Feasibility analysis on the use of geosynthetics in landfills

A.T. Garcia, Juiz de Fora Federal University, Juiz de Fora, Brazil
E.F.B. Motta, Juiz de Fora Federal University, Juiz de Fora, Brazil
J.de.A. Righi, Juiz de Fora Federal University, Juiz de Fora, Brazil

ABSTRACT
The use of geosynthetics in landfills provides easily execution, and increases the useful life of these works, since it occupies smaller volumes. However, there is a need for technical and legislative standards to guide and regulate the use of these materials. Thus, the objective of these work is to verify the normative recommendations and the state guidelines on the use of geosynthetics in sanitary landfills and to evaluate the viability of the use of these materials in comparison to the traditional methods. The methodology of this work is to consult the norms of design and execution of existing sanitary landfills, the contact with the responsible environmental agencies and in the case studies to evaluate the costs and the advantages of the application of geosynthetics. The results obtained showed that the standards did not present specifications with regard to the application in sanitary landfills and the consultation of public agencies, answers were obtained with few details. It was concluded that the feasibility of the use of geosynthetics, from the economic point of view, is related to the size of the landfill, however, the application of these materials should not be restricted to financial matters, but the feasibility analysis of factors such as environmental protection, preservation of natural resources, safety, durability, practicality and increased the useful life of the landfill. The normative approach of the subject is lagged to the present and an improvement of the regulations and inspections is necessary.

Keywords: Feasibility analysis. Geosynthetics. Landfills.

RESUMO
O uso de geossintéticos em aterros sanitários proporciona facilidade de execução, e aumento da vida útil dessas obras, uma vez que ocupa menores volumes. Entretanto, é necessário que haja normas técnicas e legislativas que possam orientar e regulamentar o uso desses materiais. Dessa forma, o objetivo do trabalho é verificar as recomendações normativas e as diretrizes estaduais acerca do uso de geossintéticos em aterros sanitários e avaliar a viabilidade da utilização desses materiais em comparação com os métodos tradicionais. A metodologia deste trabalho consiste na consulta às normas de projeto e execução de aterros sanitários existentes, no contato com os órgãos ambientais responsáveis e nos estudos de casos para avaliar os custos e as vantagens da aplicação de geossintéticos. Os resultados obtidos mostraram que as normas não apresentaram especificações no que diz respeito à aplicação em aterros sanitários e quanto à consulta aos órgãos públicos, obteve-se respostas com poucos detalhamentos. Concluiu-se que a viabilidade da utilização dos geossintéticos, do ponto de vista econômico está relacionado com o porte do aterro, porém, a aplicação desses materiais não deve se restringir a questões financeiras, sendo considerados na análise de viabilidade fatores como proteção ambiental, preservação de recursos naturais, segurança, durabilidade, praticidade e aumento da vida útil do aterro sanitário. A abordagem normativa do assunto é defasada para a atualidade e é necessária uma melhoria das regulamentações e fiscalizações.

Palavras chave: Análise de viabilidade. Geossintéticos. Aterros sanitários.

1. INTRODUCTION

According to Righi et al. (2018), the increase in waste production in recent years surpasses population growth by three times, which makes the search for its correct destination one of the biggest challenges of modernity. The final disposal considered correct of the waste is made in landfills. This engineering work has techniques to prevent soil and water contamination. To increase the efficiency and useful life of these areas an alternative is to use geosynthetics.

Geosynthetics are polymeric materials used mainly for reinforcement, drainage, waterproofing, covering, barrier, protection and stabilization of soil in geotechnical and environmental protection works. Its manufacture uses synthetic products derived from petroleum, aggregate materials and natural fibers. Although geosynthetics correspond to a major worldwide technological advance, their use in Brazil is still considerably lower than in developed countries (Palmeira 2018). An attenuating feature of this situation is the lack of normative instructions and laws regulating the implementation and handling of these elements.

Geosynthetics are alternative materials that promote the preservation of natural resources, have greater safety in the containment of contaminant residues, due to their quality control, and provide greater practicality and safety during the execution of works. In addition, its wide application range makes this material very versatile in works such as landfills (IGSBRASIL 2012).

