Review paper on Experimental Investigation on Dewatering of Sludge by using Geo-textile Tube

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Abstract
Geotextile tube is an innovative product developed by sewing permeable high strength geotextiles to form large tubes. The main application of geotextile tube is dewatering of dredge materials sediments and industrial waste slurry. the reviewed literature, it is evident that the relationship between geotextile material properties and dewatering performance is not well understood.(Moo-Young and Ochola-2000)Dewatering performance cannot be predicted based on geotextile or particle size characteristics,(Kutay and Aydilek 2004).Geotextile dewatering performance is independent of AOS and permittivity, (Koerner and Koerner 2006).AOS is a poor predictor of geotextile geotube dewatering performance, filtration efficiency is less affected by water content, head of sludge, AOS and gradation of sludge.(Shinde and Ilamparuthi 2010) filtration efficiency is less affected by water content, head of sludge, AOS and gradation of sludge. Almost all researchers stress a strong need for formulating design guidelines for understanding and predicting the relationship between index properties, dewatering efficiency, for choosing dosage 6and type of additives and above all the field performance.

***Keywords**: Geotextile Tube, Dewatering, Hanging Bag Test, Sludge*

1.Introduction
A comprehensive review on geotextile geotube dewatering, which includes analysis of geotextile tube system highlighting the important contribution made in literature on the bases of unique design parameters, also laboratory and field research that have been conducted to evaluate geotextile tube dewatering performance, and selected cases on geotextile tube dewatering application.

2.Literature review
2.1Leshchinsky et al. (1996) In the research carried out they have used geosynthetic tube which are made up of several geosynthetic sheets sewn together to form of tube to withstand confining pressurized slurry.
The stresses developed during the process are sensitive to the pumping pressure and studied the shape of a geotextile tube with its circumferential and axial tensions. Results and an associated program GeoCoPS are in agreement with Silvester (1986), Liu (1981) and Kazimierowiz (1994). An equation was also given to calculate amount of geotextile tube will decrease in height due to consolidation.
Based on analysis done author recommended safety factors for the geotextile for weak line.

2.2.Flower et al. (2000) successfully demonstrated the use of geotextile tube for dewatering the sewage sludge with experiment using geotextile bags, (The hanging bag test was (HBT)

was introduce by Flower et al. 1996 and is described in the Geosynthetic Research Institute (GRI draft GT-12) test method).
He also carried out heavy metal test in which waste was passed through the inner liner and outer fabrics for bag1 (polyester non-woven inner liner) and bag 2 (polypropylene non-woven inner liner). The results of these tests indicated that arsenic was 1.4 to 1.52 mg/l before passing through the bag and after filtration it was 0.008mg/l to non-detect (ND) and Chromium and Nickel was detected before filtration and after the filtration it was non-detected (ND). He also proved that addition of additives such as polymers, fly ash etc helps to reduce the bacterial count. He recommended this technology for small and medium water and waste water treatment plant for dewatering the sludge, as this technique is passive and does not requires extensive or constant labour and maintenance of equipment.

2.3.Moo – Young et al. (2002) Performed twenty six pressure filter test using four different geotextile example two monofilament and fibrillated polypropylene fibres like Geotextile 44T and 46T and two multifilament polyester fibres like 1016T and 1212T and five different high water content material example two dredge sediments, two pulp and paper sludge, and one harbour sediment. Figure shows pressure filter set up used by moo-young.

