Landfillworkshop 2011 November 15-17

Specialist workshop on LANDFILLS OF HAZARDOUS WASTE AND ITS IMPLICATIONS ON HEALTH AND ENVIRONMENT

LESSONS LEARNED FROM NUCLEAR DECOMMISSIONING AND WASTE MANAGEMENT RELEVANT TO LANDFILLING OF HAZARDOUS WASTE

Rolf Sjöblom[1,2], Staffan Lindskog[3] and Lale Andreas[2]

1 Tekedo AB
2 Luleå University of Technology
3 The Swedish Radiation Safety Authority

Waste Science & Technology: Senior staff

This presentation

- Introduction
- Landfilling
- Lessons learned from nuclear waste management and decommissioning
- Analysis and discussion
- Conclusions

This presentation

- Introduction
- Landfilling
- Lessons learned from nuclear waste management and decommissioning
- Analysis and discussion
- Conclusions

Trends & haute couture

- No monopoly of fashion design
- Occur everywhere
- After opening up of new areas <= new discoveries
- Sometimes considerable incubation and initiation time

Global warming known for > 100 y

=> When nuclear fission & chain reactions were introduced in 1942

- Relatively good handle on radiation protection
- Little respect for waste containing induced radioactivity

Birth of the atomic age.
Oil painting by Gary Sheahan showing first chain reaction.

THE AKA PUBLIC ENQUIRY 1973 - 1976

- State-of-the-art on spent nuclear fuel and radioactive waste
- Part of the planning process for the modern light water reactor programme
- AKA proposed:
  - *Research*: Programme Council for Radioactive Waste (PRAV)
  - *Finance*: Costs to be carried by the nuclear utilities

Shift of paradigm

- < ≈ 1975 nuclear technology development, ≈ 1,55 G€ spent by Government
- > ≈ 1975 nuclear waste technology development, ≈ 2 G€ spent by SKB

Non-nuclear waste

- Last few decades, ≈ 30 year perspective
  - Emission to water
  - Emission to air
- Long-term performance, less attention
- Study for Swedish EPA (Carlsson 2004)
  - No prognosis for cost for long times
  - But will the seals and covers function long enough?

Swedish environmental code

- Sufficient knowledge
- Compliance with the Polluter Pays Principle (PPP)
- Use of Best Available Technology (BAT)

=> New knowledge if BAT is not sufficient

- Assumed in this paper that protection of health and the environment same for future generations as for us

Hypothetical example

- Non-hazardous waste at maximum allowed concentration
- Maximum leaching for waste that meets the criteria for disposal at a landfill for non-hazardous waste
- Thickness of waste: 10 metres

=> > 1 000 000 years

- But next glaciation in < 100 000 years

Objectives and scope

- Different covers - summarize potential for long-term functioning
- Share lessons learned from
  - Nuclear waste management, and
  - Decommissioning of nuclear facilities
- Comparison with lessons learned from contaminated soil
- Implications, requirements on knowledge

This presentation

- Introduction
- Landfilling
- Lessons learned from nuclear waste management and decommissioning
- Analysis and discussion
- Conclusions

Long-term leaching

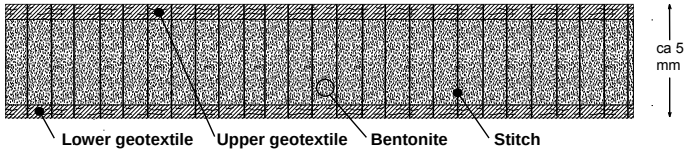
- Depends on whether
  - Sorbed on the surface, or
  - incorporated in the solid structures formed by the major elements
- Ageing phenomena may imply efficient incorporation