In this context, the present study aims to evaluate the feasibility of using geosynthetics as drainage, waterproofing and final cover in landfills compared to usual methods and based on the recommendations of technical standards and guidelines of the regulatory agencies of each Brazilian state.

2. GEOSYNTHETICS IN SANITARY LANDFILLS

According to ABNT NBR ISO 10318 (2018), geosynthetics can be used in landfills to increase the efficiency of drainage, waterproofing, reinforcement and erosion control, filtration and separation barriers systems.

2.1 Background Waterproofing

Waterproofing the bottom of the landfill aims to prevent leachate infiltration and groundwater and soil contamination. For this, low permeability and high durability materials should be used (Bueno et al. 2004). In this stage of landfill construction, the HDPE geomembrane and the clay geocompound (GCL) can be used (Silva 2014).

The application of geosynthetic materials in waterproofing ensures greater safety to prevent the infiltration of contaminants since the production of these materials is highly controlled, their permeability is very low and compared to the compacted clay, the thickness of the layer is much lower which also provides a volume gain for waste disposal (Duarte 2009). According to Rowe (2010) the GCL has permeability of 10^{-11} m/s and presents technical advantages over compacted clay. An efficient landfill configuration combines geosynthetics and compacted soil with a permeability coefficient of up to 10^{-12} m/s which reduces the possibility of contamination. In the case of double layer geomembranes interspersed with compacted soil the permeability can reach 10^{-14} m/s.

2.2 Leachate Drainage

The leachate generated within the landfill mass is collected and directed to a treatment reservoir. The system prevents leachate infiltration into the medium and decreases pressures within the waste cells. This drainage is performed with natural filtering materials such as sand, gravel, perforated pipes and geosynthetics (Maia 2016).

According to Palmeira (2018), the most effective geosynthetics for this function are draining geocomposites and nonwoven geotextiles. Geotextiles are more commonly used as filters and, when compared to conventional granular materials, occupy a smaller volume and have greater ease of construction, as well as reducing the exploitation of natural materials.

2.3 Gas Drainage

Decomposition of solid waste generates gases composed primarily of methane (CH4) and carbon dioxide (CO_2). These gases can cause fires and explosions as well as contributing to the greenhouse effect (Carey et al. 2000). Therefore, landfill gas must be properly drained and treated. This gas drainage system is composed of vertical drains that may or may not be coupled to the leachate drainage system (RIBEIRO 2016).

According to Maccaferri (2009) the gas drainage can be performed with geotubes or draining geocomposites. But geomembranes ensure that these gases do not spread. For the collection of heavier gases, geotextiles, georedes or geocomposites can be used for drainage.

2.4 Intermediate Coverage and Final Coverage

During the operation of the landfill, waste is covered daily to prevent the proliferation of disease vectors and foul smells. Intermediate and final coverings are also performed to protect the surface and prevent water infiltration (Maia 2016). This step can be performed by a soil layer or geosynthetic material such as HDPE geomembrane (IPT/CEMPRE 2010).

The advantage of using geosynthetics is that due to their smaller thickness, they occupy less volume of landfill cells and can be removed and reused for new layer coverings. The installation of geogrids or geotextiles for the application of a vegetation cover increases stability. In addition, the final cover can be performed using a geomembrane overlapping geocell (IGSBRASIL 2012).

2.5 Erosion Control and Slope Reinforcement

Erosion control on landfill slopes can also be performed using geosynthetics. The slopes can be protected by geomants or geocells filled with soil and vegetation, gravel or concrete. Geocells can also be used in conjunction with geotextile filters (Palmeira 2018).

2.6 Rainwater Drainage

The drainage of rainwater prevents water infiltration inside the landfill, which contributes to reducing the amount of leachate generated, and also prevents erosion of the final cover layer (Kajino 2005). According to NUCASE (2008), it is important to use flexible devices due to deformations of landfills over time. This drainage system can be performed using draining geocomposite.

