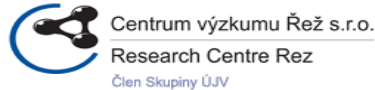




# Microbiology In Nuclear waste Disposal

Coordination: SKB

# The MIND consortium



Universidad de Granada



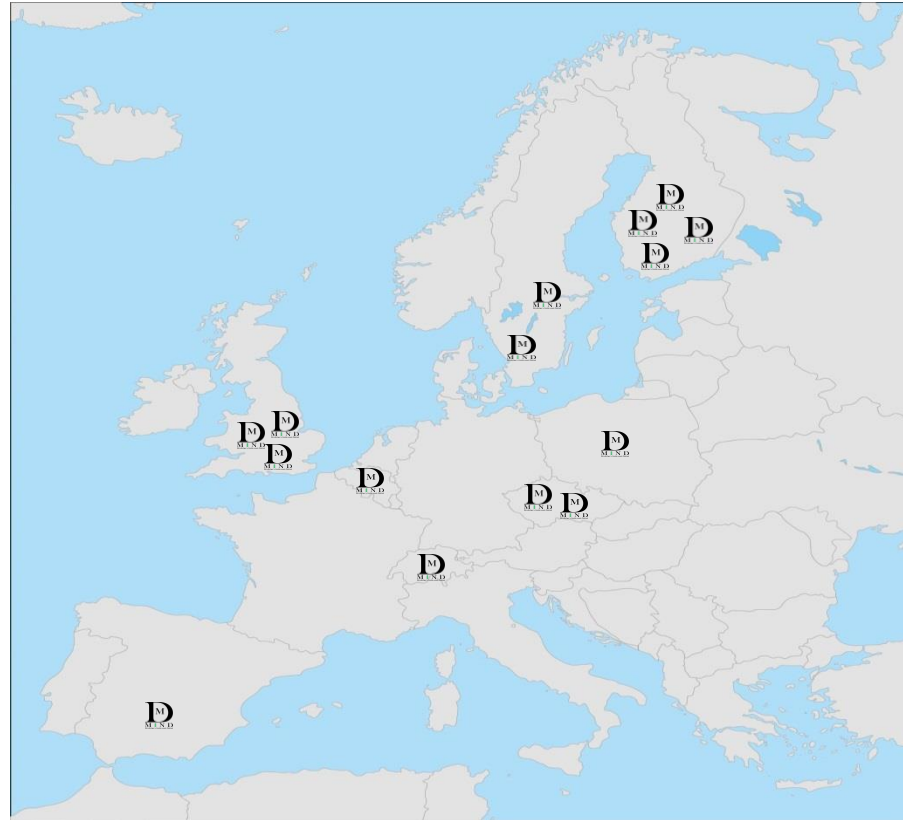
9<sup>th</sup> European Commission Conference on EURATOM Research and Training in Safety of Reactor Systems  
Pitesti, Romania, 4-7 June 2019

# The MIND consortium description

15 partners from:  
research, performance  
assessment, social  
science

8 countries represented  
in the project

Implementers Review  
Board: include WMOs,  
regulators and overseas  
contribution to the  
evaluation report



