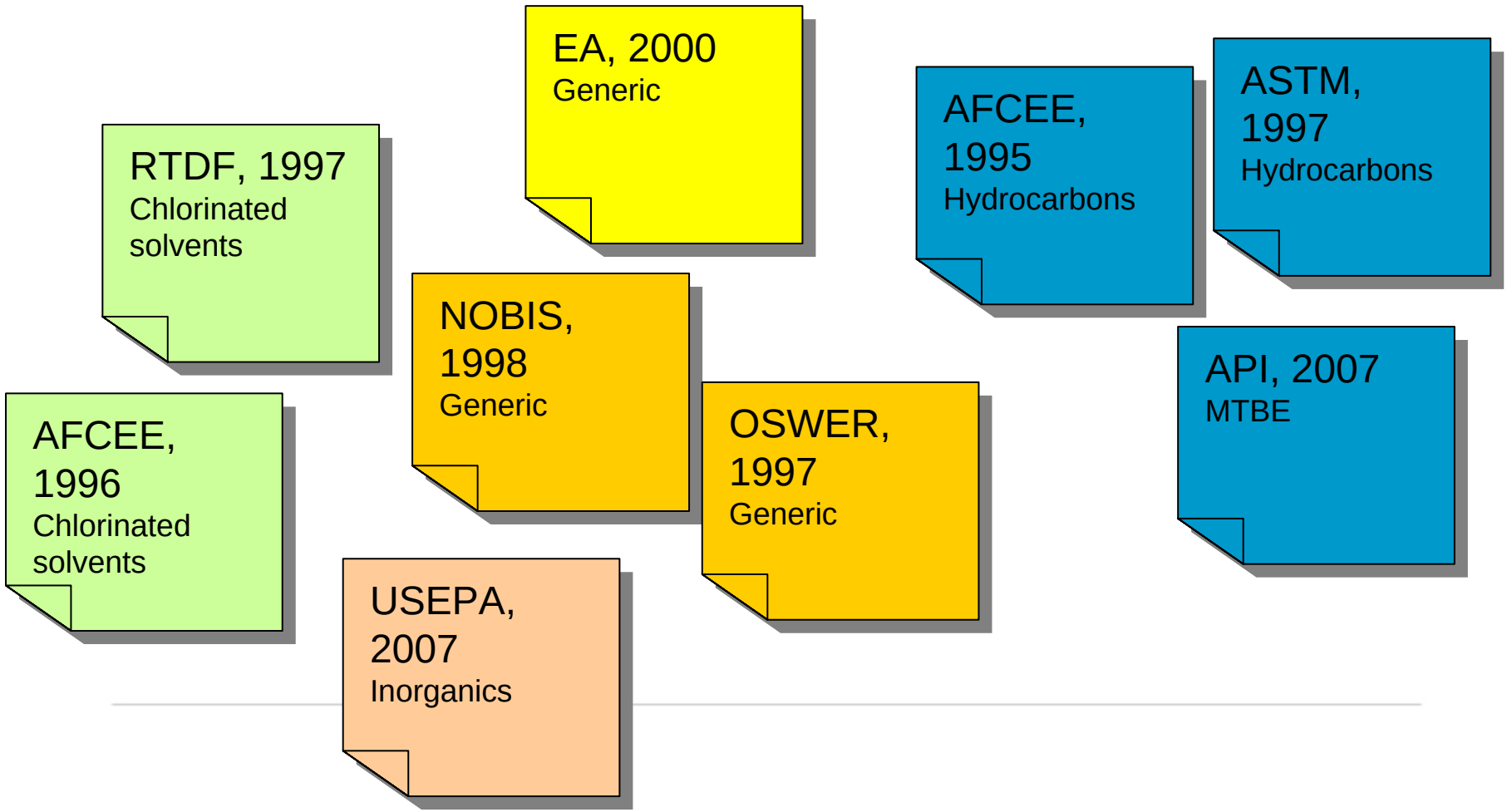
Physical
Diffusion
Advection
Dispersion
Dilution
Sorption
Volatilisation
Decay

Chemical
Speciation
Redox reactions
Precipitation

Biological
Redox reactions
Biodegradation

Risk management
(Stand-alone or combined remediation)

