TRANSNATIONAL TRAINING ON SUSTAINABLE REMEDIATION

TRAINING MATERIALS

Bydgoszcz, 10 May 2017

Venue

Idea Space for Business in Bydgoszcz Industrial and Technological Park

Bydgoskich Przemysłowców 6, 85-862 Bydgoszcz

The Transnational training on sustainable remediation is organized within the Interreg Central Europe project ReSites - Environmental Rehabilitation of Brownfield Sites in Central Europe.

ReSites is a transnational cooperation project that seeks to improve the environmental management of unused or underused industrial areas. The project aims to achieve this through the definition of strategies and tools that are based on a sustainable, integrated approach to make functional urban areas (FUAs) cleaner, healthier and more liveable places. ReSites partnership is made of 11 partners from 5 central Europe countries working together to share and enhance knowledge on integrated environmental management of brownfields. The project started in June 2016 and will end in May 2019.

ReSites aims at providing the public sector with new skills and know-how on brownfield regeneration in order to improve the sites' environmental conditions producing a positive impact on the surrounding inhabited areas. Therefore partners will organize 2 transnational trainings, 9 local trainings and 8 site visits for public employees and stakeholders to increase their capacity to effectively manage brownfield regeneration in a sustainable way.

The first transnational training is organized in Bydgoszcz and will tackle the subjects of sustainability measures in remediation. The knowledge gained will support partners in the implementation of their pilot activities and will favour the exchange of know-how to better deal with the management of brownfields. The training takes place on the area of the former chemical factory which is also the subject of project work for the Bydgoszcz partner.

The training materials include abstracts from the training experts' presentations

- ✓ Nicole's position paper on sustainable remediation
- ✓ green remediation techniques (reducing the carbon footprint)
- ✓ sustainable remediation (stakeholder involvement, broadening the scope and using time)
- ✓ practical examples of sustainable brownfield remediation
- ✓ challenges for brownfield site owners
- ✓ sustainable management aspects of the remediation process
- ✓ methodology for assessment of sustainable remediation solutions, selection of most appropriate approaches
- ✓ aspects of cost-efficiency in remediation
- ✓ innovative monitoring techniques
- ✓ introducing Bydgoszcz pilot site
- ✓ hydrogeological modelling of contamination

Discover more about ReSites
www.interreg-central.eu/ReSites

Training agenda

Morning session: Sustainable remediation approaches

8.00	Meeting at the hotel, Hotel pod Orłem (bus trip to meeting venue)
8.30 - 8.45	Registration
8.45 - 9.00	Welcome speech
9.00 - 9.45	**Erwin van de Pol** - European network NICOLE ✓ *short introduction Nicole's position paper on sustainable remediation;* ✓ *green remediation techniques (reducing the carbon footprint)* ✓ *sustainable remediation (stakeholder involvement, broadening the scope and using time)*
9.45 - 10.30	**Klaus Heise, Harald Zauter** - Brownfield Authority (DE) ✓ *practical examples of sustainable brownfield remediation* ✓ *challenges for brownfield site owners*
10.30 - 10.45	Coffee break
10.45 - 11.30	**Thomas Ertel -** et environment and technology (DE) ✓ *sustainable management aspect of remediation process.* ✓ *methodology for assessment of sustainable remediation solutions, selection of most appropriate approaches.* ✓ *aspects of cost-efficiency in remediation*
11.30 - 12.15	**Wojciech Irmiński** (PL) ✓ innovative monitoring techniques
12.15	Press conference
12.15 - 13.15	Lunch

Afternoon session: Pilot site visit and practical implementation of methods

13.15 - 13.30	Trip to Exploseum
13.30 - 14.00	Exploseum, example of industrial heritage of brownfield area
14.15 - 14.45	**Dorota Pierri**, **Mariusz Czop** - AGH University of Science and Technology (PL) ✓ introducing Bydgoszcz pilot site in Exploseum movie room
14.45 - 16.15	**Dorota Pierri**, **Mariusz Czop** - AGH University of Science and Technology (PL) ✓ pilot site visit - former Zachem and Łęgnowo
16.15- 16.45	Coffee break - Idea building
16.45 - 18.00	Parallel sessions 1. Hydro geological modelling of contamination plumes - presentation of IT programme and testing by participants - Dorota Pierri, Mariusz Czop 2. Speed dating with experts 3. Poster Session: Pilot Sites, LUMAT, UTP
20.00	Dinner

Experts introduction:

MR. ERVIN VAN DE POL has been working as consultant for 20 years on projects related to soil remediation, redevelopment and sustainability at Witteveen+Bos consulting engineers. As part of his employment at Witteveen+Bos, Mr. Van de Pol is very active in the Dutch Sustainable Remediation Forum (SURF-NL) and in the Sustainable Remediation working group of Nicole. Nicole is the Network for Industrially Co-ordinated Sustainable Land Management in Europe. In his presentation Mr. Van de Pol will represent Nicole and demonstrate how the industry in Europe is involved in sustainable remediation and sustainable land management.

DR. THOMAS ERTEL is owner of the company et environment and technology with key competences as a project manager in environment and landfill issues as well as brownfield redevelopment. Key qualifications of Dr. Thomas Ertel are investigation and remediation of contaminations of groundwater and soil, waste management, brownfield redevelopment project management. In recent years he was main expert for the assessment of soil and groundwater contamination and landfills at the industrial sites Bussi and Spinetta and technical expert to clarify liabilities for groundwater pollution caused by an ancient landfill site. Experienced in many European projects dealing with brownfields.

MR. KLAUS HEISE is team leader in the Brownfield Authority of Saxony Anhalt (Landesanstalt für Altlastenfreistellung Sachsen-Anhalt). After some years of experience in the field of remediation of contaminated sites in a consulting agency, he joined the Brownfield Authority in 2000. As one of his tasks he was involved in the remediation of former heavy metal mining and smeltering sites in the Mansfelder Land. Presently Mr. Heise is responsible for the clean-up activities in the megasites Magdeburg-Rothensee (industrial area of the port of Magdeburg) and the Natural Gas Field “Altmark”. Additionally he is representing the Brownfield Authoritiy in the WFD working groups of Saxony-Anhalt and compiling brownfield related contributions to the WFD reporting system

MR. HARALD ZAUTER has been working as hydrogeologist in several companies and in the international co-operation with developing countries. Since 2010, he is project officer in the Brownfield Authority of Saxony Anhalt (Landesanstalt für Altlastenfreistellung Sachsen-Anhalt). Presently his focus is the remediation of contaminated groundwater at the former chemical plant Bitterfeld-Wolfen in Saxony Anhalt. The principal activity at this megasite is the extraction of about 2 million cubic meters of groundwater containing chlorinated solvents, pesticides, remains from insecticide production and various contaminants and a complex water treatment system

DR. WOJCIECH IRMIŃSKI is geologist and since 1989 works on the environmental protection projects. Till 2008 was employed by Polish Geological Institute (national geological survey). 2010 established the entity Geo-Logik Wojciech Irmiński, which main goal are investigation and evaluation of soil-groundwater system quality as well as remediation and monitoring. Since 2004 he is certified specialist for soil- and groundwater sampling on the brownfield areas. He was partner or subcontractor by a few EU brownfield projects. Each year he elaborate a lot of brownfield expertise and remediation plans. Many of accepted plans were successful introduced and finalized. His challenge are cases of heavy contamination with common opinion “hopeless case”.

MARIUSZ CZOP PhD Eng. is an assistant (adjunct) professor at AGH University of Science and Technology in the Department of Hydrogeology and Engineering Geology. He is a specialist in hydrogeochemical and hydrodynamical modelling of physical and chemical processes in the groundwater environment, including reactive and multiphase transport of mass and water-rock-gas interactions. Author and co-author of about 120 scientific papers and about 350 research reports in practically all aspects of hydrogeology. Principal manager in the project of the remediation planning for the industrial waste site ‘Zielona’ in the former ‘Zachem’ Chemical Plant in Bydgoszcz and in the other projects related to the restoration of contaminated brownfield areas

DOROTA PIERRI PhD Eng. is a research – teaching assistant at AGH University of Science and Technology in the Department of Hydrogeology and Engineering Geology. She has 8-years’ experience in hydrogeological modelling, hydrogeochemistry of organic pollutants and groundwater and soil contamination. She is an author and co-author of about 20 scientific papers and about 35 research reports in the field of applied hydrogeology, especially related to the groundwater and soil remediation and brownfields regeneration. Leader expert in the groundwater and soil pollution in the area of the former ‘Zachem’ Chemical Plant in Bydgoszcz and remediation planning for the industrial waste site ‘Zielona’

NICOLE

Network for Industrially Co-ordinated Sustainable Land Management in Europe

Best Practices on Sustainable Remediation of contaminated land

Bydgoszcz, May 10th 2017

Erwin van de Pol

About myself

NICOLE Network for Industrially

SuRF SUSTAINABLE REMEDIATION FORUM NETHERLANDS

Content

Content of this presentation:

- About Nicole
- Green Remediation
- Sustainable Remediation

What is NICOLE?

NICOLE is

- A network in Europe, linking professionals from the industry, service providers and academics in the field of contaminated land management
- a leading organisation in the development and promotion of state-of-the-art solutions for contaminated land management

Nicole's members

NICOLE's members

- 23 industrial companies
- 50 service providing / technology developing companies
- 32 academic members from universities and research organisations, other (funding organisations, other networks, governmental organisations)
- Total 105 (2015)

From Sweden, Poland, Germany, UK, France, Belgium, Spain, Greece, Ireland, Luxembourg, Norway, Czech Republic, Romania, Austria, Switzerland, USA, Finland, Bulgaria, Denmark, Netherlands, Italy

NICOLE'S Activities

Nicole's Activities:

- **Two workshops per year** on all aspects of contaminated land management
- **Working Group meetings**: Sustainable Remediation, Emerging Contaminants, Regulatory Issues
- Yearly **Technology Award**
- Publications, (joint) position papers and reports

Position Paper SR

Joint Position Paper with Common Forum

On Risk-Informed and Sustainable Remediation

Position Paper SR

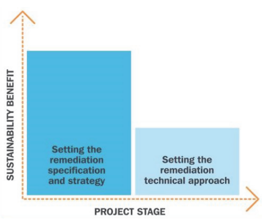
Key points of the position paper:

1. Agree on the necessity for protecting population and the environment against contaminated media
2. SR involves the assessment of risks and benefits
3. More sustainable use of resources
4. Sustainability can not be quantified in absolute terms : stakeholder engagement is crucial
5. Integration of the elements of sustainability at the early beginning but also throughout the life of the project
6. Nicole's Road Map (2010) and the Claire (2010) document on SR are considered as Good Practice

Nicole's vision on SR

Nicole's vision on SR:

- The earlier in the process the more sustainability gain
- Communication is the number one barrier and enabler
- Green remediation vs. Sustainable



Green Remediation

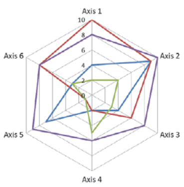
Why green remediation?
- a Quick Win: You can start today
- More sustainable use of resources
- Unique Selling Point in Tendering

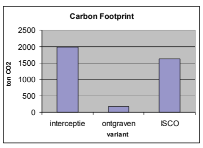
Example SBNS-remediation Bilthoven

Examples of green remediation

- Examples:

Green Remediation





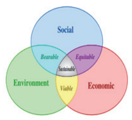
NICOLE does not prescribe Tools!
… but there is a lot available:

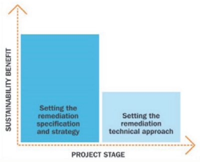
- Qualitative: narrative analysis or ranking
- Semi quantitative
  - Multi-criteria analysis, weightings and scores
  - Pairwise comparison (Weighing of benefits and burdens)
- Quantitative
  - Cost Benefit Analysis
  - Life Cycle Assessment
  - Etc.

Green Remediation

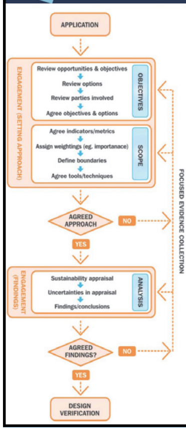
Green Remediation is a good starting point, however:
- Considers only Environmental impact
- End of Pipe methodology

So we need and there is more...





Sustainable Soil Remediation



The Road Map of Nicole:
1. Identify and review parties
2. Review objectives and starting points
3. Agree on conceptual site model (source-path-receptor linkage)

4. Explore options
5. Agree on sustainability indicators
6. Agree on tools/methodology e.g. Sustainability appraisal based on decisive benefits and burdens
7. Assign priorities or weightings

8. Technical detailing of options
9. Agree on findings (Justification rule)

Sustainable Soil Remediation

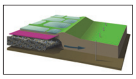
How to use the roadmap for sustainable remediation of Brownfields?

A-site B-site C-site

Sustainable Soil Remediation

- Transformation of an inner-city brownfield to Town Hall and Public Area
- 80 % private financing, combining remediation with civil works
- Key-words: stakeholders, no after-care, fast

Sustainable Soil Remediation



- Transformation of a landfill to public area
- Natural cap concept
  - take over function of the foil (long term)
  - simple and cost effective solution
- Key-words: stakeholders, public money, Risk Based Land Management, slow

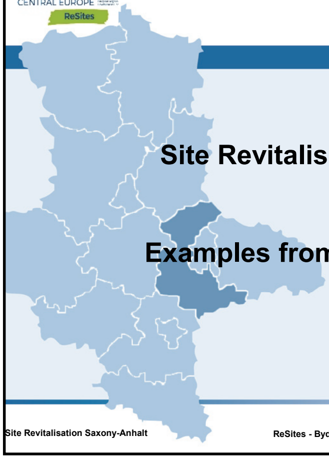
Conclusions

When it comes to remediation of brownfields:

- Sustainable remediation First!
- Tools and Nicole's roadmap are effective for communication with stakeholders and decision making
- It often requirs a long breath

Thank you for your attention

Landesanstalt für Altlastenfreistellung



Site Revitalisation Projects

Examples from Saxony-Anhalt

Landesanstalt für Altlastenfreistellung

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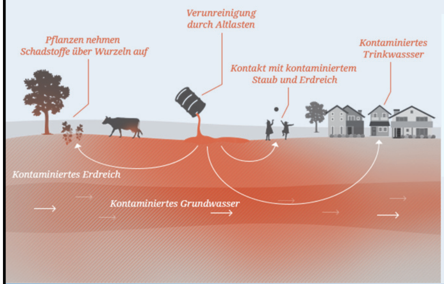
Possible pathways from contaminated sites



Revitalization of contaminated sites requires securing measures

Landesanstalt für Altlastenfreistellung

Contents

Megasite Magdeburg-Rothensee

Landesanstalt für Altlastenfreistellung

Former Main Gas Works

Subjects of protection according to planned use:
- Health of employees
- Buildings

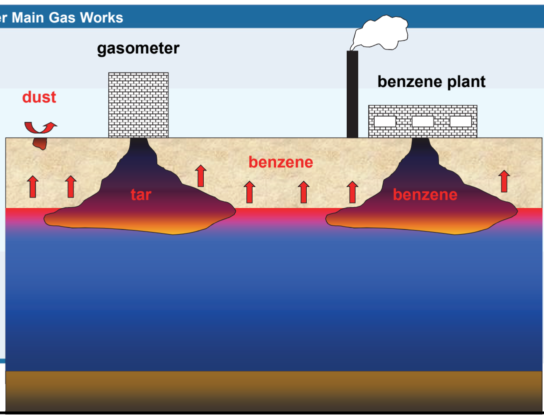
Hazards from:
- Tar
- Benzene

- Northern part of former main gas works, operational from 1930 to 1993
- The aim is to build the production facilities for the laminated wood producer (Nordlam)

Megasite Magdeburg-Rothensee

Landesanstalt für Altlastenfreistellung

Former Main Gas Works

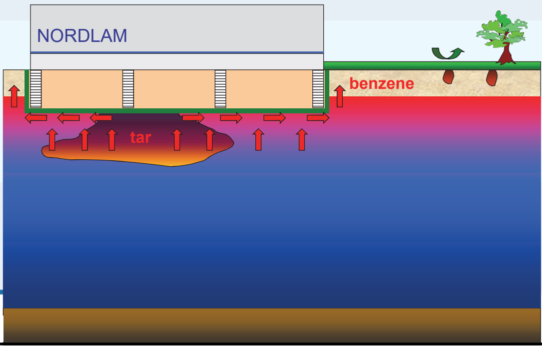


Megasite Magdeburg-Rothensee

Landesanstalt für Altlastenfreistellung

Former Main Gas Works

Securing measure: interruption of exposure pathways



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Megasite Magdeburg-Rothensee

Landesanstalt für Altlastenfreistellung

Former Main Gas Works

Securing measure: interruption of exposure pathways using plastic sealing

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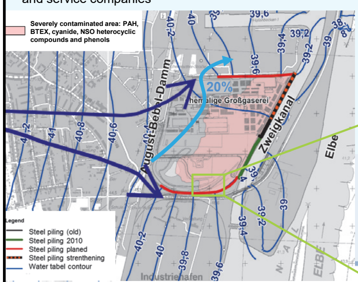
Megasite Magdeburg-Rothensee

Landesanstalt für Altlastenfreistellung

Former Main Gas Works

- Located NE of Magdeburg, at the port of Magdeburg
- Size approx. 10 km² with 96 old industrial locations
- Today increasingly used by industry, trading and service companies



Subarea TF12
former main gas production site

- Strongly contaminated with **PAH, BTEX, NSO heterocyclic compounds, cyanide, ammonia, phenols**
- remedial actions in planning stage
  → partial groundwater containment
  → inflow reduced by **80%**
- **remaining 20% inflow: EMNA treatment** (Enhanced Monitored Natural Attenuation)

Field test site for EMNA

- Stage 1: **off site**
  Batch tests and column experiments
- Stage 2: **on site**
  Infiltration of H_2O_2, subs. technical oxygen
- Stage 3: **on site**
  Infiltration of airborne oxygen

Site Revitalisation Saxony-Anhalt   ReSites - Bydgoszcz, 09-11 May 2017   9

Former main Gas Works: EMNA concept (Enhanced Monitored Natural Attenuation)

1. Step: Batch tests, off-site

Investigating the processes of **adsorption and precipitation as well as aerobic and anaerobic microbial decomposition** of the respective pollutants based on water samples from the TF12.

Results

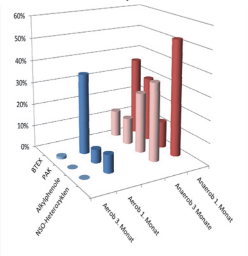
No signs of anaerobic microbial activity, aerobic microbial decomposition inconclusive.

