Pilot Stabilization Caverns Twente

Preventing potential damages caused by land subsidence
without a negative impact on the environment

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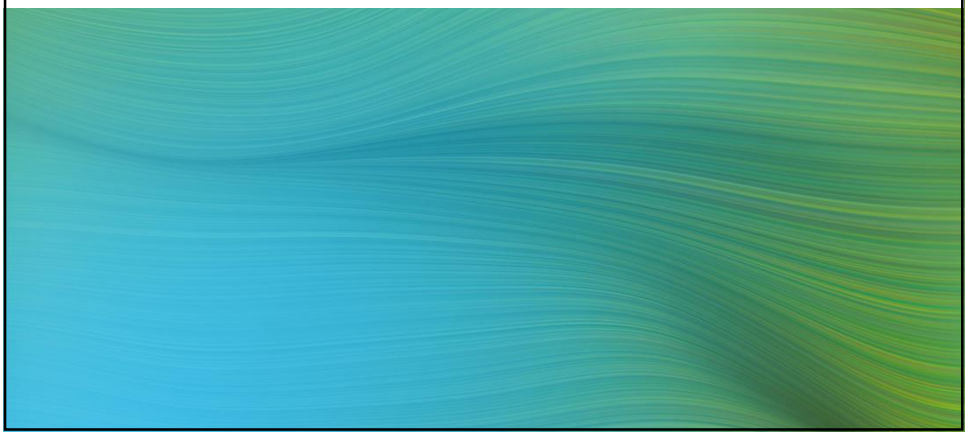

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1. Introduction AkzoNobel

AkzoNobel

- Innovative producer of paints, coatings and chemicals
- 47.000 employees in 80 countries – 5000 employees in the Netherlands
- Headquarter in Amsterdam
- Nr. 1 in the Dow Jones Sustainability Index for the chemical industry

Salt within AkzoNobel

- Part of Specialty Chemicals
- 3 production locations
  - Hengelo (NL)
  - Delfzijl (NL)
  - Mariager (DK)
- Salt mining started in Boekelo in 1919, in Hengelo in 1933
- Jozo salt is produced in Hengelo

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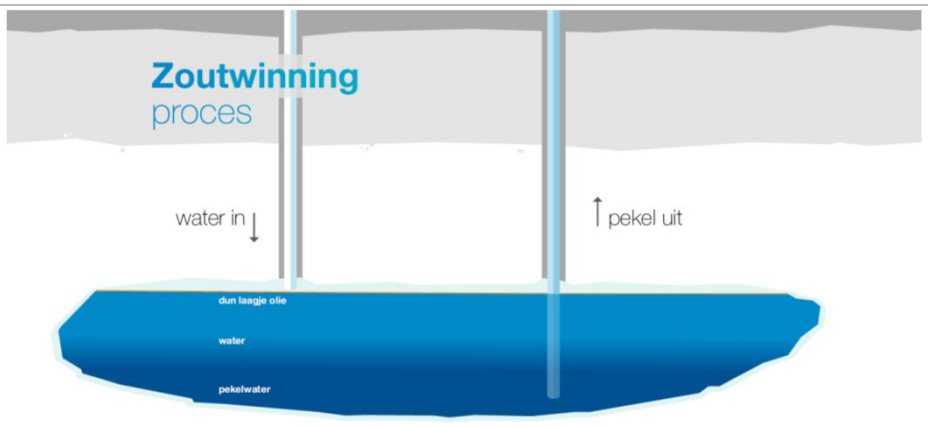
1. Introduction Mining salt by solution mining



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1. Introduction
The project in short

- Mission: Preventing potential damages caused by land subsidence without a negative impact on the environment
- Scope: Preventive stabilization of three potentially instable salt caverns under the property of Twence (waste-to-energy installation near Enschede)
- Method: Stabilization of potentially instable caverns with a non-retrievable backfill with a curing (i.e. hardening) function, based on residues from waste- and biomass-to-energy installations and the cement industry
- Potential risk: Contamination of deep groundwater (>200 m) with contaminating components from the residues (mainly lead and zinc)
- Safety criteria: No contamination of deep groundwater above drinking water standards for the next 10.000 years as a consequence of this project
- Control: From the start permanent monitoring of the entire process

