WELCOME

Site visit of the Life project Vopak-EXPERO3 (LIFE09 ENV/BE/000407)

20 June 2014

RSK

BADECO

Vopak

Vopak Chemical Terminals Belgium N.V.
Member of Royal Vopak

Demonstration project Vopak-ExperO3

LIFE09 ENV/BE/000407

Using ISCO with perozone for the remediation of a cocktail of organic contaminants at an EX-rated industrial site in operation

Toepassing van ISCO dmv perozone voor de sanering van een mengsel van organische contaminanten op een EX-gezoneerde industriële site

Info: **www.vopak-ExperO3.be**

Vopak

RSK GROUP PLC

BADECO

Agenda

Time	Topic	Responsible
10h-10h15	Welcome and Safety film (required for all visitors)	
10h15-10h30	Presentation partners	Wim Van Bogaert, Tim De Bouw, Paul Baert
10h30-11h15	Presentation of the project and interim results	Tim De Bouw
11h15-13h	Discussion of the state of play of technical, financial and administrative issues	All
13h-14h	Lunch	
14h-15h30	Site visit	Tim De Bouw / Edward Van de Ven (Verhoeve)
15h30-16h	Wrap-up of the meeting	

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Partnership

- between the owner of the soil contamination

Vopak

and the soil remediation specialist and the safety expert

RSK

BADECO

- with performer Verhoeve Milieu & Water

Aurora Solutions
Verhoeve
Milieu & Water

- under supervision of the EU by Astrale

Astrale
Life team

Life

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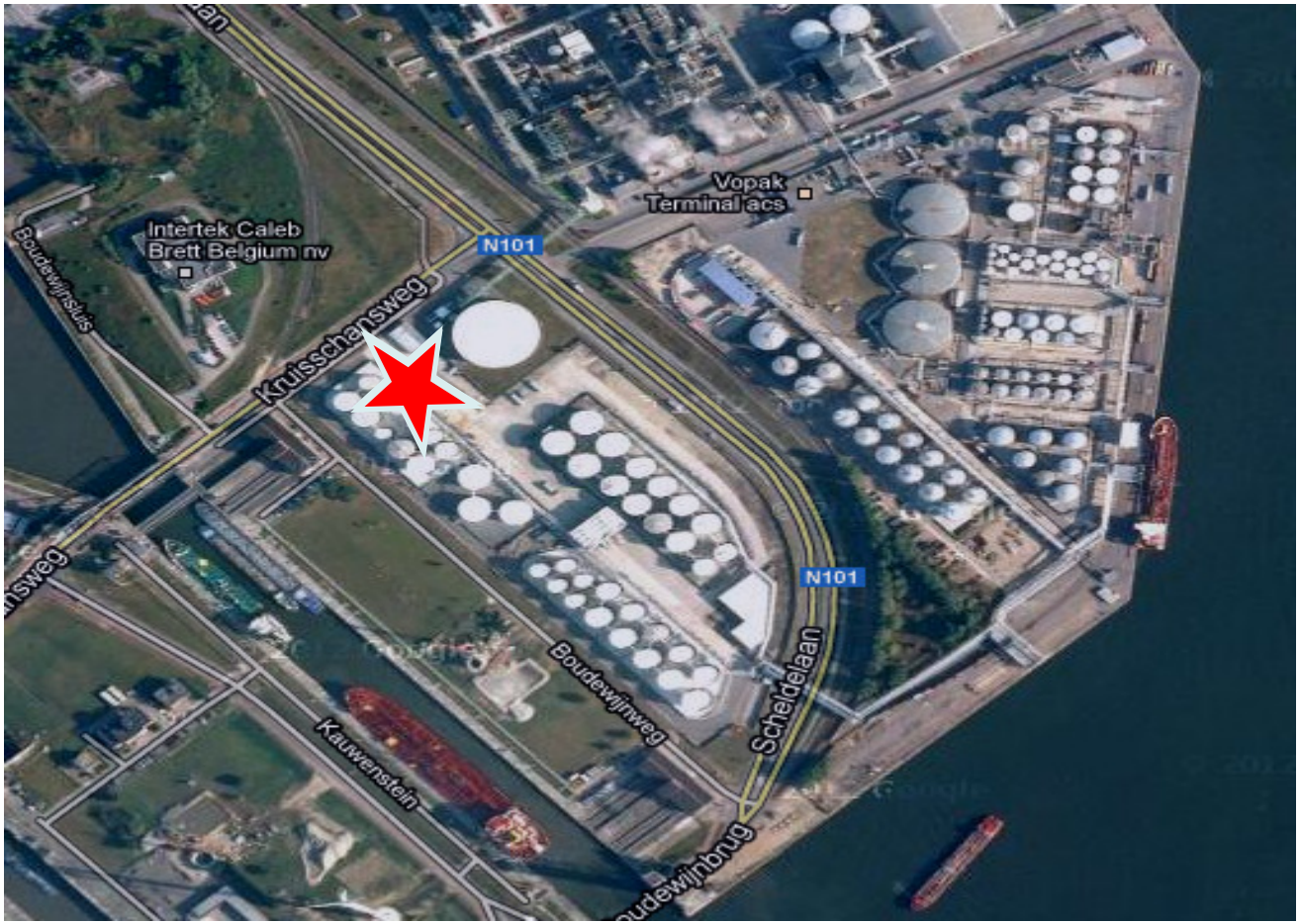
Soil & Groundwater contamination Vopak Terminal ACS

Treatment of chemicals in the seventies and eighties have caused a historical soil and groundwater contamination

Vopak Terminal ACS (VTA) – South: active remediation required, but how?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Terminal acs
Intertek Caleb
Brett Belgium nv
N101
Boudewijnsluis
Kruisschansweg
N101
Boudewijnweg
Scheldelaan
Kauwenstein

Soil and groundwater contamination VTA - South

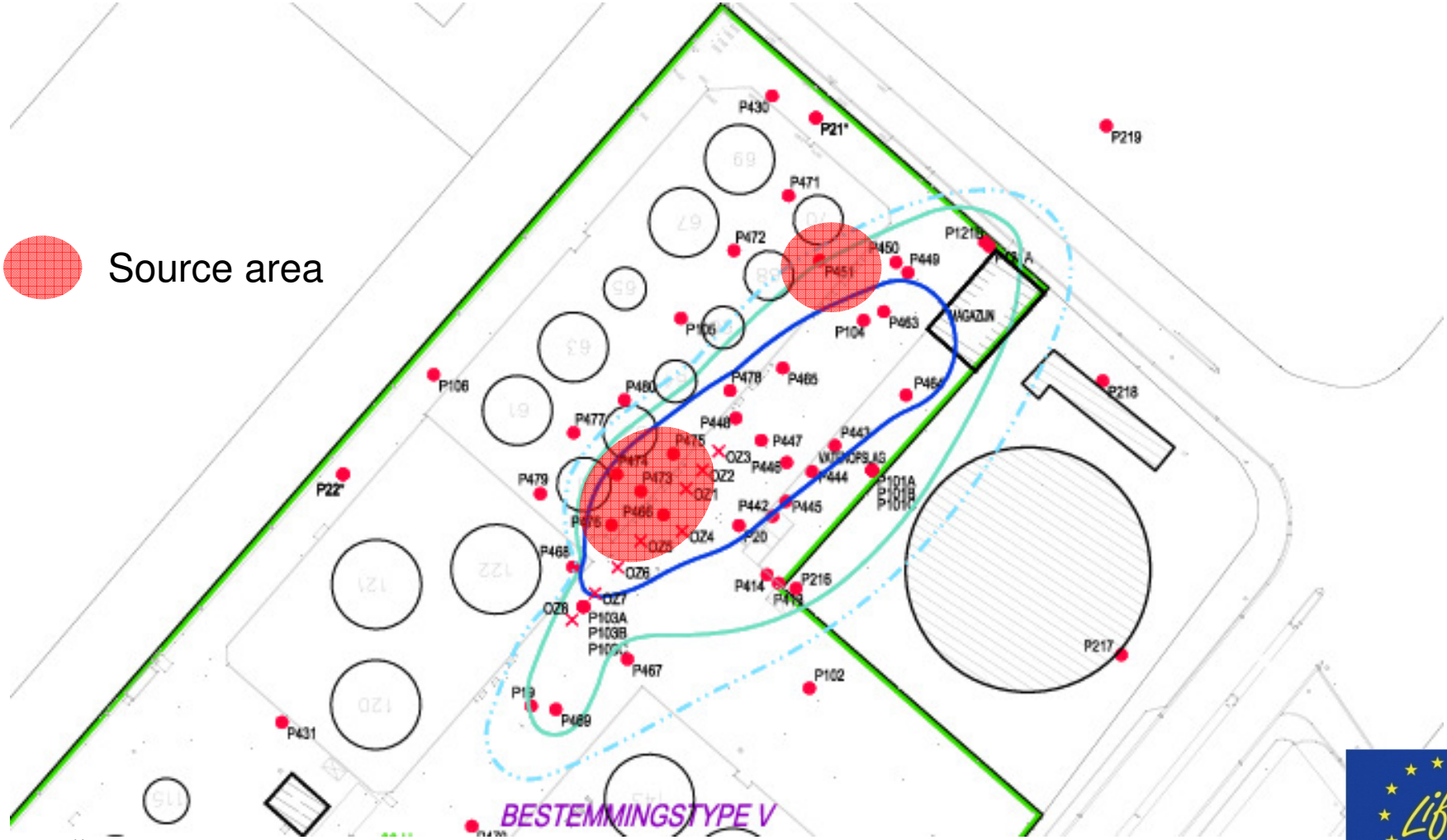
- **contamination with (volatile) mineral oil, BTEX, chlorinated solvents**
- situated near the entrance of the terminal
- about 10 years of soil investigations and pilot tests