2. Step: Column Experiments under aerobic conditions, off-site

Investigating **the release and microbial decomposition** of pollutants **in the phreatic zone** based on soil and water samples from the TF12 under **aerobic and anaerobic conditions.**

For checking purpose parallel running of poisened column experiments (mercuric chloride, sodium azide).

Former main Gas Works: EMNA concept – phase 1, off-site



Results

- Infiltration of oxygen (**aerobic depletion**): after 3 months → residual contamination < 1%
- Infiltration of nitrate (**anaerobic depletion**): after 3 months → residual contamination approx. 12 – 35%

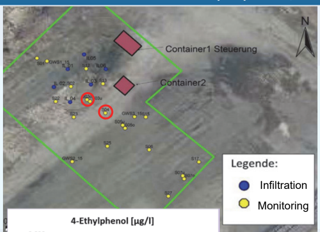
Conclusions insights from off-site investigations and transfer to on-site application:

Choosing aerob depletion

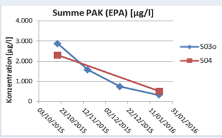
based on technical oxygen for

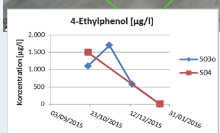
the on-site tests

Former main Gas Works: EMNA concept – phase 2, on-site

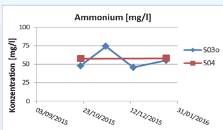


Injection of technical oxygen (11.2015 – 08.2016), temporarily infiltration of H_2O_2





Distance from injection
S03o: 2.5 m S04: 7.5 m



Megasite Magdeburg-Rothensee

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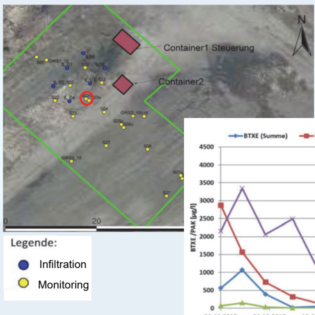
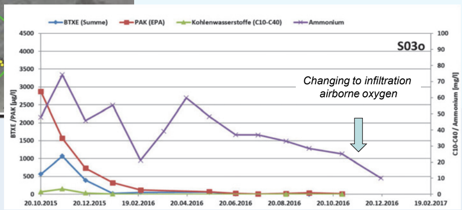
Former main Gas Works: EMNA concept – phase 3, on-site



Change from infiltration of technical oxigen to infiltration of airborne oxygen (11.2016)

Distance from injection
S03o: 2.5 m



Landesanstalt für Altlastenfreistellung

- Magdeburg Rothensee
- Messma Magdeburg
- Weissandt-Gölzau
- Megasite Bitterfeld
- RESITES TOOL

Messma Magdeburg

Landesanstalt für Altlastenfreistellung

Former production of measuring apparatus

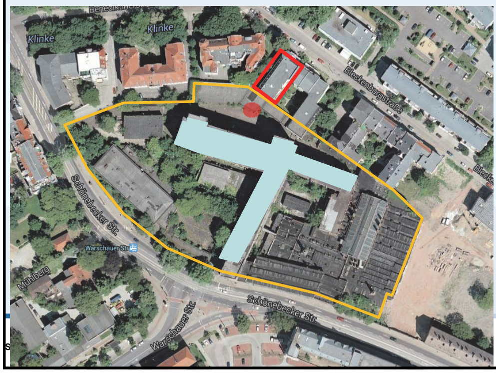
Transformation of an industrial wasteland into a residential area

Interreg CENTRAL EUROPE ReSites

Messma Magdeburg

Landesanstalt für Altlastenfreistellung

Former production of measuring apparatus



Plot limitation

Building for transformation into an apartment house

Contaminated residential building

Sub-surface tank for volatile chlorinated hydrocarbons

maps.google.de

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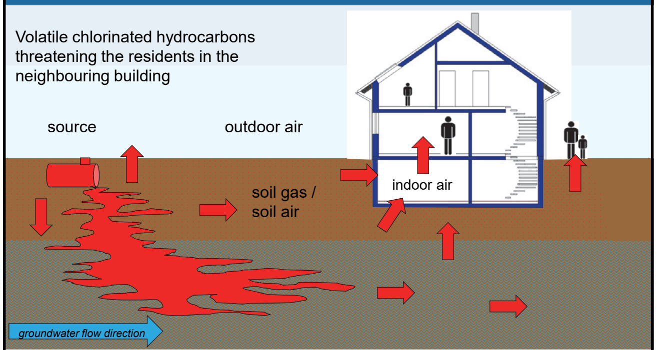
Messma Magdeburg

Landesanstalt für Altlastenfreistellung

Former production of measuring apparatus: Health risks to neighbouring residents

Volatile chlorinated hydrocarbons threatening the residents in the neighbouring building



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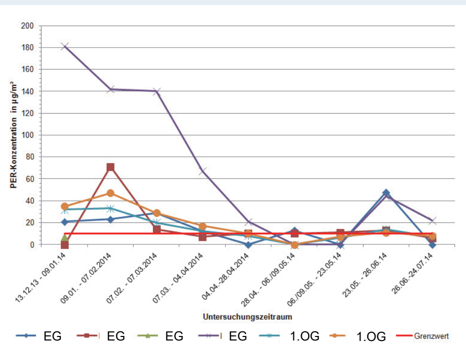
Messma Magdeburg

Landesanstalt für Altlastenfreistellung

Former production of measuring apparatus: Health risks to neighbouring residents

Measurement of volatile chlorinated hydrocarbons in the indoor air



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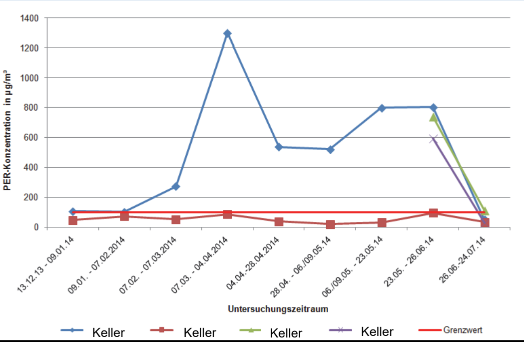
Messma Magdeburg

Landesanstalt für Altlastenfreistellung

Former production of measuring apparatus: Health risks to neighbouring residents

Measurement of volatile chlorinated hydrocarbons in the basement rooms



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Messma Magdeburg

Landesanstalt für Altlastenfreistellung

Former production of measuring apparatus: Health risks to neighbouring residents

Securing measure: polymer coating as floor sealing and wall grouting

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Messma Magdeburg

Landesanstalt für Altlastenfreistellung

Former production of measuring apparatus: Health risks to neighbouring residents

Remediation targets ?

Tetrachloroethene **100** µg/m³

Limit value according to German law (2. BImSchV) for residential rooms next to dry cleaning, 7-days-mean value

Tetrachloroethene **250** µg/m³ WHO

Tetrachloroethene **10** µg/m³

Recommended by German expert committee for immission control (Länder-ausschuss), annual mean value 1997

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Landesanstalt für Altlastenfreistellung

- Magdeburg Rothensee
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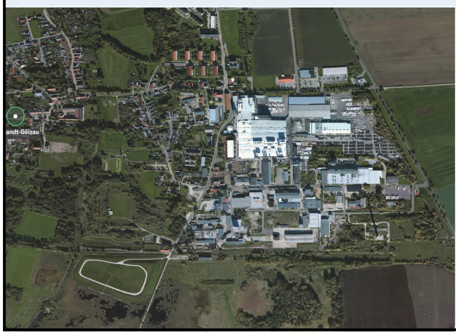
- Megasite Bitterfeld
- RESITES TOOL

Weissandt-Gölzau

Landesanstalt für Altlastenfreistellung

Former carbonize plant

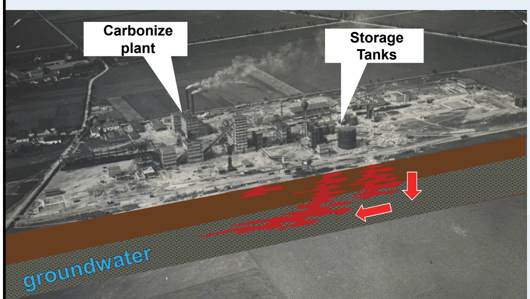
Industrial park with 1.500 employees



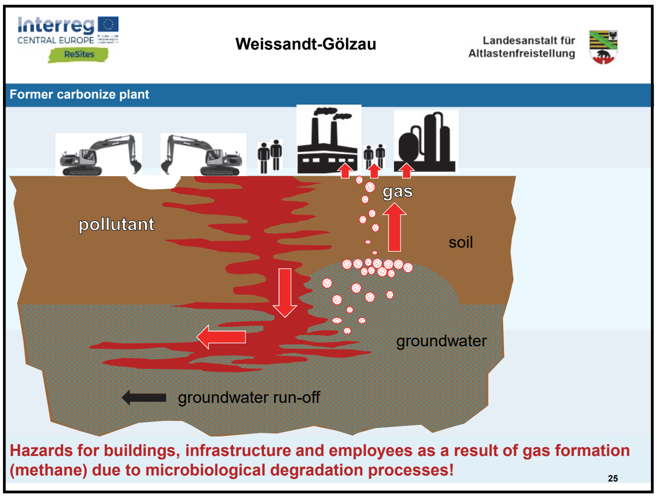
Weissandt-Gölzau

Landesanstalt für Altlastenfreistellung

Former carbonize plant



1876 – startup of lignite mining
1928 – startup of carbonize plant
1965 – shutdown of carbonize plant
1965 – VEB Orbitaplast: production of polyethylene products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Former carbonize plant
gas
pollutant
soil
groundwater
groundwater run-off
Hazards for buildings, infrastructure and employees as a result of gas formation (methane) due to microbiological degradation processes!
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Weissandt-Gölzau
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Former carbonize plant
Site Revitalisation Saxony-Anhalt
ReSites - Bydgoszcz, 09-11 May 2017
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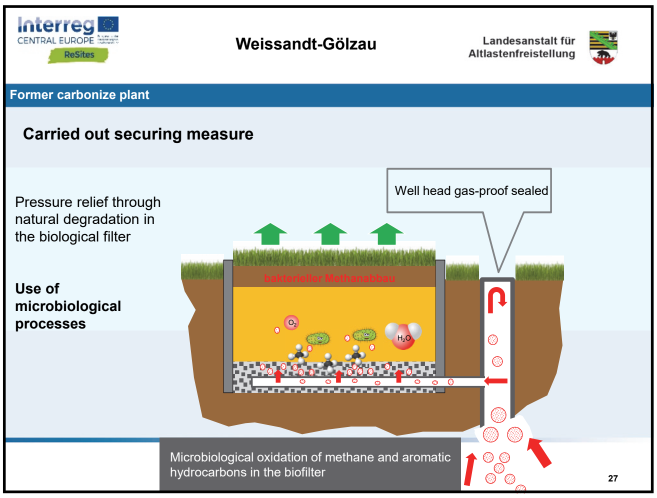
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Weissandt-Gölzau
Landesanstalt für Altlastenfreistellung
Former carbonize plant
Carried out securing measure
Pressure relief through natural degradation in the biological filter
Use of microbiological processes
Well head gas-proof sealed
bakterieller Methanabbau
Microbiological oxidation of methane and aromatic hydrocarbons in the biofilter
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Weissandt-Gölzau

Landesanstalt für Altlastenfreistellung

Former carbonize plant

Carried out securing measure

Biofilter at several places in the industrial park

28

Weissandt-Gölzau

Landesanstalt für Altlastenfreistellung

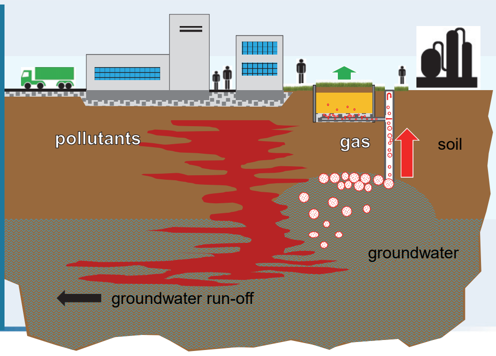
Former carbonize plant

Modern infrastructure

8.2 million EUR spent for hazard protection

1.500 jobs

MNA- concept agreed with relevant authorities



Site Revitalisation Saxony-Anhalt

ReSites - Bydgoszcz, 09-11 May 2017

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Landesanstalt für Altlastenfreistellung

- Magdeburg Rothensee
- Messma Magdeburg
- Weissandt-Gölzau
- Megasite Bitterfeld
- RESITES TOOL

Site Revitalisation Saxony-Anhalt

ReSites - Bydgoszcz, 09-11 May 2017

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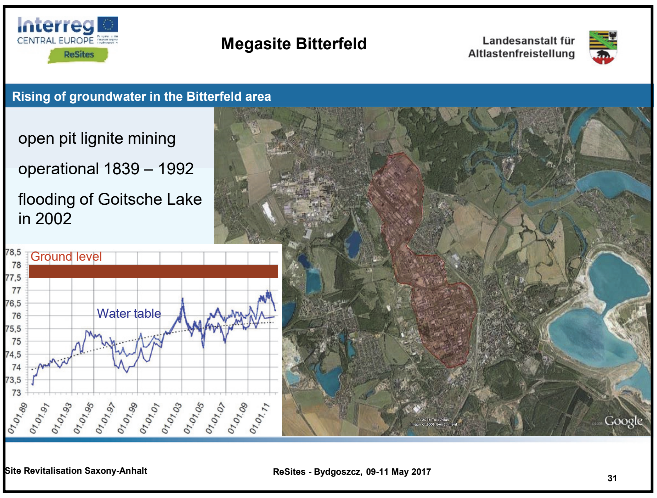
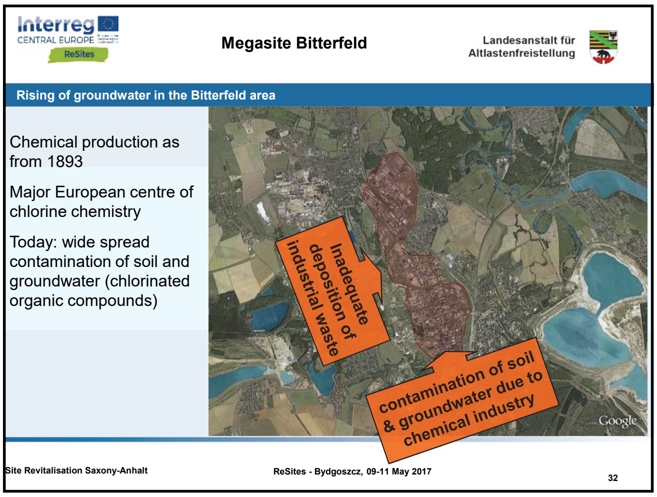
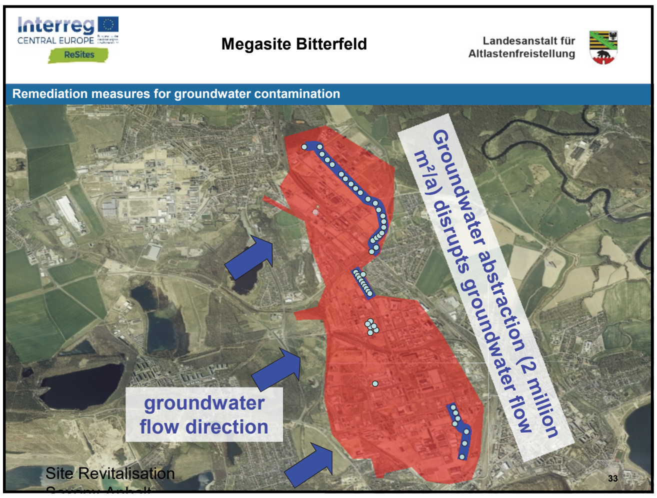

Interreg
CENTRAL EUROPE
ReSites
Megasite Bitterfeld
Landesanstalt für Altlastenfreistellung
Rising of groundwater in the Bitterfeld area
open pit lignite mining
operational 1839 – 1992
flooding of Goitsche Lake in 2002
Ground level
Water table
78,5
78
77,5
77
76,5
76
75,5
75
74,5
74
73,5
73
01.01.89
01.01.91
01.01.93
01.01.95
01.01.97
01.01.99
01.01.01
01.01.03
01.01.05
01.01.07
01.01.09
01.01.11
Google
Site Revitalisation Saxony-Anhalt
ReSites - Bydgoszcz, 09-11 May 2017
31


Interreg
CENTRAL EUROPE
ReSites
Megasite Bitterfeld
Landesanstalt für Altlastenfreistellung
Rising of groundwater in the Bitterfeld area
Chemical production as from 1893
Major European centre of chlorine chemistry
Today: wide spread contamination of soil and groundwater (chlorinated organic compounds)
Inadequate deposition of industrial waste
contamination of soil & groundwater due to chemical industry
Google
Site Revitalisation Saxony-Anhalt
ReSites - Bydgoszcz, 09-11 May 2017
32


Interreg
CENTRAL EUROPE
ReSites
Megasite Bitterfeld
Landesanstalt für Altlastenfreistellung
Remediation measures for groundwater contamination
Groundwater abstraction (2 million m²/a) disrupts groundwater flow
groundwater flow direction
Site Revitalisation
33

Megasite Bitterfeld

Landesanstalt für Altlastenfreistellung

High groundwater level threatens buildings and workers

Site Revitalisation Saxony-Anhalt

ReSites - Bydgoszcz, 09-11 May 2017

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Landesanstalt für Altlastenfreistellung

High groundwater level threatens buildings and workers

Site Revitalisation Saxony-Anhalt

ReSites - Bydgoszcz, 09-11 May 2017

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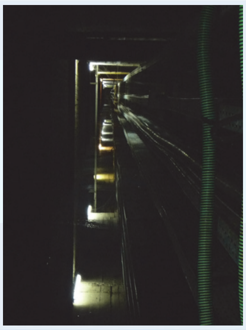
Megasite Bitterfeld

Landesanstalt für Altlastenfreistellung

High groundwater level threatens infrastructure



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Megasite Bitterfeld

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High groundwater level threatens infrastructure

Risk: contaminated groundwater enters rainwater sewage system and pollutes surface water bodies –> violation of WFD values!

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Urgent need of durable solutions

Locally installed companies try to evacuate infiltrating groundwater

Simple solutions are not always sustainable solutions !