# MIND objectives

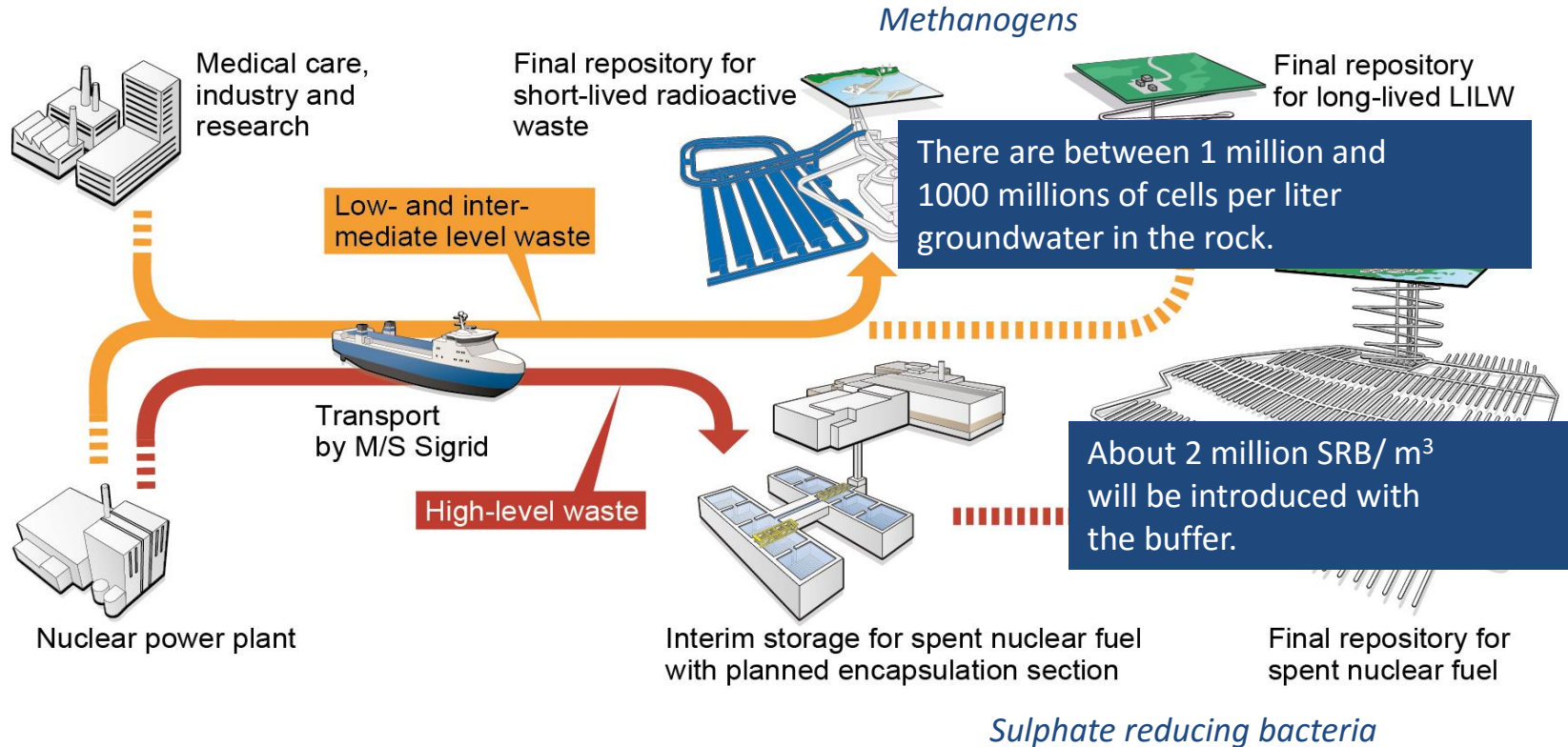
## The objectives of the project

- are to **target key technical issues, involving microbial processes**, which must be addressed to facilitate safe implementation of planned geological disposal projects in the EU.
- will **increase the understanding of how life processes will influence the safety and performance** of future repositories, by focusing on key topics as defined in the most recent version of the IGD-TP strategic research agenda (SRA) (version July 14, 2011).