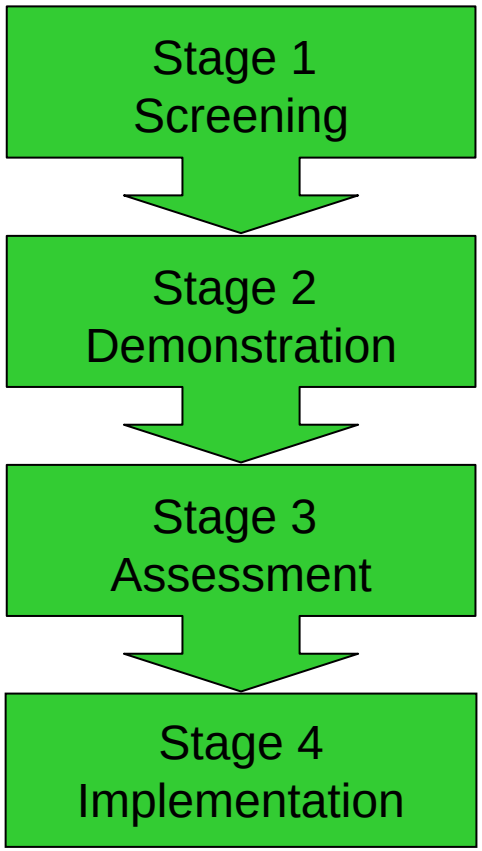
MNA guidance



Lines of evidence for MNA assessment

1. Evidence for elimination of contaminants on the field scale
    e.g. mass loss from plume
2. Field data on the processes contributing to Natural Attenuation
    e.g. degradation products, hydrochemistry
3. (Supporting laboratory evidence)
    e.g. biodegradation, sorption tests

MNA evaluation framework



Preliminary assessment
Is NA a viable option ?

MNA characterisation
What evidence is there that NA is occurring now ?

Prediction
Will MNA meet risk management objectives in future?

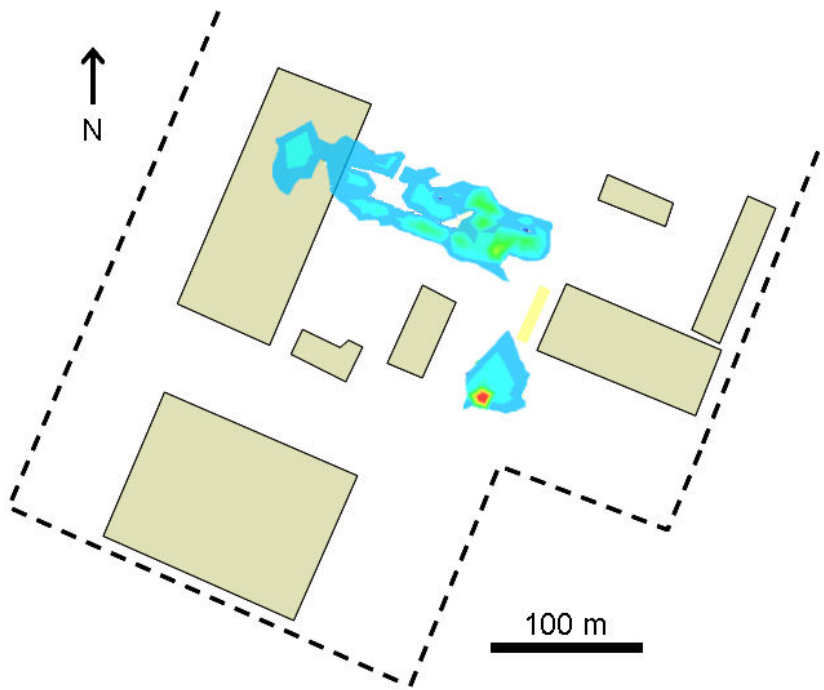
Verification and monitoring
Does MNA continue to meet objectives in practice?