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1. Introduction
Public interest in the project

- 1991: Sinkhole at the Enschedese Havenweg near Hengelo
- 1991-2000: Technical studies regarding cause of the sinkhole, inventarisation of other potentially instable caverns, improvement in salt mining
- 2000-2007: Political discussion on safety risks caused by potentially instable caverns
- 2008: Steering group Subsidence caused by Salt Mining in Twente:
  Investigate additional backfilling materials to stabilize caverns
- 2009: Pilotproject enabled by the National Waste Mangement Plan 2
- 2009-2013: Investigations in recipes and risk management
- 2013: First reading of the environmental impact assessment by the commission
  many improvement points à update EIA October 2013
  Dialogue with municipality Enschede regarding zoning plan
  Questions from Natuur- en Milieu, Huize Aarde and other stakeholders
- 2014: Review / second opinion by independant scientists
  Questions by Province Overijssel regarding environmental permit
- 2015: Questions and remarks from citizens at information session 9 June
- Now: Answers to these questions and remarks

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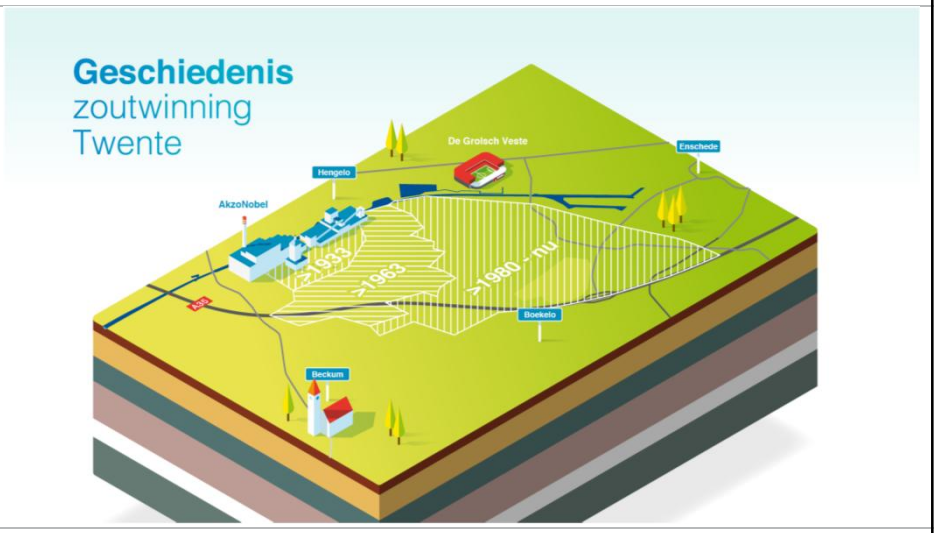
2. How urgent is stabilization? Salt mining in Twente



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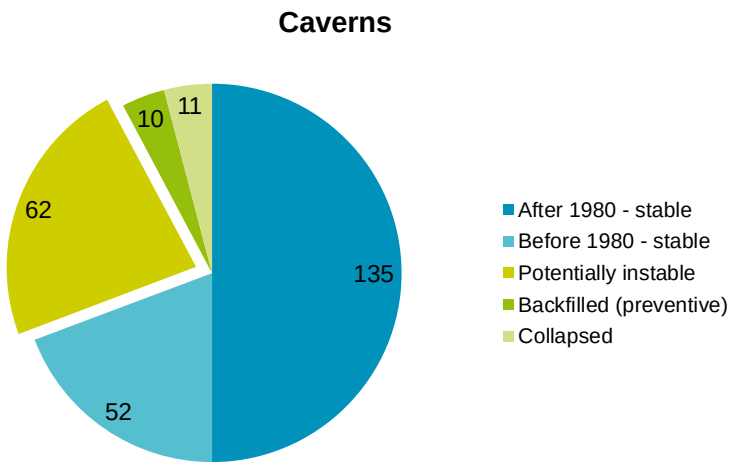
2. How urgent is stabilization?