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Landesanstalt für Altlastenfreistellung

Financial concept

LAF = Brownfield Authority, resp. for costs of contamination

Chemiepark Bitterfeld-Wolfen GmbH = Privately-owned infrastructure provider

§ Financial agreement for the implementation of the industrial area securing project §

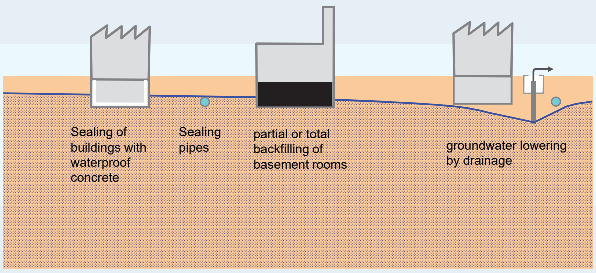
Private companies located at Chemiepark

LMBV = Federal agency for post-mining remediation activities, resp. For groundwater rising costs

Megasite Bitterfeld

Landesanstalt für Altlastenfreistellung

Technical concept



Appropriate solution to be investigated and realised

Site Revitalisation Saxony-Anhalt   ReSites - Bydgoszcz, 09-11 May 2017   40

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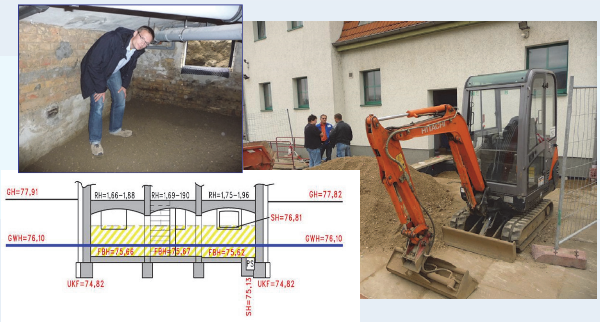
Example No 1 – partial backfilling of basement rooms



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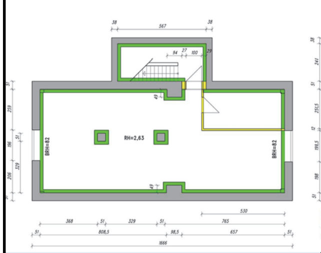
Example No 2 – waterproof concrete sealing of basement rooms

12.40.0 SIS Keller 1



demolished walls

waterproof concrete sealing

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Example No 3 – sewer rehabilitation

Replacing old sewer pipes in Hauptstrasse area

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- RESITES TOOL

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RESITES TOOL

Landesanstalt für Altlastenfreistellung

Requirements to provide information

Main targets of the RESITES - Tool

- ReSites Tool is planned as a site information system for online collaboration of public authorities that are concerned with brownfield rehabilitation.
- It will be an easy to use Web GIS tool including only the most essential maps and data.
- Sensitive data are included as metadata describing the content and providing information about the location of the original data.

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RESITES TOOL

Landesanstalt für Altlastenfreistellung

Requirements to provide information

Main information for brownfield evaluation:

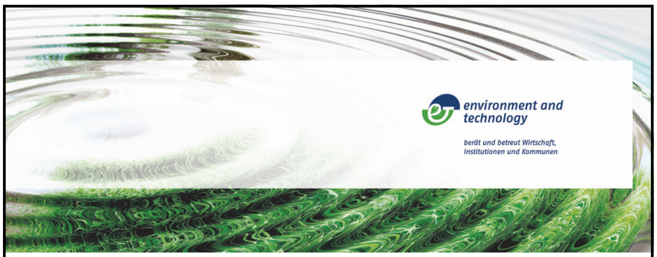
- Maps showing use-related needs of remediation, distinguished in industrial use, agricultural purpose, residential use
- Maps showing the environmental medias affected by pollutants: soil, soil gas, groundwater, surface water, atmospheric air
- Risk maps showing active exposure pathways & exposure pathways to be interrupted (related to future use options)
- Maps showing depth to groundwater table (important for the issues of hydrostatic uplift and wet basement walls)
- More information → RESITES TOOL QUESTIONNAIRE

Interreg CENTRAL EUROPE ReSites

Landesanstalt für Altlastenfreistellung

Many thanks
for
your attention

We are looking forward to a good cooperation

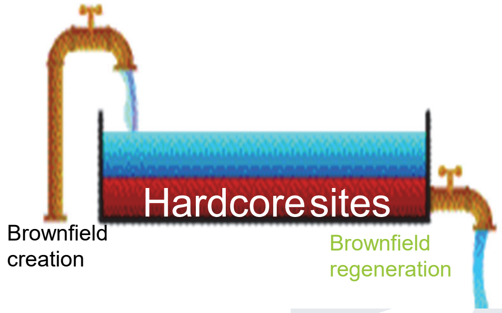


Brownfield Regeneration Management – sustainable and cost-efficient

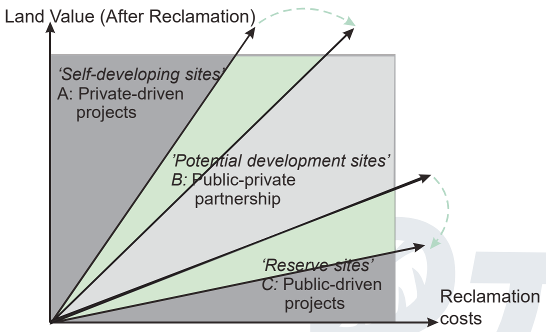
Dr. Thomas Ertel, et environment and technology

ReSites – Transnational Training on Sustainable Remediation, Bydgoszcz, 10 May 2017

Brownfield Regeneration - an ongoing process



Cabernet A-B-C model



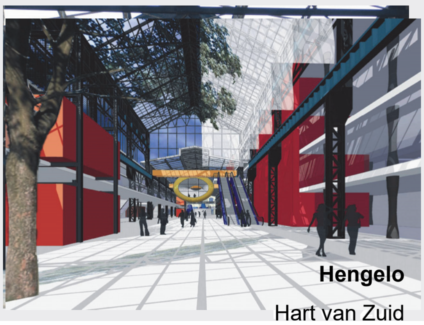
REVIT puzzle

What is obvious: Brownfield revitalisation is a long term and complex process and a wide range of professional disciplines has to be involved.

What we have learned.....

Prepare the ground – environmental remediation

Industrial Heritage



Hart van Zuid

What we have learned.....

Stakeholder engagement

What we have learned.....

Financing – a miracle?

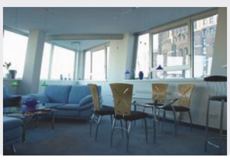
Private Public Partnerships

COBRAMAN environment and technology CENTRAL EUROPE EUROPEAN UNION

What we have learned.....

Marketing brownfield sites most important

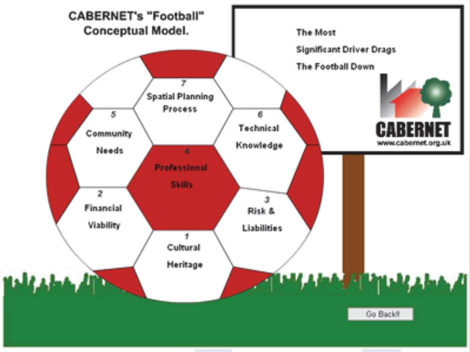
Gasometer Vienna, AUSTRIA



MARKETING

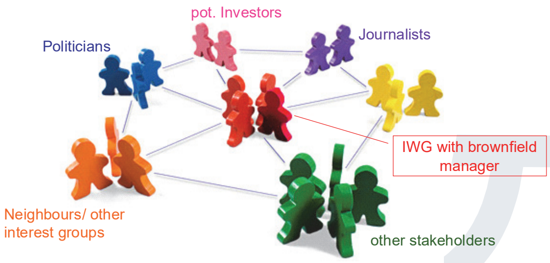
What we have learned.....

Managing the process!!!



What we have learned.....

We do need a professional brownfield manager, well educated and well situated in the administrative structure of the municipality.



Brownfield Manager - BM
A new professional discipline

- Drafting a detailed job description
- Developing a training program with accompanying training materials
- Compiling effective management tools
- Doing training on the job with selected staff of the partner cities
- Giving recommendations on optimised municipal management structures in course of brownfield redevelopment projects

COBRAMAN

BM's tasks and responsibilities

Tasks	Responsibilities
• Provision of relevant and **well targeted information** for specific groups • Identification and **involvement of** community/neighborhood and other **stakeholders** in redevelopment process	• **"one stop shop"** for internal and external stakeholders (e.g. investors as well as for site owners) • **Initiator and moderator** of the stakeholder engagement process
• **Internal communication** in the municipality, short and direct channels enable short time project results • Set-up and steering a project-specific **interdisciplinary working group**	• **acting as interface** between policy makers, administration and the technical specialists • **coordinating** information flow and **work at any step** in the development process
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• To facilitate **efficient project delivery** • **coordination of** revitalization **process** including time schedule and cost management • **quality and risk management**	• **Project manager**
• **Branding** – building a **positive image** for the area under regeneration • Marketing – **initiating** target group specific **marketing activities**	• **Initiator and coordinator of public relations** and marketing activities

Disciplines to be covered by a BM

Required skills (1)

project management

- General project management
- Conceptual and visionary thinking
- Leadership - strong team player
- Organizational skills

environmental/ technical know-how

- Civil and construction engineering
- Environmental engineering, geotechnics
- Health and safety measures

Required skills (2)

real estate economics

- Basic knowledge in project financing and calculation
- Market mechanisms and trends
- Life cycle considerations of real estate investments

legal aspects

- Basic knowledge in all related legal areas
- Municipal administration and structures
- Understanding of decision making processes and a sense of political feasibilities

Required skills (3)

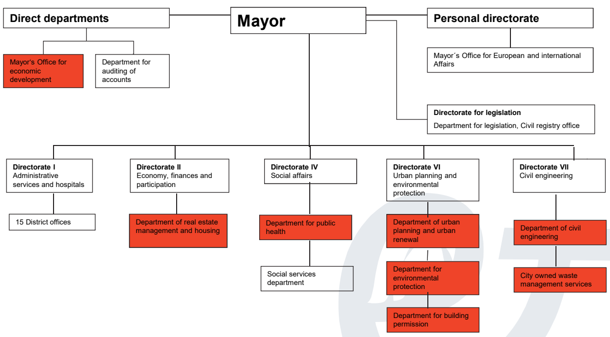
planning competences

- Landscape and urban planning
- Architecture
- Socio-economic dimension of urban development

communication

- Communication management
- Moderation, negotiation, mediation
- Ability to describe even complex issues in illustrative and simple words - spokesman qualities
- Marketing and campaigning

Typical orga chart of a city



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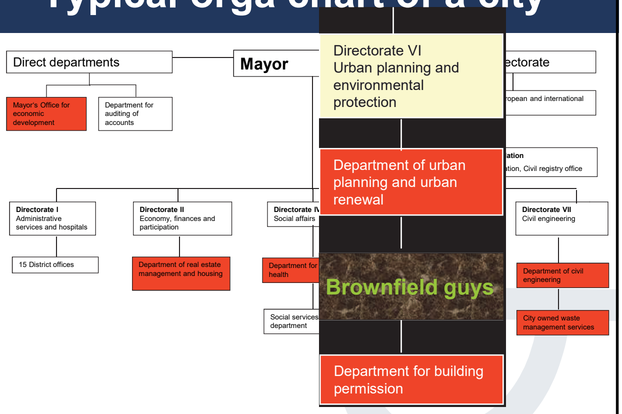
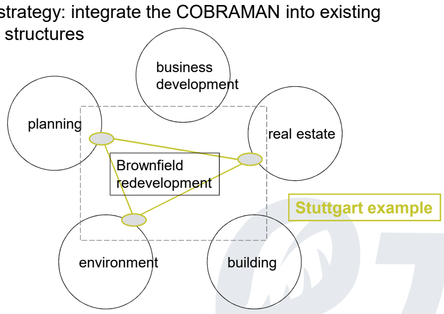


Organisation structure

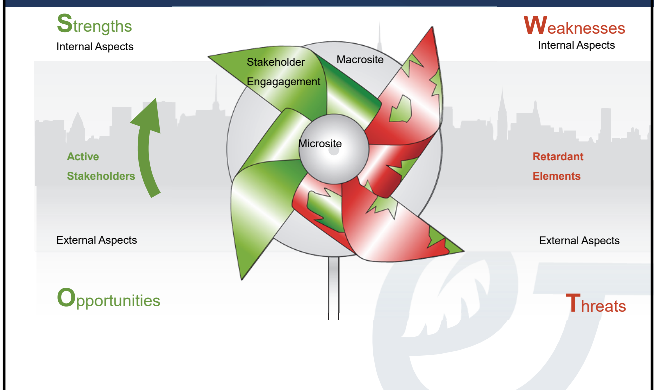
Ambiguous strategy: integrate the COBRAMAN into existing organisation structures



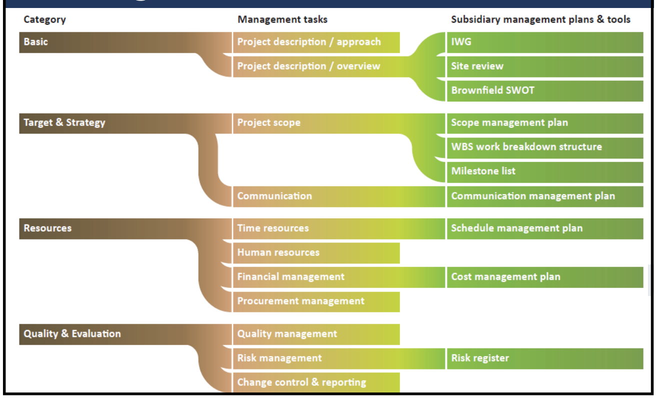
4 Key Management Tools

- the interdisciplinary working group
- the site review
- the brownfield SWOT
- the brownfield regeneration management plan

Stakeholders as key drivers



Brownfield Regeneration Management Plan



Selection of cost-efficient technologies – Operating Windows Concept

Key challenges in technology selection

1. Site specific feasibility

- Exact knowledge about mode of operation, pros and cons of all available technologies

2. Costs

- Remediation design
- Cost risks and main influencing factors
- Time required for remediation

Selection of cost-efficient technologies – Operating Windows Concept

Key challenges in technology selection

3. Fate and transport of contaminants

- Dissolved, adsorbed
- Free phase, residual or mobil
- Precursors
- Redox-Characterisation

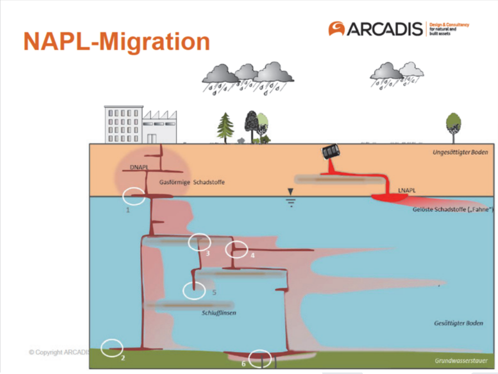
4. Heterogeneity affecting storage and back diffusion

Operating Windows

(ref. T. Held, Arcadis)

- Compilation of all critical parameters and their ranges of values as a basis for assessment of effectiveness of a remediation activity
- Strict consideration of quantitative methods and quantified boundary conditions
- Consistent decision making tools for design phase instead of trial & error in remediation phase

Example – NAPL Migration



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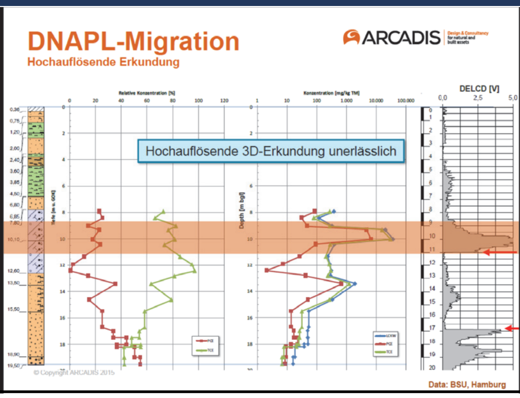


Operating Windows

- Data mining of successful remediation projects
- Lab experiments and pre-tests
- Application of conceptual remediation models

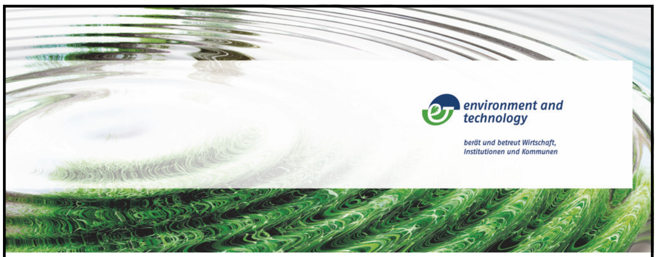
Will enable

- Knowledge based selection of technologies
- Optimised prognosis of effectiveness
- Reduced costs with more reliable etimations

But do require

- More quantitative characterisation results

= > a new generation in site characterisation



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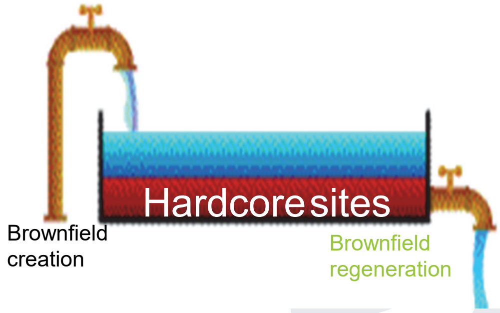

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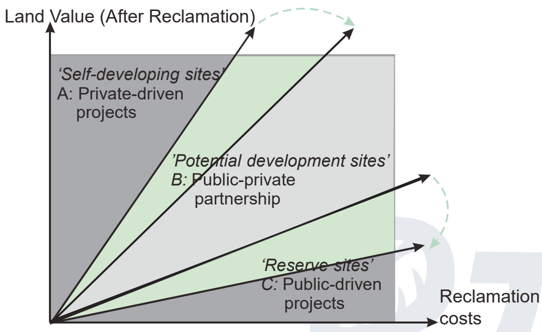

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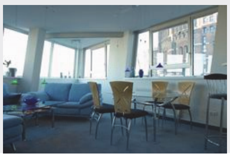

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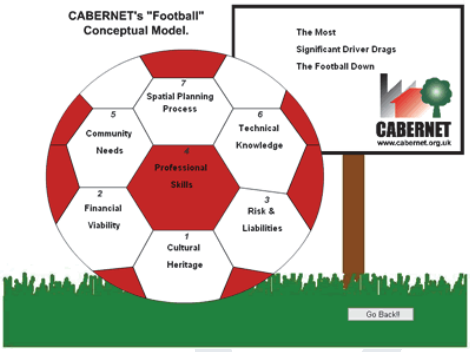

