BIORESTORATION END-POINT SCENARIO WITH BIO-ATTENUATION

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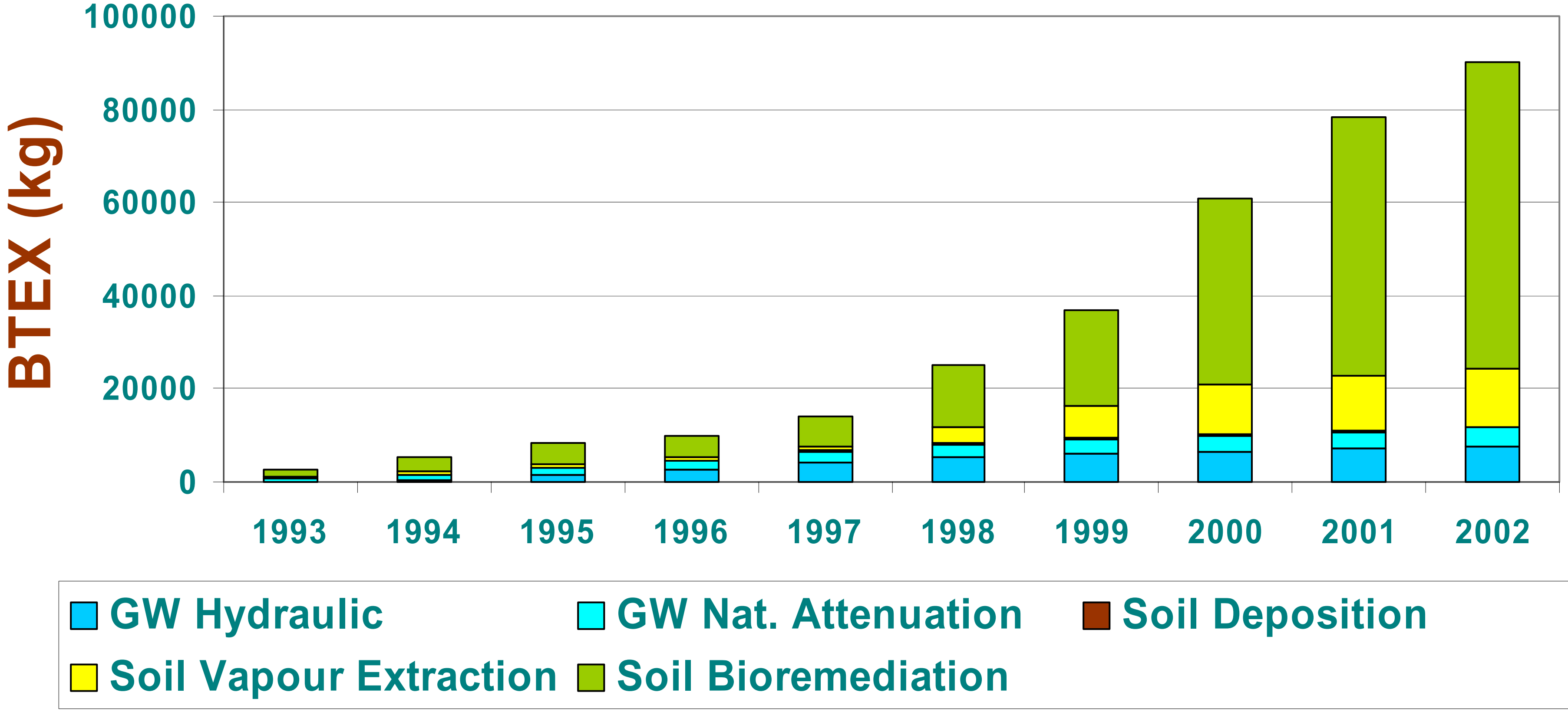
RMIT UNIVERSITY

Rheingold Project: Germany

- Four distinct BTEX plumes
- Porous sandy gravel aquifer
- Water table ~5m bgs; bedrock ~33m bgs
- Groundwater flow ~100m/yr
- Adjacent & downstream residences & receptors

