GEOENVIRONMENTAL ENGINEERING SOLUTIONS

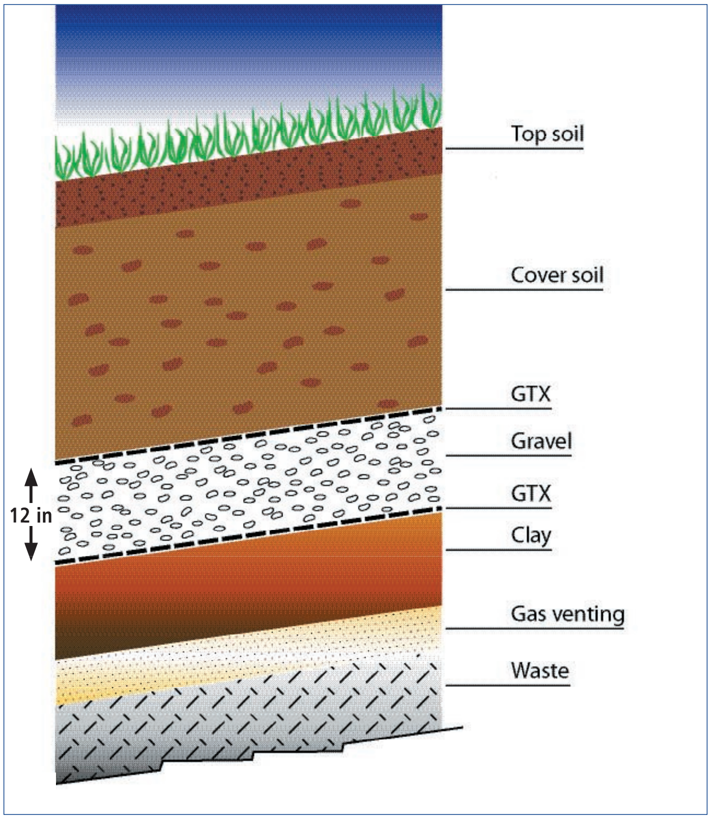
TENAX®

TENAX SOLUTIONS FOR ENVIRONMENTAL APPLICATIONS

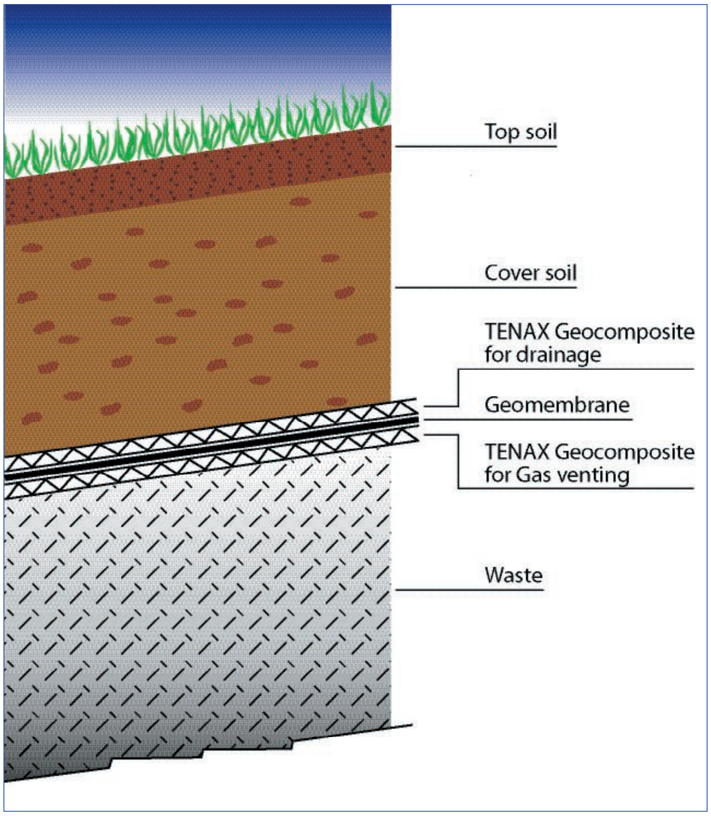
Each day, millions of tons of municipal and hazardous waste are disposed of in landfills, or other land disposal sites. A typical, modern landfill is lined with a layer of compacted clay and synthetic geomembrane to prevent the waste and leachate from leaking into the ground or ground water. Geocomposite drains and aggregate material are used at the sides and bottom of the landfill to collect the leachate that flows through the decomposing waste. The leachate collected is sent to a leachate recovery facility to be treated.

