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# Utilization of Geotextiles in Waste Management

# Utilisation des géotextiles dans les décharges controlées

Landfill and industrial waste impoundment systems require special design methods due to the required functions of the system and the unique characteristics of waste materials. Geotextiles have proven to offer cost effective design alternatives that solve some of the problems associated with impoundment design in a wide variety of waste management applications. To increase awareness of geotextile utilization in landfill and industrial impoundment design projects, six applications are presented. The applications include haul road construction over unstable waste deposits, dike construction, leachate bed drainage design, intermediate drainage layers, observation wells, and final containment cover design. Design considerations and techniques, fabric requirements, and construction considerations are discussed. Emphasis is given to special fabric requirements unique to these applications and available design techniques are referenced. A case history of geotextile use in each application is reviewed.

Les systèmes de décharge pour remblais et déchets industriels nécessitent des méthodes de dimensionnement spéciales, étant donné les fonctions que le système doit remplir et les caractéristiques unique des décets. Il est bien connu que les géotextiles offrent des alternatives avantageuses au point de vue coût et que leur utilisation aide à résoudre quelques-uns des problèmes de dimensionnement dans une grande veriété d'applications de décharges contrôlées. Pour mieux comprendre l'utilisation des géotextiles dans les projets de décharge de remblais et de déchets industriels, six applications sont présentées. Ces applications sont les suivantes: les voies provisoires non-revêtues construites sur décharges instables, la construction des digues, le dimensionnement des lits de drainage pour eaux vannes, les couches de drainage intermédiaires, les puits témoins et le dimensionnement du revêtement supérieur. Les considérations et techniques relatives à la conception, les besoins en textiles et les considérations concernant la construction sont traités. Un antécédent concernant l'utilisation des géotextiles est examiné pour chaque application.

## INTRODUCTION

Successful design and operation of industrial waste impoundments is, in the experience of the authors, often complicated by the unique character of the waste. Industrial wastes often are produced in the form of sludge type materials characterized by high moisture content and low inherent stability. Furthermore, waste materials frequently have a larger organic fraction which, through long-term decomposition, produce gases which further decrease the stability of the mass.

One approach with the disposal has been to impound the waste without extensive pretreatment. Incorporated into the landfill design must be a mechanism to induce consolidation of the sludge and associated release of pore water (leachate), channels to route the leachate to collection and/or treatment facilities, and a media for collection and venting of gas. The primary objectives of the design are to: 1) improve stability such that future use of the area may be feasible, 2) decrease the volume of the waste through consolidation with a minimum of cost for raw materials, and 3) minimize risk to the environment and include an environmental monitoring plan.

In recent years, geotextiles have become increasingly utilized as problem solvers in design and operation of waste impoundments, to accomplish the objectives noted previously. The function of geotextiles in impoundments can be broadly grouped into three areas: 1) drainage, filtration; in which the fabric serves as a medium for water movement or allows movement of the water and leachate while retaining the waste materials, 2) separation; in which layers of different particle sizes are separated by the geotextile, and 3) reinforcement; in which the geotextile is used as a reinforcing element in the landfill through direct earth reinforcement or stress redistribution.

The authors' experience has involved geotextile usage in the following landfill applications, each of which involves one or more of the three main functions:

1. Construction of haul roads over waste deposits and soft ground.
2. Direct soil reinforcement in construction of dikes.
3. Construction of leachate drainage beds.
4. Support of intermediate drainage layers.
5. Construction of observation wells.
6. Placement and support of final cover materials.

This paper contains a discussion of design considerations, fabric requirements, and construction considerations related to these applications, as well as a review of case histories involving the use of geotextiles in these modes.

## HAUL ROAD CONSTRUCTION

Two distinct types of haul roads are often utilized in operation of landfills. The first of these consists of haul roads leading to the site. Access roads must be constructed and maintained throughout the service life of the facility. Since landfills are frequently constructed in areas with marginal soil conditions, soft ground roadway construction techniques are generally required. Haul road construction over soft ground using geotextiles is widely discussed in the literature (1) (8). Design procedures presently available are both useful and adequate.