- Active remediation over several years
- Bioventing/Biosparging/Biofiltration
- Enhanced *in situ* bioremediation
- **Monitored natural attenuation**

Cumulative Total VOC Recovery



(4 plumes)

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Bioremediation Phases

BTEX > 10,000 µg/l: High toxicity no / low biodegradation rate
SOURCE REMOVAL

BTEX 1000 – 10000 µg/l: Low toxicity /High biodegradation rate
MAXIMIZE ACTIVE BIOREMEDIATION

BTEX < 1000 µg/l: low toxicity – low biodegradation rate

MONITOR NATURAL ATTENUATION

Bioremediation Phases

Source Removal (SVE, Slurping, Groundwater Recovery)

Active Bioremediation (Biosparging, Bioventing, Infiltration

Endpoint Scenario (I)

Field Target Levels Reached
Shut Down Installed Systems (Cost Savings)
Preferred Conditions Established

Low Intensity Bioremediation (ORCs, Nitrate, Sulphate, Sparge Curtain)

Endpoint Scenario (II)

Stable Biorestoration Conditions Maintained
Field & Boundary Levels Maintained
Decommission Installed Systems (Redeploy)

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Bioremediation Phases

Low Intensity Bioremediation (ORCs, Nitrate, Sulphate, Sparge Curtain)

Endpoint Scenario (II)

Stable Biorestoration Conditions Maintained
Field & Boundary Levels Maintained
Decommission Installed Systems (Redeploy)

Passive Biorestoration (Natural Attenuation, Monitoring)

No Energy,
Minimal Costs,
Extended Time Frames

(Sign-Off)

Transition to MNA?

Low Intensity Bioremediation

Decision Basis?

Passive Biorestoration

Transition to MNA?

Requirements

- Microbial Degradation Potential & Activity
- Essential Nutrients
- Absence of Toxicity (Intrinsic & Extrinsic)
- Time & Distance Safety Factors
- Electron Acceptors & Appropriate Redox

Attenuation Capacity >> Residual Contamination Demand

Monitoring MNA?

Attenuation Capacity

•Microbial Activity	Respiration
•Nutrients	Analysis
•Toxicity	Biosensors
•Safety Factors	Decay Equations
•Electron Acceptors	Analysis
•Redox	***In situ*** Measurement

Residual Contamination Demand

•Contaminants	Analysis

Natural Attenuation Capacity

Electron Acceptors	BTEX Equivalence
•Oxygen	0.32
•Nitrate	0.21
•Ferric Iron	0.05
•Sulphate	0.22
•CO_2 (methanogenesis)	1.28

•*(Manganese IV ion)*

Optimum Redox Potentials for NA

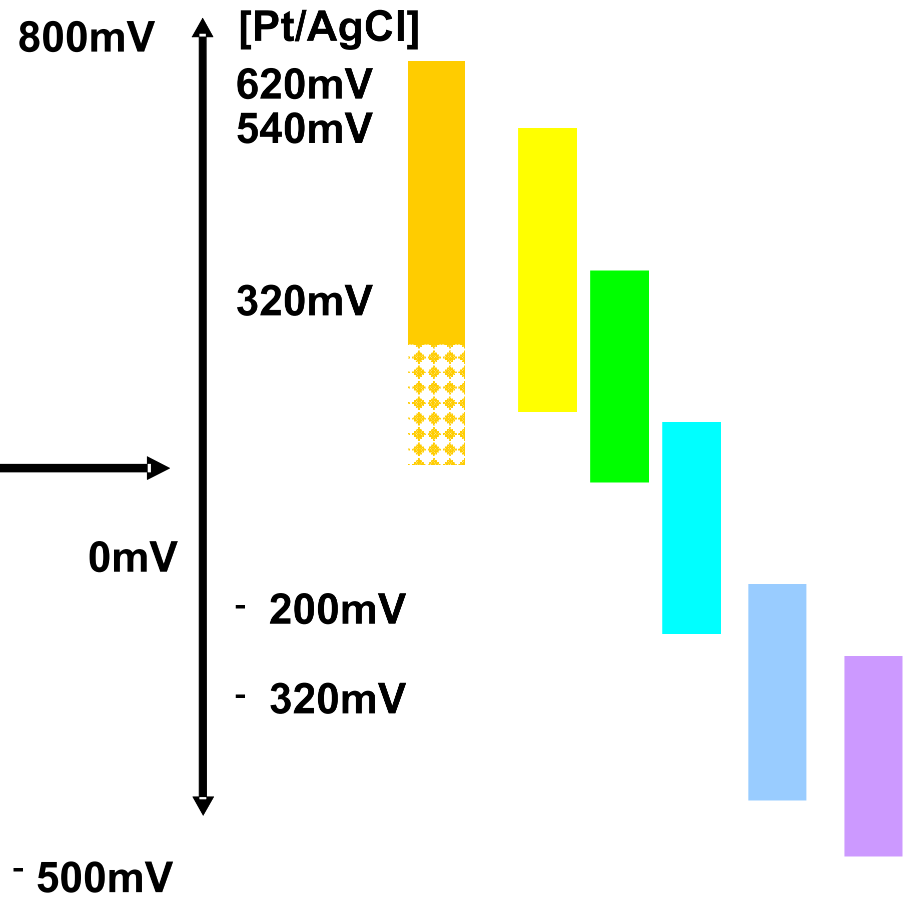
Oxidation of Toluene by Oxygen
Oxidation of Toluene by Nitrate