Case summary - hydrocarbon spill, SE England

- Major supermarket distribution centre
  - Must stay fully operational
- Historic diesel spill caused contamination of soil and groundwater
- High regulatory interest
  - Risk to adjacent river
- Integrated investigation, risk assessment and remediation

Project activities

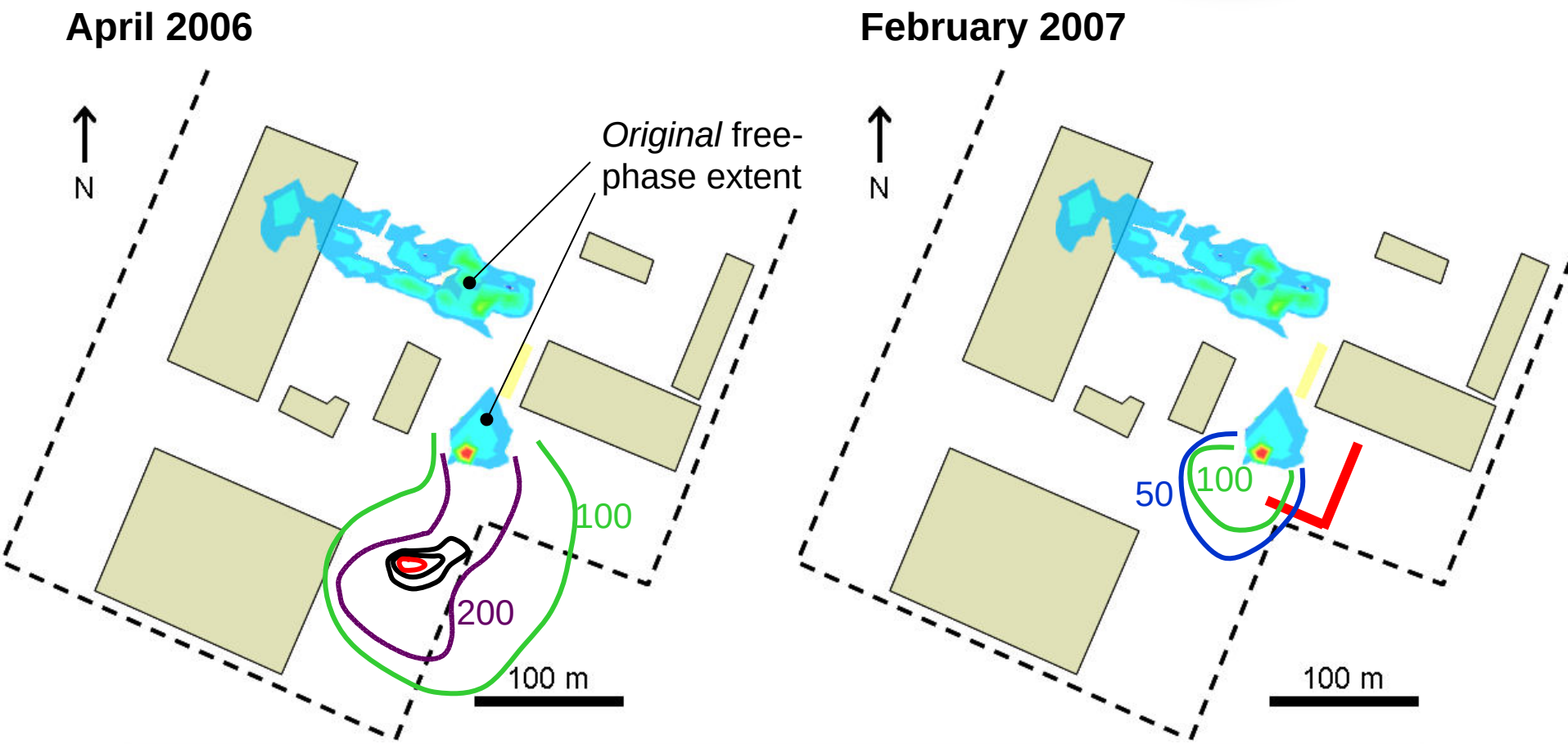
- Urgent investigation, risk assessments and remediation
- Remediation strategy:
  - Source remediation by multiphase vacuum extraction
  - Ground barrier (60 m long x 9.5 m deep) to prevent oil migration to third party land
  - Monitored natural attenuation (MNA) for plume management



Lines of evidence - 1

- Elimination of contaminants on field scale
  - Attenuation rate calculations per borehole (or borehole cluster)
    - Attenuation process contributions
  - Mass flux (flux fence) calculations
  - Contour plots

Example evidence for MNA of plume



Sum TPH (µg/l)

Lines of evidence - 2

- Field data on contributing processes
  - Ratio of readily degradable hydrocarbon components to pristane & phytane
  - Hydrochemical indicators of biodegradation
    - Dissolved oxygen only in actively remediated source area
    - Elevated dissolved Mn and Fe in plume core and immediately downgradient
    - No significant nitrate reduction, sulphate reduction or methane production
    - Mass balance with hydrocarbon degradation