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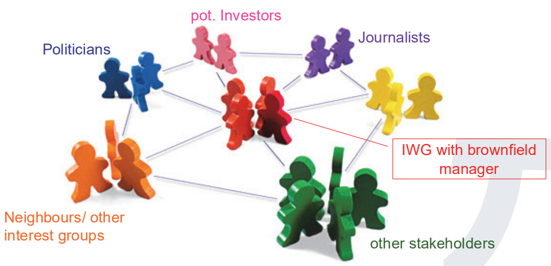

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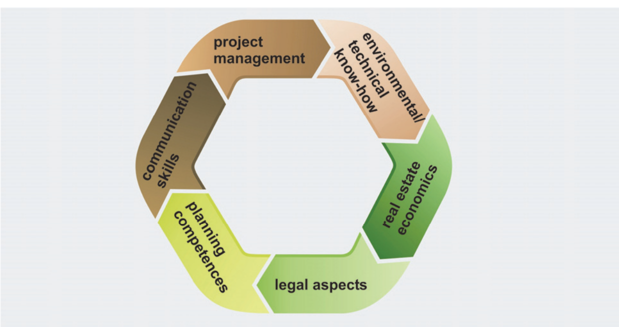

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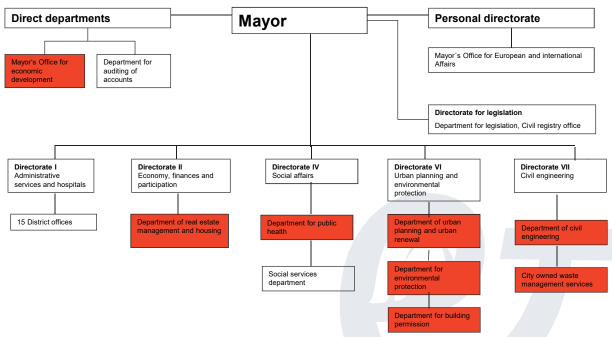

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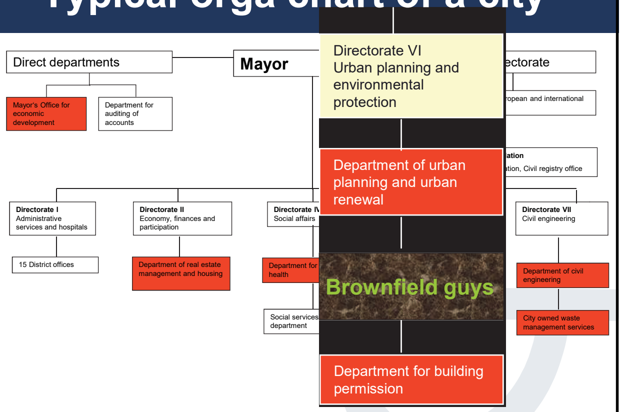

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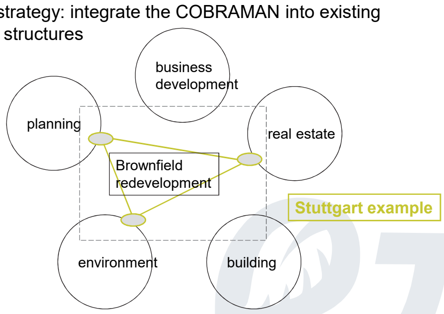

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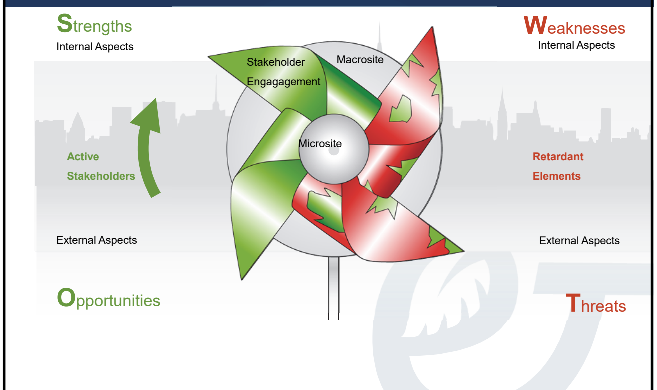

Brownfield Regeneration Management Plan

Category	Management tasks	Subsidiary management plans & tools
Basic	Project description / approach	IWG
	Project description / overview	Site review
		Brownfield SWOT
Target & Strategy	Project scope	Scope management plan
		WBS work breakdown structure
		Milestone list
	Communication	Communication management plan
Resources	Time resources	Schedule management plan
	Human resources	
	Financial management	Cost management plan
	Procurement management	
Quality & Evaluation	Quality management	
	Risk management	Risk register
	Change control & reporting	

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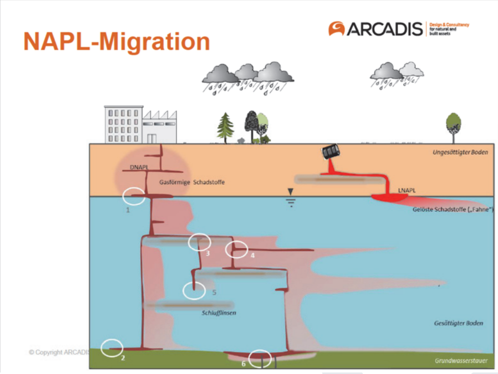
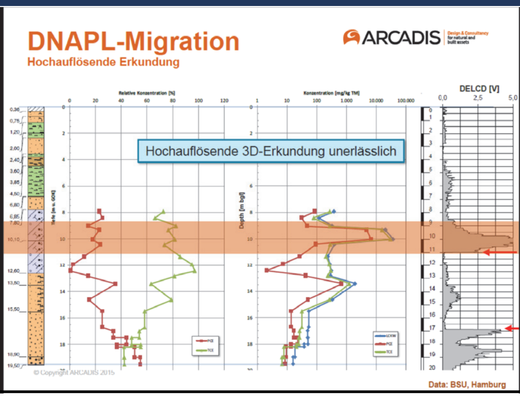


Example – NAPL Migration



Operating Windows

- Data mining of successful remediation projects
- Lab experiments and pre-tests
- Application of conceptual remediation models

Will enable

- Knowledge based selection of technologies
- Optimised prognosis of effectiveness
- Reduced costs with more reliable etimations

But do require

- More quantitative characterisation results

= > a new generation in site characterisation

BROWNFIELD REGENERATION MANAGEMENT - sustainable and cost-efficient

Dr. Thomas Ertel, et environment and technology, Boschstr. 10, 73734 Esslingen Germany	05-2017

MANAGEMENT OF BROWNFIELD REGENERATION PROCESSES

All over Europe revitalisation of brownfield sites plays an important role in avoiding urban sprawl and improving the quality of urban environment, thereby helping to create the conditions necessary for sustainable development. Brownfield land endangers public health and creates environmental risks. Moreover it strives to combat related social and spatial segregation threatening the competitiveness of European cities. Rehabilitation will be of growing importance in the EU member states, which requires large investments.

It is one of the most important lessons learnt from previous European activities in the brownfield sector, that professional process management is a key factor for successful brownfield regeneration. Accordingly it was the basic approach of the COBRAMAN project to introduce a new professional discipline: the brownfield regeneration manager. The successful implementation of brownfield regeneration managers within European cities enables effective and successful renewal and conversion processes.

Brownfield regeneration processes are often long term, complex and involve a wide range of professional disciplines as well as political actors and different stakeholder groups. Co-ordination and communication are essential to sustain complex projects. The management of the process as such is more evident to facilitate the redevelopment than sole technical aspects. Key tasks for professional regeneration managers are to develop and deliver opportunity plans and to steer revitalization processes. The responsibilities of the brownfield manager comprise further community involvement and marketing activities.

4 KEY MANAGEMENT TOOLS

The management of regeneration processes requires the application of established management tools. There is a wealth of existing instruments and tools to be used in process and project management. Those which proofed to be the most important have been specifically adapted by the COBRAMAN partnership to the regeneration business.

Coordination – the interdisciplinary working group

There might by many ideas about the best name to be assigned to a project specific working group – but it is consensus that such a working group with all actors represented is a must for coordinating the manifold activities around the brownfield regeneration process. The term “interdisciplinary working group” reflects the composition of this group comprising various departments and specialists involved. The working group structure will depend on the specifics of each case, and it might vary during the subsequent phases of project implementation. It is recommendable to set up a formal statute for the working group, outlining:

- Aims and objectives, lifetime, meeting schedule
- Membership, representation and participation
- Competences and duties of the members
- Rules for decision making
- Chair and secretariat.

The more responsibilities and decision making power can be assigned from the different departments to such a group, the more effective will be their work. Taking over the chair or secretariat is a key role for the regeneration manager.

Information and communication – the site review

From the beginning of a project a multitude of information, planning documents, technical reports etc. will be produced from various actors involved. Keeping the overview, structuring and filing, assessing according to relevance and target groups as well as drawing appropriate conclusions are fundamental tasks to ensure the information flow within the project and its environment.

The site review is the mother document, outlining and summarising all relevant aspects, and linking to the wealth of existing specific documents. It is an internal working document continuously updated, collecting information from all members of the working group. It helps to bring all working group members to the same level of knowledge; it should be easily accessible for them. It should not be focusing on different target groups, but to be considered as the source for specific documents (e.g. SWOT) and target group related information as e.g. marketing communication activities.
As many cities are already operating brownfield registers similar information systems, it has to be decided

- which parts of information,
- to which level of detail and
- in which time intervals

the transfer of updated content will be done from the site review to these public info systems.

Strategy and marketing – the brownfield SWOT

SWOT Analysis is a strategic planning method used to evaluate the Strengths, Weaknesses, Opportunities, and Threats involved in a project or in a business venture.

SWOT stands for:

Strengths:	attributes of items that are helpful to achieving the objective.
Weaknesses:	attributes of the items that are harmful to achieving the objective.
Opportunities:	external conditions, which are helpful to achieving the objective.
Threats:	external conditions, which could do damage to the objective.

In SWOT analysis a careful identification of individual SWOT items is essential because subsequent steps in the process of planning for achievement of the selected objective may be derived from the SWOT. For a brownfield regeneration specific SWOT these items have been categorised into:

- microsite aspects, e.g. current and future use, ecological aspects, financial issues, social and cultural aspects etc.
- macrosite aspects, e.g. neighbourhood uses, infrastructure / transport situation, market situation & competitors etc.
- stakeholder engagement, e.g. owners, investors, citizens in neighbourhood, politicians etc.

This third category is considered to be the key function driving or blocking development.

Project management – the brownfield regeneration management plan

This plan is similar to a classical project management plan. It is a formal, approved document that defines how the redevelopment project is executed, monitored and controlled. Depending on the complexity of the site it may be summary or detailed and may be composed of one or more subsidiary management plans and other planning documents.

It is like a roadmap for all project team members but especially dedicated to the BM. It explains how the intended project scope will be reached, guides through the stations from initiating, planning, executing, monitoring and closing the redevelopment project and helps to take care of various project constraints like scope, quality, schedule, budget, resources and risks. Once agreed and approved by at least the project team and its key stakeholders the plan is the binding framework for all activities during the redevelopment process. What makes the difference? As in general project management matters it is all about persons, their aims & goals, the financial framework, the time planning, public relation and documentation. But the special situation in a redevelopment projects even enlarge the complexity of a project. This complicates the definition of clear and broadly accepted objectives, structures and main work flows and subsequently setting up of subsidiary plans for schedule, cost, risk and quality management as well as stakeholder engagement plans.

Although at project start the urban development framework and targets seem to be well defined, the longevity of the processes or technical risks and related modifications may imply changing boundary conditions, entrance of new stakeholders or substantial shifts in stakeholder's attitude towards the development.

These unknowns hamper the set-up of well-defined management plans. On the other hand they underline the particular importance of their strict application.

The general structure is divided in 4 categories (see respective slide in ppt) and helps to keep the overview. The structure is as simple as possible but as complex as needed to cover all aspects of the redevelopment project in an adequate way. The importance of the single elements may vary from case to case but the general structure can be applied to all kind of redevelopment projects. The number of categories is NOT indicating the importance of the elements but is reflecting the logical and partly chronological sequence or a redevelopment process.

Selection of cost-efficient technologies - Operating Windows Concept

The success of characterisation and remediation activities strongly depends on the application of the most appropriate technologies and their combination. To date selection of these technologies is still based more on qualitative experience of the experts involved than on quantitative, scientific sound decision making processes. This is due to strong effects of site specific parameters and subsurface heterogeneity on characterisation results as well as on the data quality and information value of remediation reports of completed projects.

Key challenges in technology selection

1. Site specific feasibility
    - Exact knowledge about mode of operation, pros and cons of all available technologies
2. Costs
    - Remediation design
    - Cost risks and main influencing factors
    - Time required for remediation
3. Fate and transport of contaminants
    - Dissolved, adsorbed
    - Free phase, residual or mobil
    - Precursors
    - Redox-Characterisation
4. Heterogeneity affecting storage and back diffusion

The strict application of quantitative methods and considerations will enable the development of proper consistent decision making tools for the design phase instead the widespread application of trial & error in the remediation phase.
In order to achieve significant progress in the application of the operating windows approach, it is required to enlarge the data basis on operational aspects. Hence a stringent data mining of successful remediation projects is inevitable. Further a wider application of lab experiments and pre-tests in the design phase as well as the application of conceptual and mathematical remediation models will be needed.

Doing so this will enable a proper knowledge based selection of technologies in combination with optimised prognosis of effectiveness. This will lead to reduced costs with more reliable estimations, but requires more quantitative characterisation results, to be achieved through a new generation in site characterisation.

LIST OF REFERENCES

COBRAMAN final brochure: Brownfield regeneration management, from education to practice.

T. Held, Arcadis : Operating windows – Auswahl von Sanierungsverfahren. Presentation held at Seminar 03/2017 – Sanierungspraxis 2017 – Stuttgart, 06.April 2017

Bydgoszcz 10.05.2017

Optymalizacja badań i monitoringu skażeń środowiska na terenach poprzemysłowych

Optimization of testing and monitoring of environmental contamination in post-industrial areas

Wojciech Irmiński, Geo-Logik Wojciech Irmiński

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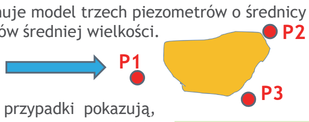

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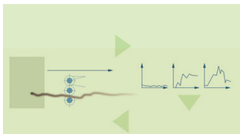

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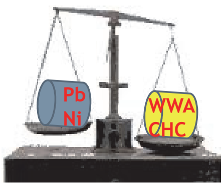
Zmiana ciężaru problemu

Metale ciężkie a substancje organiczne (pierścieniowe, chlorowane)



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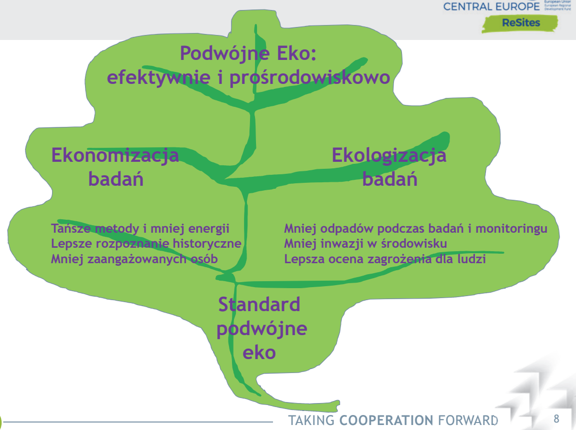

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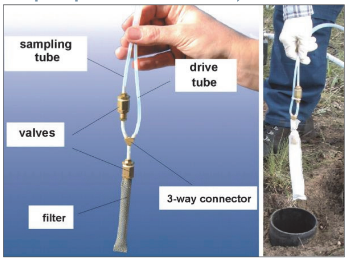

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Idealna do poboru wody z rozpuszczonymi gazami

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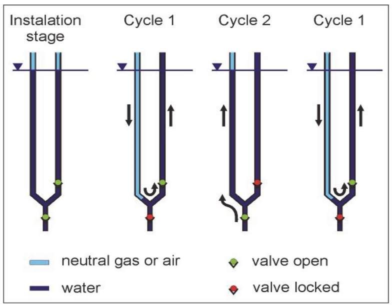
Zasada działania MPP



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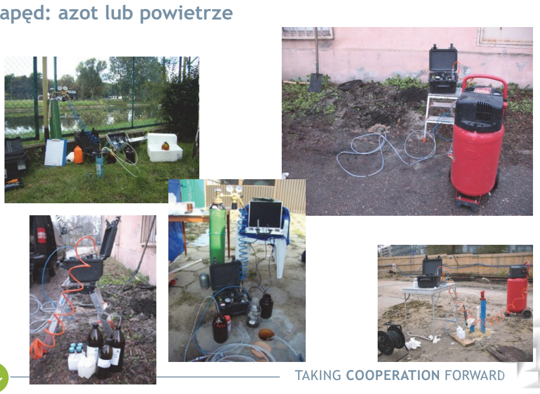
Napęd: azot lub powietrze



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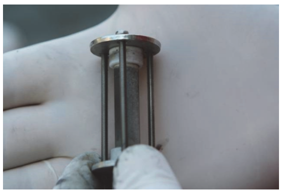

Test ETV - projekt PROMOTE
Bydgoszcz 2007,

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CONTACT

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TRANSNATIONAL TRAINING ON SUSTAINABLE REMEDIATION

Bydgoszcz 10.05.2017

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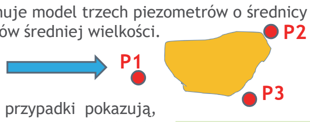

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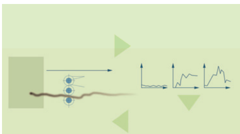

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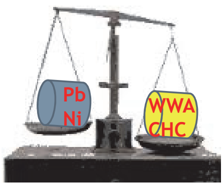

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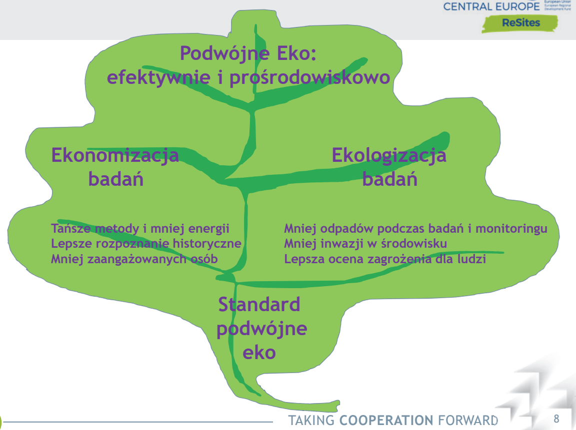

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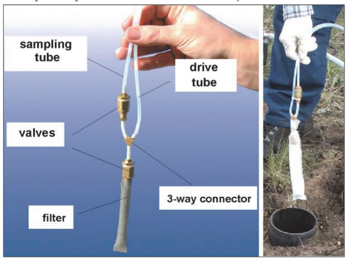

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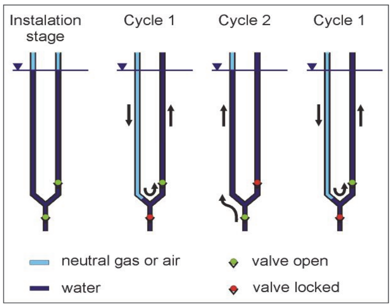

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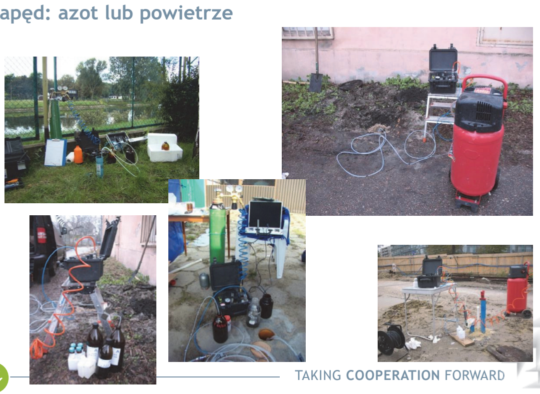

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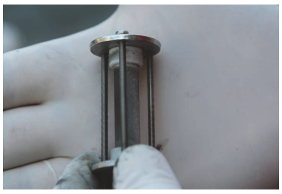

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- the results of the author's own research on the heavily contaminated post-industrial sites

CONTACT

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OPTIMIZATION OF TESTING AND MONITORING OF ENVIRONMENTAL CONTAMINATION IN POST-INDUSTRIAL AREAS

Wojciech Irmiński

05-2017

INTRODUCTION

Contamination testing in post-industrial areas has already a long history in Europe. It is evident that in the late 80s of the last century there was an unusual revival in this topic in some of the countries (Germany, the Netherlands, Denmark). Increase in funding in this area of environmental research was a result of not only constant increase of ecological awareness and society's expectations, what was brought by e.g. advances in science, but also invaluable "greenfields" areas started to be saved in developed countries. Thus, the interest shifted towards areas called "brownfields" – the name refers not only to post-industrial areas but also to all areas which were degraded, potentially contaminated and lately even "dying" areas which functions have been exhausted. Land recycling became gradually a notion as standard as paper or scrap recycling.

