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Landfilling biologically hazardous materials

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ABSTRACT: In April 1999, an outbreak of Newcastle Disease in the Mangrove Mountain area (NSW, Central Coast) led to the destruction of two million chickens. Landfilling of the chickens was identified as the only feasible disposal option and two landfill cells were constructed. A further cell was constructed for the disposal of manure and other waste from within the chicken sheds. Site selection was restricted due to the need for sites to be selected within the quarantine zone of the Mangrove Mountain Ridge and restrictions due to National Parks, and private properties. The geology encountered at the disposal sites was similar comprising permeable low strength Triassic aged Hawkesbury sandstone with a semi-confined aquifer at moderate depth. Groundwater is used extensively for domestic and commercial (mineral spring bottling) purposes and therefore a high degree of environmental protection was required. Double containment systems were used at the sites due to the sensitivity of the environment and the relatively high permeability of the geology. Groundwater monitoring bores have been installed around the landfill cells, and baseline groundwater conditions established. These bores are being used in conjunction with existing adjacent landholders bores to monitor any changes in groundwater quality over time. This paper focuses on the design considerations involved when landfilling hazardous material that had to be disposed of expeditiously.

1 INTRODUCTION

The Newcastle disease is a viral disease of birds. It is a readily communicable disease and can be transported by feathers, faeces, and aerosol particles of any bird's body fluids. The virus is destroyed by direct sunlight, by treatment with heat or with acidic or basic solutions. In cool conditions it has been found to survive within chicken manure for many weeks.

The virus affects the digestive, respiratory and nervous systems of the birds, and has an incubation period of between ten and twenty-one days. The disease can infect domestic and wild birds, however poultry are the most susceptible.

The discovery of the Newcastle disease resulted in the quarantine of the first poultry property in the Mangrove Mountain area (Central Coast, New South Wales, see Figure 1) on 1st April 1999. Within three weeks the quarantine zone was expanded to include all farms (30 in total) located on the Mangrove Mountain Ridge (see Figure 1). The two million chickens that were farmed in this area had to be immediately destroyed to prevent the spread of this highly contagious disease. This involved the collaboration of over 40 government agencies and up to 1000 workers at any one time. The total cost of the operation was $20 million which was funded by the NSW state and federal governments.

The options for disposal of the infected birds were limited due to the need to keep all of the infectious material within the quarantine zone. Immediately following the discovery of the outbreak trials were undertaken to assess the viability of burning the infected bird carcasses. Pit burners were constructed using railway sleepers for fuel. Despite the benefit of ensuring destruction of the virus by burning, this option was ineffective. The burners were found to cause the dispersion of feathers to the atmosphere, potentially spreading the virus, and were not able to cope with the magnitude of the problem.

It was determined that landfilling provided the best possible means of disposing of the infectious material as landfilling provided; a fast solution, secure containment of the infectious material and possible destruction of the virus though high temperatures reached during decomposition.

Site selection was restricted due to the need to select sites within the Mangrove Mountain quarantine area that were owned by organisations/individuals sympathetic to the need to dispose of the material as quickly and as safely as possible. The initial site chosen was the Hymix quarry where there was ample room and a benevolent owner. When this site was exhausted (approx one million chickens) the remainder were landfilled at a site owned by the Gosford City Council. A third site on privately owned land was later used for disposal of manure and litter.

The work was unusually demanding due to the following conditions:

- The need to design and construct a secure landfill within a few days.
- There was generally fierce local opposition to landfilling (the NIMBY syndrome- Not In My Backyard).
- The scope of the problem was rapidly escalating.
- There were many different government departments to deal with.

2 DESIGNING THE CONTAINMENT SYSTEM

The Mangrove Mountain area relies on groundwater for agricultural purposes as well as human consumption. The proximity of groundwater extraction bores down gradient from the landfill cell emphasized the importance of preventing groundwater contamination as well as heightening local residents concerns. The design therefore required a high degree of containment.