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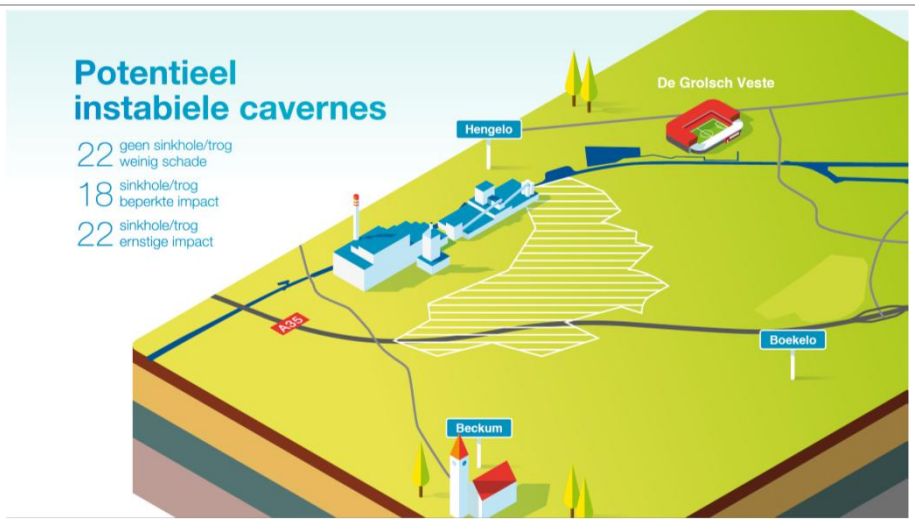
2. How urgent is stabilization?



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2. How urgent is stabilization?
Subsidence caused by cavern migration

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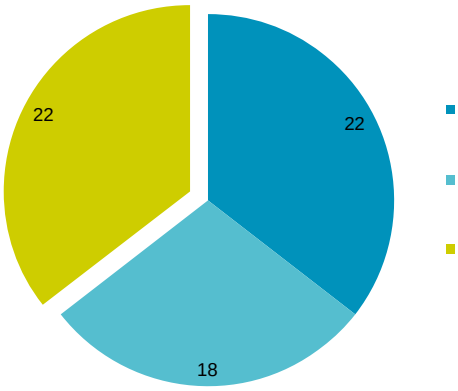
2. How urgent is stabilization?

Potentially instable salt caverns



- Stabilization of the 22 caverns with potential significant impact will take 150 years when using calcic slurry
- 15 of the 22 caverns are under the property of Twence
- The Pilot Stabilization is a research project aiming to stabilize 3 of these 15 caverns

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2. How urgent is stabilization? Alternative: controlled cavern collapse

- Caverns in Twente are as large as the Grolsch Veste
- The potential sinkholes could vary in diameter from 10 to 110 meter with depths of 3 to 23 meter. Many of these potential sinkholes will be larger and deeper than the one in 1991.

- This cannot be a desirable outcome, as it has significant disadvantages:
  - Sagging
  - Translocation of infrastructure
  - Damage above-ground facilities and functions
  - Duty of care (environment and subsidence)
- AkzoNobel aims to prevent potential damage by subsidence
- AkzoNobel is liable for any damage caused by salt mining
- Backfilling with an additional material besides calcic slurry is desirable

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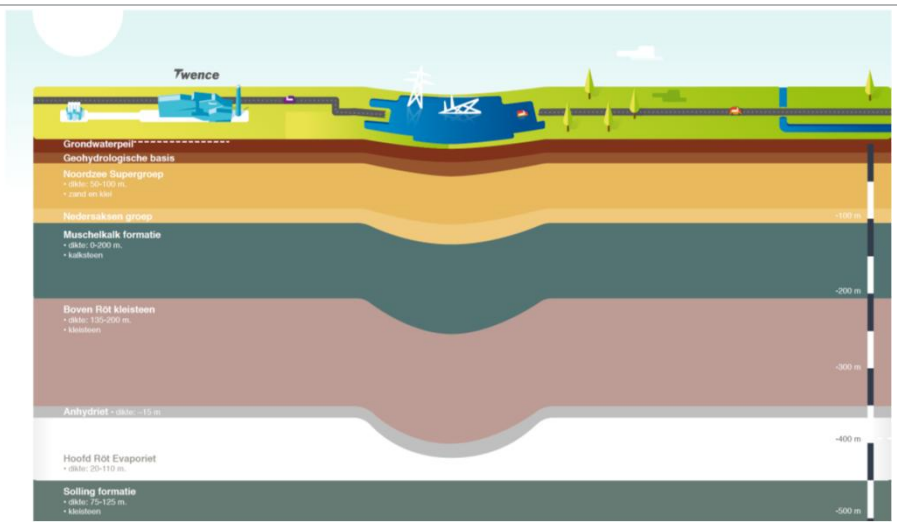
2. How urgent is stabilization?
Alternative: controlled cavern collapse