Regardless of this, scientific advances in medicine, ecotoxicology and development of analytical methods in laboratories have shown that focus of environmental studies should be shifted from problems of heavy metals contamination towards organic compounds.

The economic crisis and collapse in 1990s did not facilitate implementation of current knowledge into practice. Also, regulation of contamination prevention law was not an easy process. For example, in Poland, the State Inspectorate for Environmental Protection by the Ministry of the Environmental Protection (former name of the Ministry of the Environment) published in 1996 *Handbook on the research of old landfills - assessment, research bases* (original title: *Podręcznik badań starych składowisk – ocena, podstawy badawcze*, 1996). This was done thanks to the initiative of the Polish Geological Institute within the framework of the Environmental Monitoring Library series. It was a translation of the German textbook Altlastenhandbuch (source: Landesanstalt für Umweltschutz Karlsruhe, Baden-Württemberg) adapted to Polish realities. Some time later Agricultural University of Wrocław (nowadays Wrocław University of Environmental and Life Sciences) gradually published a similar translation of the same methodology (Old Landfill, volume I - Recognition and Evaluation - Part 1, 1997; volume I - Recognition and Evaluation - Part 2, 1999; volume II – Reform and control, 2000).

These actions did not bring the expected result and brownfield areas had not been perceived as good places for new investments for a long time. Local authorities vied with each other to attract Polish and foreign investors by offering them attractive land plots in the special economic zones, equipped with new infrastructure and long-term tax relief.

Currently, the trend to move post-industrial areas outside of the city still lasts, however now, especially in bigger cities, post-industrial areas became an interesting part for investors and developers because of their good location and big land plots with clear ownership status. Local spatial planning undergoes changes and it is allowed now to build apartments, offices and shops. For several years now, cautious investors and buyers ask about the environmental state of their potential investment. They learned to do that after many cases when there occurred problems with heavily contaminated land from excavations, that no one wanted to receive and quite often did not know how to manage. Also, legal regulations had to keep up with the dynamic situation in economy – building permits started to be accompanied with recultivation decisions and from year 2016 we can talk about remediation in Poland.

Both the detection of contamination, its right assessment needed for remediation plan and the monitoring of the environment also require changes. In Europe these are not new methods at all, however in the context of the new approach to the principles of environmental conservation and economization of testing these are innovative methods (certainly they have been used in Poland very rarely so far).

What should therefore be the optimization of testing and monitoring of the environment?

In simple terms, the optimal operation to control the state of the environment is:
• efficiency – gaining knowledge at a relatively low financial cost; and -
• pro-environmental approach – minimization of any negative impact on the environment caused by research testing and monitoring.
In other words, we can define this attitude as a double "Eco" - that is, "Economization & Ecologization" (Eco-Eco Standards).

ECONOMIZATION

The issue of financial effectiveness does not require a broader comment. This action is the result of a compromise between the need to acquire the necessary information and the budget. In practice, this is the result of the arrangements between the investigator and the funding body.
Arising question - what exactly is the needed information?
The principle of historical query research, for many years preferred in the German methodology “Altlasten” and American methodology “superfunds”, finally is in Poland also legally bound. Methods of proper investigation of contaminated areas are formulated in the decree of the Minister of the Environment dated from 1 September 2016, which treats on the method of conducting assessment of surface contamination. Unfortunately, it means that we still have a delay: in Poland we are 20-30 years behind the method makers. It is a sad reflection.
The first element of the needed information is the accuracy of the historical query. It is particularly important in post-industrial areas as the effects of different technological processes overlap most often there. The second element is the quantity and type of samples. The aforementioned regulation defined, e.g. research stages of contaminated sites, as well as a minimum number of samples, on the basis of which the geochemical quality of the soil can be characterized. An important factor in planning research testing is the need to divide the space into research sections. The number and minimum area of a section depends on the land’s category – it is similar for lands belonging to group I (residential land) and group IV (industrial land), and it is different for land belonging to groups II and III (cultivated land and forest areas respectively).
For post-industrial area, that is assessed in respect of land contamination and ultimately human health risks, the actual number of sections to divide the tested area should be determined based on historical query. This is a first point of misunderstanding between a contracting entity and a contractor, because it has clear financial consequences - as the number of sections grows, the number of samples grows.

The third element of the needed information is a type and scope of chemical analyzes. It also generates significant costs and often raises doubts on the customer’s side. At the exploratory stage, a broad but justified analyzes spectrum should be used. At the monitoring stage, it is worth pointing out key substances (indicators), in order to aim at economic efficiency.
Economization of the study also includes other factors, such as the number of people involved, the type of drilling equipment used, the hole diameters, the amount of energy needed, work intensity, waste disposal costs and other.

ECOLOGIZATION

Improvement of analytical methods in laboratories lead to a situation, when smaller volumes of material need to be tested. Following this trend of miniaturization it cannot be forgotten, however, that a sample must be representative. Hence the role of the sample-collector (sampler), the choice of surveying site, the sampling area, the sampling method and the preparation of samples for surveying.

In post-industrial areas soil, subsoil (ground) and water contamination can have very high levels. Therefore, the optimum method of making test holes are drillings of a small diameter or testing with penetrometer or rotary hammer. This limits the amount of excavated material to a minimum, which can be surprising and dangerous even for the drilling team. Leaving outside the extracted soil, which emits, for example, volatile organic compounds, is not a solution at all. However, it often happens even in companies that specialize in environmental protection, and geotechnical drilling companies do it quite regularly without paying attention to the fatal environmental effects.
The problem is most apparent when the subject of the study is the strongly contaminated groundwater. Traditional piezometers with a diameter of 4 inches and a depth of e.g. 14 meters need a complete extraction and removal of 1 m^3 of ground before embedding the pipe column. Then the piezometer passes the pumping cleaning phase (sic!), and before collecting each sample it is advised to pump 3 times the volume of water column in the piezometric tube (another method recommends removing even 3 times the volume of water from the filter tube and surrounding artificial sand zone). Assuming that in "our" piezometer the water mirror is at a depth of 4 meters, we need to develop or spill over 300 litres of water, which is often heavily contaminated.

What solution would be optimal from the point of view of ecologization of research testing and monitoring?
The following two methods are suggested by the German company Innovative Messtechnik Dr. Weiss (imw) and they were tested also in Bydgoszcz as a part of the international project PROMOTE in 2007 (6^{th} EU Framework Program). Both methods have successfully passed tests in Europe's new Environmental Technology Verification (ETV) system. Therefore they are not completely new, but still not very popular. They contribute greatly to the ecologization of research testing and monitoring. Both methods require only piezometric holes of 1-2 inches in diameter. If there is no need to study soil samples, these holes can be done using the direct-push technique (for many years this technique has been used and disseminated, e.g. within the framework of the TIMBRE project, 7^{th} EU Framework Program).

MINI PRESSURE PUMP, imw, GERMANY

This type of pump offers low-flow sampling of water without gaseous losses of volatile compounds or contamination with atmospheric oxygen.
Compressed air from a cylinder or compressor can be used as a drive, or in special cases compressed nitrogen can be used. The pump itself consists of two valves, which regulate the push of the subsequent portions of water through the pipe to the surface. Outflow takes place through the supply pipe as a result of momentary gas pressure (e.g. nitrogen). Adjustment of operation – with a pneumatic controller (pressure, frequency, cycles' length) takes place in the control box with a small battery.
Water sampling requires little energy, it causes no hypotension or turbulence, which minimizes the release and escape of VOCs (Volatile Organic Compounds). Pipes with a diameter of 4 mm are made of PE or Teflon. The double valve mini pump is fit to the tube with 20 mm (< 1 inch diameter).
The structure and actions are shown in the figures 1 and 2.

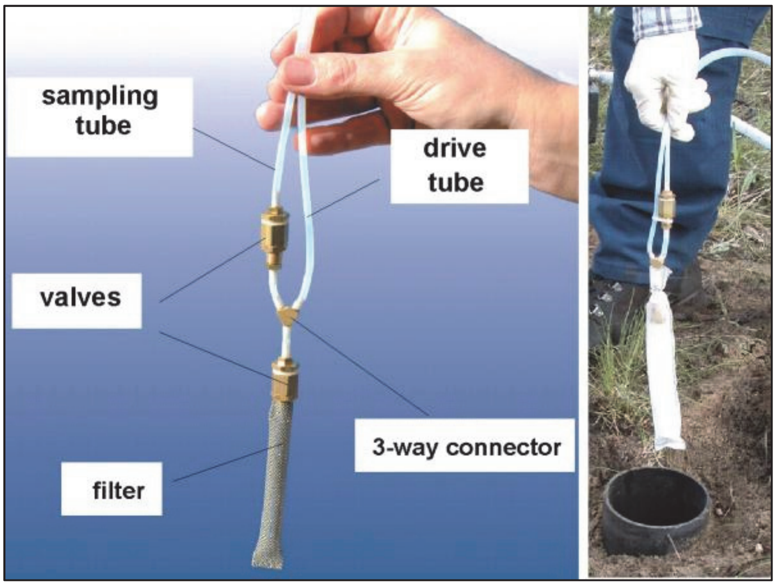

Fig. 1. Structure of MPP (mini pressure pump) made by imw dr Weiss

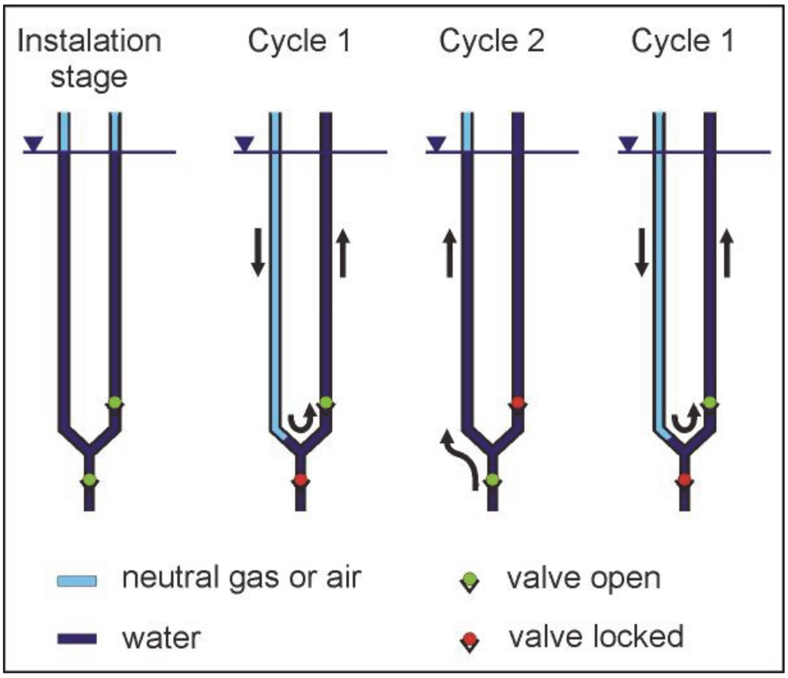

Fig. 2. Operation principle of MPP

The mini pressure pump can be used also in holes with a large diameter, preferably with packer systems it can be used as so-called daughter-pump.

This method is used in many countries in Europe, also in Poland. It is very successful in detection of all compounds – inorganic and organic – in water, but particularly of volatile and semi-volatile hydrocarbons. Thanks to this technique it was repeatedly possible to detect the presence of BTEX and PAH, but also the presence of such chlorinated hydrocarbons as highly carcinogenic and volatile vinyl chloride (CV). CV is basically impossible to detect in soil samples, because it quickly leaks from the drilled material. This compound may indicate the presence of PCE and TCE in deep aquifers, but it is impossible to be collected with the traditional technique (rotor pump) because it does not actually reach the sample.

Case 1. Site of a pre-war chemical factory with numerous scattered centres of soil contamination at different depths. Phenols, cresols, PAH, BTEX and many of their chlorinated variants were detected (October 2015). CHC source is hard to detect. Assessment of actual emissions from the DNAPL phase is necessary. The rotor dynamic pumps used in a 4 inch piezometers show concentration of VC: P4 - 72,7 µg/L, P1- <1 µg/L.
The use of a mini pressure pump in P4 shows 35 µg/L for VC and in P1 1,2 µg/L. MPP in a 2 inch piezometer (Pz19 close to P4) shows for VC 108 µg/L.

Case 2. Old brownfield site. Historical factory buildings. Low concentrations of chloroform were detected in the soil samples from the embankments. Cause unknown. In the aeration zone in the native soil (sands) chloroform and other chlorinated compounds are absent. Low-cost piezometers of a small diameter and water samples collected using the mini pressure pump have shown (for example): Chloroform 195 µg/L, TCE 21,2 µg/L, PCE 5,02 µg/L.
An elegant solution: low-cost drilling and pump operation, precise data, no waste-water in environment.
When using a mini pressure pump in holes of a small diameter, pumping is not necessary. And if the water is severely contaminated, the water collected from the pump during the flow rate adjustment can be accommodated in one litre bottle.

PASSIVE SAMPLERS – CERAMIC DOSIMETER

The ceramic dosimeter takes shape of a ceramic tube with nanopores (membrane) and a sorbing material. The tube diameter is 1 cm, the wall thickness 1,5 mm and the pore size is 5 nm. The tube is filled with sorbent and closed with PTFE caps. In application of the ceramic dosimeter in the field the tube should be covered with a stainless steel cage.
The figure 3 and 4 show the applications of ceramic dosimeter set during the PROMOTE Project test in Bydgoszcz in 2007 and groundwater monitoring project in Ostrów Mazowiecka (2008).

Fig. 3. The ceramic dosimeter set in Bydgoszcz (PROMOTE, 2007)

Fig. 4. Groundwater long-term monitoring in Ostrów Mazowiecka using passive samplers (2008)

The idea of the ceramic dosimeter was elaborated by prof. P. Grathwohl in 2003 and is patented. The use of ceramic dosimeters in water monitoring was mainly described by scientists from the University in Tübingen (e.g. Grathwohl, Pipenbrink, Martin), but for this short review the paper of Weiß et al. (2006) was selected. A number of experiments in the lab scale and field tests and works show the suitability of ceramic dosimeters for time-integrated, long-term monitoring of groundwater quality. Using different, dedicated sorbents sampling of polycyclic aromatic hydrocarbons (PAHs) as well as sampling of benzene, toluene, ethylbenzenes, and xylenes (BTEX) and chlorinated hydrocarbons (CHCs) is possible. An additional application of ceramic dosimeters is the basis for the development of the Toximeter, the first passive sampler directly compatible with toxicological tests.

The sorbents are required to have a high affinity and capacity for the uptake of the tested chemicals combined with an easy extraction at high analytic recovery rates.

Ceramic membrane, small size and diffusion process generate low sampling rates. This guarantees appropriate time for delivery of chemicals (mass) from the surrounding water. This is particularly important for low-flow sampling and generally ceramic dosimeters are not well suited for sampling periods of less than 1 month in a low concentration environment (depending on the compounds to be assessed), where the collected mass for testing would be below the detection limit.

For example: with assumed concentration of Naphthalene of 1 µg/L the device needs 33 days to reach a detection limit, of 0,1 µg/L needs 330 days and of 100 µg/L 0,3 day respectively. With assumed concentration of Toluene of 1 µg/L the dosimeter needs 1,1 year to reach a detection limit, of 0,1 µg/L needs 11 years and of 100 µg/L 4,1 days respectively.
The accumulated mass can be measured in longer periods by using sets of ceramic dosimeters. This shows trends of contamination or decontamination of the groundwater in long-term monitoring. According to the EU Groundwater Directive this method can be used as the Eco&Eco standards.

SUMMARY

Presented examples of modern, however still not very popular sampling techniques aim to detect many problematic substances. Their use for investigating the state and monitoring of the environment in post-industrial areas is recommended due to research reasons (good accuracy and validity), economic (mobility, low sampling costs) and ecological reasons (minimum environmental stresses, observation of actual trends of increase or decrease of contamination levels).
The presentation is based on: PROMOTE project's materials available on the website www.promote-etv.org; materials available thanks to the author's cooperation with imw Weiss company and the results of the author's own research performed for the assessment of heavily contaminated post-industrial sites in Warsaw.