Theoretical leakage-rates for various barrier options were presented by Giroud *et al* (1994). The comparison, shown in table 1, illustrates the benefits to be gained by using a low-permeability synthetic lining systems as an alternative to a Compacted Clay Liner (CCL). Time restraints and performance eliminated the use of CCL and opted to use a composite lining system of Geomembrane (GM) and Geosynthetic Clay Liner (GCL). This composite lining system with the GM and GCL in direct contact can essentially be regarded as a no-leak system.

Table 1. Leakage rate per unit area in litres per hectare per day (lphd) through various types of liners.
(Source: Giroud *et al*, 1994).

LINER TYPE	Hydraulic Head (m) ~0.01	~0.3
CCL, k ~ 1×10^{-8} m/s, 0.3 < thickness (D) < 0.9m.	9000	15000
CCL, k ~ 1×10^{-9} m/s	900	1500
Geomembrane, s_{oil} ~ 1×10^{-2} m/s	600	3000
GCL, k ~ 1×10^{-11} m/s, thickness (D) = 6mm	25	450
Composite Liner, GM/CCL, k_{CCL} ~ 1×10^{-9} m/s	0.05	1
Composite Liner, GM/GCL, k_{GCL} ~ 1×10^{-11} m/s	0.002	0.2

Once the lining system was determined, considerations had to be made in regards to the selection type of liner and the protection of the lining system designed. As the walls would be cut into hard sandstone, the surface will be irregular and rough. This will require the lining system to have flexibility without loss of performance properties. With this in mind a non-woven needled punched GCL having a minimum geotextile of 270gr/m^2 for the sandwich was selected.

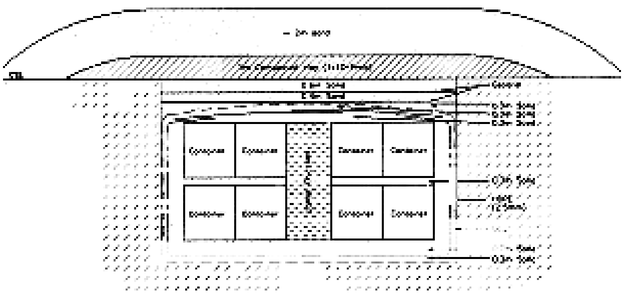

Figure 1. Cell design for Blood Tree Road, Mangrove Mountain.

To protect the synthetic lining system from potential damage by the rough, irregular surface of the wall face a thick, robust non-woven cushioning geotextile was incorporated. This will prevent excessive abrasion of the liner during filling and will minimise liner damage due to point loads when normal stress is applied. With highly irregular surfaces, some liner materials become unsuitable as the strain induced in the liner (after waste placement forces the liner to conform to the irregular surface) can exceed the materials safe long-term strain. For example, HDPE Geomembrane should not be placed under more than 3% strain in the long-term as stress cracking becomes an issue. Simple calculations using the typical geometry of the irregular surface of the cell wall can be used initially to eliminate lining materials with unsuitable mechanical properties. Selection of a suitably robust liner is critical. The thick non-woven geotextile also acts as drainage blanket under the impermeable membrane.

The near vertical side slopes caused problems relating to the stability and constructability of a lining system. It is very difficult to weld plastic sheets while abseiling vertically from the top of the cell, not mention the added expense. GCL's offer a system of sealing adjacent panels that simply relies on the bentonite's swelling/sealing capacity and confining stress, and by using a GCL made from high-elongation non-woven geotextiles, conformance to irregular surfaces ensures good contact with both the cell side-slopes and adjacent GCL panels. Anchor trenches need to be well designed to accommodate the self-weight of the liner and the down-drag forces imposed on the liner during waste filling and compacting operations.

3. GEOLOGY AND HYDROGEOLOGY

Two chicken burial cells were constructed, and a third for the disposal of manure and other waste from within the chicken sheds. These cells are referred to as the:

- *Hymix Quarry site* that is part of the Hymix quarry operations on the western side of George Downs Road, Mangrove Mountain.
- *Blood Tree Road site* located on part of the Gosford City Council (GCC) Works Depot on the eastern side of Blood tree Road, Mangrove Mountain.
- *Waratah Road site* located on a private property on Mangrove Mountain

These sites were located within the quarantine area and the site characteristics are summarised in table 2.