Haul road construction over waste deposits, however, are typically more difficult. Haul road construction over the waste materials may be required for site access, waste handling procedures, or placement of cover materials. The strength of waste deposits are often so low that pedestrian access is not possible with any significant degree of safety. In these instances, the available design procedures have proven inadequate as the waste exhibits little or no shear strength. Displacement design methods such as those used by Haliburton, 1980 (5) may not be practical. Through a trial and error approach, it has been found that the haul roads must essentially be floated over weak waste deposits. In this regard, geotextiles have been used in conjunction with a light weight fill material such as bark to produce a "buoyant" road.

In our experience, bark has been successfully utilized for haul road construction because the unit weight is typically less than 2/3 that of the waste. Other light weight materials, such as sawdust, logs, cinders, and "popcorn" slag may also be considered. However, all of these materials, including bark, are particulate and when used separately, tend to mix with sludge over time. This reduces the service life of the road. Geotextiles solve the mixing problem by separating the bark from the waste and preventing extensive waste intrusion. Thus, the prime design criteria in selection of the fabric is low porosity and, as such, most available geotextiles can be utilized. When used with "string" bark, strength properties of the fabric are secondary considerations of lesser importance due to the high intrinsic strength of the bark. It has been observed that light weight woven or non-woven fabrics are an economical selection and perform satisfactorily. However, tensile strength of the fabric may be of primary importance when used with other light weight, more granular aggregates.

A paper mill waste water treatment residue landfill constructed in Central Wisconsin illustrates this use. The general layout of this site is depicted in Figure 1. The landfill was triangular in shape and 11 hectares in size, with the fill beginning at one apex and proceeding radially to the opposite side. The depth of waste increased linearly away from the apex by ramping upwards. Tandem axle dump trucks were utilized to transport the new materials over previously deposited waste to the active fill areas. After several trials of alternate haul road designs, the workable solution consisted of first laying a light weight non-woven heat welded spun bonded geotextile over the waste to the desired width of the haul road. The fabric was then covered with approximately 0.6 m of bark and 0.3 m of gravel. This procedure has been used successfully to progressively advance the haul road as the fill base proceeded.

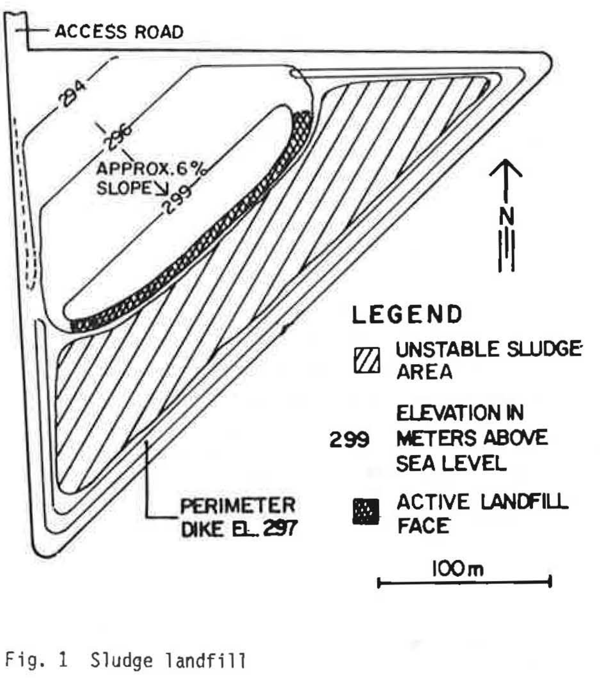


Fig. 1 Sludge landfill

## FABRIC REINFORCED DIKE CONSTRUCTION

Construction of impoundment areas usually involves construction of one or more earthen dikes. Dikes are generally required around the edges of the impoundment to form the impoundment area. These dikes are similar to earth dam designs. External slopes are generally designed at 3 horizontal to 1 vertical with internal slopes designed at 2 horizontal to 1 vertical. Internal slopes may be steepened to take advantage of the additional lateral support provided by the waste material after filling. Even in depressed areas, a dike may be required adjacent to the existing embankment to provide an impermeable liner and meet other environmental constraints. These dikes generally consist of clayey soils compacted against the embankment over a specified horizontal distance, then designed with a particular slope into the impoundment area for overall stability. A third type of embankment may be constructed within the impoundment to form cells which are used to separate disposed materials. These dikes allow for stabilization of one area while filling operations continue in another. Internal dikes generally have steep side slopes on the order of 1.5 horizontal to 1 vertical. As the impoundment area is filled, dike construction may be required out over disposed waste materials, especially with internal cell dikes. Figure 2 illustrates the different types of earthen dike design.