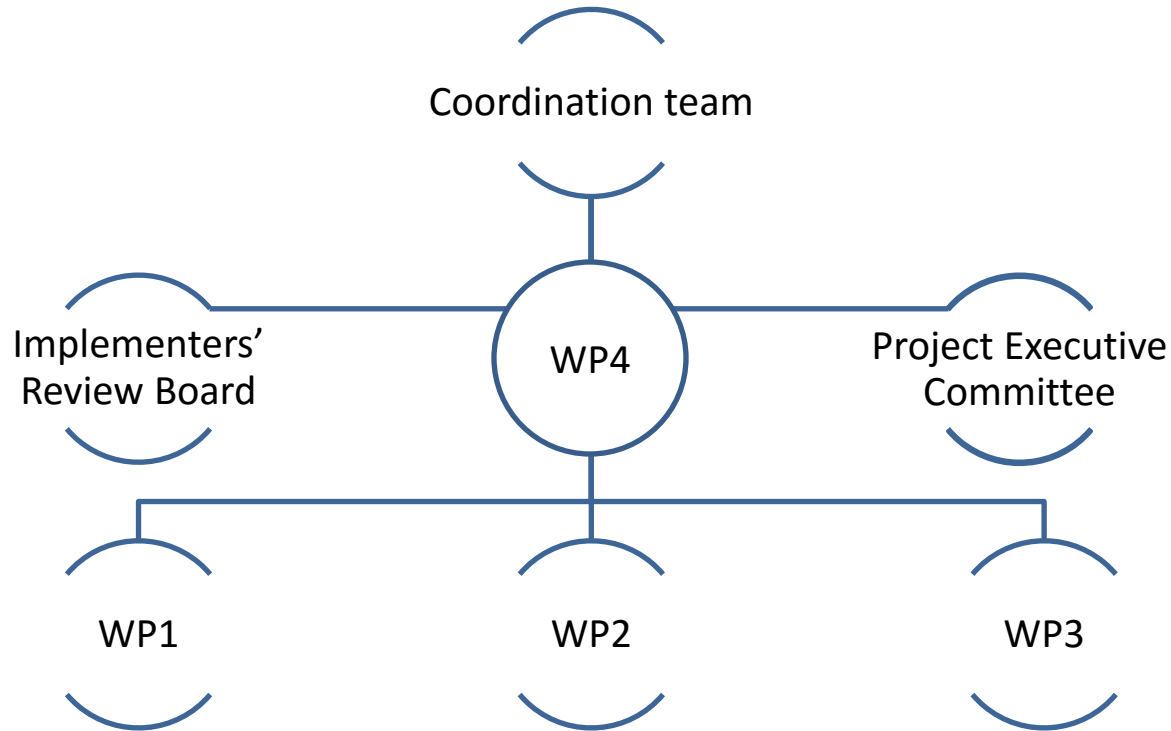
# Main microbial processes

- Microbially induced degradation
  - Corrosion of metal canisters
  - Degradation of buffer, backfill and cement
- Gases
  - Production –
  - Consumption +
- Migration
  - Mobilisation –
  - Immobilisation +

# Where are the microbes?



# MIND organization



# Work Packages

- **Work Package 1:** Improving the geological safety case knowledge of the behaviour of organic containing long-lived **ILW**
  - **Key Topic 2:** “Waste forms and their behaviour”
  - Lead: NNL (UK, Joe Small)
- **Work Package 2:** Improving the safety case knowledge base about the influence of microbial processes on **HLW** and spent fuel geological disposal
  - **Key Topic 3:** “Technical feasibility and long-term performance of repository components”
  - Lead: MICANS (Sweden, Karsten Pedersen)
- ⊙ **Work Package 3:** Integration, communication and dissemination
  - Lead: SCK•CEN (Belgium, Natalie Leys/Kristel Mijndonckx)
- ⊙ **Work Package 4:** Project Management
  - Lead: SKB (Sweden, Birgitta Kalinowski/Petra Christensen)



# EURADWASTE '19

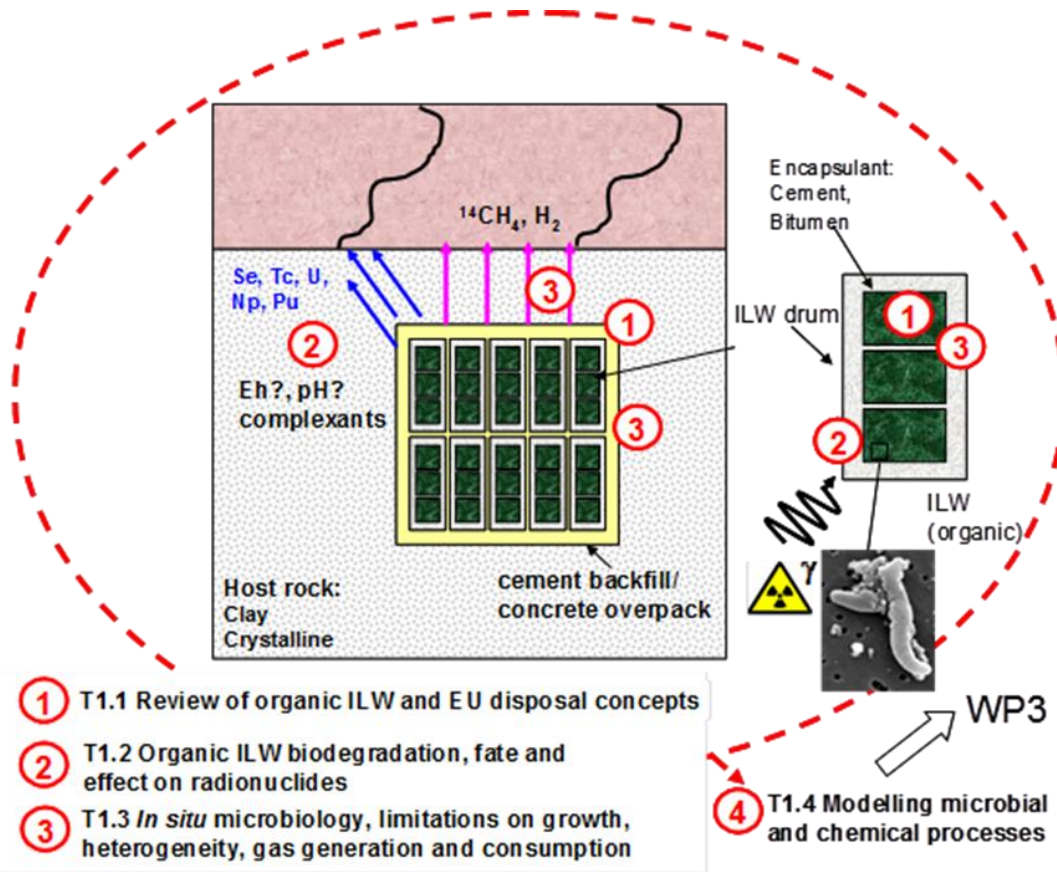
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in Radioactive Waste Management