While municipal solid waste landfills have a layer of clay and synthetic liners and a leachate system to prevent leakage, for hazardous waste landfills extra precautions must be taken. A hazardous waste landfill requires two impermeable liners layers – a geomembrane (primary liner) and a geomembrane and a thick layer of compacted clay material (composite secondary liner). Additionally, a landfill accepting hazardous waste must have two leachate drainage systems – an upper layer for Leachate Collection and Removal System (LCRS) and a lower layer as a Leak Detection System (LDS). Leaks of leachate from the primary liner may occur due to defects in the geomembrane seams or damage to the liner during placement and compaction of waste materials. Tenax high performance geonets and geocomposites provide engineered solutions, thanks to their tri-axial structure, to leachate collection or leachate detectin requirements in landfill base liner systems.

When a landfill reaches capacity, a cover system is constructed to ensure that rainfall will not infiltrate the surface. A cover system made of soils and/or synthetic materials can effectively eliminate infiltration, but

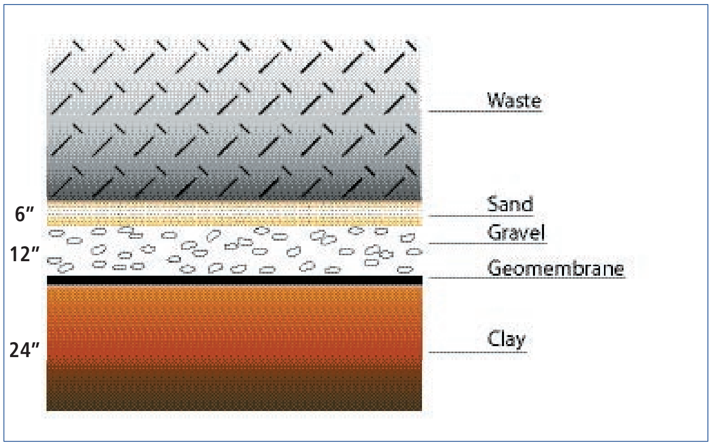


Typical landfill cover system–conventional design

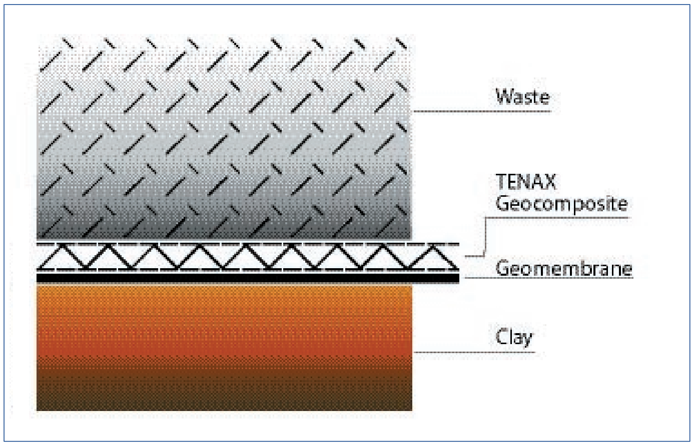


Typical landfill cover system–geosynthetic design solution must be specifically designed to address concerns such as slope stability, long-term degradation and erosion. Significant amounts of gas can be produced from decomposition of waste and calls for the design of an appropriate Landfill Gas venting system (LFG). Methane extraction system wells are used to collect landfill gas that may be used to generate electricity on site, burned at flare locations on the landfill or used in the sludge combustion process. Once a landfill is capped, the site requires monitoring for gas and leachate for a minimum of 30 years and may be used for recreation sites such as parks and golf courses. Tenax high performance capping geocomposites provide technically sound, drainage materials for both surface water and landfill gass venting layers.