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TRANSNATIONAL TRAINING ON SUSTAINABLE REMEDIATION

ReSites Meeting, Bydgoszcz 10 May 2017

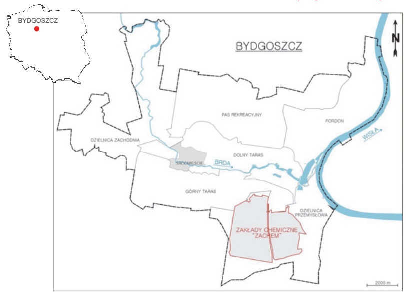
COMPREHENSIVE ASSESSMENT OF THE SOIL AND WATER ENVIRONMENT IN THE AREA OF THE FORMER 'ZACHEM' CHEMICAL PLANT IN BYDGOSZCZ

Dorota Pierri, Mariusz Czop - AGH University of Science and Technology in Krakow Prelegent, afiliacja

GENERAL DESCRITION OF THE ‚ZACHEM'

Interreg CENTRAL EUROPE ReSites

„Zachem" Chemical Plant JSC in Bydgoszcz city



occupies an area of strong anthropogenic transformation which constitutes over 11% of the city

TAKING COOPERATION FORWARD 2

HISTORICAL BACKGROUND OF THE ‚ZACHEM'

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- **from 1945** - DAG Fabrik Bromberg
- **1945-1948** - State Gunpowder Factory in Łęgnowo
- **1948-1951** - NitroFactory LabelŁęgnowo
- **1951-1959** - Chemical Plant No. 9 in Łęgnowo
- **1959-1971** - Chemical Plant in Bydgoszcz
- **1971-1976** - Chemical Plant ‚Zachem' in Bydgoszcz
- **1976-2003** - Chemical Plant ‚Organika-Zachem' in Bydgoszcz
- **2003-2012** - Chemical Plant ‚Zachem' JSC in Bydgoszcz
- **2012-2014** - Kapuściska Infrastructure JSC

TAKING COOPERATION FORWARD 3

HISTORICAL BACKGROUND OF THE ‚ZACHEM'

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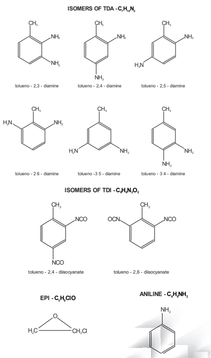
Dynamit - Aktien Gesellschaft Fabrik Bromberg
included nitrocellulose ($C_6H_7N_3O_{11}$), smokeless powder and nitroglycerin ($C_3H_5N_3O_9$), TNT ($C_7H_5N_3O_6$), dinitrobenzene ($C_6H_4N_2O_4$), V1 missiles, as well as aerial bombs, artillery shells and powder charges

Polish plant produced for the military and civil needs (after 1948)
TNT ($C_7H_5N_3O_6$), pentaerythritol tetranitrate ($C_5H_8N_4O_{12}$) and tetryl ($C_7H_5N_5O_8$) for the military and civil needs. It also produced dyes, dyeing intermediates, pigments and phenol (C_6H_6O), as well as dinitrotoluene (DNT $C_7H_6N_2O_4$), nitrobenzene ($C_6H_5NO_2$), aniline (C_6H_7N) and products from the recycled PVC

Chemical Plant in Bydgoszcz (from the 60s)
the production of isocyanates, dienes and polycarbonates, the polyurethane complex; flexible polyurethane foams, the electrolysis of brine, phosgene (CCl_2O), dinitrotoluene (DNT $C_7H_6N_2O_4$), toluene diamine (TDA $C_7H_{10}N_2$), toluene diisocyanate (TDI $C_9H_6N_2O_2$) and epichlorohydrin (EPI C_3H_5ClO) as well as rigid polyurethane foams

Basic and most important products manufactured in the Plant
toluene diisocyanate (TDI), allyl chloride (C_3H_5Cl), epichlorohydrin (EPI), hydrochloric acid (HCl), sodium hydroxide (NaOH) and sodium hypochlorite (NaClO)



TAKING COOPERATION FORWARD 4

CURRENT STATE OF THE ENVIRONMENT

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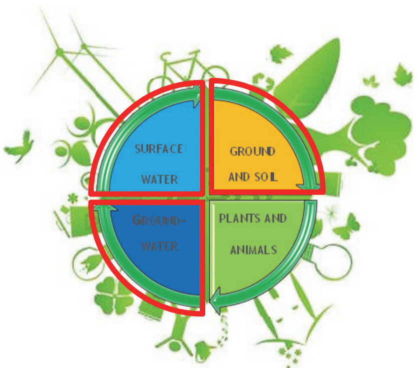
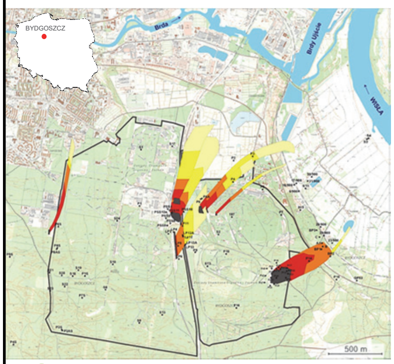


TAKING COOPERATION FORWARD 5

CURRENT STATE OF THE ENVIRONMENT

Interreg CENTRAL EUROPE ReSites



The quality of groundwater has a mosaic character

in the area of the Chemical Plant are zones of clean water but also zones of groundwater highly contaminated as a result of industrial activities.

Zones of strongly contaminated groundwater by coexisting organic and inorganic substances occur within contaminant plumes which are genetically assigned to the surface sources of contamination.

Main inorganic contaminants: Cl^- and Na^+.

Main organic cintaminants: phenol, AOX substances, diphenyl sulfone, hydroxybiphenyl, octylphenol and ethoxylated octylphenol esters and chlorinated ethenes and methanes.

TAKING COOPERATION FORWARD 6

CURRENT STATE OF THE ENVIRONMENT

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CURRENT STATE OF THE ENVIRONMENT

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CURRENT STATE OF THE ENVIRONMENT

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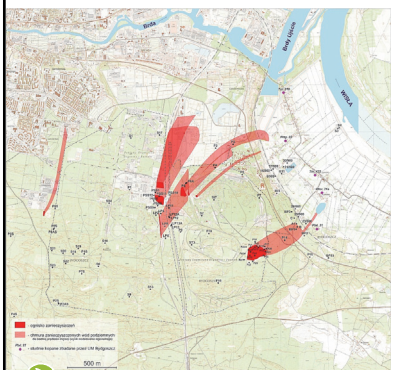

1) Large area of Chemical Plants (about 1600 ha)
2) Long history of activity
3) Accumulation of technical infrastructure components
4) „Hazardous" for human production profile
5) Identification of the most severe contamination sources

PRIORITY LIST OF CONTAMINATION SOURCES

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1) INDUSTRIAL WASTE SITE ‚ZIELONA' AMONG WITH ACCOMPANYING CNTAMINATION PLUME OF GROUNDWATER
   PHENOL, CHLOROORGANIC COMPOUNDS, INORGANIC CONSTITUENTS, SODIUM SULPHITE POLLUTED BY PHENOL

2) INDUSTRIAL WASTE SITE ‚LISIA'
   PAHS, BTEX, INORGANIC CONSTITUENTS, POST-PRODUCTION PITCHES
   SODIUM SULPHITE POLLUTED BY PHENOL

3) INDUSTRIAL WASTE SITE FROM EPI PRODUCTION
   PHENOL, NITRO-ORGANIC COMPOUNDS, INORGANIC CONSTITUENTS, PRODUCTION WASTES, SLUDGES AND ASHES FROM POWER PLANT

4) OTHER OBJECTS

TAKING COOPERATION FORWARD 10

HISTORICAL ENVIRONMENTAL RESEARCH

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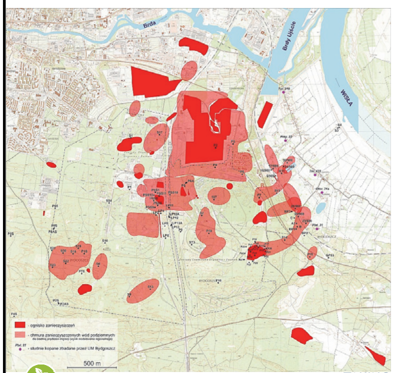
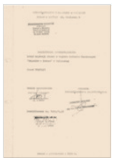


ENVIRONMENTAL RESEARCH FROM 80S



HEAVY METALS:
CR, HG, MN, AS, PB, ZN

INORGANIC COMPOUNDS:
CL^-, SO_4^{2-}, NA^+, B^{3+}, CYANIDES

ORGANIC COUMPOUNDS:
PHENOL, ANILINE, NITROBENZENE

TAKING COOPERATION FORWARD 11

COMPARISON OF ENVIRONMENTAL RESEARCH

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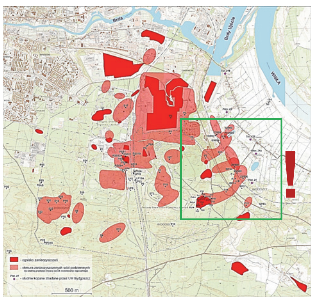
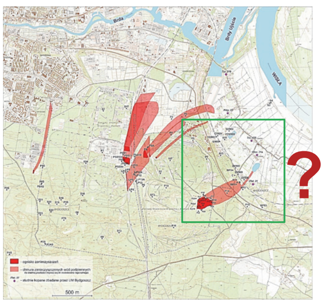


STATE OF THE ENVIRONMENT 80S

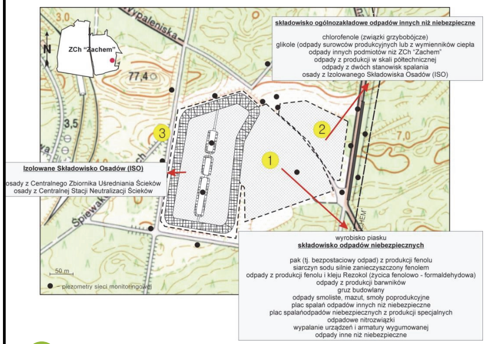


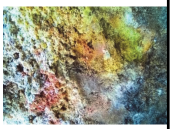
STATE OF THE ENVIRONMENT AFTER 2010

Surprising disappearance of contamination?

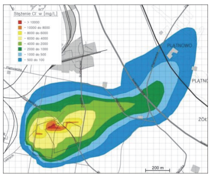
TAKING COOPERATION FORWARD 12

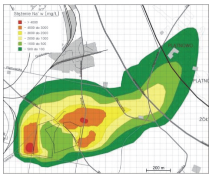
INDUSTRIL WASTE SITE ‚ZIELONA'

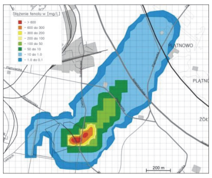




HYDROGEOLOGICAL NUMERICAL MODELLING



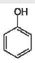


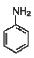


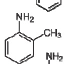
Contaminated area more than
15 times bigger than the Main Square!

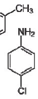
TAKING COOPERATION FORWARD 14

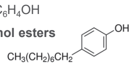
POLLUTANTS

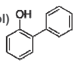

phenol C_6H_5OH **(hydroxybenzene)**

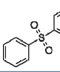
aniline $C_6H_5NH_2$ **(phenylamine)**


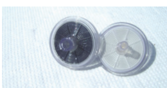
toluidine $CH_3C_6H_4NH_2$ **(methylaniline)**


chloroaniline $ClC_6H_4NH_2$


octylphenol $CH_3(CH_2)_7C_6H_4OH$
and ethoxylated octylphenol esters


hydroxybiphenyl $C_{12}H_{10}O$ **(phenylphenol)**



diphenyl sulfone $C_{12}H_{10}O_2S$



TAKING COOPERATION FORWARD 15

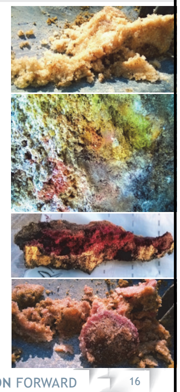
CURRENT STATE OF THE ENVIRONMENT

The use and production of various substances both organic and inorganic ones was not without the effect on the condition of soil and water environment. The pollutants were detected in the past and are now being detected within all of the components of natural environment - particularly in soils and groundwater.

Conditions of contamination of the natural environment with toxic substances (often mutagenic and carcinogenic) are particularly significant in relation to the potential impact on the natural heritage in the area of Plant, ie.

the Backwoods of Bydgoszcz

"Valley of the Lower Vistula" Nature 2000.



TAKING COOPERATION FORWARD 16

PRIORITY LIST OF THE ACTIONS

1) STARTING THE BARRIER
   LIMITING MIGRATION OF POLLUTION FROM INDUSTRIAL WASTE SITE ‚ZIELONA' INTO INHABITED AREAS (ŁĘGNOWO, OTOROWO, PLĄTNOWO)

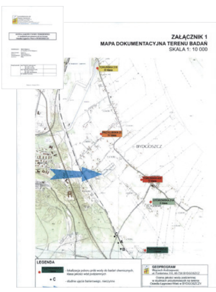
2) CREATING AND CURRENT SERVICE OF THE INTEGRATED MONITORING NETWORK OF SOIL AND WATER ENVIRONMENT
   IN THE AREA OF THE ‚ZACHEM' CHEMICAL PLANT IN BYDGOSZCZ

3) IMPLEMENTATION OF EFFECTIVE REMEDIATION
   OF THE SOIL AND WATER ENVIRONMENT IN THE AREA OF ‚ZIELONA' INDUSTRIAL WASTE SITE ALONG WITH A CONTAMINATION PLUME

4) DETAILED RESEARCH
   FOR DIFFERENT SOURCES OF POLLUTION AND THEN PERFORMANCE OF THEIR REMEDIATION PROJECTS

TAKING COOPERATION FORWARD 17

REAL THREAT TO LIFE AND HEALTH



ŁĘGNOWO

ŁĘGNOWO I	ŁĘGNOWO II
founded in 1954	founded in 1977
1 985 inhabitants	814 inhabitants

STRONG CONTAMINATION OF SHALLOW GROUNDWATER:

Total organic carbon (TOC): **32,6 mg/dm³**

Organic compounds: phenol, anilinae, Toluidine, phenanthrene (PAHs)

REAL THREAT TO LIFE AND HEALTH

Inhabitants of BRDYUJŚCIE

Inhabitants of ŁĘGNOWO

Inhabitants of HUTNICZA St.

Inhabitants of OTOROWO

Inhabitants of PLĄTNOWO

Inhabitants of AWARYJNE Hous. Est.

TAKING COOPERATION FORWARD 19

SUMMARY

1. **OCCURRENCE OF EXTREMELY HAZARDOUS ORGANIC POLLUTANTS (CARCINOGENIC AND MUTAGENIC) WITH RELATIVELY VERY HIGH CONCENTRATIONS (INDUSTRIAL WASTEWATER LEVELS)**
2. HIGH NUMBER OF THE SUPPOSED POLLUTANTS SOURCES (27 OBJECTS IN „ZACHEM" CHEMICAL PLANT ONLY)
3. **DEFICIENCIES IN THE POLLUTION STUDIES FOR THE ENVIRONMENTAL COMPONENTS (ESPECIALLY RISKS FOR HUMAN HEALTH AND BIOTA)**
4. IDENTIFICATION OF THE 7 PLUMES OF POLLUTANTS IN GROUNDWATER FROM POLLUTION SOURCES (MAINLY INDUSTRIAL WASTE SITES)
5. **SERIOUS HAZARD FOR INHABITANTS DUE TO POLLUTION OF SHALLOW GROUNDWATER (DUG WELLS) AND SURFACE WATER**
6. EXTREMELY HIGH COSTS OF THE REMEDIATION (UP TO 500 MLN EUR)

TAKING COOPERATION FORWARD 20

CONTACT

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TAKING COOPERATION FORWARD 21

TRANSNATIONAL TRAINING ON SUSTAINABLE REMEDIATION

ReSites Meeting, Bydgoszcz 10 May 2017

Comprehensive assessment of the soil and water environment in the area of the former 'Zachem' Chemical Plant in Bydgoszcz

Dorota Pierri, Mariusz Czop – AGH University of Science and Technology in Krakow Prelegent, afiliacja

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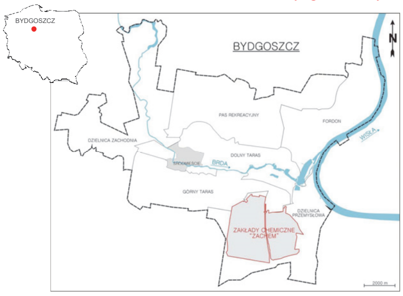
GENERAL DESCRITION OF THE ‚ZACHEM'

„Zachem" Chemical Plant JSC in Bydgoszcz city



occupies an area of strong anthropogenic transformation which constitutes over 11% of the city

HISTORICAL BACKGROUND OF THE ‚ZACHEM'

from 1945 – DAG Fabrik Bromberg

1945-1948 – State Gunpowder Factory in Łęgnowo

1948-1951 – NitroFactory LabelŁęgnowo

1951-1959 – Chemical Plant No. 9 in Łęgnowo

1959-1971 – Chemical Plant in Bydgoszcz

1971-1976 – Chemical Plant ‚Zachem' in Bydgoszcz

1976-2003 – Chemical Plant ‚Organika-Zachem' in Bydgoszcz

2003-2012 – Chemical Plant ‚Zachem' JSC in Bydgoszcz

2012-2014 – Kapuściska Infrastructure JSC

HISTORICAL BACKGROUND OF THE ‚ZACHEM’

Dynamit - Aktien Gesellschaft Fabrik Bromberg

included nitrocellulose ($C_6H_7N_3O_{11}$), smokeless powder and nitroglycerin ($C_3H_5N_3O_9$), TNT ($C_7H_5N_3O_6$), dinitrobenzene ($C_6H_4N_2O_4$), V1 missiles, as well as aerial bombs, artillery shells and powder charges

Polish plant produced for the military and civil needs (after 1948)

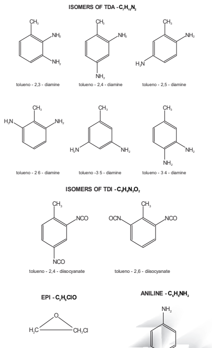
TNT ($C_7H_5N_3O_6$), pentaerythritol tetranitrate ($C_5H_8N_4O_{12}$) and tetryl ($C_7H_5N_5O_8$) for the military and civil needs. It also produced dyes, dyeing intermediates, pigments and phenol (C_6H_6O), as well as dinitrotoluene (DNT $C_7H_6N_2O_4$), nitrobenzene ($C_6H_5NO_2$), aniline (C_6H_7N) and products from the recycled PVC

Chemical Plant in Bydgoszcz (from the 60s)

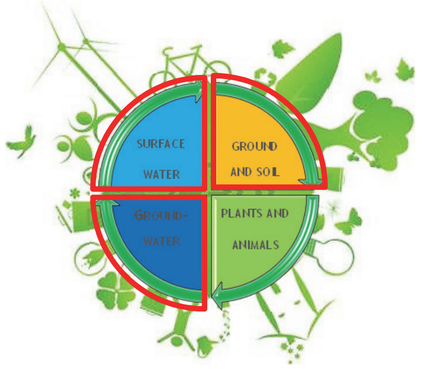
the production of isocyanates, dienes and polycarbonates, the polyurethane complex; flexible polyurethane foams, the electrolysis of brine, phosgene (CCl_2O), dinitrotoluene (DNT $C_7H_6N_2O_4$), toluene diamine (TDA $C_7H_{10}N_2$), toluene diisocyanate (TDI $C_7H_6N_2O_2$) and epichlorohydrin (EPI C_3H_5ClO) as well as rigid polyurethane foams

Basic and most important products manufactured in the Plant

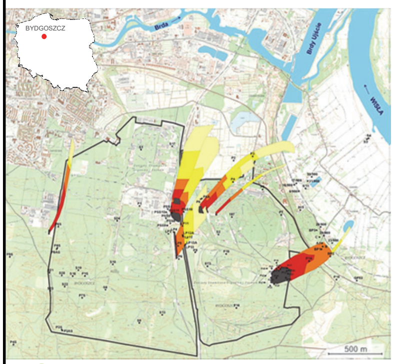
toluene diisocyanate (TDI), allyl chloride (C_3H_5Cl), epichlorohydrin (EPI), hydrochloric acid (HCl), sodium hydroxide (NaOH) and sodium hypochlorite (NaClO)



CURRENT STATE OF THE ENVIRONMENT



CURRENT STATE OF THE ENVIRONMENT



The quality of groundwater has a mosaic character

in the area of the Chemical Plant are zones of clean water but also zones of groundwater highly contaminated as a result of industrial activities.