Soil and groundwater contamination VTA – South

Date	Investigations and remedial actions
‘96 – ’98	Groundwater monitoring
’99	Initial site investigation
’02 - ‘05	Comprehensive site investigation and risk assessment
’05	periodic initial site investigation (legal obligation)
‘07 – ’13	Annual groundwater monitoring
‘06	Pilot test enhanced natural attenuation
’08 - ’09	Pilot test MPE – horizontal drains & vertical wells
’10	Pilot test ISCO - perozone
’11	Remedial action plan (approved by authorities)
’12	Start full-scale remediation works

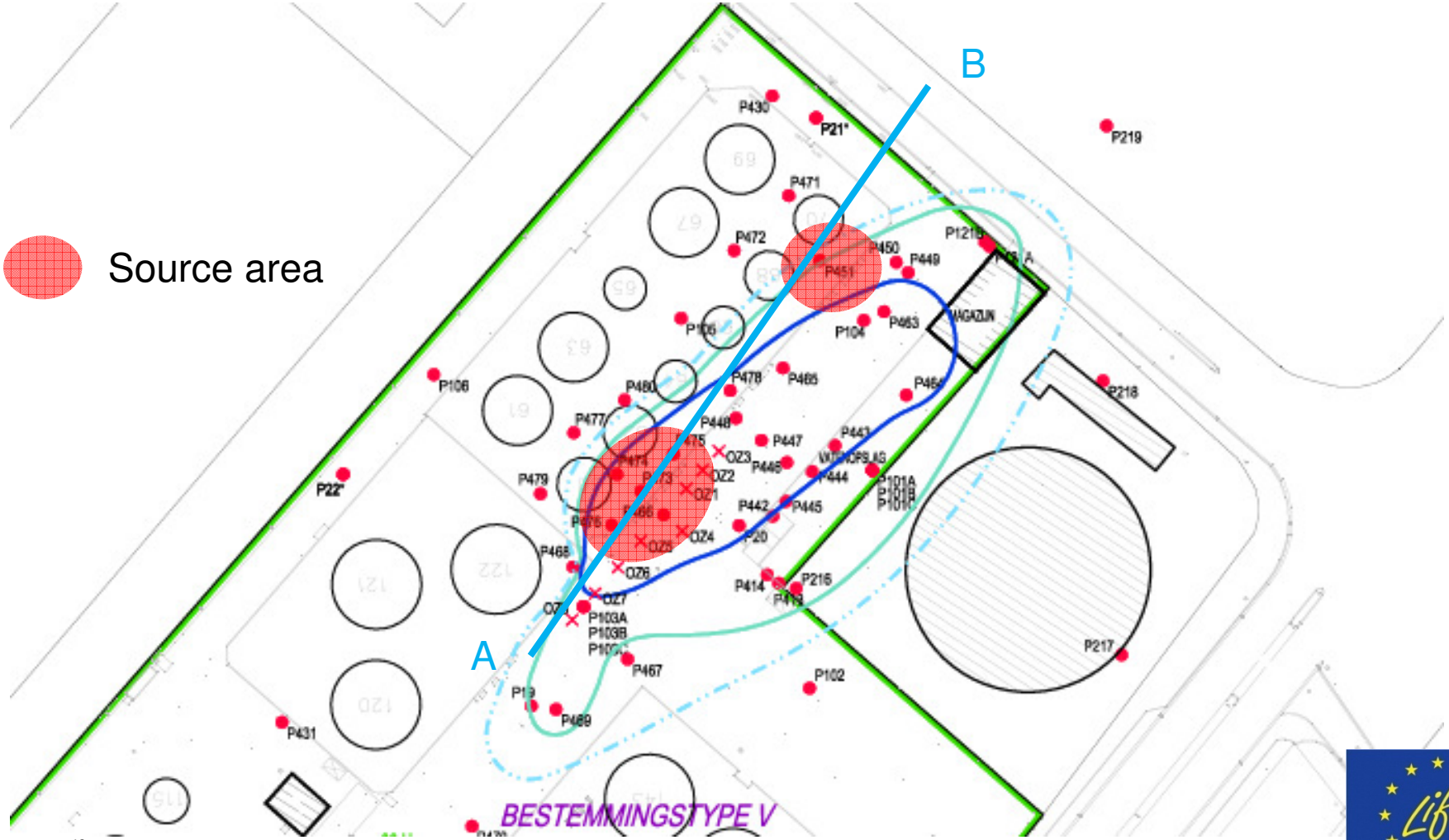
Soil and groundwater contamination VTA - South