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3. Why use residues?

Potential alternative backfill materials beside calcic slurry from AkzoNobel Hengelo are evaluated on the following criteria:

1. Functional suitability
2. Availability
3. Volume needed to stabilize a cavern
4. Transport

The potential backfill materials and backfilling processes all have to fit in our mission:
-preventing damage caused by subsidence
-no negative impact on the environment

All our processes have to comply with high safety standards

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3. Why use residues? Functional suitability

The backfill should	The backfill may not
Be pumpable	Dissolve salt in the cavern
Level in the cavern	Form a collapsed cone
Harden sufficiently	Remain soft or liquid
Remain chemically/mechanically stable	Compact or react

This means:

- Dry or salt saturated
- Fine-grained
- Water binding properties
- No / very limited amounts of organic material

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3. Why use residues? Functional suitability

Suitable	Unsuitable
Calcic slurry from AkzoNobel Delfzijl	Clay
Filling sand	Wet/coarse sand
Cement	Gravel and granules
Fine-grained residues from waste- or biomass-to-energy installations	Water purification sludge
Residue from the cement industry	Contaminated soil
	Soil treatment residue
	Dredged material
	Slag / bottom ash (coarse fraction)
	Drill mud/drill cuttings from non-salt wells

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3. Why use residues? Availability

The suitable backfilling materials are all available, calcic slurry from AkzoNobel Delfzijl in a smaller volume.

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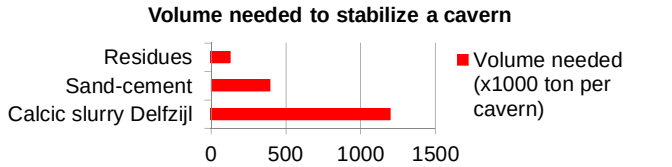
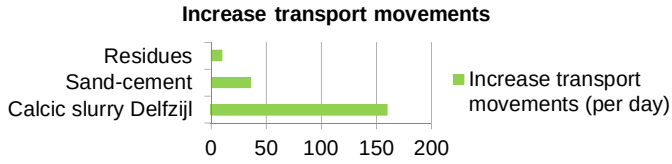
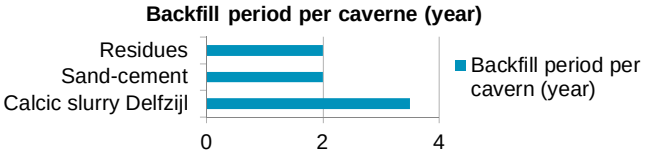
3. Why use residues? Comparison of alternatives







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3. Why use residues?
3 alternatives – residues

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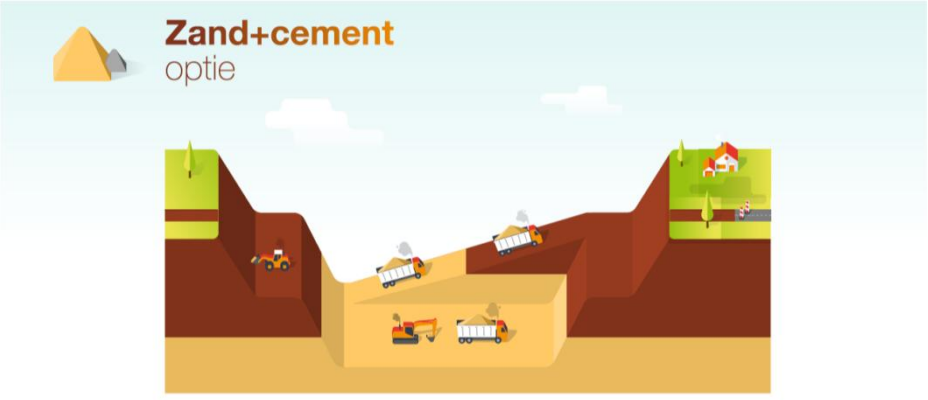
3. Why use residues?
3 alternatives – sand+cement



