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Engineering solutions for necroleachate risks in Aotearoa cemeteries'

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Thesis Overview

Necroleachate Management

- Cemeteries generate necroleachate through long-term decomposition.
- Cemeteries lack engineered containment or water controls.
- Emerging risks – urban intensification, population density, climate resilience.
- Research examines whether established landfill engineering principles can be adapted to manage necroleachate risk from existing cemeteries.
- Focus on currently operational cemeteries, groundwater interaction, and climate driven vulnerability.





Necroleachate Formation

Coffins act as both the source and the pathway

- Burial between 1-2 m bgl.
- Shallow groundwater tables in close interaction with the coffins.
- Burial process disturbs soil increasing hydraulic conductivity – coffin backfill behaves like a vertical drain.
- The coffin initially sealed structurally fails (month-years) creating an internal void for further infiltration.
- Necroleachate is produced:
 - Inside the coffin.
 - At burial depth.
- The point of generation is already:
 - Within a hydraulic shortcut.
 - Unlike surface contamination there is no soil column for attenuation.
 - Leachate enters preferential flowpaths immediately.



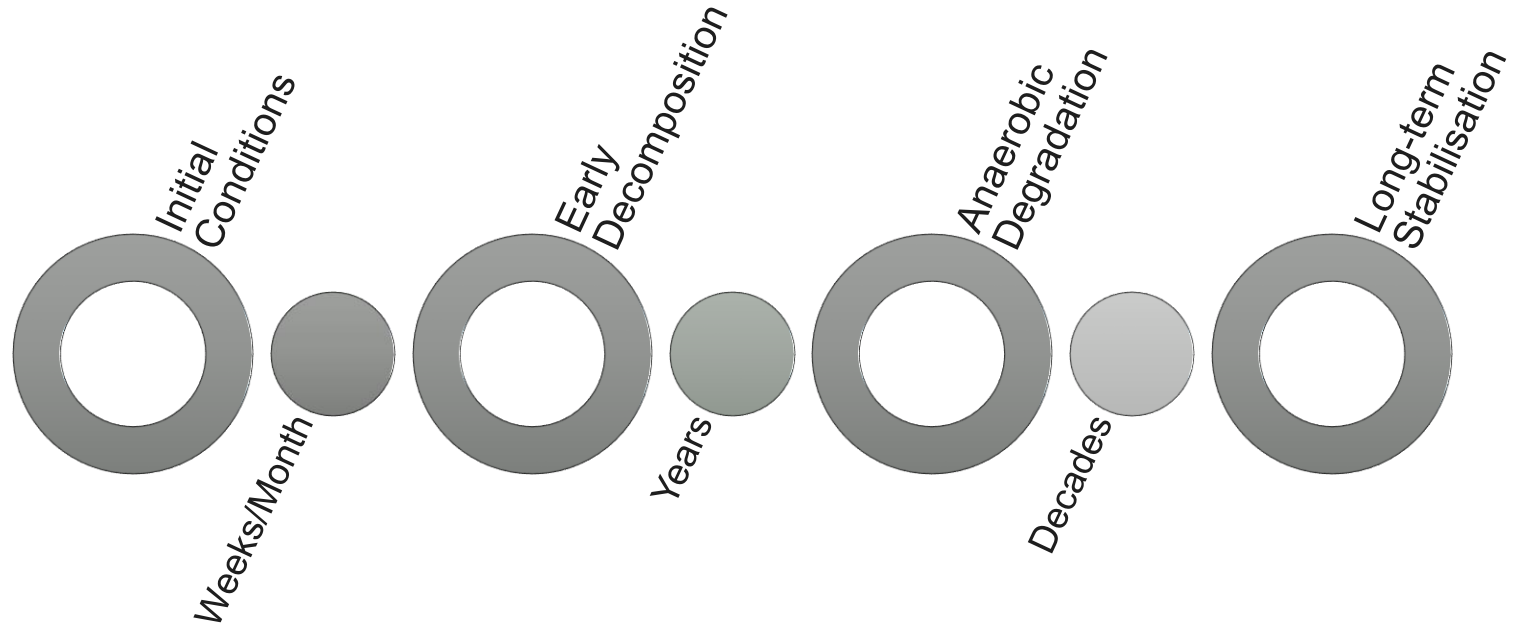


Setting and Scale

- Governance context:
 - Largely the responsibility of local and district authorities.
 - Managed through cemetery governance and bylaws.
 - Typically, outside of formal contaminated land programmes.
- National scale:
 - Approx 1,000 closed landfills.
 - Over 2,000 cemeteries and burial grounds.
- Implication of scale:
 - Cemeteries represent a much larger and more diffuse asset base.
 - Sites may be smaller but collectively more extensive.
 - Favour risk based and proportional responses over site-by-site investigation.