4-7 June 2019  
Pitesti, Romania

## WP1: Improving the geological safety case knowledge of the behaviour of organic containing long-lived

# ILW disposal concepts

Reduce uncertainty  
of safety-relevant  
microbial  
processes  
controlling  
radionuclide,  
chemical and gas  
release from long-  
lived intermediate  
level wastes (ILW)  
containing organics

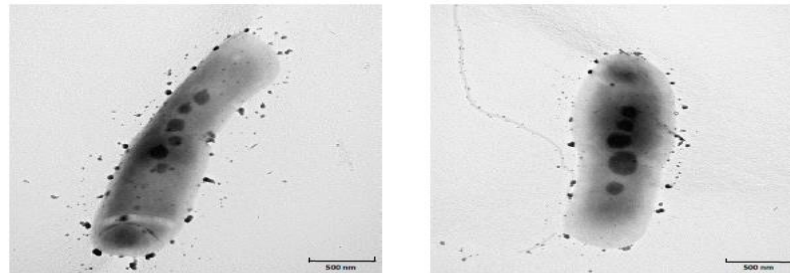


# Key findings and outlook

- Key findings
  - First radiolysis + biodegradation studies of organic polymers;
    - Cellulose, Bitumen, PVC, IEX resins
  - Novel RN interactions
  - H<sub>2</sub> consumption
    - Sulfate, nitrate reduction
  - CH<sub>4</sub> generation
    - From cellulose/steel, pH 8 threshold, HS- toxicity
    - Absence from H<sub>2</sub> injection ?
  - pH limits of specific processes
- Further areas of study
  - *In situ* URL and waste simulant experiments
    - Fate of organics
    - Waste simulant studies (e.g. GGE post mortem)
  - Scale of heterogeneity (pH)
  - Methanogens vs SRB
    - Competition for energy, trace elements
    - Sulfide toxicity

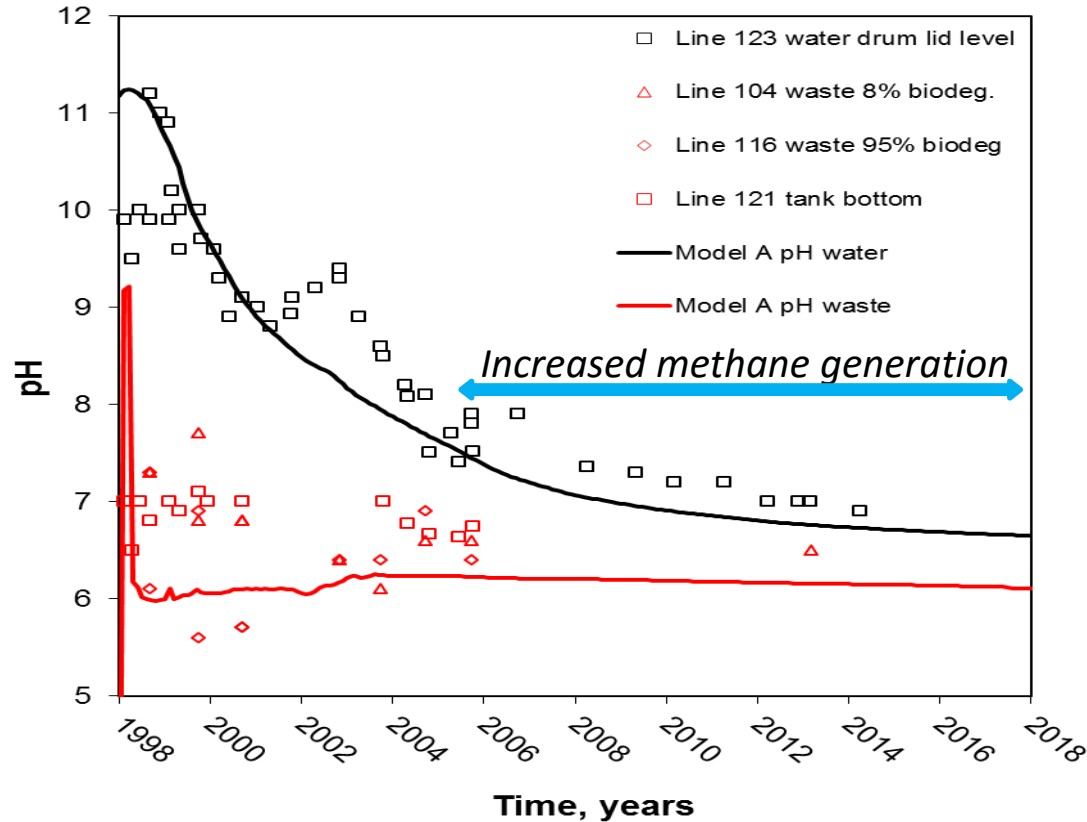
# Limits on microbial life in an ILW repository