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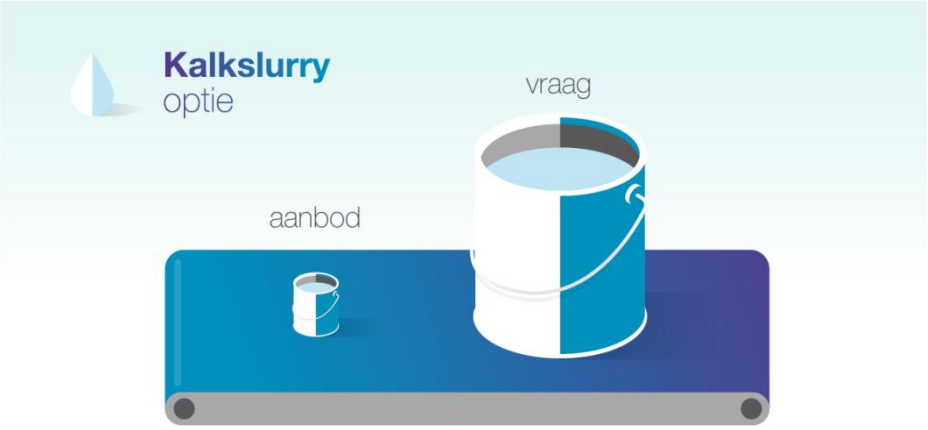
3. Why use residues?
3 alternatives – calcic slurry



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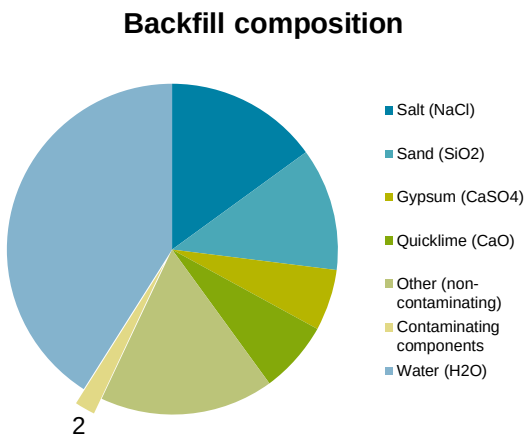
4. What kind of material will stabilize the caverns?
Composition of the backfill material based on residues



- The backfill material based on residues will contain 45% solid residues and 55% brine
- The backfill material contains maximal 2% contaminating components
- The water and the contaminating components will be bound into newly formed minerals
- Salt will precipitate

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4. What kind of material will stabilize the caverns? Origin and alternative applications of residues

- About 130.000 ton residues is needed to stabilize one cavern, one third of this volume is produced by Twence.
- The additional two thirds of the residues will be produced by installations within 250 kilometer from Twence.
- Alternative application in the Netherlands: immobilization and deposition at the Maasvlakte.
  - Recovery is better than deposition
  - Environmental effects of the deposit over a 10.000 year time period are not examined
- Alternative application in Germany: stabilization of salt caverns and –mines.
  - Transport of residues over 300 km, while we need them here for preventive stabilization

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5. How much do AkzoNobel and Twence gain from this project?

- The aim of the project is minimizing long-term risks related to subsidence for both AkzoNobel and Twence (environmental risk and liability risk)
- Over the complete pilot period AkzoNobel and Twence expect to earn back the initial investments. Profit is not the primary driver of the pilot project.
- A boundary condition for the project is that execution is operationally and commercially justifiable. This does not seem to be the case for the application of sand and cement or calcic slurry from AkzoNobel Delfzijl as backfill material. For example cement is as expensive as the salt AkzoNobel produces. For stabilization of caverns with calcic slurry from Delfzijl 80 concrete mixer trucks per day will drive back and forth between Hengelo and Delfzijl.
- AkzoNobel and Twence are confident that preventive stabilization of caverns with a backfill based on residues can be executed in an operationally and commercially justifiable manner, without negative impact on the environment.