Source area

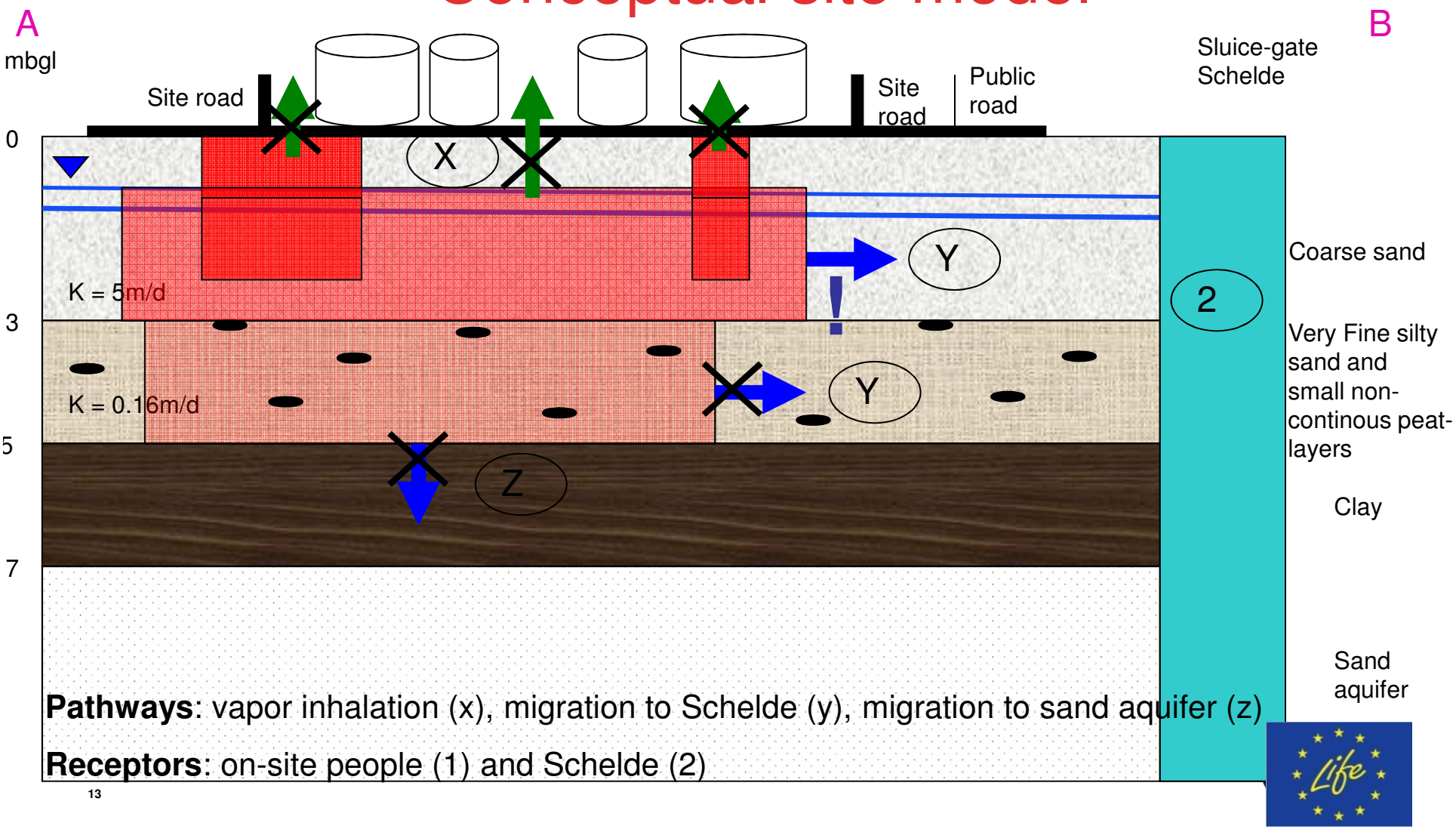


Conceptual site model

Source area



Conceptual site model



Remediation concept VTA South

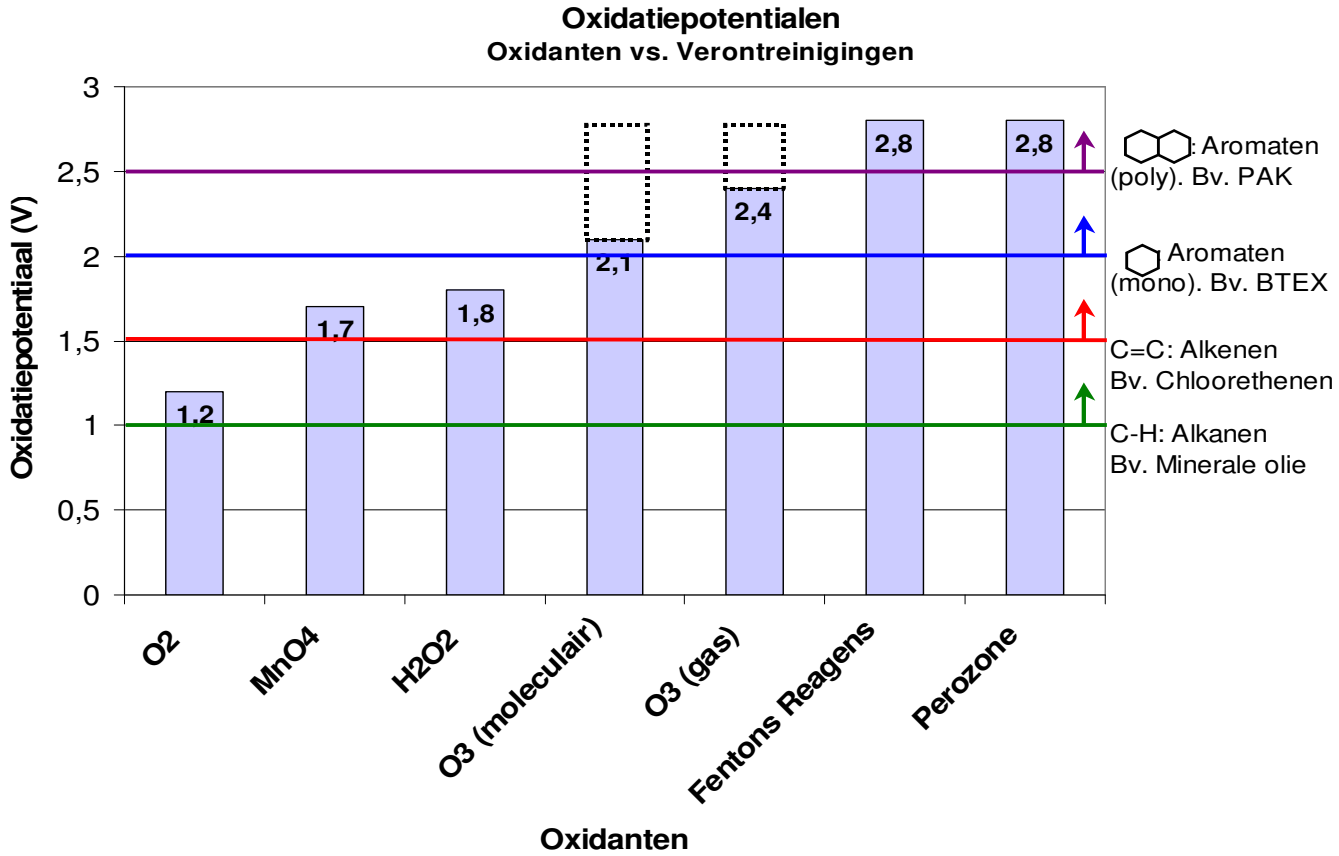
- Legal obligation for historical contamination: eliminate the (potential) risk
- **Vopaks objective** is to eliminate the risks and to achieve a stable situation in a relatively short period of time**.**
- **Two important constraints:**
  - terminal should stay operational; AND
  - Additional HSE risk for a storage terminal with flammable/explosive liquids should be manageable!

Remediation concept VTA South

- (More) traditional technologies are technically or operationally not feasible.
- Pilot test using In situ chemical oxidation (ISCO) with perozone showed promising results
- Remedial action plan (including ISCO) has been approved by the Flemish authorities (OVAM) in 2012 ;
- Remediation objective: 10 times Flemish threshold value & elimination of migration risk in the layer from 1 to 3mbgl

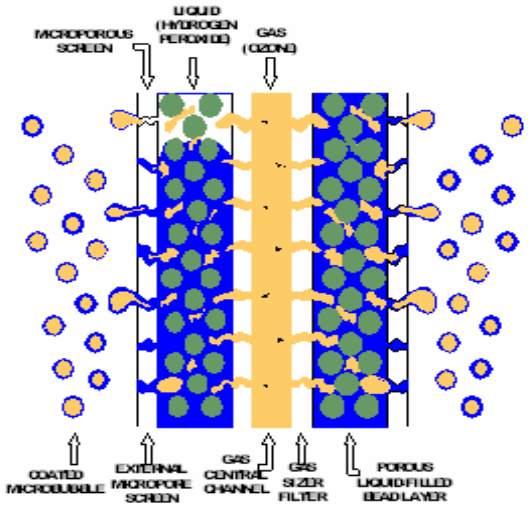
Remediation concept: ISCO (in-situ chemical oxidation)

- Application of specific chemicals with a high potential for the oxidation of contaminants



Remediation concept: ISCO - Perozone®

- Perozone® : combination ozone en hydrogen peroxide
- Injection through special Laminar Spargepoints®
- Microbubbles with ozone “coated” by peroxide



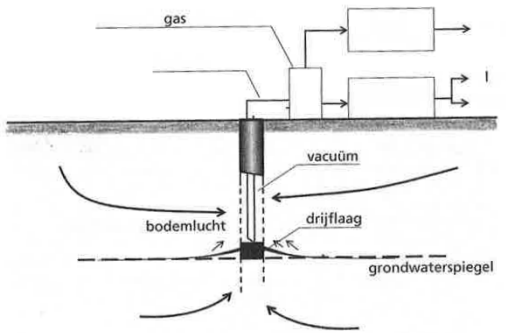
Vopak

Remediation concept: ISCO - Perozone®

- Formation of free radicals
  - 2 O3 + H2O2 →2 OH• + 3 O2
  - High oxidation potential → applicable for a mixture of contaminants
  - organic components
  - additional oxygen stimulates aërobic biological degradation
- Positive side effect : mobilisation of the contamination

Remediation concept: MPE (Multi Phase Extraction)

- Combined extraction of pure product, groundwater and soil vapor
- Physical process
- Flexible
- Treatment of pure product groundwater and soil vapor

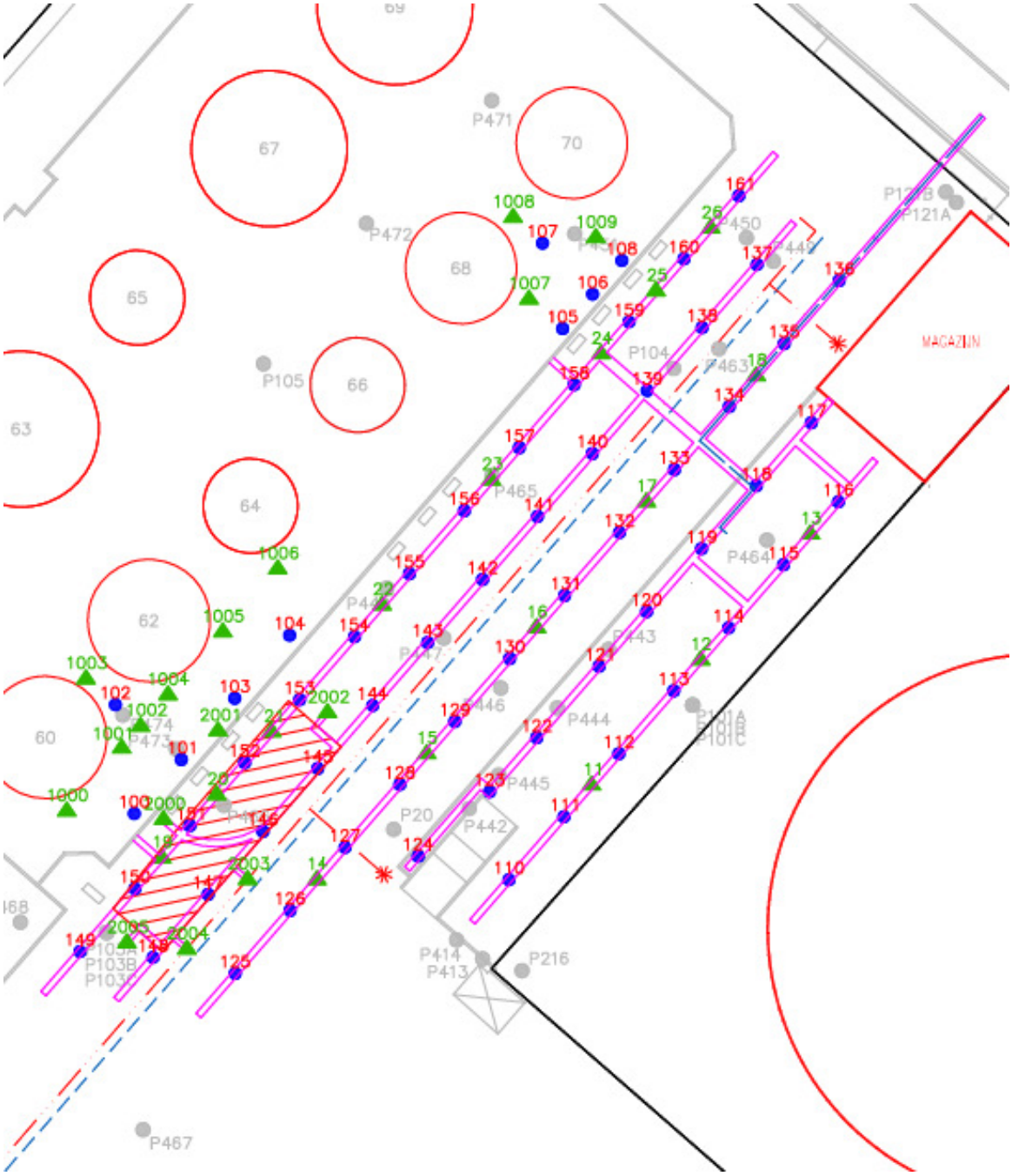


Remediation concept: SVE (Soil vapor extraction)