Oxidation of Toluene by Manganese

Oxidation of Toluene by Iron
Lower limit of RedOx for use of Oxygen

Oxidation of Toluene by Sulphate

Oxidation of Toluene by Methanogenesis



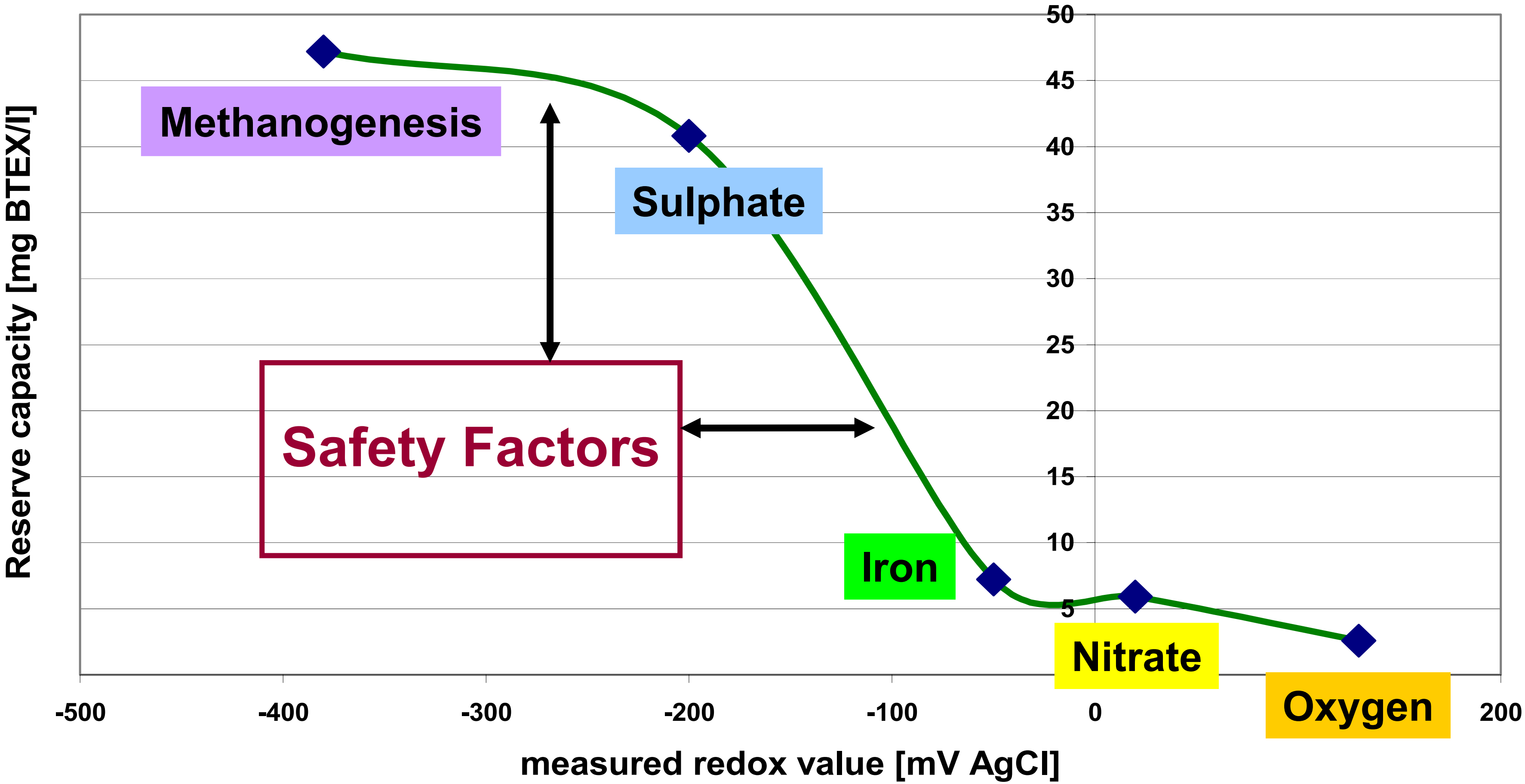
Groundwater Changes Through NA

Sample Point	O_2 (mg/l)	NO_3 (mg/l)	Fe^{II} (mg/l)	SO_4 (mg/l)	CH_4 (mg/l)
Upstream	5	25	0.06	200	0
In Plume	0	0	20.0	32	29
Differences	-5	-25	+19.94	-168	+29
Toluene Equivalence Factors	0.32	0.21	0.05	0.22	1.28
Toluene Equivalent Degraded	1.6	5.2	1	37	37

(Tankfarm 2 plume, Dusseldorf)

TOTAL 81.8 (mg/l)

Reserve Capacity vs. Redox



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Monitoring MNA?

Attenuation Capacity

•Microbial Activity	Respiration
•Nutrients	Analysis
•Toxicity	Biosensors
•Safety Factors	Decay Equations
•Electron Acceptors	Analysis
•Redox	***In situ*** Measurement

Residual Contamination Demand

•Contaminants	Analysis

Non-specific biosensors

e.g. *Ps. fluorescens* pUCD607 (non-degrader)

Monthly MNA Summary Sheet TF2

Well	Redox	EAC O2-NO3	EAC O2-NO3 Fe SO4	Total BTEX	Consent Value	Safety Factor (aerobic)	Safety Factor (total)	Microb Act.	Nutrients		Tox
	mV	mg/l	mg/l	µg/l	µg/l	Aim>1	Aim >10		N	P	