Problems associated with conventional dike construction involve import of offsite materials, decrease in usable impoundment area, construction in marginal soil areas, erosion of embankment slopes, and differential bearing over existing dike and waste materials. The latter problem results in sagging edges and limits the height of construction.

Utilization of geotextiles to construct retained earth dikes offers a unique alternative design that can be used to maximize disposal volume and minimize cost by decreasing the amount of soil and time required for dike construction. Utilization in each type of dike construction is shown in Figure 2. In retaining structures, geotextiles are placed in the backfill to give the backfill potential resistance, and thereby, reduce earth pressure against the wall. In addition, geotextiles can be used to control erosion problems at the face of slopes and increase stability for construction over marginal ground. Internal cell dike construction can take advantage of near vertical walls such that construction over in-place waste materials can be avoided. Where construction is required over waste materials, the utilization of geotextiles as a reinforcing element within the embankment can be used to reduce differential movement.

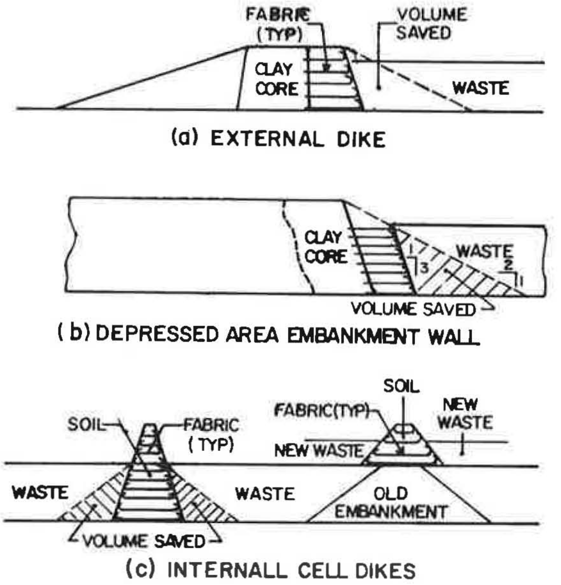


Fig. 2 Fabric reinforced dike systems for impoundment design

Numerous design methods are available in the literature for design of fabric reinforced embankments (1) (3) (6) (8). These procedures generally present classical approaches to slope stability problems and are not unique. Analysis of stress value for the reinforced soil mass generally consists of either a rigid block analysis, equivalent homogeneous soil model, or tie-back action. In addition to the reinforced soil mass, the overall stability of the system must be evaluated, especially when constructed over a marginal soil area. Since the interior walls of the embankment may be completely covered by the waste materials, a less conservative design approach from those indicated in the previous references may be considered. Increased stability may be realized as the impoundment area is filled, therefore, long-term design may not be as critical as in conventional systems. Use of cohesive soils which have not previously been considered in design of retained walls due to creep potential may be feasible due to the stabilization effect.

The geotextile properties required for fabric reinforcement and retaining structures are well covered by Bell and Hicks, 1980 (1). Additional considerations include chemical and biological aggressiveness of the waste materials on the fabric. Ultraviolet exposure, which usually deteriorate the geotextiles, may only occur over a short period of time and as such, coating of the fabric for ultraviolet protection may be reduced.