3. METHODOLOGY

The present study sought, from a literature review, real cases of landfills where geosynthetics were used. Thus, advantages and disadvantages of this alternative over the use of conventional materials could be presented.

Subsequently, research was conducted consisting of a legislative and normative review on national recommendations on the use of geosynthetics in landfills.

National standards do not clearly determine the criteria for the use of geosynthetics in landfills, nor do they specify how to choose the most appropriate material to use. Therefore, the research was directed to the legislative structures of each of the Brazilian states.

Therefore, we investigated the existence of regulatory guidelines for the use of geosynthetics in all Brazilian states. First the search was performed through the email addresses of the agencies. If no document was found, an e-mail was sent to the agency concerned and awaited a position on the technical recommendations and procedures used from the use of geosynthetics in landfill works. Ultimately, if the email was not answered, the contact was made by phone. After that, the guidelines of each state were evaluated, observing their relevance, and how it regulates the use of geosynthetics in the absence of technical recommendations by environmental agencies.

Table 1 presents the state environmental agency consulted and the type of information obtained. The information found will be displayed in the results.

Table 1. Environmental agencies consulted by Brazilian state.

State	Consulted Environmental Agency	Information Obtained
Acre	Secretaria de Estado de Meio Ambiente (SEMA) www.sema.ac.gov.br	No return
Alagoas	Instituto do Meio Ambiente de Alagoas (IMA) www.ima.al.gov.br	No return
Amapá	Instituto do Meio Ambiente e de Ordenamento Territorial do Amapá (IMAP) www.imap.ap.gov.br	No return
Amazonas	Instituto de Proteção Ambiental do Amazonas (IPAAM) www.ipaam.am.gov.br	No return
Bahia	Secretaria do Meio Ambiente (SEMA) www.meioambiente.ba.gov.br	No return
Ceará	Agência Reguladora de Serviços Públicos Delegados do Estado do Ceará (ARCE) www.arce.ce.gov.br	No return
Distrito Federal	Secretaria de Estado do Meio Ambiente do Distrito Federal (SEMA) www.sema.df.gov.br	No return
Espírito Santo	Secretaria de Estado de Meio Ambiente e Recursos Hídricos (SEAMA) www.seama.es.gov.br	No return
Goiás	Secretaria de Estado de Meio Ambiente, Recursos Hídricos, Infraestruturas, Cidades e Assuntos Metropolitanos (SECIMA) www.meioambiente.go.gov.br	No return
Maranhão	Secretaria de Estado de Meio Ambiente e Recursos Naturais (SEMA) www.sema.ma.gov.br	No return
Mato Grosso	Secretaria de Estado de Meio Ambiente (SEMA) www.sema.mt.gov.br	Answer by phone
Mato Grosso do Sul	Instituto de Meio Ambiente do Mato Grosso do Sul (IMASUL) www.imasul.ms.gov.br	No return

Minas Gerais	Secretaria de Estado de Meio Ambiente e Desenvolvimento Sustentável (SEMAD) www.semad.mg.gov.br	Answer by phone
Pará	Secretaria do Meio Ambiente e Sustentabilidade (SEMAS) www.semas.pa.gov.br	Returned Email
Paraíba	Superintendência de Administração do Meio Ambiente (SUDEMA) www.sudema.pb.gov.br	Answer by phone
Paraná	Secretaria do Meio Ambiente e Recursos Hídricos (SEMARH) www.meioambiente.pr.gov.br	Returned Email
Pernambuco	Companhia Pernambucana de Saneamento (COMPESA) www.servicos.compesa.com.br	No return
Piauí	Secretaria Estadual de Meio Ambiente e Recursos Hídricos (SEMAR) www.semar.pi.gov.br	Booklet on the website
Rio de Janeiro	Instituto Estadual do Ambiente (INEA) www.inea.rj.gov.br	Returned Email
Rio Grande do Norte	Companhia de Águas e Esgotos do Rio Grande do Norte (CAERN) www.caern.rn.gov.br	No return
Rio Grande do Sul	Secretaria do Meio Ambiente e Desenvolvimento Sustentável (SEMA) www.sema.rs.gov.br	Answer by phone
Rondônia	Secretaria de Estado do Desenvolvimento Ambiental (SEDAM) www.sedam.ro.gov.br	Answer by phone
Roraima	Fundação Estadual do Meio Ambiente e Recursos Hídricos (FEMARH) www.femarh.rr.gov.br	No return
Santa Catarina	Instituto do Meio Ambiente de Santa Catarina (IMA) www.ima.sc.gov.br	No return
São Paulo	Companhia Ambiental do Estado de São Paulo (CETESB) www.cetesb.sp.gov.br	Answer by phone
Sergipe	Secretaria de Estado do Meio Ambiente e dos Recursos Hídricos (SEMARH) www.semarh.se.gov.br	No return
Tocantins	Instituto Natureza do Tocantins (NATURATINS) www.naturatins.to.gov.br	No return