- Supporting technology (H&S)
- In the vadose zone (unsaturated zone above groundwater table)
- Extraction by horizontal drains
- Extraction of soil vapor (possibly) containing:
  - contaminants
  - ozone
  - oxygen
- Treatment of soil vapor is necessary

Remediation concept VTA South: “the whole picture”

- Source area (1 tot 3m-mv):
  - Excavate where possible (= outside tank farm): 6 x 25 meter, until 2 mbgl
  - Multi phase extraction if excavation impossible (=inside tank farm)
  - ISCO using perozone in combination with SVE: as soon as pure product / very high concentrations eliminated
- Plume (1 to 3mbgl):
  - ISCO using perozone in combination with SVE
- Soil layer 3 tot 5mbgl:
  - ISCO using perozone in combination with SVE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Life+ - program

- Innovation?
  - ➢ ISCO on a EX-rated site:
    - Strong oxidants on a site with (strong) inflammable/explosive products
    - Problem owners are very reluctant to use ISCO
    - ISCO doesn't get opportunities on EX-rated sites

FOCUS ON H&S aspects!

Life+ program

- Objectives
  - Demonstrate the application of ISCO with perozone on EX-rated sites.
  - Develop an extensive health and safety plan defining the necessary safety measures for the use of the technique at EX-rated sites.
  - Develop working procedures for implementation of the technique.
  - Demonstrate the advantages (less carbon emission, more time-, cost- and energy efficient) of the technique in comparison with traditional remediation techniques.
  - Evaluate the remediation technique in terms of viability and economical and environmental feasibility
  - Dissemination of knowledge gathered in this project to target groups and stakeholders.

Action 2 and 3

- Action 2: Extensive H&S-plan for pilot test ISCO with perozone
- Action 3: Pilot test ISCO with perozone
- Both actions undertaken before September 2010 = start of Life+- project
- Result: ISCO with perozone seems both technically and economically feasible and H&S issues seem to be manageable.

Action 4

- Action 4 – Extensive H&S plan for full scale remediation
- H&S-plan has been drawn up (see slides with “H&S considerations”)
- work procedure, incorporating a list of all safety measures that need to be followed during the remediation activities, to enable other parties to transfer the methodology used to other sites

Action 4 – H&S plan / risk inventory

- ONSITE PEROZONE VS. BULK STORAGE FLAMMABLE LIQUIDS

CATALYST FOR IGNITION OR FIRE

- PEROZONE INJECTION IN THE SOIL

UNCONTROLLED EMISSIONS OF VOC & OZONE

Action 4 – H&S plan / risk inventory

- AERATION OF THE SOIL & DEGRADATION OF CHLORINATED VOC

CORROSION OF METALS (TANK BOTTOMS)

- CHEMICAL BREAKDOWN OF HYDROCARBONS

RAISING TEMPERATURE > Δ SOIL CONDITIONS (E.G. EVAPORATION)

Action 4 – H&S plan / risk inventory

- DEGRADATION OF ORGANIC LAYERS IN THE GROUND (PEAT)

SUBSIDENCE - LOSS OF CARRYING CAPACITY > TANK SHELL STRESS

- SOIL VAPOR EXTRACTION & ABSORPTION TO ACTIVATED CARBON (AC)

EXCEEDING LEL (EXPLOSION) & HEATING OF AC (FIRE)

Action 4 – H&S plan / risk inventory

- WORKING IN ATEX ENVIRONMENT

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EXPLOSION INDUCED BY ELECTRICAL EQUIPMENT

Action 4 – work procedure / Lessons Learned

- INVENTORY OF SUBSOIL SITUATION:
  - DISTURBANCES (FOUNDATIONS,…)
  - PREFERENTIAL ROUTING (E.G. BACKFILLING, SEWERS,…)

- INVENTORY OF POTENTIAL RECEPTORS:
  - PRESENCE OF OPERATORS/OTHERS
  - VULNERABLE STRUCTURES (E.G. TANK BOTTOMS)

- EXPLOSION RISKS:
  - LOCATION OF EQUIPMENT
  - MOVING CONTAMINATED SOIL VAPOR & WATER: (RE-)CONSIDER EX-ZONING

Action 4 – work procedure / Lessons Learned

- EQUIPMENT SAFETY:
  - TECHNICAL DEMANDS
  - AUTOMATISATION & SAFETY CONTROLS

- DESIGN OF SVE:
  - COVERING ALL INJECTION AREAS
  - CAPACITY / SAFETY MARGIN

- FIELD QUALITY CONTROL OF:
  - INJECTION WELLS (PRESSURE TEST, DISTRIBUTION OF RAISING AIR BUBBLES)
  - EXTRACTION SYSTEM (LEAKS, WATER LOCKS,…)

Action 4 – work procedure / Lessons Learned

- PRODUCTION/STORAGE OF OXIDISING AGENTS:
  - LOCATION ON SITE VS. CUSTOMER FACILITIES
  - CALCULATION OF CAPACITY NEEDED

- MONITORING OF AIR QUALITY:
  - EQUIPMENT NEEDED
  - SCHEDULE

- MONITORING OF SOIL PARAMETERS:
  - ACIDITY
  - TEMPERATURE
  - REDOX (E.G. NEARBY RECEPTORS)

Action 4 – work procedure / Lessons Learned

- FINETUNING OF PEROZONE INJECTION:
  - SUBZONE CHARACTERISTICS
  - RESIDUAL CONTAMINATION
  - AVOIDING LEAKS TO THE ATMOSPHERE

- TRAINING OF OPERATORS & CUSTOMER SERVICES:
  - INFORMING WHAT TO DO IN CASE OF EMERGENCY
  - DETERMINATION OF SAFETY MATERIALS NEEDED (PPE, FIRE FIGHTING EQUIPM.,…)

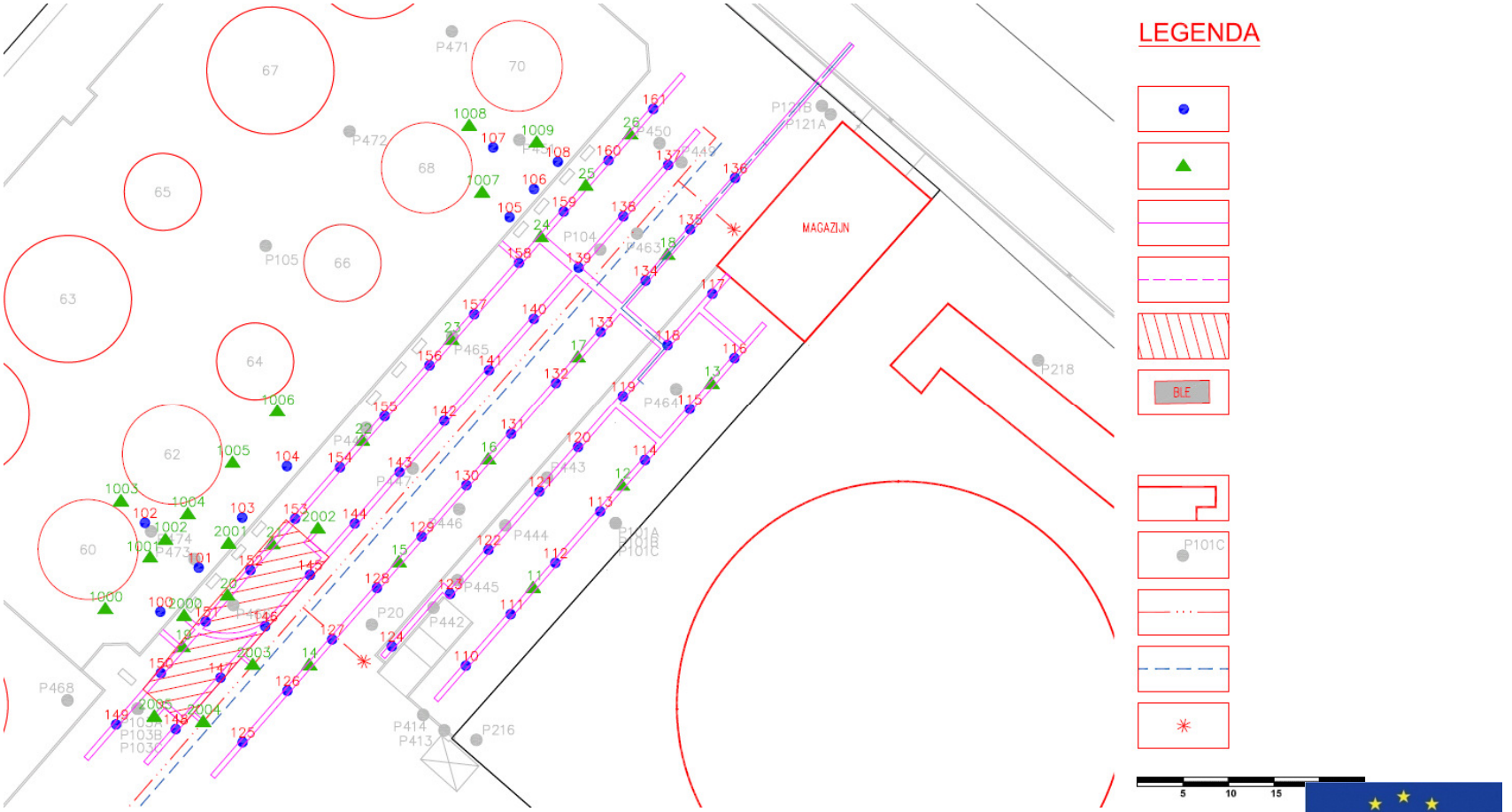
- SOIL STABILITY:
  - KNOWLEDGE OF VULNERABLE SOIL LAYERS
  - MONITORING CRITICAL STRUCTURE SUBSIDENCE