Geomembranes

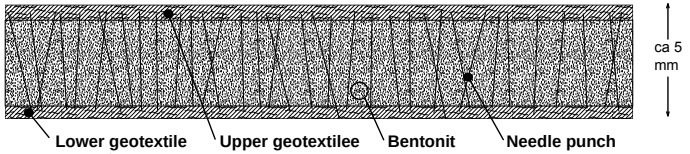
- Made of polyethylene or polyvinyl chloride
- Presence of antioxidants needed
- Increased rate in deterioration can be expected when the antioxidants have been consumed
- Stress corrosion an issue to consider
- No natural or anthropogenic analogue available

Geo clay liners

STITCH BONDED GEOCLAY LINER



NEEDLE PUNCHED GEOCLAY LINER



Geo clay liners

- Comprise composite of synthetic fabric and bentonite clay
- Bentonite content of montmorillonite swells on contact with water to form a seal
- Long-term shear strength depends on properties of polymer joining the two sheets
- Bentonite sensitive to chemicals, including salt
- Installations sensitive to differential settlements
- Natural analogues exist for the clay

Natural clays

- Can provide considerable buffer capacity
- Have a much higher hydraulic conductivity compared to bentonite
- Can show variations in properties
- Sources are scarce in Sweden
- There are good natural analogues

Ash from combustion of wood

- May compare with natural clays in terms of
  - Chemical buffer capacity, and
  - hydraulic conductivity
- Hydraulic conductivity might increase if content of salt is lost
- Natural and anthropogenic cements are analogues

Mixtures of ash and activated sewage sludge

- May form tight seals, at least in the short term
- Long-term stability has been repudiated based on anthropogenic and natural analogues

Conclusion

- It is not trivial to select the sealing material that best corresponds to the requirements of
  - Sufficient knowledge
  - Implementation of the polluter pays principle (i e protection of health and environment now and in the future)
  - Best available technology

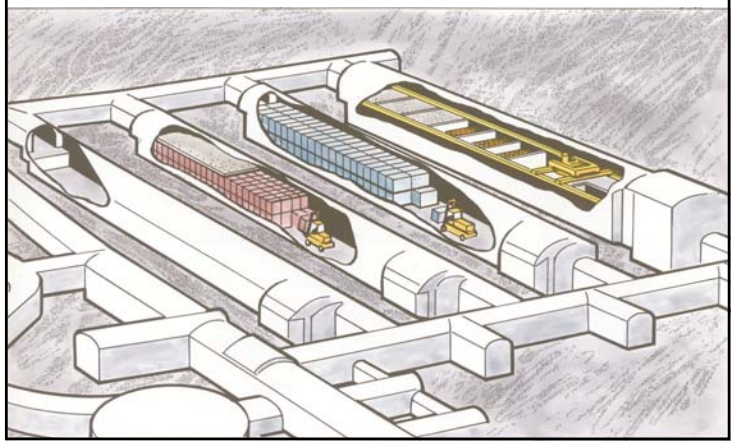
This presentation

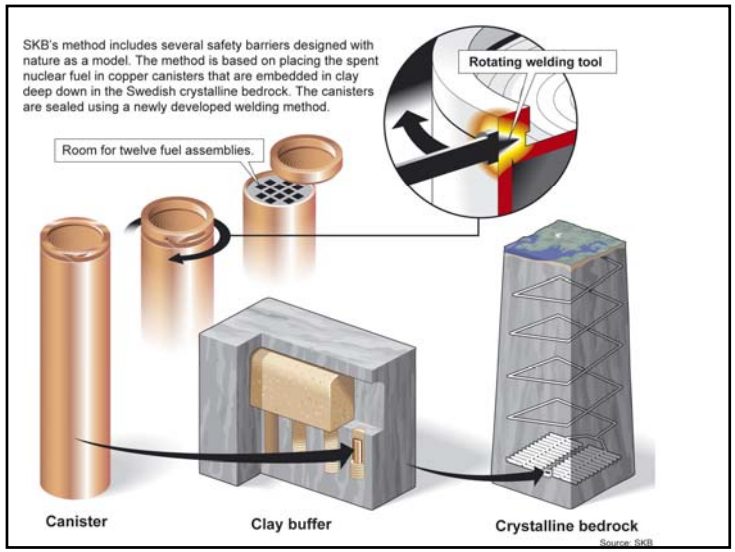
- Introduction
- Landfilling
- Lessons learned from nuclear waste management and decommissioning
- Analysis and discussion
- Conclusions

