Proposal of a Descriptive Modeling of Portland Cement Behavior under Radioactive Waste Repository Environment

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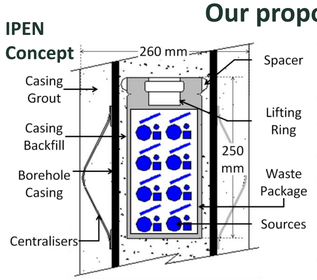
Disused Sealed Radioactive Sources (DSRS): a worldwide problem

Storage and disposal of DSRS is a problem in many countries over the world. Brazilian inventory is about 300,000 sources (in use or stored), many of them with high activity and long lived radionuclides.

Disused Radioactive Sealed Sources

Our proposal to deposition of DSRS



- Dispose of the DSRS in a deep borehole repository. The IPEN concept was adapted from the BOSS Concept, developed by the NECSA/IAEA.
- Cementitious materials are intended to be used as a backfill material between the steel casing and the geological formation around the borehole and between waste packages and the steel casing.
- The required service life of the installation is counted in thousands of years.

Issues to be addressed

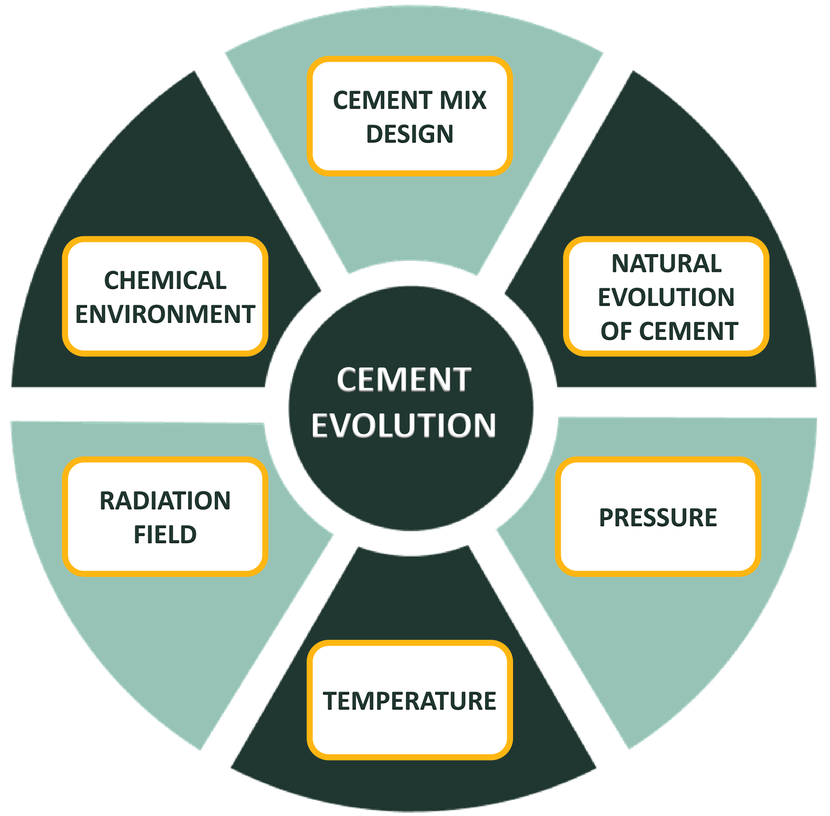
Assessment of cement paste long-term durability and its behavior under radiation, high pressure and temperature and penetration of groundwater containing chemically aggressive species.

Objectives

The present study aims at defining the relevant external factors and their influence on the durability of hydrated cement. This study will be helpful on modeling the long-term reactions in the cement matrix and can improve the safety assessment.

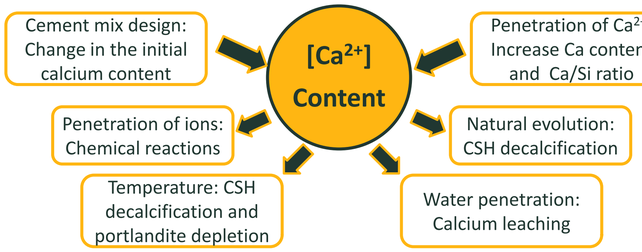
Expected Output	Assessment of the effects of environmental factors in long-term properties of cement in a borehole repository environment
Expected Outcome	A better understanding of the effects of environmental factors in cementitious matrices. Improvement in repository safety assessment.

CEMENT EVOLUTION IN THE LONG TERM



DESCRIPTIVE MODEL

Factors	Mode of action	Effects
Cement mix design	• Chemical composition of cement • Physical properties • Minor components composition • Additives	• Chemical and physical properties effects on cement matrix • Influence of minor components in long term • Long-term reactions (AAR and ASR)
Natural evolution	• Natural evolution of phases • CSH recrystalization	• Changes the chemical equilibrium • Changes in crystal structures
Pressure	• Changes in reaction kinetics • Increase of mechanical load • Effects on resistance and cohesion	• Changes the chemical equilibrium • Changes in crystal structures • Decreased porosity / mechanical failure / reactions influence
Temperature	• Changes in reaction kinetics • Water evaporation • Thermal decomposition • Lost of Ca^{2+} from portlandite and CSH	• Changes the chemical equilibrium • Increase hydration rate in early ages and promote deleterious reactions in long term • Increase cracking and porosity
Radiation Field	• Water radiolysis • Break chemical bond • Increase of Temperature	• Radicals formation • Favors chemical reactions (eg carbonation) • Changes in crystal structures • Gas formation
Chemical Environment	• Water penetration (ions transport in and out cement matrix) • Ions penetration leading to chemical reactions (Cl^-, CO_3^{2-}, SO_4^{2-}, $Fe^{2,3+}$, Mg^{2+}, Ca^{2+}, Na^+, K^+)	• Dissolution of minerals and leaching of chemical species (eg lost of calcium) • Increase porosity • Alter solubility of compounds • Volume and mineralogical changes



SYNERGISTIC EFFECTS

The synergism between all factors that can affect the cement is hard to predict and have to take into account many processes. For example, the calcium ion content in a cementitious matrix can be altered by many factors and depends on the cement mix designs and environmental factors that will prevail at the repository.

Calcium Leaching + CO_3^{2-} Penetration	**Carbonation**	Block Pores: decrease porosity and water penetration
Calcium Leaching + Water Penetration + Sulfate ingress	**Ettringite Formation**	Matrix Expansion: Increase porosity and water penetration
Natural Evolution + Mg, Al Penetration + Water Radiolysis	**Lost of cohesion: CSH decalcification**	Increase porosity, water penetration and ions ingress

Acknowledgements

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