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ABSTRACT: The increasing level of Municipal Solid Waste (MSW) is now a days, a serious problem in the urban areas of the world. This is more so in the case of developing countries like Papua New Guinea, where large quantities of solid waste are dumped haphazardly, thereby, polluting the subsurface soil as well as ground water, gas and minerals and at the same time adversely affecting the health of human beings. Leachate in MSW landfills are contaminated liquids that contain a number of dissolved or suspended materials. An effective liner system should be designed to prevent the danger of contamination of the surrounding soil, ground water, gas and minerals. The proposed research involves the set up of landfill test plots using Elcoseal® Geosynthetic Clay Liners (GCLs) at the campus of The PNG University of Technology, Lae, Papua New Guinea and monitoring the probable contamination of the environment and recommends a potentially viable hydraulic barrier to prevent contamination of the environment of this mineral rich country. One more key aspect of this research is to create the awareness among Government bodies and public in the area of waste management.

1. INTRODUCTION

A high level of enlargement of population and growing per capita income have resulted in the generation of massive solid waste posing a serious hazard to environment quality and human health.

Municipal Solid Waste (MSW) consists of household waste, construction and demolition debris, sanitation residue and waste from lanes. With rising urbanization and change in lifestyle and food habits, the amount of municipal solid waste has been increasing rapidly. Waste generation rates are often quoted in the range 1–2 kg per capita per day in developed countries and perhaps 0.4–0.8 kg per capita per day in developing countries. For a developing country like Papua New Guinea (PNG) disposing of rubbish or solid waste is a more serious problem. The country still has got long way to go to get rid of its MSW in structurally constructed landfills. The standards of waste disposal are still almost low, with open dumping as the standard method. At present there are no landfills in Papua New Guinea and all the waste is being dumped on barren soil. The difference between a dump and a landfill is that the latter is a structurally designed, controlled and monitored waste disposal area where leachate and gas emission are collected and treated whereas dumps are areas where the MSW is just dumped on barren soil without any consideration whatsoever regarding underground water being contaminated by the leachate. The use of Composite Clay Liners (CCLs) in all parts of PNG is not feasible because of unavailability of clay material. Hence the Geosynthetic mat is used in place of clay. An attempt has been made to construct a test plot of landfill using Elcoseal Geosynthetic Clay Liner (Elcoseal GCL) at the campus of The PNG University of Technology, Lae, Papua New Guinea to check the performance of GCL as a hydraulic barrier against leachate migration under heavy downpour and seismic areas of PNG.

2. PROBLEM STATEMENT

Two major landfills in Lae, Papua New Guinea, were visited. One is at Second Seven, just about two hundred meters away from Telekom Training College. At this Second Seven dump Municipal Solid Waste is being dumped, and is usually dumped on barren soil. The other landfill is located at the back road towards the Malahang industrial area, to which hazardous waste from industry and the hospital, is dumped. Since the waste is dumped on barren soil at these two landfills there is high risk of contamination of soil and ground water.

3. MATERIALS AND THEIR PROPERTIES

3.1 Elcoseal

In this experimental study Elcoseal Grade X 1000, a needle punched GCL, was used. It contains a continuous layer of premium grade sodium bentonite powder, sandwiched between a needle punched poly-propylene (PP) geotextile as a cover layer and a slit film PP woven geotextile as the carrier layer. The Elcoseal GCL consisted of powdered sodium bentonite and was placed at a mass per unit area of 4930 g/m². The lower geotextile was a non-woven, needle punched with a mass per unit area of 220g/m², while upper geotextile was a woven geotextile with a mass per unit area of 110g/m².
The components shall be needle punched uniformly together across the entire Elcoseal GCL and then thermally treated on the woven side to ensure high long-term shear strength. The standard roll dimensions are listed in Table 1.

Table 1: ELCOSEAL Standard Grade Roll Dimensions and Weight (Source: Elcoseal GCL Standard Guideline)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Width (m)</th>
<th>Length (m)</th>
<th>Diameter (m)</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1000</td>
<td>4.7</td>
<td>35</td>
<td>0.52</td>
<td>875</td>
</tr>
</tbody>
</table>

3.1.1 Storage of Elcoseal GCL

The ELCOSEAL GCL roll was stored in their original, unopened packaging sufficiently close to the proposed landfill to minimize handling.

The designed storage was level, dry, drained, stable, and Elcoseal GCL roll was protected from:
- Precipitation
- Chemicals
- Standing water
- Excessive heat.

3.1.2 Transportation of Elcoseal

For unloading and spreading techniques taken into consideration, a Spreader Bar was adopted to unload and spread the Elcoseal GCL from a tyre wheel crane.

After transportation and unloading the plastic wrapping was checked. No minor damages were encountered.

3.1.3 Installation Requirements

- Excavator (tracked or wheeled) or front-end loader
- Spreader Bar/Loading Frame
- Bentonite Paste
- Trowel
- Carpet knife or knife with covered blade (for safety)
- Felt pens or Chalk
- Measuring Tape
- Dusk Mask & Goggles (optional).

3.2 Poly Vinyl Chloride (PVC) Pipe

A 100 mm diameter PVC pipe is used to collect and transport the leachate from the constructed landfill for treatment and disposal.

4. SITE INVESTIGATION AND LABORATORY TEST RESULTS

Prior to final design and construction of landfill, a thorough investigation of the site’s hydrogeology was performed.

Site soils were sampled to determine the soil characteristics. Particle size distribution was conducted and it turned out to be a sandy soil. Density tests revealed that the soil was medium dense and non plastic soils.

Leachate samples were collected from two waste dump sites of Lae city and tested for contamination. Table 2 shows the test results.

