TECHNOLOGY FOR BUSINESS

Biodegradation of low-level radioactive waste under *in situ* conditions

Vikman[1], M., Itävaara[1], M., Paaso[2], N.
[1]VTT Technical Research Centre of Finland Ltd
[2]Teollisuuden Voima Oyj

Low-level radioactive nuclear waste

In addition to energy nuclear power plants produce high-level radioactive, intermediate- (ILW) and low-level nuclear waste (LLW). In Finland low-level radioactive waste LLW (activity < 1 MBq/kg) includes scrap metals and considerable amounts of paper products, cardboard, cotton gloves, natural rubber and various kind of plastics. Compressible LLW is compacted in steel drums and disposed in repositories situated inside the bedrock in the plant sites at a depth of 60–110 meters. The biodegradation of cellulose-based LLW in anoxic conditions can result in gas generation and accelerate corrosion, deteriorate the performance of multi-barrier systems, and enhance the mobility of radionuclides from the repository to the surrounding environment.

Gas generation experiment (GGE)

In 1997 the Gas Generation Experiment was constructed to simulate the amount of gases generated from LLW to estimate the risks for the final disposal. Sixteen waste drums (200 dm^3) were filled with LLW originating from the nuclear power plant and closed in the concrete box. The GGE has been monitored for quantity and composition of generated gas, water chemistry and microbiology. Bacterial, archaeal and fungal communities were studied using molecular technologies including quantitative PCR and high-throughput sequencing.

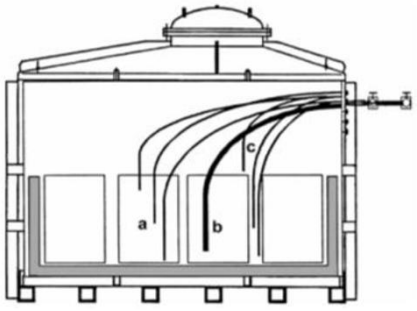
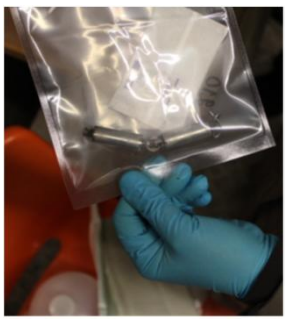
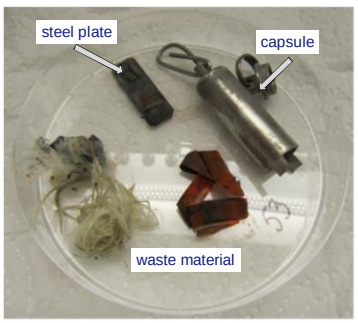


Figure 1. The gas generation experiment GGE with waste drums containing LLW waste and sampling lines for water samples and capsules. Before closing the GGE was filled with local river water and has been maintained at temperature of 8-11°C. *(Small et al., 2008).*





Figures 2 and 3. Capsules containing LLW and steel plate have been loaded to the GGE tank and removed at certain time points to study corrosion and microbiology. In addition, water samples have been taken from different compartments of the tank.

Heterogeneity in the GGE

Extreme alkaline conditions created by concrete structures was considered to limit microbial processes in the GGE but gas generation started already after one year of operation. The chemical conditions were very heterogenic which created optimal niches for microbial action. Microbial activity was higher at the bottom of the GGE tank and inside the waste drums than in the lid level of the tank.

Microbes related to gas generation

LLW contained approximately 40% of cellulose and hemicellulose, and was converted to methane and carbon dioxide in several phases by complex microbial consortia.

- Several microbial groups potential to hydrolyze cellulose and hemicellulose were identified. Produced mono- and disaccharides were further utilized by other microbes.
- In the final stage of anaerobic biodegradation process CH_4 is formed from acetate or from hydrogen and CO_2. Both acetate and CO_2/H_2 utilizing methanogens were found in the GGE.
- The amount of methanogens increased during the GGE. Sulphate reducing bacteria compete with methanogens for electron donors like H_2 and can thus influence the gas generation. In GGE the relative ratio of sulphate reducers compared to methanogens was rather small (Fig. 4).
- According to sequencing microbial community structure was to some extent different in tank water and in waste materials.

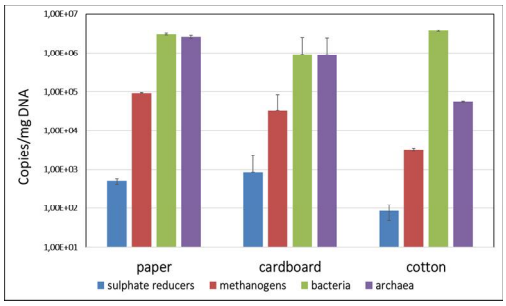


Figure 4. The amount of sulphate reducers, methanogens, total bacteria and archaea in cellulose-based waste materials taken from the GGE capsules.

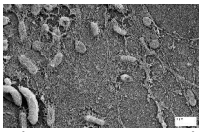


Figure 5. Bacteria attached on the surface of material removed from the capsules. (FESEM).

Acknowledgements

The research was funded by the KYT Finnish Research Program on Nuclear Waste Management and VTT. We also thank Teollisuuden Voima Oyj which operate the gas generation experiment. The research has been supported by the Horizon 2020 project MIND through funding from the Euratom research and training programme 2014-2018 under Grant Agreement no. 661880.

References

J. Small, M. Nykyri, M. Helin, U. Hovi, T. Sarlin, M. Itävaara (2008). Experimental and modelling investigations of the biogeochemistry of gas production from low and intermediate level radioactive waste. Applied Geochemistry 23, 1383-1418.

Contacts

Minna Vikman
Tel. +358 40 525 7428
minna.vikman@vtt.fi