- Several studies relevant to upper pH limit
  - Nitrate reduction; PVC & Bitumen studies D1.2, D1.3, P7
  - Cellulose studies D1.2, P1, P5
- Controls on Methanogenesis
  - pH, competition with SRBs, sulfide toxicity, thermodynamics, trace elements?
  - TVO experiment D1.6, D1.8, P4, P10
  - Mont Terri H<sub>2</sub> injection D1.7
- Other toxicity effects
  - Cs P9 (Shrestha et al, 2018)
  - Se D1.5, P2, P2, P8



*Figure 3: TEM image showing the presence of bacteria in 0.5 mM Cs<sup>+</sup> after 8 days.*

# Methanogenesis: pH 8 threshold



Gas Generation experiment GGE, Olkiluoto (Small et al, 2017; Vikman et al, 2019)



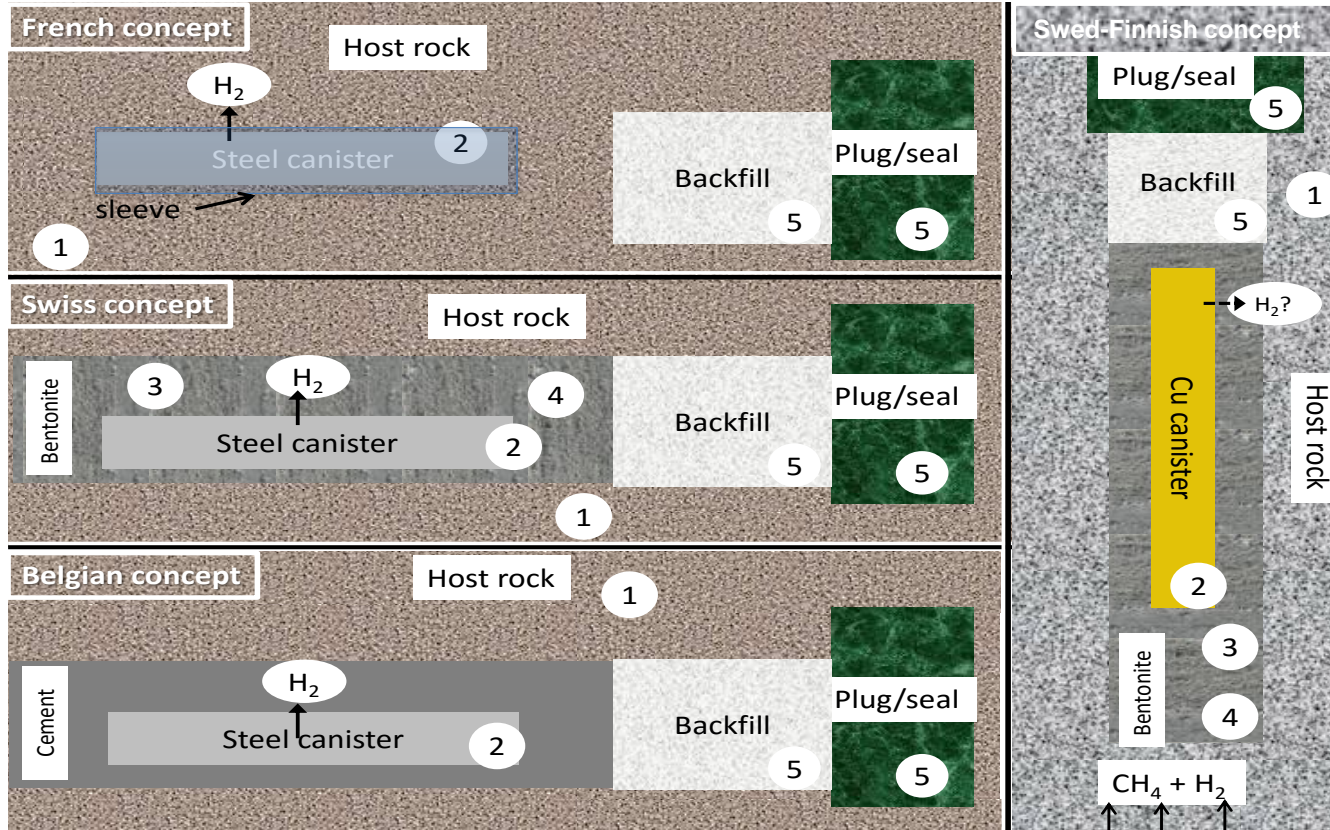
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**WP2: Improving the safety case  
knowledge base about the  
influence of microbial processes  
on and spent fuel geological  
disposal**

