Challenges in the flooding of coal mines
- case study ‘Ruhr area’

Further development of the ‘box model’ simulation concept for the German hard coal mines

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Development of the hard coal mining industry in Germany

Challenges in the hard coal mine closure / future tasks

Special tasks
- Forecasting mine water rise
- Substance loads in the receiving waters - pollutant prognosis
- Narrowing or closure of mine water pathways
- Subsidence / uplift

Development of forecasting tools
Coupled reactive mass transport for the East Rand Basin of SA
(East Rand Basin Source Apportionment Study)
Holistic approach example: East Rand
Reactive mass transport: coupling of groundwater – mine water – rivers
TÜV NORD GROUP Overview

Headquarters in Hannover, Germany

Natural Resources

Industrial Service, Mobility, Education

Aerospace

Information Technology
DMT - Hydrogeology & Water Management in the TÜV NORD GROUP

TÜV NORD GROUP
Headquarters in Hannover, Germany

Natural Resources

Department: Hydrogeology & Water Management
DMT at a Glance

The international engineering & consulting service provider DMT serves the four markets **Mining, Infrastructure & Civil Engineering, Oil & Gas, and Plant & Process Engineering.**

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<th><strong>DMT’s roots</strong> dating back to 1864</th>
<th><strong>About 1,000 employees</strong> mainly with academic background</th>
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<td>DMT comprising <strong>13 operational consulting and engineering companies</strong></td>
<td>DMT’s attitude is dedicated to <strong>excellence, responsibility &amp; innovation</strong></td>
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<td><strong>About 110 million € turnover</strong></td>
<td><strong>Today DMT is a core brand of</strong> TÜV NORD GROUP</td>
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RAG-Stiftung at a Glance

Tasks of RAG-Stiftung

- Socially acceptable closure of the hard coal mining activities until end 2018
- Launching of EVONIK Industries on the capital market. Building up the foundation’s asset portfolio.
- Financing perpetual mine management obligations (as from 2019)
- Supporting education, science, and culture in the mining regions
Post-mining activities
Technical Activities of the RAG AG after 2018

- Old mine shafts, shallow mine workings
- Perpetual obligations, mine flooding
- Renewable energy
- Surface subsidence, subsidence damages
- Water issues, permissions, geospatial data management
- Real estate, property

Historical damages & consequences
Today's obligations & tasks
Future possibilities & chances
Financing perpetual mine management obligations

Shareholdings

Investments

Approx. € 220 million per year

65%

6%

29%

Mine water management

Groundwater purification

Polder measures
The future mine water management concept for the Ruhr area has 4 major targets:

- **Conversion to well operation**
  The underground pumping stations shall be replaced by submersible pumps operated from above ground.

- **Reduction of pumping stations**
  The number of pumping stations shall be reduced by using existing underground water pathways (interconnectivities).

- **Mine water level -680 Meter**
  The regional mine water level shall rise but shall not reach the drinking water resources.

- **Reduce environmental impact**

**Modeling of mine water flow & reactive mass transport**
Conversion to well operations
Installation of cladding tubes: Mine water level regulation as required

Today: Conventional pumping stations
Tomorrow: Submersible pumps
Reduction of pumping stations

Today: Mine water discharge system is decentralized
Reduction of pumping stations
Tomorrow: Use of underground water pathways, centralized drainage

East: (3->1 drainage station)
• Mine water drainage into the river Lippe as before

Middle: (1 drainage stations)
• Central drainage into the river Rheine (35 Mill qbm / year)
• Water pumped from -680m
• Underground water pathways

West: (3->1 drainage station)
• Mine water drainage into the river Rhine as before

South: (3 drainage stations)
• Drainage into the river Ruhr as before
• Water can be pumped from shallow levels

S: stopped drainage station, B: continued or new drainage station
Mine water management concept of RAG

Aligning / adjusting of the pumping levels

März 2015
Special features of water flow in mining districts

- Defined points of overflow
- Partially turbulent flow (pipes, drives, shafts, drill holes)
- Interconnections between minefields (roadways, drill holes, shafts, nearby production lines, etc.)
- Time-varying flow properties (settlement, convergence, roadway collapse)
- Density-dependent flow (high salt content)