Necroleachate Formation Phases





Necroleachate Composition

- Closely comparable to a dilute landfill leachate:
 - Biological decomposition of organic material.
 - Predominantly anaerobic conditions.
- Elevated:
 - Nitrogen species (NH_4^+ dominant).
 - Dissolved organic carbon.
 - Metals.
 - Formaldehyde.
- Landfill leachate typically records higher contaminant concentrations than necroleachate.
- Necroleachate impact can be persistent due to the mixed-age and continual burial inputs.



Necroleachate Comparison

Aspect	Necroleachate	Landfill Leachate
Organic Matter	Moderate to high DOC	Very high DOC
Nitrogen	Dominated by nitrogen	Dominated by nitrogen
COD/BOD	Moderate	High to extreme
Pathogens	Present (esp early)	Generally reduced over time
Metals	Present	Present
Synthetic chemicals	Embalming fluids, coffin materials	Broad mix of household and industrial organics
Salinity	Low to moderate	Often elevated



Necroleachate Migration

- Graves are repeated, aligned, closely spaced.
- Creating lateral rows of connectivity.
- Over time preferential zones can form:
 - Shallow flow paths.
 - Lateral migration zones.
 - Localised plums.
- Necroleachate plumes often:
 - Spatially discontinuous
 - Difficult to predict.
- Detected intermittently in monitoring bores.
- Many NZ cemeteries:
 - Sit on floodplains, coastal margins, or permeable soils.
 - Have seasonally shallow groundwater tables
- Migration controlled by hydrology, coastal process, geology, hydrogeology not chemistry.





Shared Legacy of Problems

- Both feature on the HAIL.
- Established prior to modern environmental regulation.
- Located where land was historically:
 - Peripheral to urban centres.
 - Convenient.
 - Cheap land/reclamation.
- Commonly sited on:
 - Alluvial soils.
 - Coastal margins.
 - Floodplains.
- Evolving risk context:
 - Urban encroachment.
 - Rising groundwater tables.
 - Increased rainfall intensity.
 - Flooding and coastal inundation.
- Historic landfills:
 - Are now recognised as contaminated sites.
 - Monitored and remediated.
- Historic cemeteries are:
 - Rarely assessed as contaminant sources.
 - Unmanaged from a leachate perspective.





Perception Barriers

Cemeteries

- Viewed primarily as:
 - Sacred spaces not infrastructure.
 - Static landscapes not active systems.
- Decomposition framed as:
 - A natural process.
 - Morally distinct from 'waste'.
- Necroteachate framed as leachate often seen as:
 - Disrespectful
 - Clinical or dehumanizing.
 - Equating burial with disposal.

Landfills

- Socially accepted as:
 - Managed pollutant sources.
 - Appropriate targets from intervention.
- Environmental harm recognized through:
 - Historic landfills.
 - Coastal dumping.
 - Legacy dump sites.
- Risk normalized through common practice:
 - Everyone produces waste.
 - Often remembered through a nostalgic or benign lense that downplays environmental consequences



Engineered Solutions

Retrofitted Leachate Collection/Interception

- **Objective**
 - Intercept contaminated groundwater after necroleachate generation.
 - Offsite disposal or recirculation.
- **Approaches**
 - French drains/toe drains.
 - Perimeter or downgradient interception trenches.
 - Passive sumps or daylighting drains.
- **Relevance**
 - Effective for long-term and low-rate releases.
 - Can be installed without disturbing burial areas.

Surface Water Management

- **Objective**
 - Reduce infiltration and necroleachate generation.
- **Approaches**
 - Swales and diversion drains.
 - Regrading and recontouring.
- **Relevance**
 - Often the single most effective control.
 - Low intrusion and culturally acceptable.
 - Directly aligned with climate-adaptation needs.



Engineered Solution

Rock Revetment and Coastal Protection

- **Objective**
 - Prevent erosion, exposure, and mobilisation at site boundaries.
- **Approaches**
 - Rock revetments.
 - Seawalls.
 - Geotextile reinforced slopes.
- **Relevance**
 - Prevents physical exposure of buried material.

Hydraulic Control

- **Objective**
 - Limit contact between burial zones and groundwater.
- **Approaches**
 - Subsurface drainage layers.
 - Underdrains.
 - Seasonal groundwater drawdown zoning.
- **Relevance**
 - For floodplain or wetland adjacent cemeteries.



Engineered Solutions

Enhanced Biodegradation

- **Objective**
 - Reduce contaminant mass and mobility downgradient of burial areas.
 - Enhance natural attenuation
- **Approaches**
 - Upgradient reactive media zone.
 - Downgradient interception and recirculation/disposal.
- **Treatment Mechanisms**
 - Metals: Adsorption and precipitation
 - Fomaldehyde: enhanced biodegradation and oxidation.
 - NH₄: biological transformation
- **Relevance**
 - Where groundwater interaction cannot be avoided.





Making Sustainability Happen