# European HLW disposal concepts



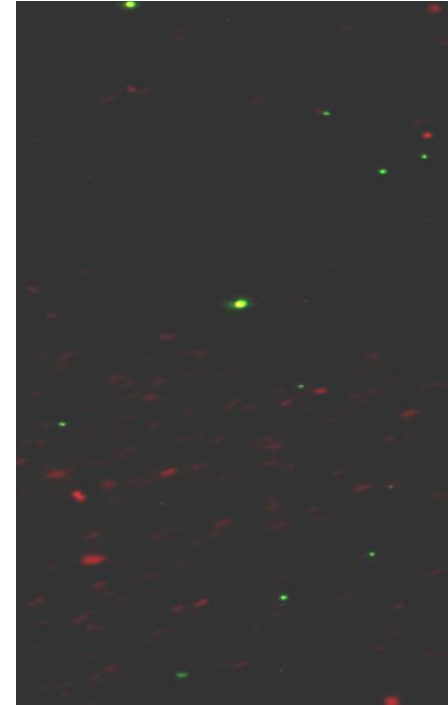
- Representation of European high level waste disposal concepts (not to scale). Microbial processes are possible at the numbered points, which correspond to task numbers.

1. Microbial generation of sulphide in the geosphere
2. Microbially induced corrosion of canisters
3. Microbial activity in bentonite buffer
4. Microbial degradation of bentonite buffer
5. microbial activity in backfill and plug/seals

# Visualization of microbes in clay



Images of extracted bacterial cells from non-spiked FEBEX clay sample B-C-60-18 after hydration



Viable (green fluorescence) and dead (red fluorescence) cells detected in the sample 10 (ring 2, layer 3) of 1400 kg/m<sup>3</sup> bentonite

# Key findings and outlook

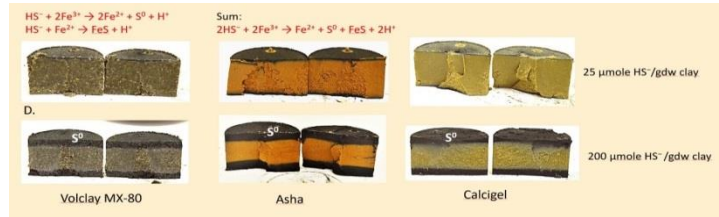
- Key findings

- ◉ The MIND project has identified factors of importance for sulfide production in the geosphere
  - Energy sources, groundwater mixing, electron acceptors etc
- ◉ Swelling pressure is an important limiting factor for microbial activity, but not for presence and survival.
- ◉ The MIND project thoroughly confirms previously published and reported data that have shown microbes to be present in commercial clays as well as in compacted clay in laboratory and in field scale experiments.
- ◉ Microbial activity may decrease pH in high alkaline repository barriers
- ◉ Clay may act as a sink for sulfide

- Further areas of study

- *In situ* URL and waste simulant experiments

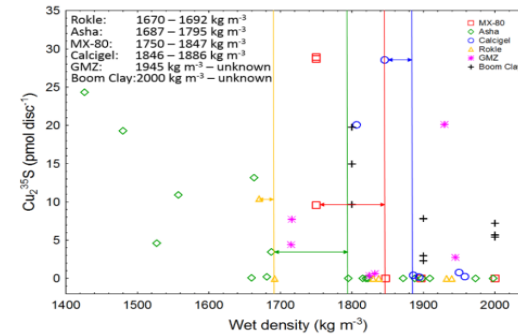
# Some research findings



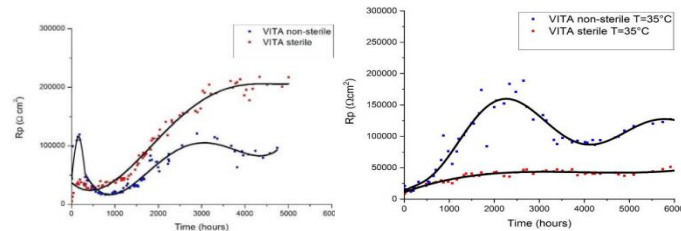
Bentonite clays have a significant capacity for **adsorption** of sulfide.

Difference in reactivity between bentonites

Present data indicates that sulfate and methane may coexist in deep fluids, indicating that **methane is not a very effective electron donor** for microbial sulfate reduction.



The microbial activity highly influences carbon steel **corrosion** under anaerobic conditions. The **biofilm formation** differed depending on the temperature (~20 and 35 °C).