Zones of strongly contaminated groundwater by coexisting organic and inorganic substances occur within contaminant plumes which are genetically assigned to the surface sources of contamination.

Main inorganic contaminants: Cl^- and Na^+.

Main organic cintaminants: phenol, AOX substances, diphenyl sulfone, hydroxybiphenyl, octylphenol and ethoxylated octylphenol esters and chlorinated ethenes and methanes.

CURRENT STATE OF THE ENVIRONMENT



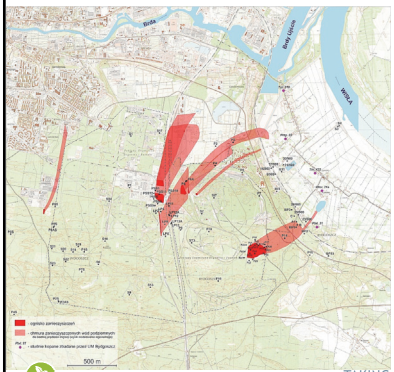

TAKING COOPERATION FORWARD 7

CURRENT STATE OF THE ENVIRONMENT



TAKING COOPERATION FORWARD 8

CURRENT STATE OF THE ENVIRONMENT



1) Large area of Chemical Plants (about 1600 ha)

2) Long history of activity

3) Accumulation of technical infrastructure components

4) „Hazardous" for human production profile

5) Identification of the most severe contamination sources

TAKING COOPERATION FORWARD 9

PRIORITY LIST OF CONTAMINATION SOURCES

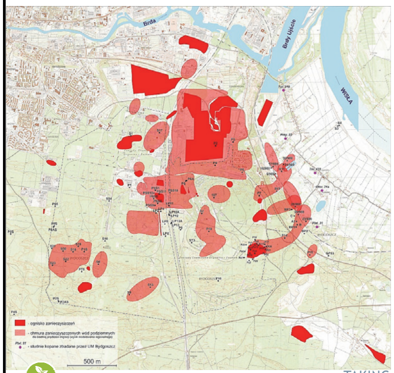
1) INDUSTRIAL WASTE SITE ‚ZIELONA' AMONG WITH ACCOMPANYING CNTAMINATION PLUME OF GROUNDWATER
   PHENOL, CHLOROORGANIC COMPOUNDS, INORGANIC CONSTITUENTS, SODIUM SULPHITE POLLUTED BY PHENOL

2) INDUSTRIAL WASTE SITE ‚LISIA'
   PAHS, BTEX, INORGANIC CONSTITUENTS, POST-PRODUCTION PITCHES
   SODIUM SULPHITE POLLUTED BY PHENOL

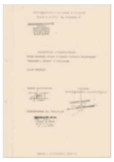
3) INDUSTRIAL WASTE SITE FROM EPI PRODUCTION
   PHENOL, NITRO-ORGANIC COMPOUNDS, INORGANIC CONSTITUENTS, PRODUCTION WASTES, SLUDGES AND ASHES FROM POWER PLANT

4) OTHER OBJECTS

HISTORICAL ENVIRONMENTAL RESEARCH



Environmental research from 80s

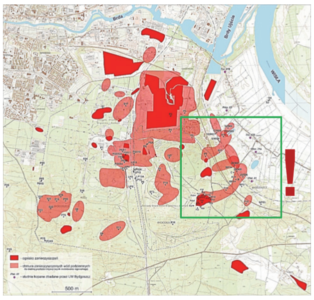


Heavy metals:
Cr, Hg, Mn, As, Pb, Zn

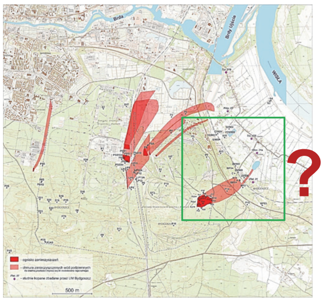
Inorganic compounds:
Cl$^-$, SO_4^{2-}, Na$^+$, B^{3+}, cyanides

Organic coumpounds:
phenol, aniline, nitrobenzene

COMPARISON OF ENVIRONMENTAL RESEARCH



State of the environment 80s

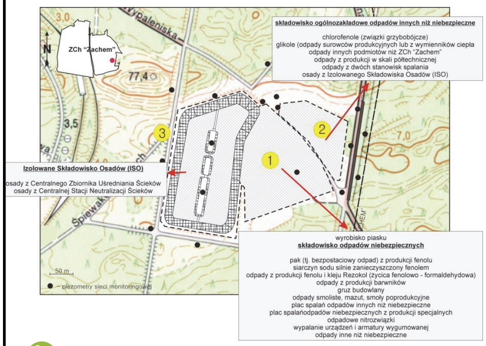


State of the environment after 2010

Surprising disappearance of contamination?

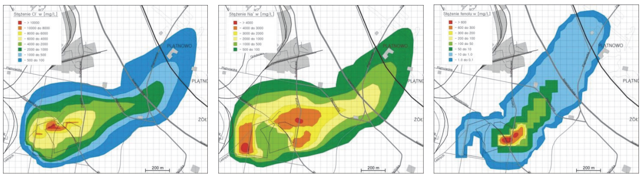
INDUSTRIL WASTE SITE ‚ZIELONA'

Interreg CENTRAL EUROPE ReSites



HYDROGEOLOGICAL NUMERICAL MODELLING

Interreg CENTRAL EUROPE ReSites

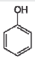


Contaminated area more than

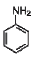
15 times bigger than the Main Square!

POLLUTANTS

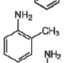
Interreg CENTRAL EUROPE ReSites



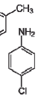
phenol C_6H_5OH **(hydroxybenzene)**



aniline $C_6H_5NH_2$ **(phenylamine)**



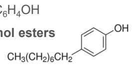
toluidine $CH_3C_6H_4NH_2$ **(methylaniline)**



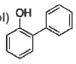
chloroaniline $ClC_6H_4NH_2$

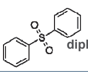
octylphenol $CH_3(CH_2)_7C_6H_4OH$

and ethoxylated octylphenol esters

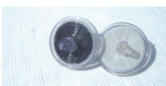


hydroxybiphenyl $C_{12}H_{10}O$ **(phenylphenol)**





diphenyl sulfone $C_{12}H_{10}O_2S$



CURRENT STATE OF THE ENVIRONMENT

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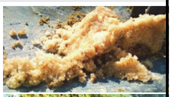
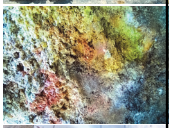




PRIORITY LIST OF THE ACTIONS

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LIMITING MIGRATION OF POLLUTION FROM INDUSTRIAL WASTE SITE ‚ZIELONA' INTO INHABITED AREAS (ŁĘGNOWO, OTOROWO, PLĄTNOWO)

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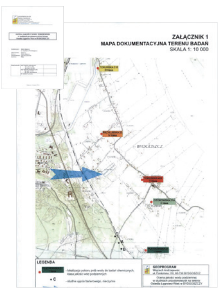
REAL THREAT TO LIFE AND HEALTH



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founded in 1954	founded in 1977
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REAL THREAT TO LIFE AND HEALTH

Inhabitants of BRDYUJŚCIE

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Inhabitants of HUTNICZA St.

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SUMMARY

1. **OCCURRENCE OF EXTREMELY HAZARDOUS ORGANIC POLLUTANTS (CARCINOGENIC AND MUTAGENIC) WITH RELATIVELY VERY HIGH CONCENTRATIONS (INDUSTRIAL WASTEWATER LEVELS)**
2. HIGH NUMBER OF THE SUPPOSED POLLUTANTS SOURCES (27 OBJECTS IN „ZACHEM" CHEMICAL PLANT ONLY)
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CONTACT

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ReSites

MODELLING OF CHEMICAL MIGRATION UNDER THE OVERLAPPING IMPACT OF MULTIPLE AND DIVERSE POLLUTION SOURCES IN THE AREA OF THE „ZACHEM" CHEMICAL PLANT (BYDGOSZCZ, NORTHERN POLAND)

Dorota Pierri, Mariusz Czop

05-2017

Abstract: Modeling studies of chemical migration in the area of the “Zachem” Chemical Plant in Bydgoszcz started from the analyses of the production profile. Those studies were conducted to investigate the potential contamination. Organic compounds still represent a substantial concentration in soil and water environment, including total organic carbon (TOC) reaching values above 1600 mg/L, aniline, nitrobenzene and phenol (up to 500-800 mg/L), organochloride and organometallic compounds, as well as hydrocarbons, such as benzene, toluene and PAHs. Groundwater contains most of the major ions (chlorides, sulphates and bicarbonates, sodium and calcium) and trace elements (Al, Co, Cr and Ni).

A reliable conceptual model of the geological structure was constructed for 3 continuous layers with variable bottom morphology. This model represents the complex structure containing permeable and impermeable Quaternary and Neogene deposits. A hydrogeological numerical model was created for the area of the “Zachem” Chemical Plant using the Visual MODFLOW program. Low values of two key statistical measures confirm a good model fit to the measured data: root mean square (RMS) amounts to only about 1.5 m and normalized RMS reaches only about 4.4%. The differences between measured and calculated values are normally distributed. A Modpath module was used to analyze the potential extent of contaminant plume. Accurate hydrogeological 3D sampling was conducted using a “low flow” technique.

The results of full and reliable modeling of the chemical migration under the overlapping impact of multiple and diverse pollution sources in the area of the “Zachem” Chemical Plant are essential for further planning of remedial strategies.

Key words: groundwater pollution, “Zachem” Chemical Plant, organic and inorganic contamination, pollution migration, numerical model

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INTRODUCTION

Chemical plants are objects of potentially high risk to the soil and water environment. Production of chemical substances with a high potential for toxicity, both organic and inorganic ones, poses high risk of pollutant infiltration into the soil and groundwater. These substances do not occur in natural conditions and are strongly related to the specificity of the manufacturing industry.

Modeling of chemical migration in industrial areas, heavily modified by human activity, is a relatively difficult task. One of the particularly characteristic features of such industrial areas is having a number of pollution sources, often extremely varied in terms of the type of chemical substances hazardous to soil and water environment and/or migrating within. In addition to typical pollution sources (industrial waste dumps), industrial areas are characterized by technological infrastructure of high density, including pipelines, technological ponds, pools and sewage systems. In case of accident, all these elements can negatively affect the environment, which cannot be avoided even in a perfectly functioning plant (Witkowski et al. 2008; Weingran, Meiners 2015).

Until recently (year 2013) the "Zachem" Chemical Plant in Bydgoszcz was the largest producer of organic chemicals for the Polish market. Hydrogeological studies revealed a significant environmental contamination by both organic and inorganic substances within the area of the plant.

This paper presents methodological solution to the problem of migration modeling, emphasizing the importance of the field work and sampling stages, described in this paper. Credible hydrogeological model is not restricted only to computing. The entire study consists of: laborious and detailed fieldwork, understanding and accurate mapping of the geological structure of the area as well as hydrogeochemical processes occurring in the aquifer. Only consideration of all stages of research allows to create a correct and reliable model.

PRECEDING STUDIES

The modeling of chemical migration should always begin with a detailed analysis of the plant's production profile in order to identify the expected pollutants (Figure 1). Initially, the "Zachem" Chemical Plant in Bydgoszcz produced explosive materials for the mining industry. Then the production was adapted to both military and civilian needs, producing trinitrotoluene $C_7H_5N_3O_6$, PENT $C_5H_8N_4O_{12}$ or tetryl $C_7H_5N_5O_8$. It also produced dinitrotoluene $C_7H_6N_2O_4$, nitrobenzene $C_6H_5NO_2$, aniline $C_6H_5NH_2$, products from recycled PVC (mer structure -CH_2CHCl-), dyeing intermediates, dyes, pigments and phenol C_6H_6O. Experimental isocyanate systems (isocyanate group -N=C=O-), diene (chemical bonds -CH=C=CH- or -CH=CH-CH=CH-) and polycarbonates were tested in the plant in the early 60's of the last century. Studies on the construction of polyurethane complex were also conducted. Allyl chloride C_3H_5Cl, dinitrotoluene $C_7H_5N_2O_4$, epichlorohydrin C_3H_5ClO, phosgene CCl_2O, hydrochloric acid HCl, sodium hypochlorite NaClO, toluenediamine $C_7H_{10}N_2$, toluene diisocyanate $C_9H_6N_2O_2$ and sodium hydroxide NaOH were also produced from the 70's until 2013. Polyurethane, rigid foams and polyurethane foam fittings for the automotive industry were also among the products manufactured in the "Zachem" Chemical Plant (Pietrucin 2013).

The use and production of various substances, both organic and inorganic, in the "Zachem" Chemical Plant had an impact on the conditions of adjacent soil and water environment. Contaminants have been reported in the past and currently detected within all components of the natural environment, particularly in soil and groundwater. Identification of all substances used in production processes of the plant is the most important task to recognize the type of soil and water pollution.

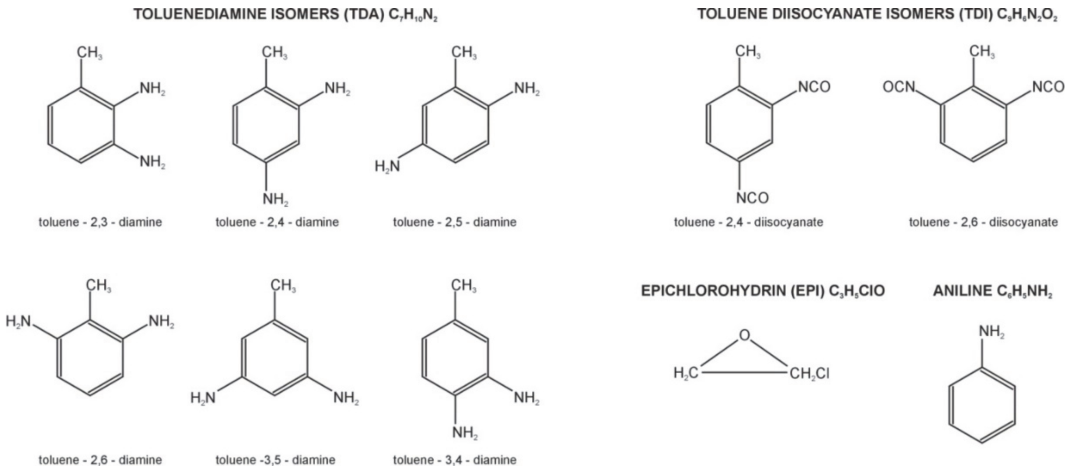

Fig. 1. 'Zachem' Chemical Plant production profile - selected chemical compounds

Very high concentration of organic compounds is one of characteristic features of groundwater polluted by chemical plants. It is manifested by an extremely high concentration of total organic carbon (TOC), reaching values above 1600 mg/L. The identified organic substances in groundwater included aniline, nitrobenzene and phenol (with determined concentrations up to 500-800 mg/L). Groundwater contains also organochloride and organometallic compounds as well as hydrocarbons, including benzene, toluene and PAHs.

Among inorganic components found in groundwater in the vicinity of the chemical plants there were very high concentrations of most of the major ions (chlorides, sulphates, bicarbonates, sodium and calcium) and trace elements, including those of high toxicity to living organisms and humans (Al, Co, Cr and Ni).

CONCEPTUAL MODEL

The development of a conceptual model is the second key step in understanding the migration of pollutants in groundwater. It is the basis and foundation for any further action. This includes understanding of the system layout and structure together with the development of its objectives. Errors made at this stage are of fundamental importance for the adequacy of hydrogeological model. Computer modeling from this point of view, is a verification or confirmation of the author's understanding of the analyzed aquifer system (Woessner 1995).

Organic and inorganic substances originating from different sources of pollution after infiltrating into the soil, migrate with the direction of groundwater flow (Pietrucin 2013). In general, in the area of the former "Zachem" Chemical Plant groundwater flows to the north and north-east to the rivers Vistula and Brda. The most important factors affecting the direction of groundwater flow include simultaneous occurrence of permeable sands and gravels together with impermeable boulder clays, buried valleys and hydrogeological windows constituting contact zone between aquifers. Groundwater flowing from the High Plane towards the Vistula Valley emerges at the surface in the form of leaks and wetlands. Precise recognition and understanding of the geological structure is the key element of credible mapping of the geological structure and hydrogeological conditions of the model, leading to the solution of the problem of chemical migration in groundwater. Emphasis should be put on the precise recognition of the location of any elements disturbing groundwater flow directions (boulder lenses and buried valleys) and bottom morphology of the aquifer. All these aspects allow to conclude that the geological structure of the area of the former "Zachem" Chemical Plant is highly complex (Czop 2010).