A dike similar to systems A and B in Figure 2 was recommended to increase the design slope of an industrial paint sludge disposal area in southern Michigan. The impoundment area was an abandoned gravel pit with the new impoundment area to be located adjacent to an existing system. A 300 by 100 meter dike was to be constructed around the perimeter of the containment area. Because of a clay core construction requirement and required height of embankment (15 to 20 meters), a 3 horizontal to 1 vertical slope was required for conventional construction of the interior face. This design would have decreased the operating life of the impoundment by several years due to the volume occupied by the embankment and possibly have precluded the use of this area for the impoundment. Property boundaries prohibited other alternative solutions. A fabric reinforced dike system was designed to replace the conventional embankment design. The approved design fabric reinforced wall is shown in Figure 3.

For design of the wall, advantage was taken of the lateral stability of the sludge by constructing the embankment in three 5 to 6 meter stages. Each stage was to be constructed after sludge had been placed within 1 m below the top of the embankment from the previous stage. In this manner, up to a 20 meter high wall could be constructed at a 1 horizontal to 3 vertical slope.

Several methods from the previous referenced fabric reinforced embankment design procedures were utilized for evaluating the stability of the wall. The geotextile to be used in the design was selected on the basis of a minimum strength and modulus requirement assumed for the stability analysis and evaluated using wide-width tensile test methods. The chemical constituents of the paint sludge were evaluated as to their potential aggressiveness on the fabric. Several alternative fabrics were selected and, as of this writing, were undergoing chemical and biological resistance testing. In addition, direct shear and pull-out tests will be performed on the soil fabric system once the borrow material has been selected to evaluate the coefficient of friction between the fabric and the soil. A conservative value of 2/3 the estimated friction angle for the soil was used for the design.

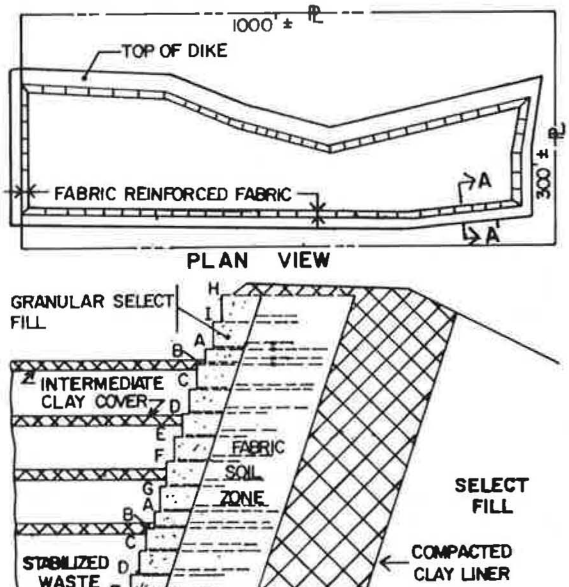


Fig. 3 Fabric reinforced dike design

Construction of the first stage of the embankment is to begin in March of 1982. An embankment monitoring system consisting of inclinometers and a fabric strain monitoring device will be utilized to monitor the wall during and after construction. Due to the stage method of construction, the entire wall will be completed over a 10 year period.

LEACHATE DRAINAGE BEDS

One component critical to landfill management is a media for collection and transport of leachate to treatment facilities. This generally takes the form of a trench(s) or bed at the base of the landfill typically composed of some combination of drainage aggregate and perforated pipes. In a related matter, when an aquiclude or aquitard is present at shallow depths below a landfill, it may be possible to cut off lateral ground water flow with a slurry trench or clay cutoff wall. In this case, it may be possible to use a ground water collection facility in lieu of or in combination with a leachate drainage bed.

Recent and developing legislation shows signs of increasing responsibility of leachate management to the owner for an extended period of time after landfill closure. It is increasingly necessary to enhance long-term performance of these facilities. One concern, particularly with wet, unstable waste, is intrusion of the waste into the drainage aggregate. This can impair, or in several cases, obstruct leachate or ground water collection.