# EURADWASTE '19

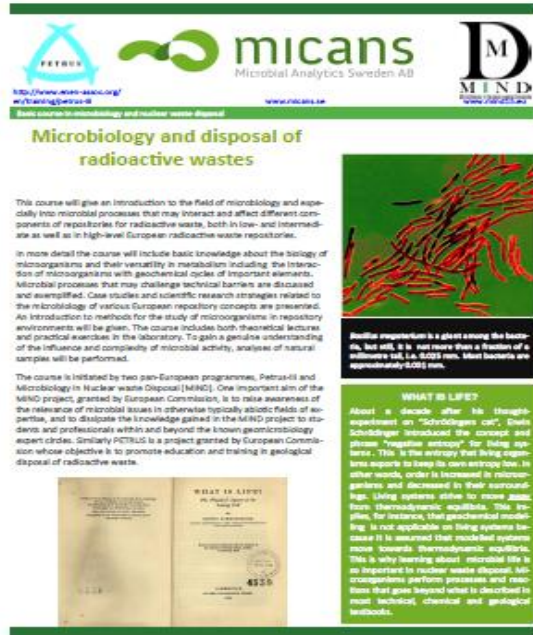
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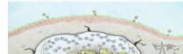
## WP3: Integration - Communication - Dissemination

# Final integration and synthesis

## Perception of lay public and professional: waste disposal design with and without microbial processes by interviews, questionnaires



Kindly watch a three minutes long video, designed by École polytechnique fédérale de Lausanne (EPFL) and published on YouTube VIDEO:



microbiology  
work packages

to a broad audience, including students, professionals, the scientific community, stakeholders and the lay community.

### Final integration and evaluation report

Editors: K. Mijnders (SCK-CEN)  
J. Small (NNL)  
L. Abrahamson-Mills (NNL)  
K. Pedersen (Micans)  
J. Goverts (SCK-CEN)  
N. Leys (SCK-CEN)

Date of issue of this report: 31.05.2019

Report number of pages:

Start date of project: 01/06/2015  
Duration: 48 Months

This project has received funding from the European research and training programme 2014-2019 under Grant Agreement no. 651880		
Documentation Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission services)	
RP	Restricted to a group specified by the partners of the MIND project	
CO	Confidential, only for purposes of the MIND project	

# Exchange opportunities and conferences

## Exchange opportunities

In this section you will find the exchange opportunities in microbiology and nuclear waste. Applications should be submitted by email to [mind.project@sckcen.be](mailto:mind.project@sckcen.be) and should contain – a motivation letter with MIND-reference to the opportunity as mentioned on this website; – a CV of the candidate.

Approval of your request will be subject to the evaluation of your application file by a Jury composed by members of the MIND project WP3, as well as the host institution. You will be informed about the status of your application via email.

In case of questions, please contact us via [mind.project@sckcen.be](mailto:mind.project@sckcen.be) and always mention the MIND reference number of the opportunity.

If you want the exchange opportunities of your institute to appear here, please contact us via [mind.project@sckcen.be](mailto:mind.project@sckcen.be).

MIND reference	Title	Exchange opportunity for a	Host	Country	More information
MIND01	Customized DNA-extraction from clay materials	PhD or Professional	SCK-CEN	Belgium	<a href="#">Read more about MIND01</a>
MIND02	Microscopic characterization of different samples (clays, radionuclide bacteria samples, radionuclide bacteria/organic samples, etc.)	Master, PhD or Professional	University of Granada- Department of Microbiology	Spain	<a href="#">Read more about MIND02</a>
MIND03	Flow cytometry characterization of the radionuclide toxicity towards microbial cells	Master, PhD or Professional	University of Granada- Department of Microbiology	Spain	<a href="#">Read more about MIND03</a>
MIND04	Excursion and sample collection at Bukov Underground Research Facility	Master, PhD or Professional	Technical University of Liberec	Czech Republic	<a href="#">Read more about MIND04</a>
MIND05	DNA extraction from Czech bentonite samples	PhD or Professional	Technical University of Liberec	Czech Republic	<a href="#">Read more about MIND05</a>
MIND06	In-house DNA extraction protocol for bentonite, clay samples	PhD or Professional	HZDR, IRE	Germany	<a href="#">Read more about MIND06</a>
MIND07	Ru-La speciation studies using spectroscopic techniques	PhD or Professional	HZDR, IRE	Germany	<a href="#">Read more about MIND07</a>

To enhance a cross-border dissemination of expertise for Master and PhD students and professionals

[http://www.mind15.eu/exchange\\_table/mind.project@sckcen.be](http://www.mind15.eu/exchange_table/mind.project@sckcen.be)

+ October 24-28th, 2016 Geomicrobiology primer training course, Mölnlycke, Sweden

+ August 9th, 2016 HydroFrame Summer School on Radioactive Waste Disposal, London, UK

+ July 10-15, 2016 + March 1, 2018, open call on European Nuclear Mobility Fund

+ June 13-14, 2017 + September 10-14, 2017, GDCh-Wissenschaftsforum Chemie, Berlin, Germany

+ June-July, 2017 + September 3-7, 2017, EUROCORR 2017, Prague, Czech Republic

+ Netherlands + August 13-18, 2017, Goldschmidt conference, Paris, France

+ May 2-4, 2016 + August 13-17, 2017, The 5th International Conference on Selenium in the Environment and Human Health, Stockholm, Sweden