Action 5

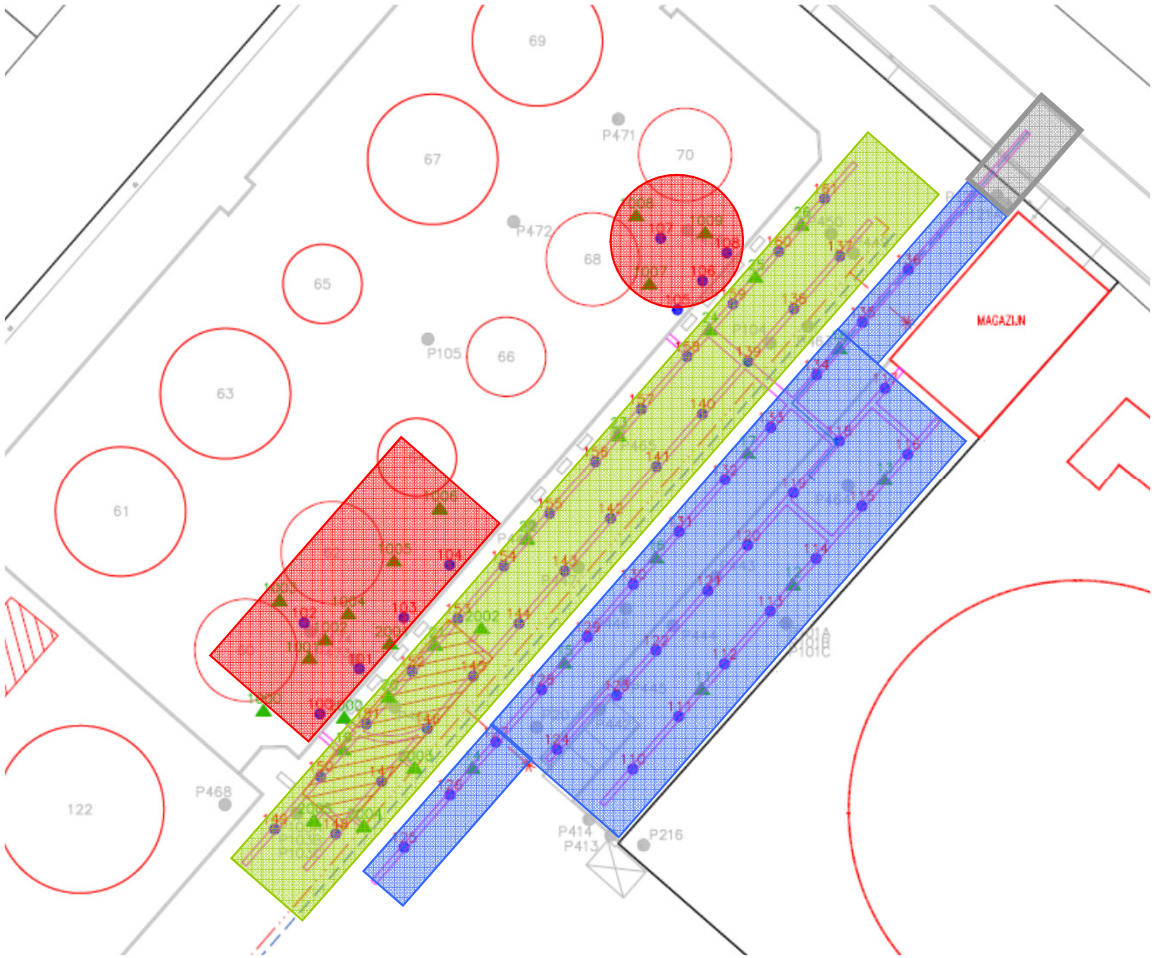
➢Action 5 – Full scale remediation

Period	Action description
October 2012 – March 2013	Civil engineering works: • Installation of 61 injection wells (LSP's), 32 MPE wells, 5 drains and piping • Excavation of source area outside the tank farm until 2mbgl (including groundwater lowering and groundwater treatment) • In 4 phases to minimize disturbance of the terminal
April 2013 – October 2013	ISCO with perozone in former drum storage in combination with SVE
April 2013 – July 2013	MPE around the former excavation area.
November 2013 – January 2014	ISCO with ozone in and around the former excavation area
February 2014 – May 2014	ISCO / SVE on hold due to total repair of the concrete floor outside the tank farm AND due to ozone / VOC emissions Emission tests
June 2014 – December 2014	ISCO with perozone of the plume beneath the central road
June 2014 – June 2015	ISCO with ozone in and around the former excavation area
December 2014 – August 2016	ISCO with (per)ozone in the source areas in the tank farm