Geotextiles can be utilized to enhance drainage performance by reducing the potential for waste intrusion. This is accomplished by either partial or complete encapsulation of the aggregate with the fabric. The fabric must be designed and selected to be compatible with the materials retained and those restrained. Significant considerations include the particle size of the restrained material (waste or soil), the permeability of the fabric compared to that of the waste or the soil and aggregate, and clogging potential of the fabric. These can be evaluated by standard testing procedures and geotextile-sludge system filtration and clogging model studies such as the gradient ratio method (4). Also of concern are characteristics of the fluid such as its aggressiveness towards the fabric, and the susceptibility of the fabric to biological attack when in direct contact with the waste. This latter criteria can only be evaluated presently with specialized testing specific for each project. Additional research is recommended for these applications. A summary of geotextile drainage design methods and considerations have been presented by Rankilor, 1981, and Bell, 1980 (7) (1).

In the authors' experience, it is recommended that drainage beds and trenches always be constructed by partial or full encapsulation of the aggregate. Not only does this procedure separate the restrained materials from the drainage material, but may also allow for backflushing of the system if clogging should occur. Alternate procedures which have consisted of fabric encapsulated pipe surrounded by aggregates seem less desirable. The potential for waste or soil intrusion into the aggregate remains and the possibility of successful backflushing of a clogged system is reduced.

A ground water collection trench using a geotextile encapsulated system was incorporated in the design of a landfill in Central Wisconsin. Prior landfilling at the site had resulted in ground water degradation below the site and the leachate fluid was detected moving laterally towards the bordering river. In conjunction with the landfill expansion, a bentonite slurry trench was excavated around the site perimeter to cut off lateral migration of ground water flow. At this site, a leachate drainage media was placed at the base of the landfill. However, since the prior landfill was not lined, and since some leachate was expected to pass the primary collection media, the ground water collection system was installed. The site stratigraphy consisted of approximately 7 m of washed sand alluvium over weathered bedrock of a clayey consistency. The system was installed at the sand/weathered rock interface where the highest contaminant concentration was observed, apparently due to a leachate density gradient.

The system consisted of a 200 mm nominal diameter perforated PVC pipe surrounded by 230 mm to 300 mm of 10 mm to 20 mm aggregate. This was further encapsulated in the non-woven heat bonded fabric. In this application, the non-woven fabric was suitable due to the low clogging potential associated with the washed sands and adequate permeability properties. The system has been functioning satisfactorily for approximately 2 years.

INTERMEDIATE DRAINAGE LAYERS

As noted previously, one landfilling method currently employed involves impounding waste in a non-stable condition and then surcharging the mass to increase stability. As with any consolidation problem, one key to improving stability has been to incorporate internal drainage. Our experience with early landfills indicated that sludge lifts in excess of 5 to 7 m resulted in near uncontrollable conditions. It is now recognized that lifts must be limited to 5 m, with overlying drainage layers, to successfully layer wet sludge. Geotextiles have been utilized to aid in placement and support of drainage layers. In many ways, this is identical to the haul road application. However, because the fabric can be secured at the perimeter dikes in this application, the strength properties of the fabric can be more fully utilized.

The authors' experience is presently limited to using geotextiles to support and maintain a drainage layer consisting of .3 to .6 m of sand due to the ready availability and relative economy of sand near all of the landfill sites. In less fortunate areas, geotextiles may have even more significant roles. For instance, two layers of fabric could be utilized to sandwich a relatively thin (10 to 20 mm) layer of sand to form a drainge layer. Alternately, a thick fabric could be utilized independently to provide drainage in the plane of the fabric. Combinations of fabrics bonded to compression-resistant open mesh polymer matting could also be considered. These latter two approaches appear useful for vertical as well as primarily horizontal drainage applications.

Primary fabric selection criteria includes porosity and permeability of the fabric relative to gas and fluid infiltration, the equivalent opening size relative to particle size distribution of adjacent materials, percent open area, and fabric strength. Procedures are available in the literature for determining factors of strength for embankment construction in soft ground and are useful for estimating allowable loadings on the fabrics in landfill locations (2) (5) (9).

The landfill site discussed in conjunction with the haul road considerations (see Figure 1) is also useful in illustrating the use of drainage layers. Initial filling began in 1976 starting at the northwest apex. The landfill was to be filled using a progressive ramp technique, sloping upwards from the apex of the 6% slope with sideslopes dressed at 3 horizontal to 1 vertical. Haul roads were constructed over the sludge to allow the sludge trucks access to the active filling phase. The landfill was operated successfully in this manner when the waste stream consisted only of primarily treatment residue.