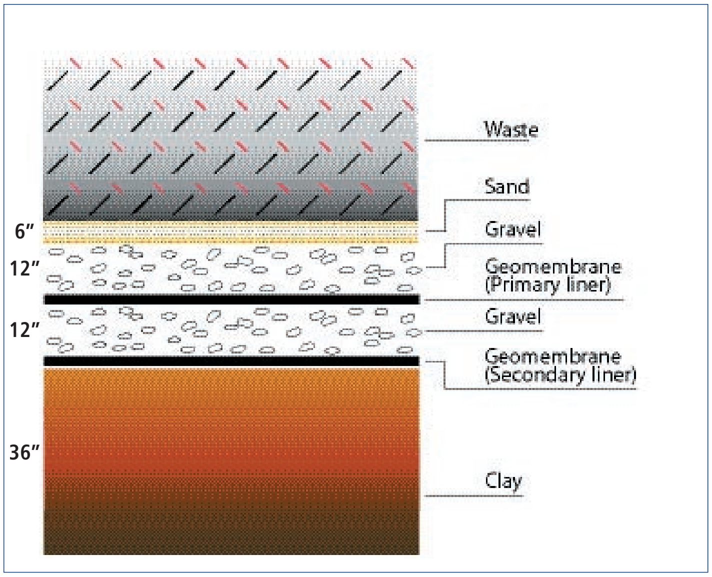
Tenax engineered drainage geocomposites also offer cost effective solutions to subsurface drainage in liquid containment facilities. Tenax multilayer geogrids provide the engineers unique solutions to stabilize weak soils in lanfill base subrade or landfill capping.



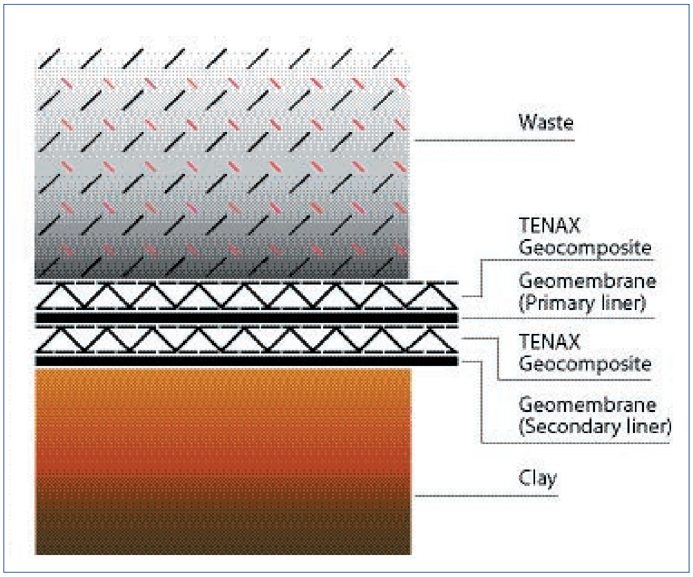
Municipal solid waste system
Minimum liner system – conventional design



Municipal solid waste system
Minimum liner system – geosynthetic design solution



Hazardous waste landfill
Minimum liner system – conventional design



Hazardous waste landfill
Minimum liner system – geosynthetic design solution

SURFACE WATER COLLECTION AND REMOVAL SYSTEM

Surface water infiltrating through the cover soil accumulates above the barrier layer and generates detrimental pore water pressure if it is not drained. Excessive head buildup due to inadequate drainage may cause catastrophic failure of the cover. Numerous seepage-induced landfill slope failures have been recorded and analyzed to confirm this phenomenon. Recurring severe storms such as those generated by El Nino and La Ninas require designers to assume that the cover soil will be saturated during the service life of the final cover and account for this in SWCRS design.

LANDFILL GAS VENTING

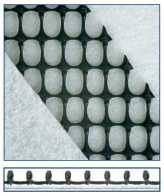
Landfill gas (LFG) pressure underneath a lined cover system significantly reduces the effective normal stress on the liner. Large-scale landfill cover slope failures have been directly attributed by an inadequate LFG venting layer. Based on intrinsic permeability theory into gas transmission rates, the rate of LFG transmissivity is ten times lower than the hydraulic transmissivity in any porous media. Until recently, this relationship was believed to be inverse as the air transmissivity was thought to be 100 times greater than the hydraulic transmissivity. The resulting miscalculations under-designed the required transmissivity of the LFG venting layer, which may cause landfill cover slope failures revealing a need for a high flow geocomposite layer for gas venting design.

EROSION CONTROL FOR LANDFILL FINAL COVERS

Rain, wind and surface run-off cause solid and vegetation to erode off of the landfill cap exposing the critical landfill cap liner system. Erosion control is a critical component for designing effective landfill final covers.

Landfill final covers are typically designed to limit soil loss less than 2 tons/acre/year. Even within this limit, nearly 60 tons of soil may be lost per acre over the 30-year post-closure monitoring/performance life of the cover. Areas of a landfill cap that require particular attention to erosion control include side slope surfaces, swales used to subdivide the slopes, and the down chutes used to drain the swales.