Overview civil engineering works



Overview civil engineering works - phases



Phase 1: okt – nov 12

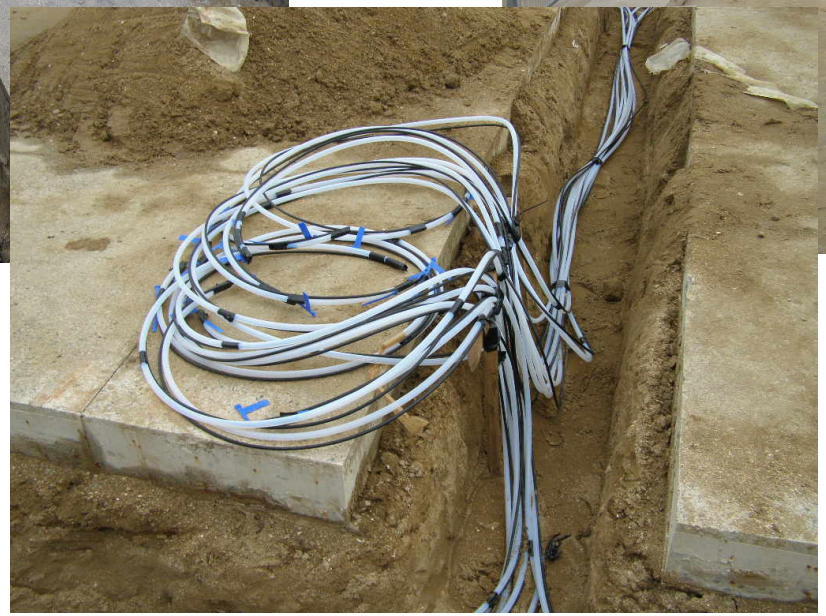
Phase 2: dec12 – feb 13

Phase 3: dec12 – feb 13

Phase 4: end feb 13

Installation LSP en MPE wells

Piping and drains



Connecting wells with piping

- + injection test LSP well

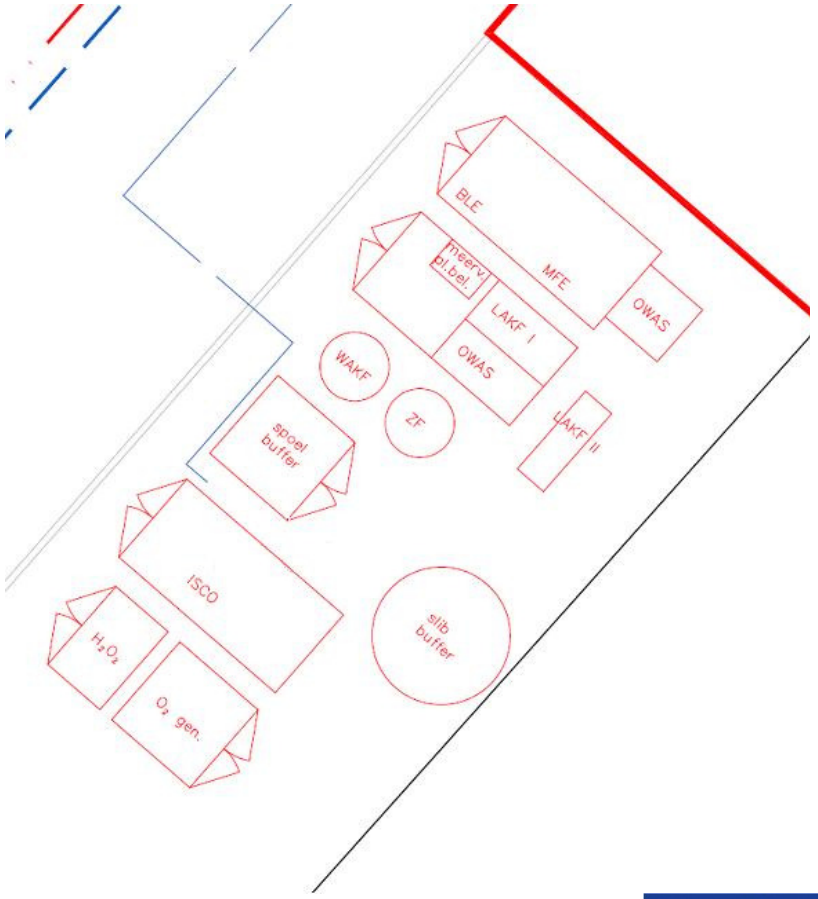
Excavation source area outside the tank farm

- Undergound utility detection – trial pits
  - → Manually with assistance of crane
  - → Emission of contamination
  - → Independent respiratory protection and gas tight and flame retardant clothes

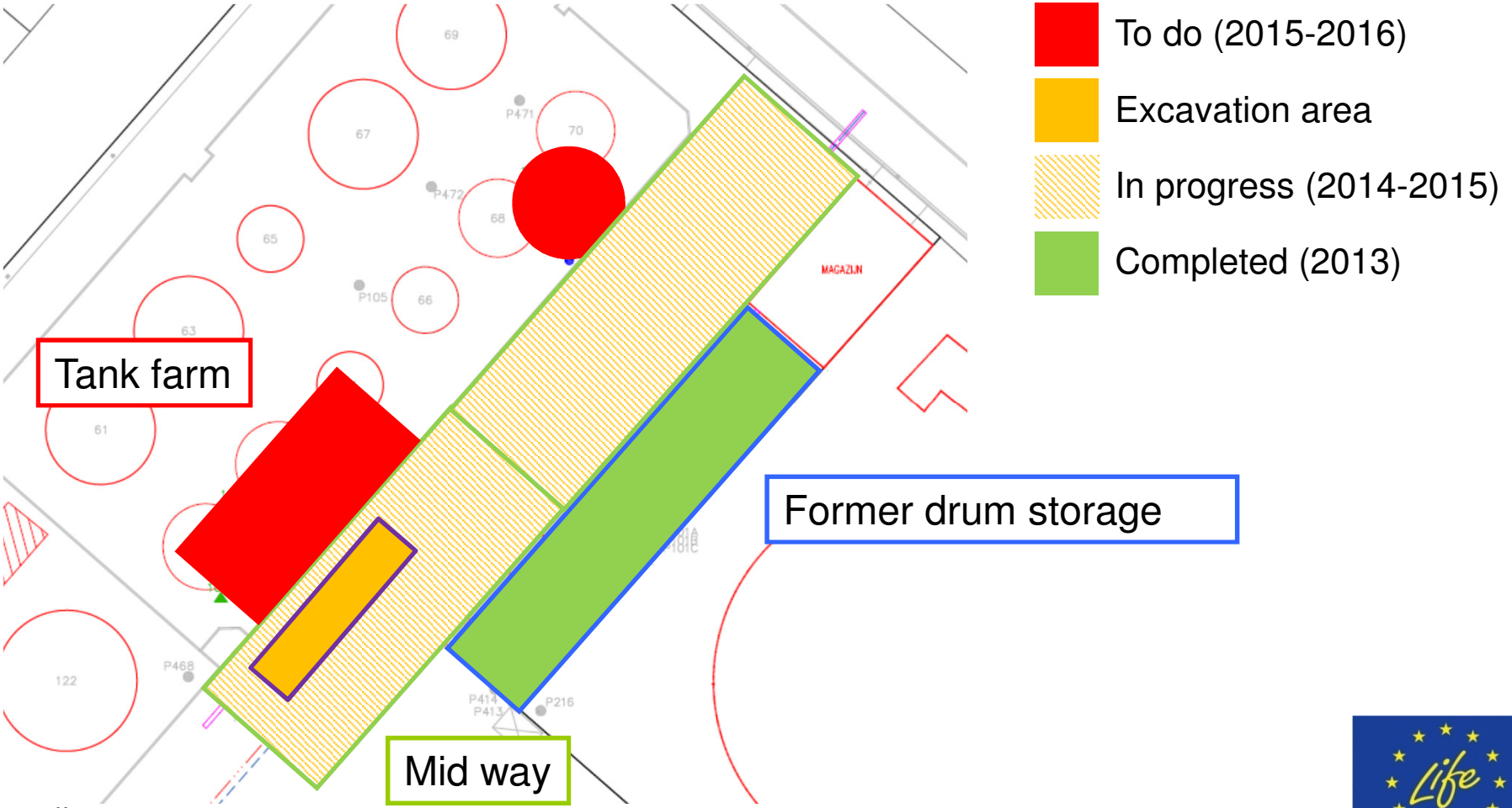
Excavation source area outside the tank farm

Original in-situ installation

- Groundwater and soil vapor treatment plant
- ISCO injection unit, OXYMAT en hydrogen peroxide storage



Current status



Action 5: Issues

- MPE – air treatment
  - Air treatment by active carbon
  - Very high VOC concentrations in air => fast saturation of active carbon
  - Opinion OVAM = zero emission
  - Very frequent active carbon renewals = excessive costs
  - Decision to stop MPE and treat the source areas directly with ISCO
  - Demobilisation of groundwater treatment plant and mobilisation of extra ozone generators

Action 5: Issues

- Ozone and VOC emissions in and around the former excavation area
  - Observation in January 2014 during periods of (continuous) rainfall
  - No ozone / VOC measured in sewery
  - Very important issue related to corrosion of tanks
  - ISCO installation immediately stopped
  - Reasons for emission:

1. Concrete floor not yet completely repaired

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Water infiltration and SVE drains flooded

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SVE doesn't work properly

2. The backfill material (excavation area) is much more sensible for preferential pathways

Action 5: Issues

- Ozone and VOC emissions in and around the former excavation area
  - Solutions:
    1. Make concrete floor liquid tight again (finished in May 2014)
    2. Check functionality of injection wells: 6 injection wells that were clogged with sand have been repaired (clogging probably during installation of piping
    3. Check integrity of piping and connection between piping and injection wells: connection of one injection well has been repaired
    4. Install more (specific) SVE points/drains: 3 extra drains have been installed during concrete floor reparation
    5. Find injection regime (per zone) where ozone and VOC emissions are minimized.

Tests in former excavation area and in plume zone of the mid way

Action 5: Issues

- Ozone and VOC emissions in and around the former excavation area
  - Tests to find optimal injection regime (carried out in April and May 2014):
    - Excavation area: 4Nm³/h air, 46g/h ozone, injection time: 2 min/cluster
    - Plume area mid way: 6Nm³/h air, 100g/h ozone, 120ml H2O2/min, injection time: 2 min/cluster
    - FYI: original injection regime: 12Nm³/h air, 200g/h ozone, 240ml H2O2/min, injection time: 10min/cluster

Each zone has its own characteristics and its own injection regime!