4. CASE STUDIES

4.1 GCL

Sobiesiak (2017) analyzed the performance of using clay geocomposites in comparison with the compacted clay for bottom waterproofing at São Carlos Ambiental Sanitary Landfill. The landfill previously sized for compacted clay has been scaled to clay geocomposite. The initial disposal of waste was 160 tons per day reaching 320 tons daily at its closure. The waste disposal area is 219.234,48 m^2. This study is justified by the fact that the use of geosynthetic is able to increase the capacity and useful life of the landfill in addition to reducing costs and implementation time.

Table 2 shows the comparative study performed by the author.

Table 2. Background waterproofing comparison (from Sobiesiak 2017).

Waterproofing Method	Occupied Volume (m^3)	Execution Time (h)	Execution Cost (R$)
Compacted Clay	125.762,71	169	4.260,21
GCL	1.362,43	192	3.434.097,17

The use of GCL enables an increase of 124,400.28 m^3 in waste disposal which promotes the increase of landfill life in less than one year.

The author considered the use of GCL unfeasible for this case presented. One of the reasons is that the landfill does not require additional waterproofing and there was no need to transport soil from the loaner to the compaction site, as the local soil is a low permeability clay. Sobiesiak (2017) proposes an analysis with the variation of the thickness of the compacted clay liner and a case study with the deposit far from the landfill.

Previti et al. (2018) conducted a study to evaluate the permeability coefficient of bentonite, component of GCL, for different residue heights on this compound. The permeability for different confinement stresses and residue height decreased with increasing confining stress. Thus, the efficiency of the use of GCLs is proven, which besides presenting smaller volume than the compacted clay, have a much lower permeability coefficient which is still decreased as the landfill transmits high confinement stresses.

4.2 Landfill Closure Using Geosynthetics

The use of different types of geosynthetics with their varied functions can be exemplified in the design by Junior and Panta (2018) for the definitive closure of an old class 1 blast furnace landfill in Cariacica. The project used geocells and geogrids in reinforced soil walls, non-woven geotextiles for protection and filtration, HDPE geomembranes for waterproofing, drainage geocomposites and HDPE corrugated geotubes for leak detection. The adoption of geosynthetics aimed to safely incorporate hazardous waste into the environment and generate a vegetated visual appeal.

The authors pointed out that the use of geosynthetics to close the landfill allowed the integration of the work with the environment through vegetation, high durability, flexible structure, allowing the work to be accommodated to possible differential repression and increased work productivity.

4.3 Gas Capture

According to Feldkircher (2008), the Bandeirantes Sanitary Landfill, São Paulo, has as its main objective the capture of biogas for electric power generation. However, due to the high heat temperatures, cracks occurred in the landfill cover surface which was composed of a layer of soil and vegetation. This problem caused the waste of biogas to the atmosphere and compromised the production of electricity. The solution to the problem was to deploy a portion of the landfill cover portion with smooth HDPE geomembrane on both sides of 1.0 mm thickness. After installation, there was a high increase in biogas uptake, proving the importance of landfill coverage, especially those that capture biogas for electric power generation. The use of HDPE geomembrane provided a 115% increase in gas uptake considering the area that was covered.