TENFLOW FOR LANDFILL CAPPING SURFACE WATER DRAINAGE AND LANDFILL GAS VENTING



Tenax tri-axial geocomposite has at least 2-3 times the transmissivity of conventional bi-axial geocomposites for both fluid or gas transmission. This high performance geocomposite allows for wide levels of gas venting to occur preventing gas pressure build-up under the liner. Tenflow also allows for greater variances in cover soil permeability, and a longer slope length while still preventing induced slope failure.

MULTIMAT 100 FOR LANDFILL CAPPING EROSION CONTROL

Geosynthetic erosion control materials offer cost advantages and improved aesthetics in landfill final covers. MULTIMAT 100 is a three dimensional structure formed by mechanically securing two high strength, high modulus biaxially oriented grids above and below a corrugated center grid. The three layers of netting are secured with multiple rows of polypropylene stitching. This creates a porous, thick and resilient structure that is extremely resistant to deformation and damage during installation, yet flexible enough not only to provide the intimate contact between the soil and the geosynthetic, but also allow soil to be easily filled into, and physically retained by the overall structure of the matrix. Used as a TRM or ECRM, Tenax MULTIMAT 100 provides long-term stability and performance since it is manufactured from select UV stabilized polypropylene that is resistant to chemical and biological breakdown. Additionally, MULTIMAT 100 will not absorb moisture, which would rob the soil and inhibit the establishment of vegetation.

Central landfill final cover, Tenflow for surface water drainage, Rhode Island.

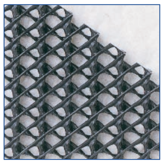
LEACHATE COLLECTION AND REMOVAL SYSTEM

The Leachate Collection and Removal System (LCRS) is commonly the only lateral drainage system provided in the base liner of a solid waste landfill and serves as the primary means for leachate collection and removal. The LCRS experiences a reduction in its capacity because of compressive creep caused by sustained normal load, and biological and chemical clogging caused by the leachate. The leachate collection system must be capable of providing adequate flow capacity for the life of the landfill. Traditionally, natural materials such as gravel have been used, but these materials take up a great deal of valuable airspace and need a heavy cushion layer to protect the underlying liner. Natural materials can also be very costly if quality gravel is not readily available and needs to be transported long distances. Bi-axial geocomposites fall short of this goal due to lack of resistance to high compressive forces and excessive geotextile intrusion.

LEAK DETECTION SYSTEM

A Leak Detection System (LDS) must provide rapid detection of a major breach in the primary liner system and limit the head acting on the secondary liner to less than the thickness of the LDS.

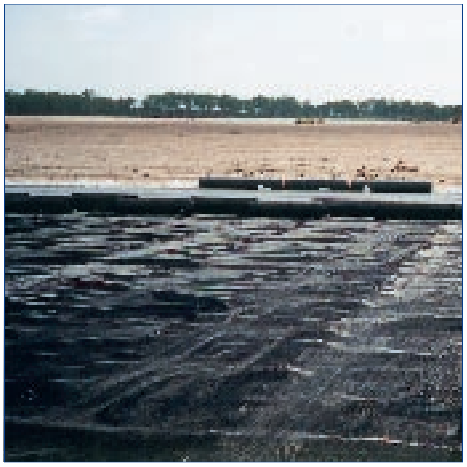
TENDRAIN FOR LEACHATE COLLECTION OR LEAKAGE DETECTION



Tenax Tendrain tri-axial consists of three structural ribs. The top and bottom ribs keep the filter geotextile layer out of the central flow channel while the center structural ribs provide load bearing and create flow channels. Moreover, the significantly larger central ribs run parallel to the flow direction, resulting in tremendous hydraulic performance especially for long-term flow requirements under heavy compressive loads. Thus, creating a leachate collection and removal system that can withstand heavy compressive loads as well as maintain the flow capacity necessary to limit the head within the drainage layer.

Tendrain provides the most efficient material for rapid detection of leaks in the overlying liner systems. Tendrain geonets have very limited storage capacity and a high transmissivity. The combination of these characteristics means that the tri-axial geonet will not store fluids, but move them quickly through the net to detection locations minimizing the time between leak occurrence and detection, to ensure unconfined flow and provide a reliable and accurate Action Leakage Rate (ALR).

As a leak detection layer undrer a GM/GC composit liner, Tendrain also minimizes geotextile intrusion even with the presence of a very soft GCL layer.

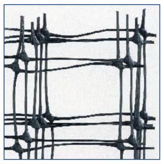


Sarasota, FL, landfill, Tendrain for leachate collection. Kent County, MI, Tendrain strips for leachate collection. Waverly, VA, landfill, Tendrain for leakage detection.