Action 5: Lessons learned

- **Each zone has its own characteristics and its own injection regime**
- **Solid connection between injection well and piping: double check!**
- **Good sealing of injection wells and piping during installation of the piping is essential**
- **Ensure flexibility in the design of the SVE system to respond to unexpected circumstances**

Action 6

- Action 6 – Monitoring of demonstration
- Goal: measure and document effectiveness of the project
- Monitoring indicators:
  - Evaluation of process parameters
  - Evaluation of safety parameters,
  - Evaluation of remediation conditions, and
  - Evaluation of trends of contaminant levels in groundwater

Action 6 – Former drum storage area

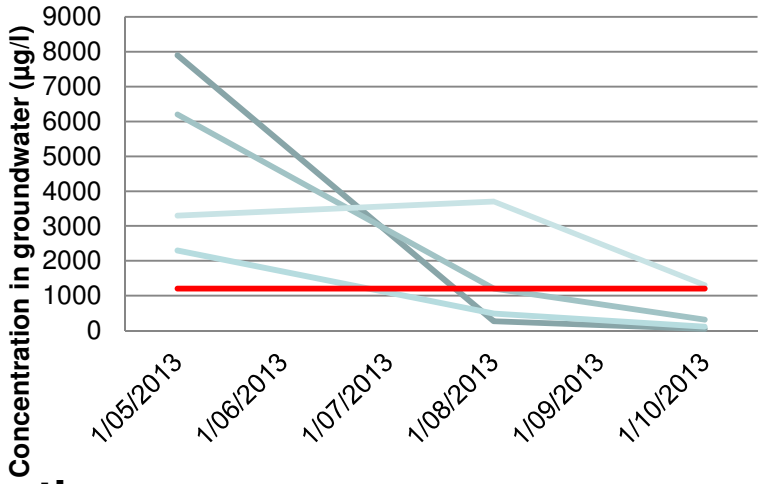
- April 2013 – November 2013
- Evaluation of process parameters:
  - All process parameters indicated good operation of the installations
- Evaluation of safety parameters:
  - No elevated oxygen, ozone and PID-levels in installation, surroundings, cracks in concrete, above monitoring wells and in sewery
  - No elevated groundwater temperature
  - No subsidence

Action 6 – Former drum storage area

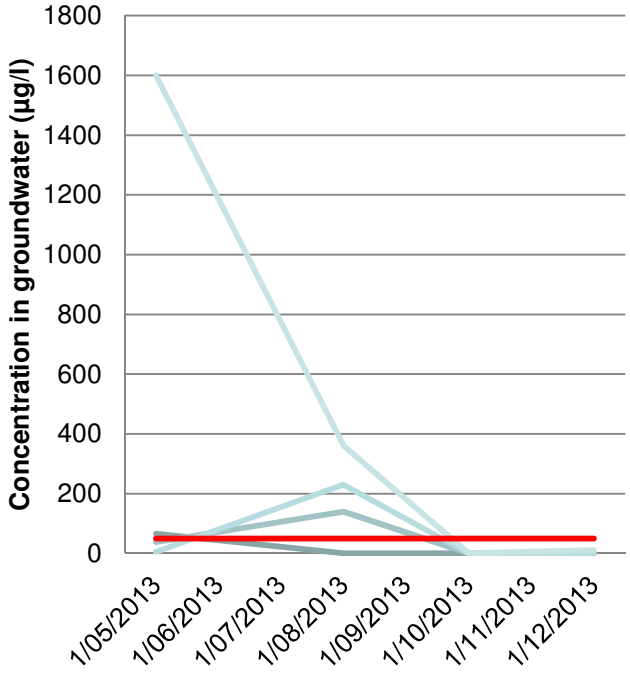
- Evaluation of remediation conditions:
  - Conditions OK, however lower oxygen and ozone levels in the groundwater than expected => test with only ozone in source area
- Evaluation of trends of contaminant levels in groundwater:

Action 6 – Former drum storage area

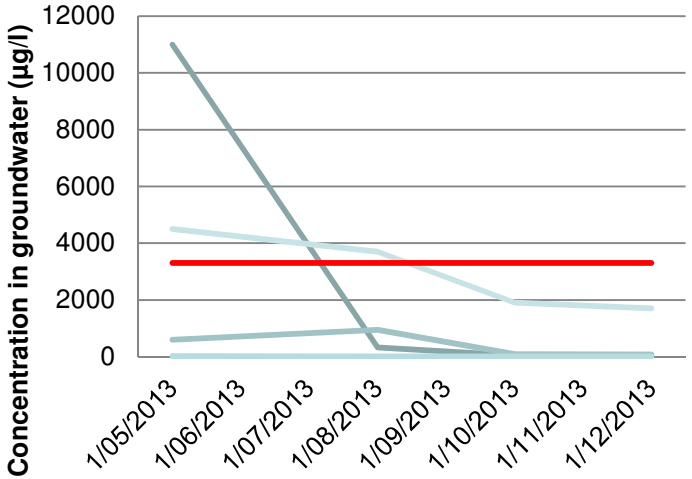
mineral oil C5-C8



vinylchloride



1,1-dichloroethane



Action 6 – Source area around excavation zone MPE

- April 2013 – July 2013
- Evaluation of process parameters:
  - Low groundwater and vapor extraction rate
  - High saturation rate of active carbon (air treatment)

MPE not effective

Stop MPE

- Evaluation of safety parameters:
  - All safety measures OK

Action 6 – Source area around excavation zone ISCO using ozone

- November 2013 – Jan 2014. Restarted June 2014
- Evaluation of process parameters:
  - All process parameters indicated good operation of the installations
- Evaluation of safety parameters:
  - No elevated oxygen, ozone and PID-levels in sewery and in installations
  - No elevated groundwater temperature
  - No subsidence

Action 6 – Source area around excavation zone ISCO using ozone

! January 2014: Elevated oxygen, ozone and PID-levels ambient air and above monitoring wells. Ozone odor in surroundings near the injection zone.

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Health risks for workers

Tank corrosion

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Stop ozone injections

Repair concrete floor

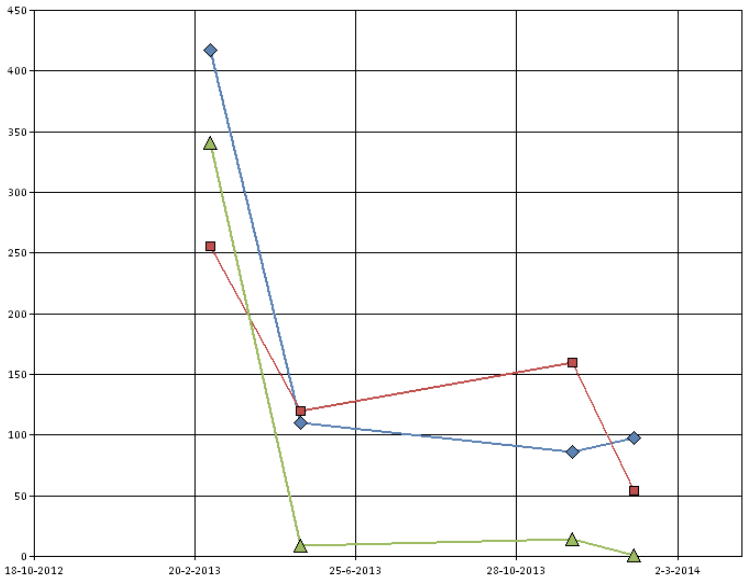
Determine optimal injection regime/zone (see A5)

Action 6 – Source area around excavation zone ISCO using ozone

- Evaluation of remediation conditions:
  - Period (November 2013 – January 2014) too short to evaluate the (positive) change in remediation conditions (oxygen level in groundwater and redox potential).
- Evaluation of trends of contaminant levels in groundwater:

Action 6 – Source area around excavation zone ISCO using ozone

mineral oil C5-C8



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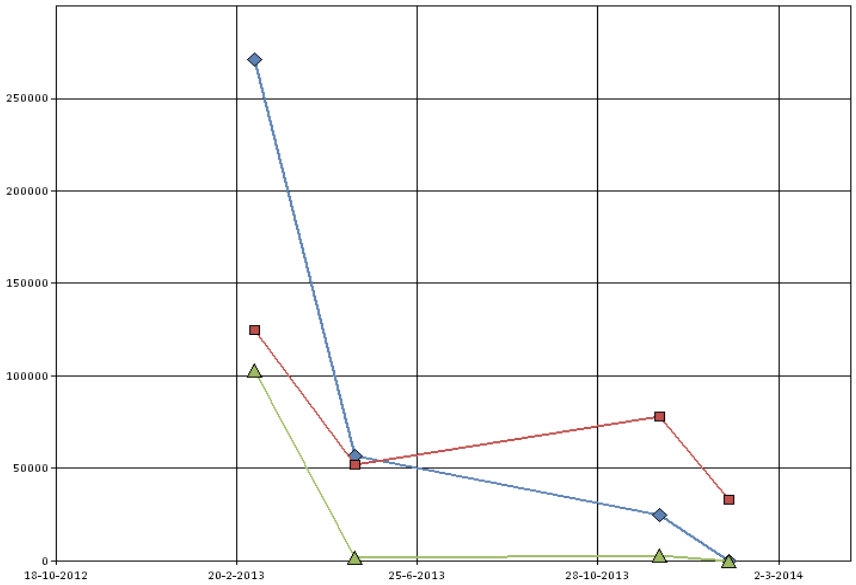