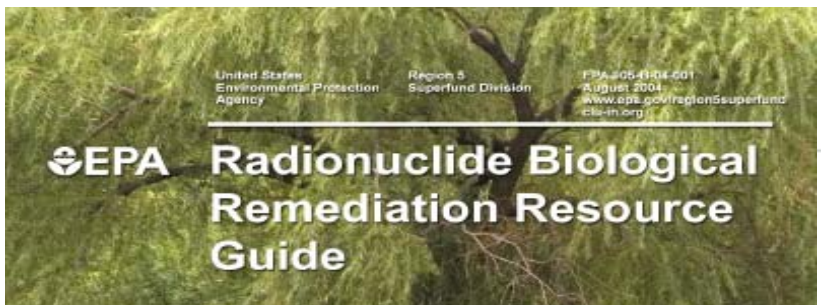
MNA's track record

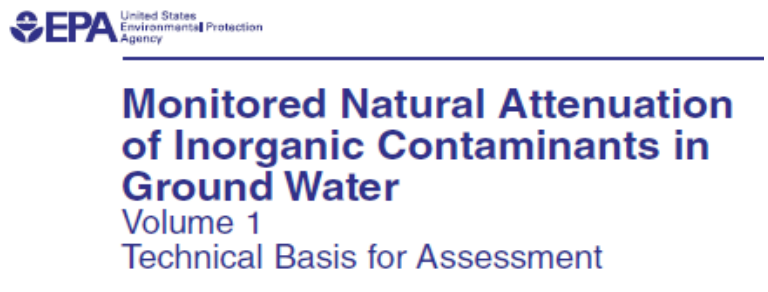
- Reported cases include:
  - Landfill leachate
  - Petroleum hydrocarbons
  - Chlorinated solvents
  - Chlorinated aromatics
  - Some nitroaromatics
  - Phenolics
  - Pesticides
  - Certain inorganics

- Nitrate
- Ammonium
- Cyanide
- Metals
- Radionuclides

Application of MNA for radionuclides

- No specific UK guidance
- Inorganic attenuation processes will apply
  - Reversibility?
- Decay chain
  - Properties of daughter product(s)?
  - Duration?
- Effectiveness likely determined by the most mobile and persistent components





Screening MNA potential – a hydrogeologist's first pass?

Intergranular	Oxford Clay	Sand and gravels	Greensand
Intergranular and fracture	Mercia Mudstone	Coal Measures	Permo-Triassic Sandstone
Fracture	Shales	Millstone Grit	Chalk & Carboniferous Limestone
	Non-Aquifer	*Minor Aquifer*	*Major Aquifer*

Increasing ease / confidence in demonstrating NA effectiveness

Indicative only! Site-specific!

Smith & Lerner (2007) *QJEGH* **40**, 137-146.

Screening MNA potential – some more primary considerations

Criteria	Feasibility		
	High	Intermediate	Low
Source of groundwater contamination	Removed	Under removal or exhausted	**CONTINUING**
Contaminant plume status	Shrinking	Stable	Expanding
Receptor	No external receptors	Receptors present (low risk)	Receptors present (high risk)
Operating windows	Within	On boundary	**OUTSIDE**
Groundwater SPZ	Outside SPZ	Within SPZ III	In **SPZ I** or SPZII
Objectives of landowner for site	Long-term interest (>10 yrs)	Medium-term interest (3-10 yrs)	Short-term ownership (< 3 yrs)

Indicative only! Site-specific!

In summary

- MNA is a viable risk management option for groundwater plumes
  - Subject to site circumstances
  - Alone or in combination with enhanced remediation
- Good guidance exists
- Applicable to a wide variety of contaminants

When MNA?

- ✓ When you can demonstrate it is protective of the receptor(s)
- ✓ When longer-term treatment is needed and appropriate
- ✓ When the plume's future can be understood
- ✓ When it is economic
- ✓ When it can be monitored
- ✓ When the end-point is stable and acceptable

- ✘ When risk(s) to receptor(s) is or will become unacceptable
- ✘ When rapid "closure" is desired
- ✘ When a plume is still expanding significantly
- ✘ When the economics don't make sense
- ✘ When a monitoring programme cannot be implemented or continuity ensured