An example of efficiency in biogas collection and power generation can be observed at the Metropolitan Sanitary Landfill Center, Bahia. According to Andrade (2014), the energy generating unit of this landfill, Termoverde, has an installed capacity of 19,73 MW and a production of 150.000 MW / year. According to BATTRE (2016), the project guarantees the destruction of methane by 99%. The company introduces Clean Development Mechanism (CDM) as a way to assist the process of reducing greenhouse gas emissions and obtained the Carbon Credits certification in 2004.

The Metropolitan Sanitary Landfill Center receives an average of 3.000 tons per day of municipal solid waste. In addition to HDPE piping for biogas collection, soil sealing is composed of a layer of clayey geocomposite, 2.0 mm HDPE geomembrane and non-woven geotextile (BATTRE 2016).

4.4 Costs of Waterproofing and Leachate Collection

Silva (2014) conducted a study to analyze the costs of building the Suldouro Sanitary Landfill in Portugal. Cost analysis was performed by excluding the rainwater drainage system and the biogas treatment and drainage system. The total cost of construction of the structure is estimated at € 10.829.542,25. The solution implemented for leachate waterproofing and drainage using geotextiles, HDPE geomembranes, GCLs and HDPE pipes corresponds to 15% of the total value of the work.

The author also made an alternative solution in the drainage aspect. It was evaluated the application of drainage geocomposites to the detriment of the traditional drains. This solution guarantees savings of € 6,900 and increases storage capacity by 16.000 m^3. Silva (2014) says that although this is a relatively low value, it represents significant savings and that the use of draining geocomposite has other advantages such as shorter execution time, lower cost than natural aggregates and ease of installation.

4.5 Structural and Operational Assessment

A research conducted by Ribeiro (2016) was based on the study and monitoring of landfills, CTR Campos - RJ, CTR Macaé - RJ, CTR Rio - RJ, Municipal Landfill of Itú - SP and Sanitary Landfill of Caieiras - SP. This analysis focused on the description of the project, structural aspects and operational criteria, by completing forms and technical visits.

According to Ribeiro (2016), the waterproofing projects studied are similar. The small and medium size landfills have a base waterproofing composed of a layer of HDPE clay and geomembrane. Large landfills have a waterproofing composed of more layers due to the larger amount of waste having a primary leach collection coating and a secondary leak detection coating. The clay geocompound was used in CTR Rio and Caieiras Landfill, which receive a large amount of waste. This material was applied below the first HDPE geomembrane.

For leachate drainage, in small and medium size landfills, 15 cm HDPE perforated pipes were used, while in large works, the diameter used was 40 cm. Also according to the author, the leachate generated is collected and removed by various drainage systems such as parallel mesh, fishbone and draining mattress.

According to Ribeiro (2016), in all analyzed landfills the drains of the gas drainage system are composed of concrete base, steel mesh, hand stone, perforated concrete shackle or HDPE and geotextile piping. To promote higher biogas uptake rate, in large landfills, the perforated concrete shackle can be replaced with HDPE perforated pipe, but due to the high cost of this material, designers prefer to incorporate this geosynthetic at the very end of the biogas drain by mixing the material used for drainage. Large landfills have biogas recovery and treatment projects for power generation. According to Figueiredo (2007), the return on investment in materials and systems that promote energy collection and generation more efficiently happens in a short time, demonstrating the economic viability of using HDPE pipes and reducing the environmental impacts.

5. RESULTS AND DISCUSSIONS

5.1 Normative Considerations

ABNT NBR 8419 recommends that materials for flow barrier, drainage and gas capture in urban solid waste landfills should be specified, but do not provide details on implementation.

ABNT NBR 10157 (1987) and ABNT NBR 13896 (1997) recommend a flow barrier system composed of natural or artificial materials, however they do not distinguish which materials fall into place.

ABNT NBR 15352 (2006) sets out the requirements that polyethylene blankets must meet in the flow barrier function.

ABNT NBR 15849 (2010) states that base waterproofing can be dispensed with, when technically proven to be safe, due to soil permeability, groundwater depth, local water surplus and organic fraction. This norm has great relevance to the Brazilian reality of many small municipalities and lack of resources.