Table 2: National Analysis Laboratory (NAL) Analysis Results of Leachate Samples

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Industrial waste dump</th>
<th>Municipal waste dump</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>0.010 mg/l</td>
<td>1.5 mg/l</td>
</tr>
<tr>
<td>Calcium</td>
<td>94 mg/l</td>
<td>204 mg/l</td>
</tr>
<tr>
<td>Chloride</td>
<td>24 mg/l</td>
<td>89 mg/l</td>
</tr>
<tr>
<td>Hardness</td>
<td>254 mg/l as CaCO₃</td>
<td>627 mg/l as CaCO₃</td>
</tr>
<tr>
<td>Iron</td>
<td>2.0 mg/l</td>
<td>4.1 mg/l</td>
</tr>
<tr>
<td>Magnesium</td>
<td>4.7 mg/l</td>
<td>29 mg/l</td>
</tr>
<tr>
<td>Nitrate</td>
<td>8.3 mg/l</td>
<td>7.7 mg/l</td>
</tr>
<tr>
<td>pH</td>
<td>6.4 pH units</td>
<td>6.1 pH units</td>
</tr>
<tr>
<td>Potassium</td>
<td>15 mg/l</td>
<td>58 mg/l</td>
</tr>
</tbody>
</table>

5. LANDFILL DESIGN

Storage of any waste material in a landfill poses several potential problems. One problem is the possible contamination of soil, groundwater and surface water that may occur as leachate produced by liquid wastes moving into, through and out of the landfill migrates into adjacent areas. With the possibility of contamination, landfills should be designed to prevent any waste or leachate from ever moving into adjacent areas.

Generally landfill design is influenced by:

1. Ground Water Table
2. Slope Stability.

5.1 Ground Water Table (GWT)

Ground water table at the proposed landfill area is at a depth of 1 to 1.5 meters below the landfill floor during rainy season (Fig. 1) and falls below 6m during dry season. Increase in rainfall causes the GWT to rise which may eventually damage the landfill floor if not monitored.

![Fig. 1: Depth of GWT to Landfill Floor](image-url)
5.2 Designed Landfill at Lae, Unitech Campus

The proposed and constructed landfill is located just between the staff club and the old quarry and two hundred meters from the Independence Drive of The PNG University of Technology. This test plot is having all the components of a landfill’s requirements, but on a smaller scale.

The actual dimensions were 7 m × 3 m base bottom and 11.2 m × 7.2 m outer sides with side slopes of 2 horizontal to 1 vertical, with a internal height of 1m from landfill floor. To stabilize the slope, compaction was performed along the slopes and at intervals above the original ground level for anchorage purposes. This is to prevent the seismic earth movements experienced within the particular region which may cause the landfill to collapse.

Having an annual rainfall of 4000 mm here at Lae, Papua New Guinea, the GWT is measured at about 3 meters. This shows that the proposed landfill of 1 metre depth, giving the landfill depth of 2 meters from the landfill floor to the GWT.

The required depth is said to be 1 to 1.5 m. Therefore the proposed landfill is satisfying the design requirements from GWT and slope stability criteria.

6. CONSTRUCTION OF LANDFILL TEST PLOT

6.1 Subgrade Preparation

The preparation of the subgrade before placement of any lining material is critical to the system’s performance. Elcoseal GCL was placed on compacted earthen subgrade and slope.

6.2 Elcoseal GCL Placement

The Elcoseal GCL roll wrapping was removed immediately prior to installation. On site, Elcoseal GCL was unrolled along the prepared subgrade using the Spreader Bar assembly. The Elcoseal GCL was trafficked by light, low tyre pressure vehicles. The roll of Elcoseal GCL was laid without folds on the subgrade with a standard overlap of 300 mm in both the longitudinal and transverse direction. For longitudinal or edge overlaps, the blue coloured line on the underside of the panels was used to ensure the correct overlap width.

The transverse or end overlaps was sealed using bentonite paste that was applied in two layers with different consistencies. The Rolls can be cut to length with a carpet/ stanley knife. While overlapping cut panels bentonite paste was applied as per the requirements for transverse overlaps. No trafficking or walking was allowed over the region. Overlaps should occur in the direction of ground slope in similar manner to roof tiles.

6.3 Anchor Trenches

The Elcoseal GCL mat was placed down the front face and along the base of the anchor trench and anchored with wooden pegs. The base of the anchor trench was cleared from large gravel or loose material and the trench backfill material was compacted.

7. CONCLUSIONS AND RECOMMENDATIONS

The purpose of this landfill test plot study was to propose and evaluate GCL as the ideal barrier in solid waste landfill systems in Papua New Guinea. The following are the important conclusions drawn from the results of this investigation:

- It is recommended that Elcoseal GCLs should be used in the construction of landfills in urban areas of PNG in order to protect the soil properties and the underground water from leachate contamination as Elcoseal GCL is an effective hydraulic barrier having very low permeability of 5 × 10⁻¹² m/sec.
- The NAL laboratory leachate analysis shows that soil and ground water contamination will be very high if the dump sites are not protected with liners.
- The soil in many parts of PNG is sandy and non plastic and are high permeable. The position of GWT is also very high. Dumping of MSW on bare lands leads to severe threat to environment quality and human health and hence should adopt Engineered landfills.
- The needle punched Elcoseal GCL having high long-term shear strength hence can be used on slopes of otsized landfills. Also the stability of GCLs on slopes is to conduct direct shear tests and then to use limit-equilibrium methods of slope stability analysis to calculate factors of safety based on the results of those tests (Koerner M. Robert and et al. 1998).

REFERENCES