After approximately one year, secondary treatment residue was introduced in the waste stream. The combined sludge had a consistency of approximately 20% solids. Introduction of the combined sludge resulted in an instability of the active landfill face and sloughing of the sludge pile towards the perimeter dike, particularly to the southeast. To permit continued landfilling, the perimeter dike was raised and additional sludge was added to the active face. Ultimately, this resulted in an uncontrolled sludge section, approximately 60 meters by 370 meters in plan dimension, and 6 meters in depth. The sludge was in an extremely unstable condition, and unable to support even personnel access. The wet sludge areas are indicated in Figure 1.

To provide area for additional waste deposition, an expansion was constructed to the east of the landfill. The filling plan, however, required that additional waste material ultimately be placed over the wet area. Thus, stabilization of this area was necessary.

Stabilization was accomplished using a geotextile overlay which was in turn covered by 0.6 m of sand. The sand was required to increase the effective stress on the sludge, thus promoting pore water release and consolidation, to act as a media for removal of pore water expelled to the surface, and as an underdrainage layer for subsequent lifts of sludge. The geotextile served to confine the sludge under the weight of the sand and separate these materials.

A woven monofilament polypropylene geotextile was selected. The particular fabric was selected on the basis of its apparent opening size, filtration characteristics, compatibility with the sludge and selected sand, and most importantly, its strength and elongation characteristics. Due to the anticipated variability of sludge consistency, large differential settlements were anticipated. The selected fabric was therefore required to have relatively high tensile strength and modulus which would aid in distributing the load and reduce differential movements. The strength properties required for the fabric were calculated on the basis of anticipated loading during construction and the maximum anticipated differential movement.

The geotextile was manufactured in 1.8 m wide strips and to lengths as required. Four adjacent panels were sewn together at the place of manufacture to form panels of 7.2 m widths which were used on the project. Panels were unrolled over the sludge beginning at the southwest corner. The panels were unrolled in a direction perpendicular to the southeastern dike. The geotextile was anchored at the southeastern dike in soil and was extended to the opposing dike in stable sludge areas where it was again anchored. Anchorage requirements were calculated on the basis of the load imposed on the anchor during construction, estimated frictional characteristics of the soil-fabric interface, and required length of fabric and overburden to resist pull-out (8).

All adjacent panels were field stitched using a hand-held electric sewing machine. The panels were double lapped and double stitched using a monofilament nylon thread. Workmen were generally able to walk on the geotextile to complete the stitching. However, in certain areas, planking was required on top of the fabric to provide access.

Sand placement began at the southeastern dike and proceeded toward the northwestern or active face. In this manner, the mud waves ahead of the sand placement were pushed toward the active face where it ultimately blended in, forming a gradual slope toward the perimeter. Sand placement was accomplished using a "clam" bucket from the dike to place the sand in the desired position. Soil spreading and shaping was done with a light weight dozer. During construction, a separation problem was noted with a few of the factory seams which was found to be due to inadequate stitching. This resulted in localized failure of the sand layer. A satisfactory remedial measure consisted of placing an oversized piece of fabric over the problem zone and again covering that area with sand. This failure indicated the importance of quality control in the textile plant and field observation during placement of the fabric.

The design procedure has resulted in a stable cover. The surface has settled approximately 0.6 to 1.0 m since cover was placed. No additional waste will be deposited in the area for approximately 1 to 2 years. Sludge consolidation during this period should result in a stronger mass capable of supporting the new load.