ABNT NBR 16199 (2013) discusses the surface preparation for the installation of geomembrane in geotechnical and environmental sanitation works.

IGS Brasil published in 2014 Recommendation 004 - Application of Geosynthetics in Waste Disposal Areas which aims to provide information for the use of geosynthetics. This recommendation is general and does not replace technical standards, national regulations and documents issued under the responsibility of environmental agencies or not (IGSBRASIL 2014). This document is of great importance in the evolution of the use of geosynthetics and shows IGS Brasil's contribution to the development of the application of these materials in waste disposal works.

5.2 State Environmental Agencies

The first part of the research conducted on the existence of guidelines and regulations in state environmental agencies on the use of geosynthetics in urban solid waste landfills was conducted through the email address of each state environmental agency.

The answer obtained from the consultation through the SEMA, MT website was that the state has no regulations or guidelines regarding the use of geosynthetics.

The research on SEMAR, PI, resulted in the booklet prepared by the State Court of Auditors, TCE (2008) that provides specifications on the use of Class II landfill geosynthetics, which can be made by HDPE blanket welded or clay with K = 10^{-6} cm/s and thickness of at least 80 cm. This booklet mentions alternative gas destination treatments with geosynthetics, but does not mention implantation procedures.

As not much information was obtained from the websites, an email was sent to each environmental agency in all Brazilian states.

SEMAS, PA, returned the contact made stating the use of ABNT standard NBR 13896 (1997) and environmental standards and legislation. It is reiterated that the use of geosynthetic, although widespread has few regulations.

The contact made with SEMARH, PR, returned that it is mandatory to use a complementary flow barrier system, as established by Resolution CEMA 94/2014, article 15 and 18. These articles reiterate that the landfill should have a barrier system side and bottom, with geomembrane or similar flow barrier systems, being directly disposed of on the ground and prohibiting the issuing of environmental permit for landfills where ditches without geomembrane or similar flow barrier systems exist in the side and bottom.

In contact with INEA, RJ, it was informed that the use of geosynthetic, specifically geomembrane, is a function of soil characteristics. According to information provided by the head of the agency, 90% of licensed landfill projects already propose the use of geomembrane in the flow barrier, which shows that this material is already widespread in the technical environment. In cases of large landfills such as Seropédica or industrial landfills, it is common to use a double flow barrier. However, there are no state-specific norms and guidelines on which to base these choices.

As most state environmental departments did not respond to the e-mail sent, contact with the agencies was made by telephone.

The SEMA, MT, answered by telephone that the state has no specific standard and that the choice of material used is in agreement with the responsible technician seeking to apply the most viable method. The environmental agency asked to forward an email, but it was not answered.

In contact by telephone with SEMAD, MG, the environmental agency asked to forward an email so that it could send the answer. That done, the agency's Special Waste Management reported that the main criteria for landfills are defined in NBR 8419 and that it does not know a specific national or state standard on the use of geosynthetics in landfills. The email was forwarded again by the agency itself to a member of SEMAD's Urban Solid Waste Management to forward a more complete response. So far not answered.

SUDEMA, PB, answered by phone that only use and know the geomembrane. There are no specific regulations and the agency only monitors the use of a 2 to 5 mm layer of geomembrane for waterproofing in landfills. He also reported that in many cases of the state, the rock is outcropping, with the water table very deep, dispensing with waterproofing with this material.

In contact by telephone with SEMA, RS, the environmental agency asked to forward an email so that it could send a response. Forwarded the e-mail, the agency reported that uses the Technical Directive FEPAM Nº 04/2017 in which has an item that deals with the waterproofing of cells in landfills. According to this guideline, the waterproofing should be composed of compacted soil, with a permeability coefficient of 10^{-7} cm/s with a minimum thickness of 60 cm, compacted in 20 cm layers, and 2 mm HDPE geomembrane. A minimum distance of 2 m from the water table is also considered. Regarding the effluent drainage system, the document guides the need for the use of piping and HDPE due to the affinity with the geomembrane. For biogas drainage, it is recommended to drain preferably composed of perforated concrete pipes. (FEPAM 2017).