BrXV	-57	0.16	33.82	1			>500	Yes	no	Yes	No
F1	69	4.34	44.15	1			>500	Yes	Yes	Yes	no
GW25	-88	0.20	31.48	561			56	Yes	no	Yes	no
GW28	-42	0.14	40.02	1			>500	Yes	no	Yes	no
GW30	13	0.47	39.73	1			>500	Yes	Yes	Yes	no
GW31	105	6.24	31.75	3518			9	Yes	Yes	Yes	no
GW32	-114	0.10	24.80	5710			4	Yes	no	Yes	no
BrXIII	41	7.32	38.11	1	85	7321		Yes	Yes	no	no
F2	-44	1.19	37.22	1	85	1194		Yes	Yes	Yes	no
P23	-77	0.14	38.36	1	85	145		Yes	no	Yes	no

Summary

•Active remediation goals, including bioremediation goals were achieved

•Transition from active bioremediation to MNA was successfully implemented

•The MNA monitoring and reporting tools meet the needs of the stakeholders (simple & effective)

•Safety factors and consent values can be tailored to individual contamination and risk contexts

Conclusions

Monitored Natural Attenuation (MNA) requires active monitoring of key, relevant parameters with simplified reporting appropriate for all stakeholders.

Reserve capacity (and safety factors) change over time and must be monitored closely.

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Land Management

Bioremediation Feasibility

Biorestoration

Project Management

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