→ Uncertainties about the temporal behavior of underground water pathways
Box model - mine water management simulation software considers special aspects of water flow in mine areas

- Most of the water flows through open systems such as roadways and shafts
- Within these systems, there is mainly hydraulic short circuit
- Nearly identical mine water levels within interconnected mine districts (3-dimensional definition of volume elements / cells)
- Mine water qualities are considered with discretization, possibly refinement necessary
Mine water management in the Ruhr area
Today: Decentralized mine water pumping in the “water provinces”
Automated model generation
Assigning model data from CAD System (Points, Lines, Polygons)
Ruhr area: Box Model parameters

- East-West dimension: app. 120 km
- North-South dimension: app. 80 km
- Pumped amount of mine water per year: app. 75 Mill. m³
- 139 boxes, 26 slices = 3614 volume balance elements
- Hundreds of shafts
- Floodable void space > 2 Billion m³
- Extracted coal > 10 Billion m³
Ruhr area: Major tasks of the modeling

- Prediction of rising mine water levels
- Geochemical forecast of flooding water quality
  - Including pollutants such as Sulphate, Iron, Chloride, PCB, turbidity
- Uncertainty considerations / sensitivity analyzes
- Safety assessments: Standing water levels next to active mining operations
Calibration and Prognosis: Flooding Ruhr-Area
Predicted and measured mine water levels
Calibration and Prognosis: Flooding Ruhr-Area
Predicted and measured mine water levels

Water level simulation in the water province Lohberg / Prosper-Haniel
Development of Sulphate in Lohberg

Sulphate concentration simulation at Lohberg drainage station
Sensitivity Analysis:
possible flooding levels in case of water pathway collapse
(number per 1000 model runs)
Conclusions and major results of the modeling

The ‘box model concept’ is a very powerful tool to simulate mine flooding even in very large coal mine regions with many individual mines involved

- Rising mine water levels for different flooding scenario
- Geochemical forecast of flooding water quality
  - Sulphate, Iron, Chloride, …..
  - special pollutants such as PCB, turbidity
- Uncertainty considerations / sensitivity analyzes
- Safety assessments: Standing water levels next to active mining operations
Thank you for Your attention
Examples of model discretization

Ruhr area (Germany)

Upper Silesia (Poland): 3 GWL above coal mining

Oviedo (Spain): Includes a mountain region
Examples of model discretization

Ruhr area (Germany):
Linked flow model 'Schwarzbach' (2 GWL above coal mining)

East-Rand (South Africa):
Including fault systems

Oelsnitz, Saxony (Germany):
3 GWL above coal mining
Further applications of the box model

- Durham coalfield since 2006
- Ruhrkohle since 2002
- Southern France, 2004
- Lothringen coal basin, 2004
- Saarland since 2003
- Oviedo, 2008
- South Africa: Ermelo, Hartogshof and East-Rand
- Ronneburger mining area since 1992
- 2005: density effects
- 2006: Upper Silesia
- 2005: Oelsnitz
- 6 models in Pb/Zn-mines

Since 2002: Ruhrkohle
Since 2004: Southern France
Since 2003: Saarland
Since 2004: Lothringen coal basin
Since 2006: Durham coalfield
Thank you for Your attention
Historical development of the RAG

- **1969**: Gründung als Ruhrkohle AG
- **1997**: Umbau zum diversifizierten Spartenkonzern RAG
- **2007**: Konzentration auf den deutschen Steinkohlenbergbau
- **2018**: Beendigung der subventionierten Steinkohlenförderung
- **2019**: Fortführung der RAG mit Bergbaufolgeaktivitäten
Installation of cladding tubes: Mine water level regulation as required
Conversion to well operations

Cladding pipes in a shaft before shaft filling

Tomorrow: Submersible pumps

Installation of cladding pipes allow attachment and operation of submersible pumps
Ruhr region – Emscher area
Central mine drainage ‘Lohberg’

- Lohberg central dewatering system will pump the mine water from (today) seven dewatering points and discharge it directly into the river Rhine
- Planned start of operation is 2035
Development of Iron in Lohberg
Development of Chloride in Lohberg

![Graph showing chloride development with reactions - Endflutung Lohberg-640 mNN](image)