In contact with SEDAM, RO, the agency responded by telephone that it has no specific regulations yet and asked them to forward an email to better respond to the survey. The same was sent but not answered.

CETESB, SP, in contact by telephone, asked to forward the survey on Contact Us available on the website of the environmental agency. The procedure was done, but no response was obtained.

With regard to the other states, searches conducted by e-mail and telephone were not answered. In many states, telephone contact has only resulted in call transfers with no response. In others the call was not completed or was not answered. The contact was made on different days and times and was made more than once. As for direct departmental research, none resulted in specific definitions regarding the use of geosynthetics in landfills. However, some accessed documents and designs have shown that geosynthetics are primarily used for flow barriers, usually with usage specifications provided by the manufacturer itself. This fact tells us that the use of geosynthetics has been widespread and its proven advantages, reaffirming the need to improve their studies and definitions.

This research shows that although there is an evolution of geosynthetics, most state environmental agencies do not follow such development, not having knowledge of the use of many of these materials. Due to the lack of specific regulations for the use of geosynthetics in most states, and as there is no obligation imposed by norm, the choice of materials used in the structure of landfills is at the discretion of the designer.

5.3 Analysis of Presented Cases

The feasibility of using geosynthetics in landfills is mainly related to the size of the work. In general, in the cases presented, landfills that receive large amounts of municipal solid waste daily employ these materials in their structure.

The use of GCL has advantages of rapid installation, self healing, easy repair, independence of natural materials and consequently its non-extraction, provides greater volume of landfill operation due to its small thickness, low permeability and when hydrated, function as a gas barrier. In addition, it is not subject to cracking like compacted clay.

In small sanitary landfills the base waterproofing happens mainly by the use of a compacted clay layer followed by a HDPE geomembrane. Another observed application of geosynthetics was the use of these materials to close a hazardous waste landfill providing greater safety than conventional materials.

Gas collection in landfills can be performed more efficiently through the use of HDPE pipes that are lighter materials and longer life. However, it was observed that this application is more economically viable in large works, which produce large amount of biogas. In addition, to promote higher biogas uptake, the landfill can be covered with HDPE geomembrane.

6. FINAL CONSIDERATIONS

Economically, the viability of geosynthetics is related to the size of the landfill. Large works benefit from the application of these materials because in addition to providing financial gain provide greater safety and environmental protection. However, it is important to emphasize that the viability is not strictly economic. Environmental protection, preservation of natural resources, reduction of water consumption, safety, practicality, long term duration and increased landfill life reinforce the viability of geosynthetics. It is also important to evaluate costs in relation to the total of the project and not only of isolated values.

Regarding the feasibility in relation to the recommendations and technical standards, it is still necessary that the environmental agencies follow the evolution of these materials. As there is no standard requirement for the use of geosynthetics and few documents governing its application, the choice of material is at the discretion of the designer. Stricter financial and environmental standards are needed.

It is important that, along with the technological evolution of the sector, there is an improvement and advancement of legislation and normative recommendations, so that the changes are accompanied by professionals and agencies that license this type of work. For this, it is important that the technical staff of the area, together with state agencies and private companies, contribute to the elaboration of new propositions, advancing, for example, the detailing and specifications of other elements in which the use of geosynthetics is justified, as in leachate and gas drainage by geotubes, geocell cover layer and GCL base coat, not only contained in flow barrier geomembranes. Thus, it is understood that the application of geosynthetics, specifically in landfill works, would be made with greater technical support, with a smaller gap between what already exists in the market and the execution of projects in Brazilian states.

With the application of geosynthetic materials, the final disposal of solid waste in landfills can be performed viably, more efficiently, with less environmental impact, making it possible to deposit a larger volume of waste in the same area as using conventional methods, greater safety and preservation of natural resources. However, the disposal of waste to landfills is only the last step of a long process. Decreasing consumption imposed by a diseased system and a selfish society, recycling, reuse, the application of waste treatment techniques prior to final disposal and, of course, the awareness of the entire population are fundamental to environmental and social preservation.

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7.1

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