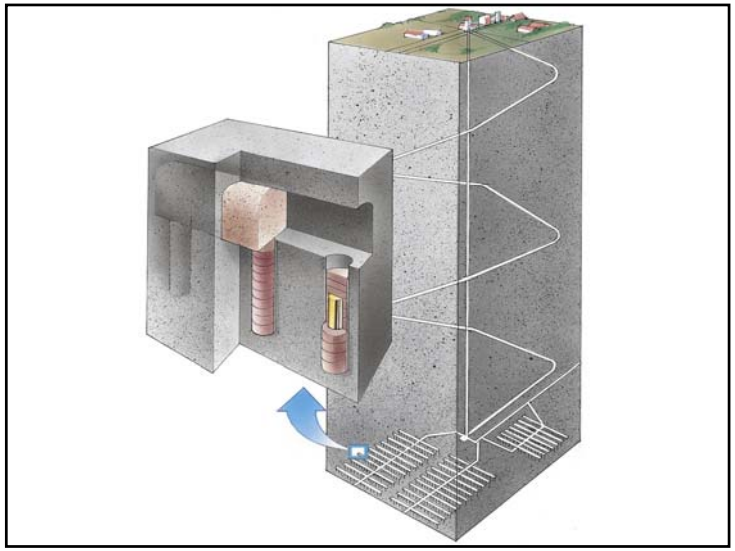
Nuclear waste in Sweden

- Sea dumping < 1972
- Crystalline rock repository for low level waste was taken into operation in 1988
- Application for building a repository for the spent nuclear fuel in 2011

Repository for low level waste







Natural and anthropogenic analogues

- Natural analogues for
  - Crystalline rock
  - Bentonite clay
  - Copper
  - Iron
- Anthropogenic analogues
  - Copper
  - Iron

Decommissioning of nuclear facilities

- Known since the 1970's that cost for decommissioning is ≈ 10 – 15 % of that for new build
- Funds must be available at the time when they are needed
- Sweden has segregated funds since ≈ 30 years
- It has proven notoriously difficult to make precise (± 15 %) estimates
- especially at early stages of planning

Comparison with landfilling & contaminated soil

- No remediation of landfill cover in Sweden (so far)
- Swedish EPA responsible for financing parts of remediations that refer to < 1969 activities
- 50 M€ paid each year for this
- No reporting found on relation between estimated and incurred costs
- US EPA estimated total (non-nuclear) remediation in the US to 6 G$ in 1970
- Present figures may exceed 1 000 G$

This presentation

- Introduction
- Landfilling
- Lessons learned from nuclear waste management and decommissioning
- Analysis and discussion
- Conclusions

Common misconceptions & far from universally true

- At thermal equilibrium, all elements appear as a major element in one phase or another
- Thermal equilibrium can be achieved in practice
- Reaction rates can be estimated from the energies determined in the calculations
- Rates determined experimentally can be extrapolated to long times

In oxide systems (e g ash)

- Formation of phases is dictated by the major elements
- Minor elements form solid solution, i e are dispersed in the matrices defined by the major elements
- Such ”dilution” is associated with a high entrophy
- This enthropy strongly influences the Gibbs free energy ⇔ incorporation

Thermal equilibrium

- Thermal equilibrium is rarely achieved in real systems undergoing ageing
- Ageing typically includes dissolution and reprecipitation
- New phases are not the same as the old ones
- Composition of new phases will change as the ageing proceeds

Arrhenius’ equation

Rates of reaction are frequently assumed to follow an Arrhenius type of relationship