Table 2 Site Characteristics of Landfill Sites

Site	Ground-water Level (m)	Permeability (m/s)	Groundwater Flow rates (m/year)	Field pH	Field EC µS/cm
Hymix	23.6-30.8	9×10^{-7}-1×10^{-6}	1	6.1	78-154
Blood Tree & Waratah Road	13.4- 7.5	8×10^{-8}-2×10^{-6}	15	5.2	67-74

The geology at each site generally comprised a shallow layer of residual sandy clay overlying low strength sandstone derived from the Triassic aged Hawkesbury Sandstone Formation. The Hymix site also comprised interbedded shale layers of low permeability with the landfill area fortuitously characterised by a pocket of deeply weathered profile (clay). Groundwater was encountered at depths of around 25m at the Hymix site and about 15m at the Blood Tree Road site. Groundwater occurs in a semi-confined aquifer with the flow direction mirroring the topography at rates of between 1 m/day (Hymix) and 15 m/day (Blood tree). The groundwater is of low salinity and acidic especially at Blood Tree Road.

The sandstone was generally massively bedded and flow is considered to be due to primary porosity rather than along fractures that were only encountered spasmodically.

4. CELL CONSTRUCTION

The cell construction was project managed by Gosford City Council. Robert Carr and Associates were engaged by the NSW Department of Public Works and Services to provide an independent third party overview of the construction and provide design advice where appropriate.

Chickens were loaded into shipping containers for transport to the burial cells and buried in the containers. Each container weighed about 25 tonnes and contained about 20,000 chickens.

4.1 *Hymix Site*

The cell at Hymix was constructed by excavating a 50m long trench approximately 6 - 8m deep into the residual clay. Approximately one million chickens were placed in the cell that was unlined but natural clays were observed at the base of the excavation. The containers were covered with over three metres of compacted clay that had been won from the excavation and the cell has been vegetated with grasses.

4.2 *Blood Tree Road*

The landfill was constructed by excavating a 50m by 13m long trench approximately 8m deep into the sandstone bedrock. Originally the cell was designed to house 28 containers (0.5m million chickens) but this was increased after construction commenced to 55 containers. (1 million chickens) by deepening the cell from 5m to 8m.

The construction and lining of the cell was completed in seven days with container placement taking a further four days. The sandstone was ripped using two D9 bulldozers working 24 hours/day, and produced fine sand suitable for use as the bedding and cushioning layers in the containment liner system. The excavation was stable with vertical sides to maximise the useable volume of the excavation. The vertical sides were smoothed as much as possible with excavating equipment and the base of the cell rolled with a vibrating drum roller to ensure that there were no sharp edges that might rupture the liner.

Figure 2. Installation of the HDPE

The completed excavation was lined with a composite liner composed of Geosynthetic Clay Liner (GCL) and a 2.5mm thick High Density Polyethylene (HDPE) liner and capped with GCL, HDPE and one metre of clay (refer to figure 2). A non-woven needle punched geotextile and natural materials (sand) were used to separate and protect these liners.

The GCL was made by non-woven geotextile sandwiching a layer of polymer enhanced sodium bentonite. The composite is held together by fibres needle punched and thermally locked to ensure high long-term shear strength.

The leak detection layer was made from 300mm of compacted sand was used between the two liners to ensure that any penetration of the upper liner did not impact on both liners.

The remaining cell was then filled to surface level and compacted using a 45 tonne roller. Two layers of 30 Kn/m geogrid were placed, in between layers of sand to provide resistance to settlement. In the event of the containers breaking down, it is anticipated that these layers will provide a bridging affect and achieve a relatively uniform settlement and give early warning before any dramatic collapse. Settlement of the final surface level is being regularly monitored.