+ January 28-29, 2017 + July 17-21, 2017, 16th International Clay Conference, Granada, Spain

+ November 4, 2017 + June 26-30, 2017, PETRUS-ANNETTE PhD and Early-Stage Researchers Conference, Lisboa, Portugal

+ October 19, 2017 + June 5-9, 2017, SCANDEM, Reykjavik, Iceland

+ Management + May 3-5, 2017, MIND Project Annual Meeting 2, Prague, Czech Republic

+ October 12, 2017 + April 11, 2017 New Scientist article. Waste-munching bacteria could make nuclear stores safer

+ August, 2015 + April 11, 2017, Linnaeus University, Kalmar, Sweden

+ June, 2015 EU + April 4, 2017, seminar, Helsinki, Finland

+ March 19, 2015 + April 3-6, 2017, Conference, Edinburgh, Scotland

+ March 21-23, 2017, Conference, Hustopeče u Brna, Czech Republic

<http://www.mind15.eu/public-meetings/>

+ February 7, 2017, Workshop on Environmental Chemistry, Switzerland

# Dissemination

## Scientific papers (20 +)



Research paper

**Mobility and reactivity of sulphide in bentonite  
clays – Implications for engineered bentonite  
barriers in geological repositories for radioactive  
wastes**

Karsten Pedersen , Andreas Bengtsson, Ande

**samples**


Part of: **2nd Petrus-OPERA PhD an**

**Title**

Characterization of microbial co

Articles

**The anaerobic corrosion of carbon steel in compacted  
bentonite exposed to natural Opalinus Clay porewater  
containing native microbial populations**

N. R. Smart , B. Reddy, A. P. Rance , D.J. Nixon , M. Frutschi, R. Bernier-Latmani  & ...show all

Pages 101-112 | Received 14 Dec 2016, Accepted 23 Mar 2017, Published online: 23 Aug 2017

 Download citation  <https://doi.org/10.1080/1478422X.2017.1315233>

 Check for updates



**activates deep subsurface fracture fluid  
ial communities in Olkiluoto, Finland**

en (Corresponding Author), Malin Bomberg, Minna Vikman

**obial communities  
bentonite**

Jean-Charles Robinet <sup>d</sup>, Jonathan R.

**Long-term experiment with compacted bentonite**

Minna Vikman (Editor), Michal Matusewicz, Elina Sohlberg, Hanna Miettinen, Joonas Järvinen, Aku Itälä, Pauliina Rajala, Mari Raulio, Merja Itävaara, Arto Muurinen, Mia Tiljander, Markus Olin

BA3607 Metals and materials recovery, BA2504 Nuclear waste management, BA3407 Food and process microbiology, BA2406 Materials performance, BA25 Nuclear safety

**and aerobic microbial community in  
radioactive waste repository**

a Ševců Technical University of Liberec

**Jakub Kokinda** Research Centre Rez

: Chemistry and Biochemistry of the CAS

[ja@cvrez.cz](mailto:ja@cvrez.cz)



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RATEN  
ICN PITESTI  
INSTITUTUL DE CONCENTRARE NUCLEARE

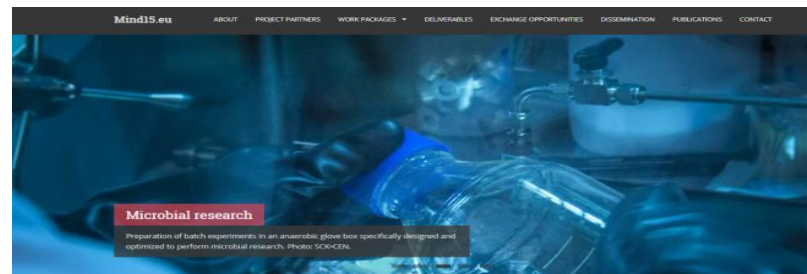
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Pitesti, Romania

## WP4: Project management

# Reporting



# MIND IN NUMBERS

- 661880 MIND-Project

In almost 48 months, 15 organizations from 8 countries have managed to produce:

- 52 Quarterly reports delivered to the Coordinators
- 35 Deliverables (a few more to come)
- 37 Milestones have been reached
- 2 Periodic reports have been approved by the EC (the last one to come)
- 6 Newsletters
- More than 20 publications
- 2 Advanced courses
- About 20 WP-leaders' meetings
- 4 Project Annual Meetings

All to the cost of: **EUR 4,160,234.50** (four million one hundred and sixty thousand two hundred and thirty four EURO and fifty eurocents) and in 490,50 (four hundred and ninety and a half) person months.

# Thank you!



Acknowledgement: This project has received funding from the Euratom research and training programme 2014 - 2018 under grant agreement No. 661880