- This presupposes that there is only one mechanism
- And that it is of first order
- Reaction energy ≠ ≠ activation energy
- Extrapolation to longer times ⇔ there exists proof that the mechanism is the same
- E g not valid for inhibitors
- Kinetics usually empirical
- => analogues are necessary in practice

Waste archaeology

- Practiced from time to time
- Sometimes with good results

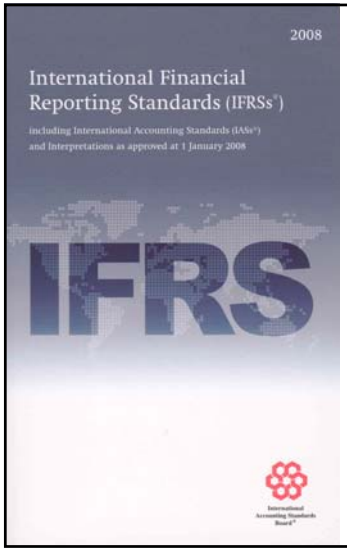
- General experience, however,
  Better to do it right from the beginning

Environmental liability

- Collective responsibility –
  Government can sue anyone involved
- Tempting to conclude that early planning not necessary
- However, much will change in a few decades
- Better technical solutions with early planning
- End of licence ≠ end of responsibility

Annual reporting

- Level reported for closure / decommissioning should be the same with regard to
  - Financial securities / segregated funds
  - Annual reporting according to IFRS
- Environmental liability should be treated the same as depreciation
- Exact figures are expected –
  - otherwise scenario analysis
- Penal law requires ”*essentially correct financial situation*” to be reported
- Noncompliance => maximum 6 years in jail



IFRS *International Financial Reporting Standards*
IAS *International Accounting Standards*

- Stringent requirements on assessing and securing assets for liabilities (financial accruals)
- Precise calculations are to be presented each year
- In case estimation is difficult, various scenarios should be considered and a weighed average presented

The Carlsson 2004 report

- Many companies who have liabilities do not declare them
- Most of them use taxed assets
  ≠ IFRS
  ≠ Government proposition in 1977 leading to the system of finance for nuclear liabilities (always untaxed assets since real liability)
- Reasons?
  – *Put forward*: fear for tax authorities
  – *Less flattering*: untaxed assets ⇔ ⇔ less bonuses for the management

This presentation

- Introduction
- Landfilling
- Lessons learned from nuclear waste management and decommissioning
- Analysis and discussion
- Conclusions

Conclusions 1

- Awareness comes in trends. Actors in the area of landfilling need to foresee what may be reasonable bases for future trends.
- Long-term effects do not usually evidence themselves in the short-term, but have to be searched for in order to be found and identified sufficiently early.

Conclusions 2

- Timely action is essential, since "waste archaeology" and other unplanned remedial actions are usually much more costly than doing things right from the beginning.
- Identification of issues of interest and significance requires relatively detailed studies already at early stages.

Conclusions 3

- The fundamental difficulties of long-term predictions and the associated high value of comprehensive studies of anthropogenic and natural analogues should be fully realized.
- BAT may not be enough. There is also a requirement on sufficient knowledge.

Conclusions 4

- Lessons learned from completed projects in related areas (such as nuclear waste and decommissioning) can provide valuable input for the planning
- Frequently, the requirements on correct declaration of the financial situation are harsher than the technical ones with regard to detailed and early planning.

Conclusions 5

- In many cases, it should be the need for financial planning that determines the timing of the technical planning.
- End of responsibilities takes place when all obligations have been fulfilled. It is entirely different from end of license.

Conclusions 6

- Long-term environmental liabilities are debts that we owe to future generations. It is essential that such liabilities be correctly balanced against financial assets which can be used at the time when they are needed. Such assets do not represent any income and should consequently not be taxed.

Haute couture
may not be so hot after all

The trend of today is
reuse & recycling …

Santa's spent beards

Old newspapers

So watch out for
new and upcoming trends

and

thank you
for your attention