Action 6 – Source area around excavation zone ISCO using ozone

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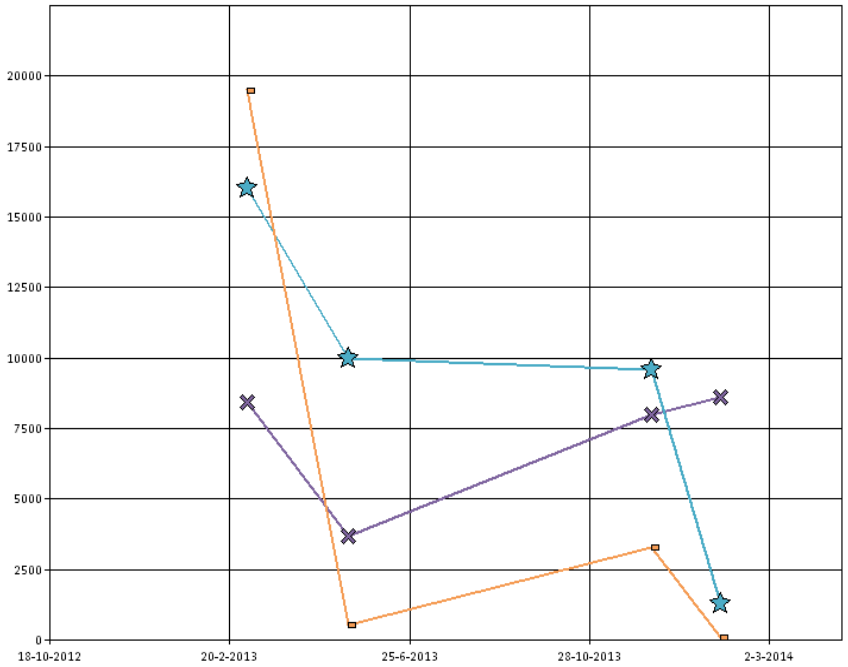
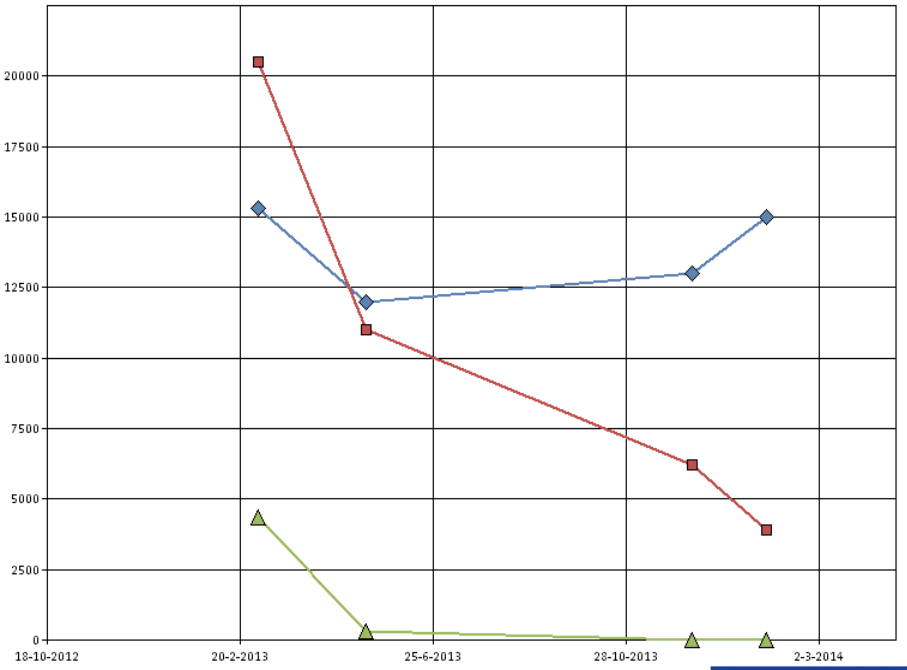


Xylene



Action 6 – Plume area midway ISCO using perozone

- Started June 2014
- Based on injection regime determined during emission test
- No emissions detected during start of the injections

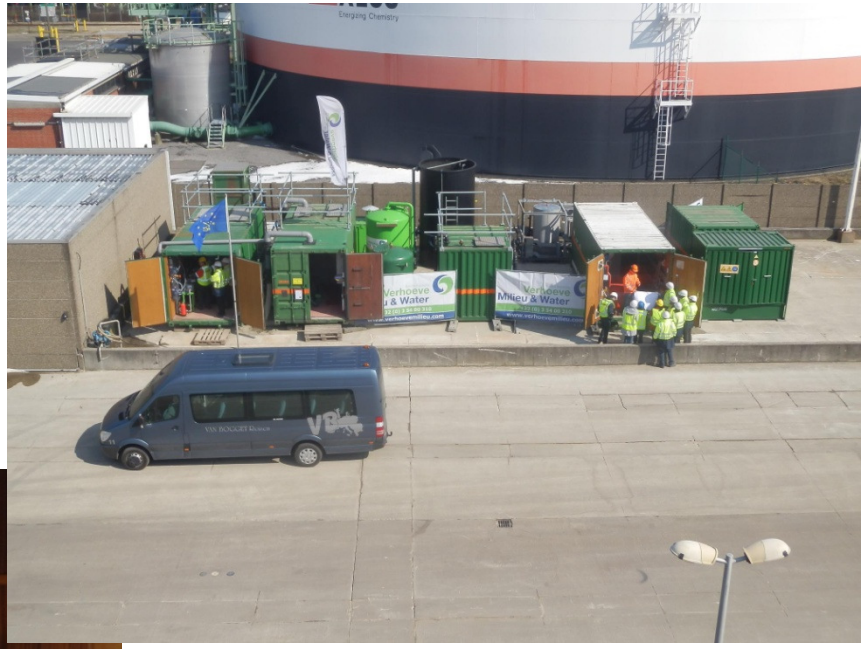
Action 7 – Dissemination

Action	Internal due date	External due date	Completion date
Presentation Life+ project to BATO			18-2-2011
Operational website			1-3-2011
Notice board on-site			1-3-2011
Leaflet written and published			28-2-2013
Sustainability report Vopak (legal report)			31-3-2013
Site visit stakeholders			26-3-2013
Site visit by ERM (environmental consultant - 5 visitors)			3-5-2014
Site visit by Tauw (environmental consultant - 2 visitors)			29-5-2013
Newsletter for stakeholders 1	31-8-2013	15-11-2013	15-11-2013
Interim report OVAM	31-8-2013	30-9-2013	27-9-2013
Presentation "Vlaams bodemcongres"			10-12-2013
BATO environmental meeting: presentation Life project			28-2-2014
Site visit Lanxess			19-3-2014
Sustainability report Vopak (legal report)	28-2-2014	31-3-2014	31-3-2014
Site visit Port of Antwerp			29-4-2014
BATO environmental meeting: presentation Life project			17-5-2014
Newsletter for stakeholders 2	15-5-2014	31-5-2014	
Site visit by Sino EPA (China - 1 visitor)			27-5-2014
Green week	5-6-2014	5-6-2014	5-6-2014
Newsflashes website	10-6-2014	15-6-2014	15-6-2014
Timeschedule/project progress on website	10-6-2014	15-6-2014	19-6-2014

Action 7 – Dissemination

Action	Internal due date	External due date	Completion date
Technical note: first area "vatenopslag" succesfully cleaned up	31-5-2014	30-6-2014	
Interim report OVAM	15-6-2014	30-6-2014	
Newsflashes website	30-6-2014	15-7-2014	
Progress report (EC)	15-7-2014	31-7-2014	
Newsletter for stakeholders 3	31-7-2014	31-8-2014	
Presentation at Conference in Finland	5-8-2014	5-8-2014	
Newsletter Verhoeve Milieu	31-8-2014	31-8-2014	
Site visit by environmental coordinators from Belgian Defense	18-9-2014	18-9-2014	
Newsflashes website	30-9-2014	15-10-2014	
Technical note: evaluation remediation source area	31-10-2014	30-11-2014	
Article in magazine "Milieu en Bedrijf"	30-11-2014	31-12-2014	
Article in "Radar" (newsletter Port of Antwerp)	31-12-2014	31-1-2015	
Newsflashes website	31-12-2014	15-1-2015	
Sustainability report Vopak (legal report)	28-2-2015	31-3-2015	
Newsletter stakeholders 4	28-2-2015	31-3-2015	
Presentation/paper at conference	28-2-2015	30-4-2015	
Newsflashes website	31-3-2015	15-4-2015	
Technical note: progress and evaluation remediation	30-4-2015	31-5-2015	
Interim report OVAM	15-6-2015	30-6-2015	
Newsletter Verhoeve Milieu	30-6-2015	30-6-2015	
update website	30-6-2015	15-7-2015	
Site visit stakeholders	31-8-2015	31-8-2015	
Technical publications and final report	31-7-2015	31-8-2015	

Action 7 – Dissemination – Site visit 26-03-2013



Interim conclusion

- ISCO using perozone is an effective solution for the remediation of multiple-parameter soil and groundwater contamination with high contaminant-concentrations but no pure product present.
- ISCO can be used on explosion sensitive sites, taking into account the necessary safety measures and taking into account flexibility in the design of these safety measures

Interim conclusion

- Following questions still need to be answered:
  - ISCO using (per)ozone effective for pure product zones?
  - ISCO using (per)ozone effective / safe in previously excavated zones (~ preferential flow paths, emissions, active carbon use)?
  - ISCO using (per)ozone safe in areas with corrosion and subsidence sensitive tanks?
  - Effective functioning of SVE in areas with high groundwater table (1mbgl in this particular case)?
  - Cost and time efficiency + environmental benefits compared to traditional techniques

Questions

Site visit

- No use of mobile phone (shut down or leave in the meeting room)

- PPE
  - ✓ helmet en safety glasses
  - ✓ safety shoes
  - ✓ hig visibility vest

- Stay with the supervisors

Soil remediation Vopak Terminal ACS

"We have built our company over 400 years on trust and reliability."

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