LANDFILL SOIL STABILIZATION

The Landfill liner system must be built on a stable soil subgrade to have an adequate bearing capacity to construct the liner system, and to support the weight from the overlying wastes, and to minimize differential settlement. Unstable areas of high moisture content and low bearing capacity soils, which are common locations for landfills, can also exist prior to the construction of the landfill cover system, that could cause differential settlement and lack of compaction for a clay cap. This could further lead to cracks and undesirable infiltration.

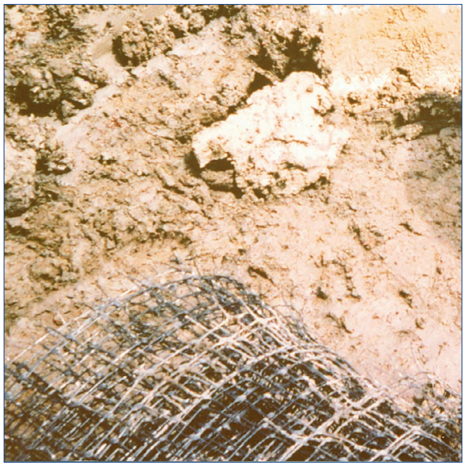
MS MULTILAYER GEOGRIDS FOR WEAK SOIL STABILIZATION



When site specific soils do not meet design requirements, failure is inevitable. Tenax MS multi-layer geogrids have been developed to reinforce fine and weak soils. By combining the number of grid layers, a unique geogrid with considerable resistance is produced.

Geogrid research indicates that for fine-grained or poor quality fill materials, geogrid effectiveness diminished due to the fill materials' inability to effectively transfer stress to conventional single-layered geogrids. Tenax's MS geogrid has a greater number of tensile elements per unit area while still providing high tensile strength, modulus and appropriate aperture geometry.

In addition, the multiple layers of TENAX MS geogrids provide an increased cross-sectional thickness as compared to a single layer geogrid. This increase in profile allows for better interlocking with a wide range of soils.



Mead paper mill landfill closure, MS 330 geogrid for fly ash stabilization. Grand Prairie, TX, sludge landfill capping, MS 550 geogrid for stabilization.

WASTE WATER CONTAINMENT FACILITIES

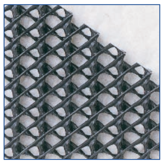
A key component in the construction of wastewater treatment plant facilities is drainage under the water process vessels. The subsurface drainage system under the process vessel serves three functions:

- Relieves hydrostatic pressures below the process vessel structure,
- Provides leak detection and removal,
- Provides a capillary break.

The vessel can be lined with concrete, a geomembrane or earthen material. Concrete lined vessels typically utilize a sacrificial nonwoven geotextile or sacrificial layer of gravel with a binding agent between the concrete and drainage layer to prevent blinding of the drainage layer. In geomembrane-lined vessels a nonwoven geotextile may also be used, but here it is used as a cushion to provide interface friction on slopes.

Irwin Creek flow equalization facilities, Tendrain for subsurface drainage, North Carolina.

TENDRAIN



The benefits of tri-axial Tendrain over natural materials in this application are numerous . Only a tri-axial structure is capable of meeting all of the requirements of the subsurface drainage layer. These requirements include:

- High flow capacity
- Compressive Resistance over long periods of time
- Constant void space for capillary break
- Rapid fluid movement from point of entry to collection

For concrete liner, additional requirement includes the ability to pour concrete directly on top of the geocomposite without blinding the flow voids. The bottom layer of geotextile provides filtration and retention of underlying soil.

ABOUT TENAX

Established in Italy in 1960 as a company specializing in the extrusion of thermoplastic polymers, TENAX has been the rising star with constant growth in production. Its corporate and organizational growth now places it as an International Group with a turnover of around $100 million of which 40% comes from outside the European Union. TENAX has 500 staff working in production units, technical and sales departments and distribution centers which are responsible for contacts within the various markets.

Its detailed attention to the development of markets has led the TENAX Group to progressively extend its organization, favoring the establishment of numerous specialized production units. After the establishment of the original Italian headquarters in Viganò in the province of Lecco, the first company specializing in agricultural products was established in the province of Rieti, followed by a large production centers in Maryland and Alabama in the USA. A further seven subsidiaries located in strategic countries throughout the world complete this multi-national organization. The subsidiaries act as receiving centers for the geographical area under their responsibility in order to implement the Group's 'know how' there and from where they benefit from operational autonomy for planning their development.

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