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6. How does AkzoNobel know the backfill performs?

- Chemical composition
  - The different components react with each other forming new minerals
  - Water and contaminating components will be bound into these newly formed minerals
- Laboratory research
  - Simulation of cavern conditions
- Testing strength and stiffness
  - Simulation of cavern roof collapse and application of load on the backfill
- Outflow simulation
  - Simulation of outflow of the backfill in the cavern
- Pore fluid composition
  - Pore fluid pressed out of the backfill after three months of curing complies with drinking water standard (except for salt)
- Conclusion: the base recipe for backfill complies with our mission

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6. How does AkzoNobel know the process is safe? Mission translated into safety criteria

- National Waste Management Plan 2: AkzoNobel is enabled to execute a pilot project aiming to: 'determine which residues, not original to the subsurface, could be applied for stabilization of a potentially instable cavern **without environmental risks**'.
- Mining Law: AkzoNobel has the obligation to **prevent** that it's mining operations would cause **a negative impact on the environment**.
- This is translated in two safety criteria:
  - **No contamination of deep groundwater above drinking water standards**
  - **Not within a period of at least 10.000 year**
- Compared to the risk analysis there are additional certainties:
  - 80 meters impermeable clay is present between the deep groundwater and the shallow ground water
  - The nearest drinking water extraction is more than 10 km away from the caverns
  - The risk analysis is based on a worst-case variant of the backfill recipe
  - The risk analysis is based on pore fluid pressed out of the backfill right after production (after 3 months of curing the pore fluid pressed out complies with drinking water standards)
  - Monitoring the backfill and the backfilling process is possible and will be done

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6. How does AkzoNobel know the process is safe? The process of risk management

- Safety criteria – no contamination of deep groundwater above drinking water standards for at least 10.000 years
- Risk analysis – the possible scenarios that are worse than planned, are analyzed
- Preventive measures – design measures which prevent that threshold values will be exceeded when one of the analyzed scenarios becomes reality
- Monitoring – measurements that enable signaling when one of the analyzed scenarios becomes reality
- Mitigating actions – actions that will be done when the monitoring indicates one of the analyzed scenarios has become reality. Mitigating actions will prevent that threshold values are exceeded

à Supervision by State Supervision of Mines on all these aspects

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6. How does AkzoNobel know the process is safe? Example: collapse of cavern roof during backfilling

- Cavern roof will collapse layer by layer, not all at once
- Preventive measure:
  - Stabilization of the cavern with backfill – this is not yet in place when the roof collapse occurs before finishing the backfilling of the cavern
- Monitoring (continuous):
  - Pressure and flow
  - Micro seismicity
- Mitigating actions:
  - Stop backfilling
  - Sonar measurement inside the cavern (how thick is the collapsed layer)
  - New modeling to determine if there is still enough impermeable rock between the cavern and the deep groundwater to guarantee long term isolation of the backfill
  - If yes: restart backfilling
  - if not: complete backfilling with calcic slurry

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7. Societal relevance

- Preventing subsidence is in the interest of the local community
  - Cavern collapse could lead to significant damage on above-ground functions
  - The potential damage includes a negative impact on the environment (groundwater quality/level)
  - Once the cavern has collapsed the negative impact will remain for many decades
- Stabilization of caverns with a backfill based on residues is the best option on the condition that the process is safe and does not cause a negative impact on the environment
  - Stabilization prevents damage to above-ground functions
  - The responsible company takes its responsibility, no taxpayer money is involved
  - New developments are possible in the area after stabilization
- AkzoNobel does not strive to change the generic waste management policy of the Netherlands, however the execution of this project requires an exemption
  - Stabilization is desirable for a limited scope of old caverns in Twente, current caverns are stable
  - This is a local problem, which should be solved by mainly local stakeholders

Thanks for your attention

Questions?

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