A numerical model was prepared based on lithological profiles of approximately 90 boreholes (wells and piezometers). The conceptual model of geological structure is composed of 3 layers which reflect lithological separations. This is the key of the description of hydrogeological conditions within the “Zachem” Chemical Plant area. Model layers were created taking into consideration their morphology and variable thickness (Figures 2, 3). The numerical model includes:

- 1st layer – Quaternary deposits predominantly present in the form of sand and locally boulder clay,
- 2nd layer – Pliocene clays and silts in the area of the moraine upland and Quaternary sands in the area of the Vistula River Valley,
- 3rd layer – Miocene sandy deposits (isolated from Quaternary aquifer in the area of High Plane and connected with them in the area of Vistula and Brda Rivers Valleys).

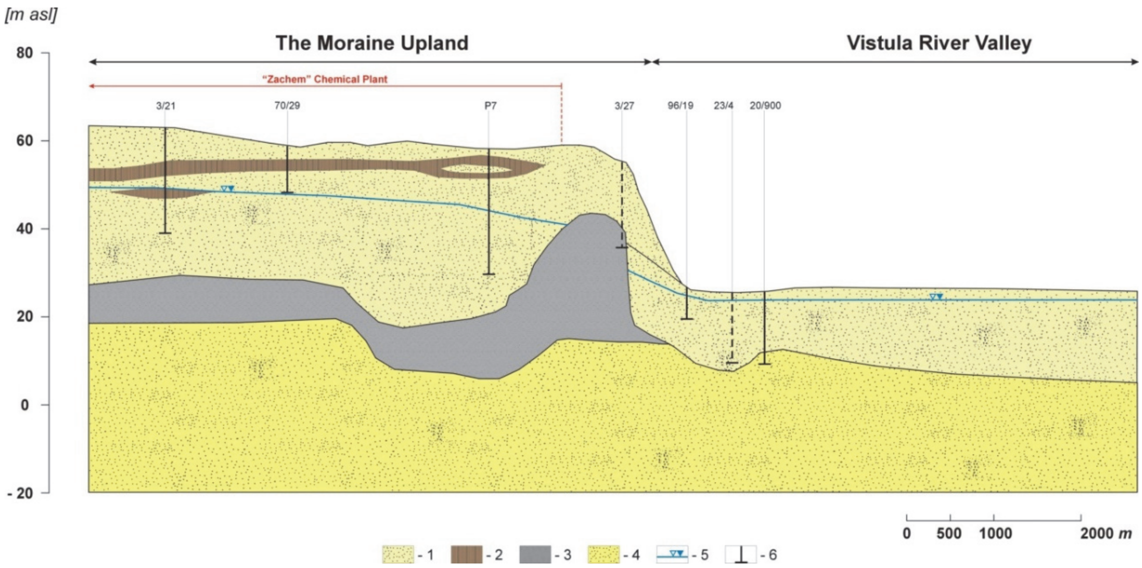

Fig 2. Geological cross-section of “Zachem” Chemical Plant in Bydgoszcz (based on Narwojsz 1987)
Legend: 1 – Quaternary sands, 2 – Quaternary boulder clay, 3 – Pliocene clay and silts, 4 – Miocene sands, 5 – groundwater table, 6 – borehole(well, piezometer)

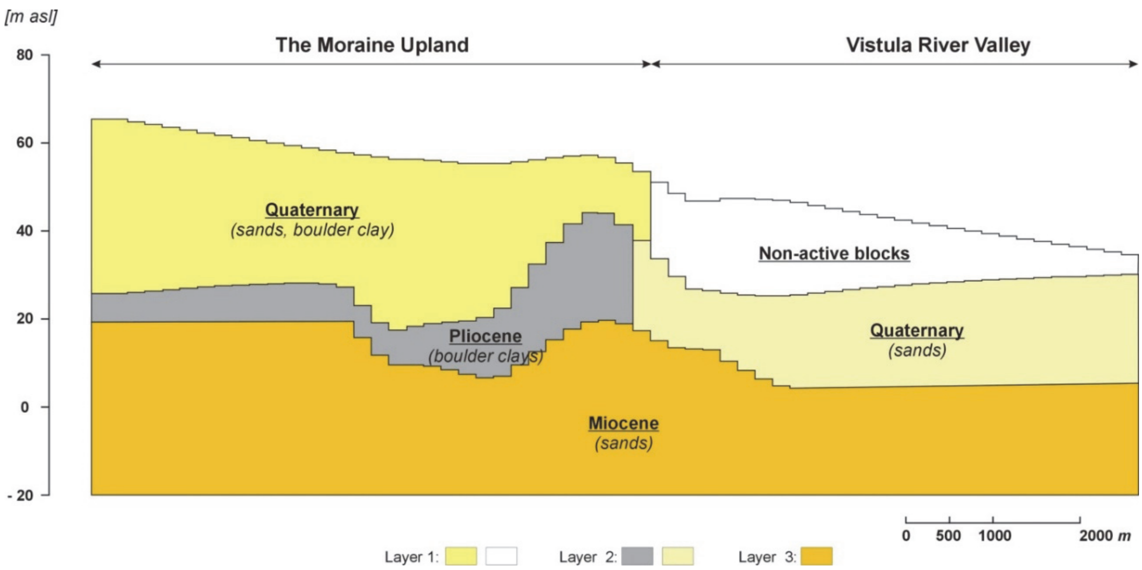

Fig. 3. Conceptual model of geological structure

Such detailed mapping of the geological structure based on a conceptual model allows to create a precise hydrogeological numerical model and to investigate the migration of chemical substances. From the viewpoint of the accuracy of modeling studies this methodology is more appropriate than the application of flat layers with constant thickness.

NUMERICAL MODEL

The hydrological model was created using the Visual MODFLOW program for the purpose of mapping the migration of chemical substances from the area of the "Zachem" Chemical Plant. Visual MODFLOW is currently the most popular and most widely used program for modeling in hydrogeology. It was developed by Schlumberger Water Services (formerly Waterloo Hydrogeologic). The creation of the numerical model is therefore the third and fundamental stage of modeling of chemical migration in industrial areas.

The model domain covers the area of a significant size of 8 km × 12 km, i.e. 96 km^2. The study area comprises both the chemical plant in Bydgoszcz and the land up to the Vistula and Brda riverbeds – this is the direction of pollution migration in groundwater from the above chemical plant. Discretization of model domain was conducted. The size of square calculation blocks is 200 meters. In total, there are 2400 blocks in one layer of the model area (60 columns and 40 lines) including the majority of active blocks.

The hydrogeological model of the analyzed area very well reflects the actual condition of hydrodynamic field, which was achieved based on field measurements of about 90 piezometers and wells. With respect to the measurement from December 2009 the differences between the actual and calculated elevations of groundwater table fall within ± 2 m for the vast majority of study sites. Larger differences occur only in about 15% of the boreholes, mainly in the area of very sharp decrease of the groundwater table at the border of the High Plane and Vistula River Valley. It is very difficult to show the accurate reflection of groundwater table morphology in this area, because a slight change in the location of a borehole gives a significant difference in the level of the groundwater table. Low values of two key statistical measures confirm good model fitness to the measured conditions: root mean square (RMS) amounts to only about 1.5 m and normalized RMS is only about 4.4%. The differences between the measured and calculated values are normally distributed (Czop 2010, Pietrucin 2013).
The main aim of creating a prognostic model was to map the directions of contaminant migration from the pollution sources in the area of the "Zachem" Chemical Plant in Bydgoszcz. Due to the complex hydrogeological conditions within this area and coexistence of both organic and inorganic chemical substances, the discussed problem is very difficult to resolve.

The simulation was performed by assuming a worst-case scenario of non-reactive pollutants' migration with the groundwater flow, i.e. no chemical reactions with the liquid (water) and solid (soil) phase. This approach to the problem allows to use the Modpath module. It was used to visualize the flow directions of contaminants and the maximal possible range of contaminant plume in groundwater (Figure 4).

The predicted ranges of contaminant plumes according to both organic and inorganic pollution migration in "Zachem" Chemical Plant should be regarded as preliminary and require further detailed studies.

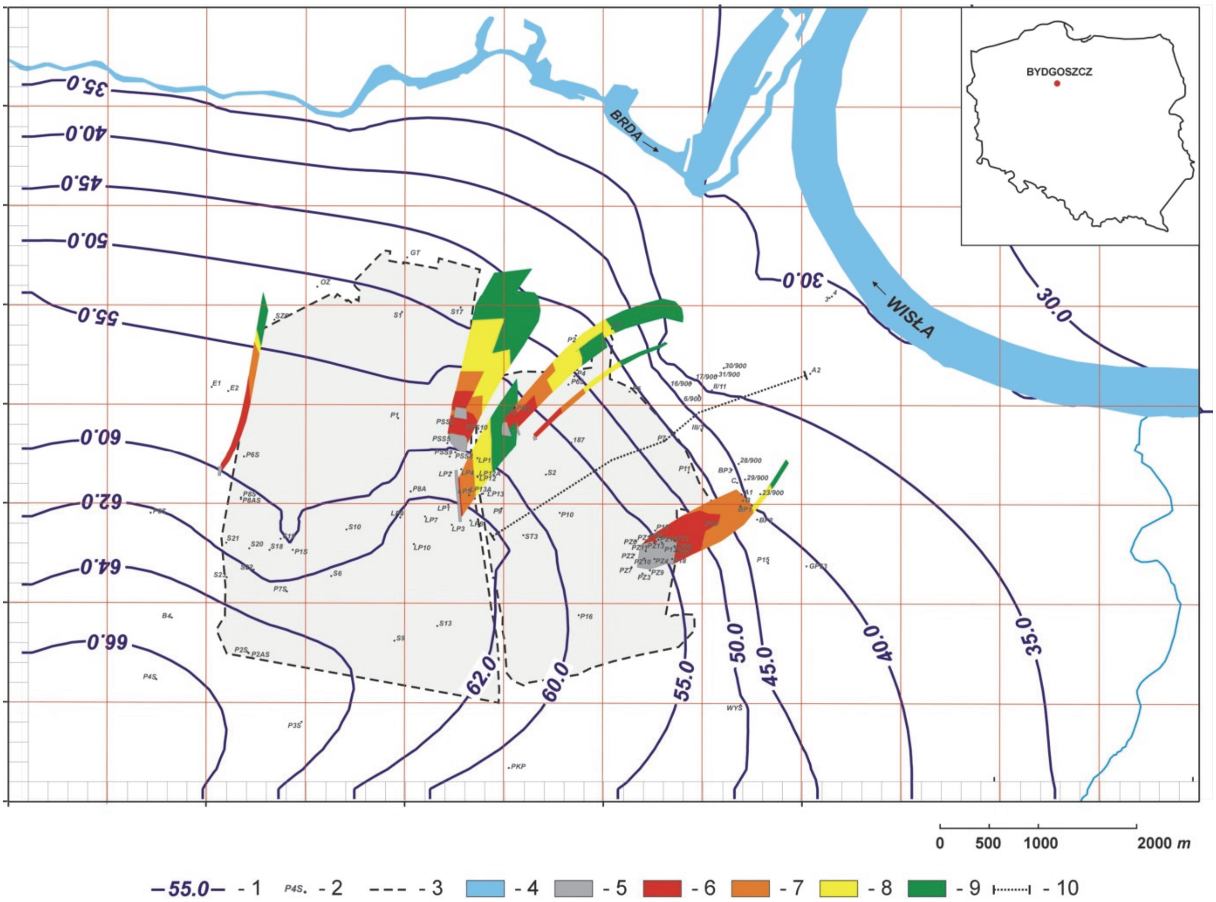

Fig. 4. Predicted ranges of contaminant plumes from pollution sources identified in the "Zachem" Chemical Plant in Bydgoszcz
Legend: 1 –groundwater table contour [m asl], 2 – hydrogeological borehole (well, piezometer), 3 – border of the "Zachem" Chemical Plant, 4 – surface water, 5- source of pollution, 6 – range of contaminant plume after 25 years, 7 – range of contaminant plume after 50 years, 8 – range of contaminant plume after 75 years, 9 – range of contaminant plume after 100 years, 10 – geological cross-section line (Fig. 3)

DETAILED STUDIES

The visualization of the contaminant flow directions and range of contaminant plume in groundwater is often mistakenly considered as the final stage of the modeling process. Authors take for granted that the border of the range is accurate and precisely mapped. After completion of a reliable conceptual and numerical models, the verification of the results should always require detailed research. Understanding of the research study area, geological structure and hydrogeochemical processes allows the authors to clarify the range of contamination. This task is relatively simple for one source of pollution and one contaminant plume but complicated and interesting conditions exist in mixing zones.

Organic substances originating from the identified sources of pollution in the area of the chemical plant (primary substance) migrate in groundwater in unchanged form or can be transformed by chemical reactions with other compounds (organic and inorganic) occurring within the contaminant plume, but new organic compounds (secondary substances) may therefore be formed in the contaminated groundwater. Because of diverse chemical composition of individual streams of contaminated groundwater and different Eh-pH conditions, chemical reactions (both degradation and the formation of new compounds) may occur in different directions. According to the world literature (Eisenhauer, 1968; Kuo et. al., 1977; Montgomery, 2000), soil and water pollutants in the area of chemical plants decompose into dozens of various substances (Figure 5). All of these transformations, due to their high complexity, are difficult to describe. Cross-reactions occur between organic and inorganic compounds and between a wide range of new products.

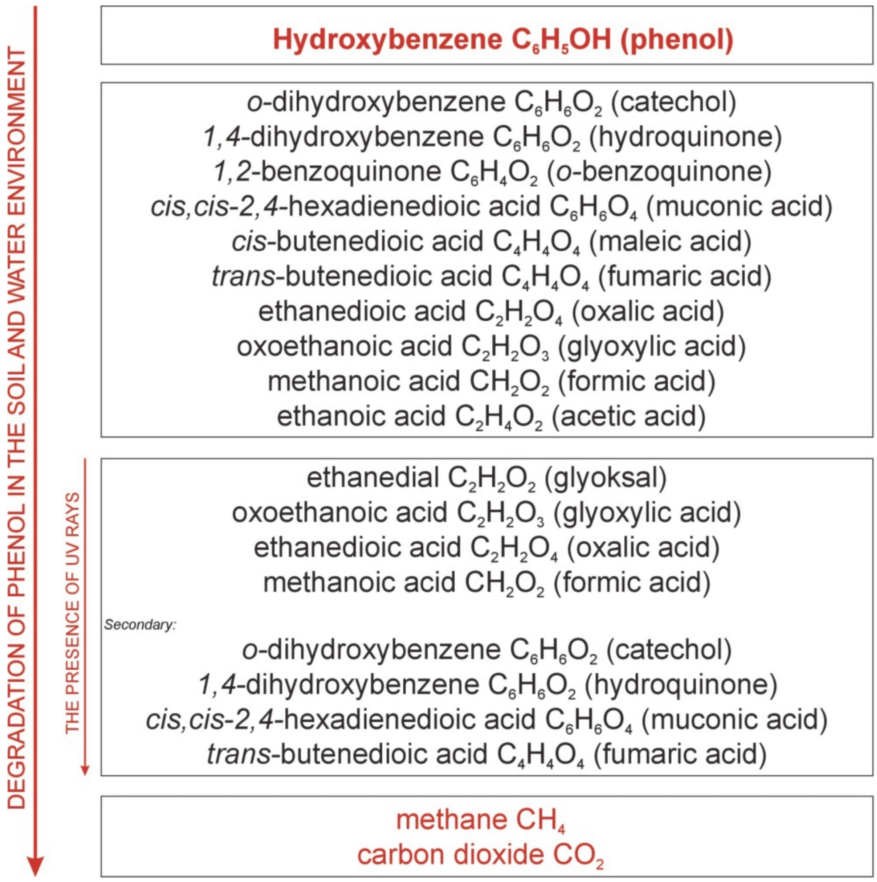

Fig. 5. Phenol degradation scheme in the soil and water environment

In the context of the contaminant plume there is also an important issue of determining the chemical composition of groundwater, taking into account the stratification of pollutants in the vertical profile of the aquifer. Such studies have been carried out at the "Zachem" Chemical Plant in the period from 2012 to 2013. Those studies were carried out under conditions of "low flow" sampling technique. Continuous measurements of variation in physicochemical parameters such as temperature, electrical conductivity, pH value, redox potential and dissolved oxygen were performed at the same time within the columns of individual boreholes (Witkowski 2009).

This technique allows for the spatial sampling of contaminant plume taking into account the stratification of the concentration of pollutants in the studied borehole: (x) samples along the length of contaminant plume from the pollution source in the direction of its drainage zone, (y) variation in the concentration from the center to the edge of plume and (z) vertical stratification in piezometer. These three monitoring directions of contamination spread in the aquifer are the most significant and allow for complete analysis and subsequent control of the contaminant plume propagation (Pietrucin 2013).

SUMMARY

Modeling of the chemical migration in groundwater in industrial, highly urbanized areas is very complicated. It also applies to the area of the discussed "Zachem" Chemical Plant in Bydgoszcz. This problem is even more complex under the conditions of overlapping impact of multiple and diverse pollution sources. Coexistence of organic and inorganic substances together with chemical reactions occurring in the aquifer in the vicinity of the studied chemical plant also cause a number of problems in this context. The only reasonable solution to this complex task is to broaden the numerical model with thorough research including accurate identification of the potential contamination. Then it is necessary to understand and map the geological structure which allows to create a target numerical model. Interpretation and critical assessment of the results justifies undertaking detailed studies. Those studies will verify ranges of contaminant plumes.

Modeling of chemical migration in the "Zachem" Chemical Plant in Bydgoszcz is one of the elements that allow for the development of an environmental reclamation plan. It is essential to purify the soil and water environment due to the real threat to the health and life of local inhabitants of Bydgoszcz and its nearby areas - Otorowo, Plątnowo, Łęgnowo. Due to very complex geology and hydrogeological conditions as well as extreme organic and inorganic contamination of groundwater, specialized remediation methods should be used in this area. These methods are designed for specific chemical compounds and individual contaminant plume.

Based on detailed analysis of chemical composition of groundwater in the context of inorganic substances and a wide range of organic compounds, particularly including the stratification of the water column in boreholes, it is planned to calculate subsequent numerical models of migration for reactive contaminants. The regional model allows to trace the directions of pollution spread in groundwater. In order to obtain a detailed analysis of the site, local models should be developed for each of the industrial waste dumps (e.g. "Zielona" industrial waste dump) or when their effects overlap - for their groups. The development and design of the optimum scenario for soil and water remediation can be based only on a reliable model. Preliminary costs of land restoration are estimated to be at least several hundred million PLN.

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Originally printed in:

Bulletin of Geography. Physical Geography Series, No. 9 (2015): 31-38
http://dx.doi.org/10.1515/bgeo-2015-0013

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