OBSERVATION WELLS

Landfill designs typically call for installation of observation wells to monitor the impact of the landfill on ground water systems, both in terms of water quality and water gradients. These wells may be required to perform for a significant number of years following abandonment of the impoundment area. A well design that has been found to be dependable consists of PVC pipe with a perforated or slotted end section wrapped with a properly selected geotextile. Selection criteria for the fabric are similar to any drainage application (1) (7). The opening characteristics, both apparent opening size and percent open area, of the fabric must be selected to be compatible with the particle size of the pertinent soil strata. Permeability properties of the fabric should be compatible with the intended use of the well. One other consideration is the method of fastening the fabric to the slotted pipe. Failures have been observed where fasteners came off during installation, or have deteriorated with time. Plastic fastening straps have been found to be very effective. One important aspect of observation well design is that the fabric selection criteria will on occasion be contradictory, particularly for multiple use wells.

If the particular well is to be used both for water quality observations and possibly bail down tests, the designer may be faced with the choice of selecting a fabric with small opening characteristics to limit the quantity of soil fines entering the well, or selecting a fabric with large openings and high porosity to preclude erroneous bail down test results. In early stages of landfill siting, an additional complication is that the selection may have to be made without extensive knowledge of the soil stratigraphy.

It is the authors' experience that fabric selection for observation wells is often casually made. Although there may be no singular (correct) selection, the user should be aware of the potential problems and tailor the geotextile selection as best suits the primary intended use of the well.

## FINAL CONTAINMENT COVER

The role of geotextiles in final cover placement on unstable landfills is similar to placement of the intermediate drainage layers. However, higher emphasis must be placed on fabric strength. With intermediate covers, irregular surface settlements may temporarily decrease the effectiveness of the drainage layer, but in time will be covered and regain usefulness as additional materials are placed above. With the final cover, however, excessive differential settlements likely cannot be accommodated, as these will result in permanent surface depressions where surface waters can collect, stagnate, and possibly ultimately increase leachate volumes. Therefore, the fabric selection should be based on the strength and modulus required to distribute loads if differential settlements occur.

One additional concern in design of the final cover is that the geotextile will likely be in the non-saturated zone. It is the authors' opinion that the possibility of a misguided formation (e.g. mud) on the fabric or biological growth could impede release of decomposition gases. It is recommended that the potential for fabric blockage by these methods be evaluated in a testing program prior to final fabric selection. In the extreme, if this phenomena were to occur, the fabric may function similar to a geomembrane.

A project which demonstrates the importance of the strength and gas release functions has been observed in the final abandonment of a paper mill water treatment residue landfill. An abandonment attempt had previously involved placing an unreinforced 20 mil PVC sheet (a geomembrane), directly on top of the waste, with an additional 0.6 m of clay soil to be placed over the membrane. The membrane was to provide support during placement of the clay. Filling operations proceeded from the edge of the fill area. After extending the clay cover only a few meters out over the fill, it was reportedly found that the membrane would not support any equipment available for placement of the clay. A method of placing the clay was finally established where sheets of plywood and straw matting were placed over previously placed materials, and wheelbarrows were used to transport the clay cover. The entire operation was completed by hand. Shortly after placing the cover, bubbling of the geomembrane through the clay cover in numerous areas was observed. Bursting of these bubbles, which were up to 2 m in diameter, indicated gas entrapment was occurring below the liner.

The abandonment currently proposed involves placement of a woven monofilament polypropylene fabric, overlain by 0.3 m of sand and 0.6 m of clay. The fabric was selected on the basis of strength, modulus, and opening characteristics. Potential for gas entrapment due to meniscus formation in the pores was evaluated and found to be negligible. Thus, the fabric should allow passage of gases through the sand layer which will serve as a media for gas collection and venting.

## CONCLUSIONS

The examples in this paper demonstrate practical uses for a relatively new and valuable engineering tool in waste management. The utilization of geotextiles was shown to complement the primary objectives of the design of impoundment systems including improving stability, enhancing and facilitating release and collection of pore water and gases, and maximizing disposal volume. In many instances, existing design techniques available in the literature can be utilized for the design. However, unique characteristics of the waste materials must be considered and designs modified accordingly. These characteristics include low inherent stability, high moisture content, large organic fraction which results in large deformations, and production of gases.

Of utmost importance is the possibility of chemical and biological effects on the properties of the geotextile required for the specific design function. Designed and selected correctly, geotextiles may be used to solve problems, reduce cost, and increase utilization of materials.

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