One metre of clay was imported as the final capping layer. This was compacted to 2% wet of optimum to achieve a permeability of 1 x 10 $^{-8}$ m/s. The surface of the clay was graded at approx 5% to prevent ponding. The clay was then covered with between 2m and 3m of sand that had been won from the excavation and contoured to blend in with the surrounding topography.

It was foreseen that the breakdown of the containers would present a threat to the integrity of the liners resulted in the following construction modifications:

- The containers were placed close to the wall of the cell with a central cavity so that collapse would be preferentially towards the centre and away from the composite lining system (see Figure 1)
- The HDPE was protected with cushioning geotextile to minimise impact of the container collision
- A 700mm thickness of sand was placed and compacted in between the base of the containers and the liner to reduce the risk of puncture from fatigued metal.

Figure 3. Containers being loaded into Blood Tree Road Cell.

4.2 *Waratah Road site*

The cell was constructed by excavating a 75m square hole by approximately 8m deep into the sandstone bedrock. To maximise the useable volume all the walls were cut vertical. This cell was designed to dispose all the manure and litter from the 30 farms. Originally a composite liner system was designed (GCL/HDPE) but due to delays experienced in the installation and welding of the HDPE in the Blood Tree Road cell, was replaced by a secondary GCL on the base, walls and cap (refer to figure 4). This cell was excavated within 4 days and filled within a week.

Figure4. Waratah Road Cell being lined using twin GCL wall and base.

5. GROUNDWATER MONITORING

Groundwater monitoring bores were installed at each site, one up gradient and two immediately down gradient of the cell. The aim of the monitoring programme is to assess any landfill impact by comparing up gradient to down gradient results whilst being careful to account for natural variations.

The following analytes were selected for baseline analysis and the reason for their inclusion is also given in the table.

Table 3 Groundwater Monitoring Analytes

Analyte	Reason for Selection
Ph Total Dissolved Solids Major Cations- Sodium Potassium Magnesium Calcium Major Anions - Sulphate Chloride Bicarbonate	General Water Quality
Nitrate Ammonia TKN Total Phosphorus	Nutrient load from decomposition
Copper Cadmium Chromium Lead Nickel Zinc Iron	Solubilisation of metal containers
Faecal Coliforms E.Coli Total Coliforms BOD	Biological Indicators
OCP	Pesticides from sheds etc
OPP	Pesticides from sheds etc
Total PAH	Tar lining of containers
Benzene	Benzene is part of one of the ingredients of Virkon (a viruscide used on the Newcastle Virus)
Newcastle Virus	Presence of virus
VOC	Early indicator of organic contaminant
Cyfluthrin	Pesticide used in poultry sheds to control mites

A commitment to a minimum of 20 years monitoring was given to the community with monthly monitoring for the first two years at Blood Tree road and for the first year at Hymix. T frequency is to be relaxed to quarterly monitoring until the fi year mark after which the frequency will be reviewed. Adjace landholders bores were also assessed to establish baseline conc tions.

A monitoring committee reviews results and contingenci and plans are in place should an impact be identified.

6. CONCLUSION

Biologically hazardous waste has been successfully landfilled unfavorable siting conditions using dual liner syster GCL/HDPE and GCL/GCL. The unusual technical concerns tl were addressed during the operation were settlement and the i tegrity of the liner system after the collapse of the shipping co tainers. The settlement concerns where addressed by the plac ment of a multi layer of a biaxial geogrid above the containe Also the collapse of the containers was counter-acted by t presence of protective layers on the walls and the presence o void in the centre of the cell to encourage the containers to to ple inwards rather than towards the walls of the cell.

The main consideration in landfilling biologically hazardo material in the Mangrove Mountain area was ensuring that t groundwater underlying the cell was not significantly contan nated as a result of the landfill. The groundwater resources the area are used for agriculture and human consumption. Ma of these users are located down gradient of each of the landf sites. This potential for contamination resulted in the issue b coming as much political as technical. A comprehensi groundwater-monitoring program has been implemented at ea of the sites as well as at existing bores located down gradient the sites. This will provide early detection of any groundwa contamination that may occur in the future and contingen plans are in place should an impact be identified.

REFERENCES

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