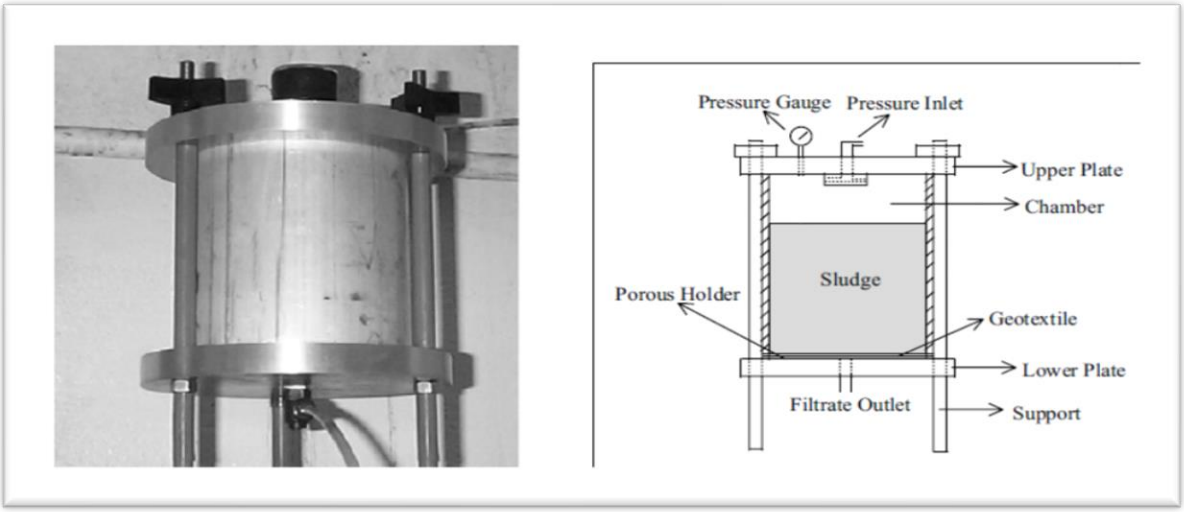


Figure 1: Pressure filter apparatus

This test was carried out under pressure 35 kPa and 70kPa and concluded that woven geotextile geotubes are far better filtration containers for dewatering high water content materials, and also by using the woven geotextile geotube for dewatering soil retention is not a problem. As even when common soil retention criteria are not satisfied, a large portion of fines retains inside the tube because of formation of filter cake and one cannot predict dewatering success based on a geotextile's AOS or grain size of the material.
There appears to be some distinct characteristics of sediment-based high water content materials versus biologically based sludge, namely the shape of the dewatering curves and final achievable water content.
The study also identified the thrust area for further research, which included developing criteria to guide the selection of proper geotextile; investigating the effect of initial water content on the final percentage of solids; determining the pumping flow rate, pressure and other important operational parameters such as internal pore pressure in a full-scale tube, compared to the test filtration pressure; and prediction of final percentage of solids and consolidation time.

2.4.Mori et al. (2002) the applicability of geo-tubes in a containment method for dioxin contaminated sediment was studied. Soil sample used for the studies were taken from the dioxin contaminated sites in Japan and particle size distribution of sample prepared is shown in figure.

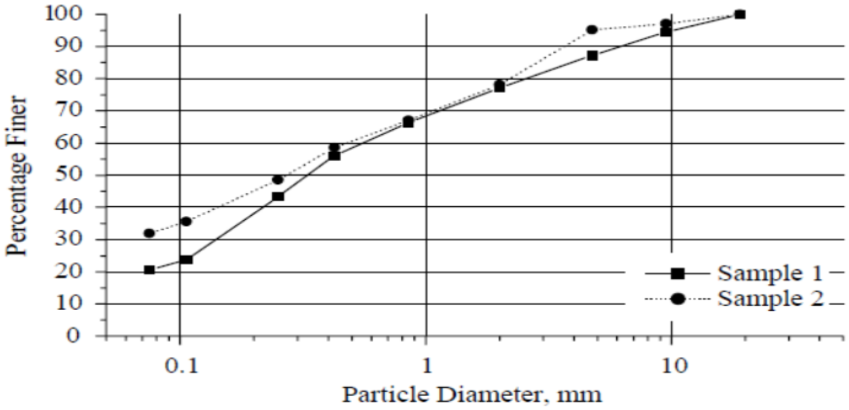


Figure 2: Grain size distribution of sediments

Pressure test where performed to choose the geotextile, use to manufacture the geotextile geotube and one layer geoxtextile geotube was used for study. Slurry sample was prepared by adding 600% water content and organic and inorganic flocculants were used to accelerate the dewatering process addition of accelerate enhanced trapping of dioxins, improved containment removal efficiency. A leach test was conducted and the concentration of dioxin in water was measured on first day, 90 days and 365 days. And the dioxin leached from geotextile geotube is scarcely observed

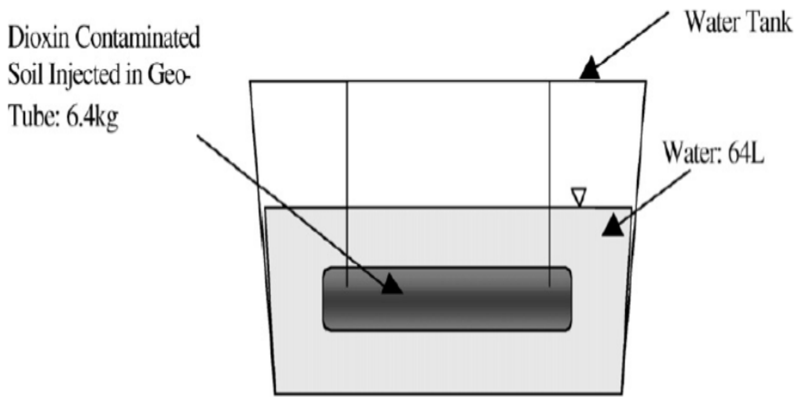


Figure 3: leaching test apparatus

2.5.Kutay and Aydilek (2004) compared dewatering performance using several combination of eight geotextiles (four woven and four non-woven) with the primary aim of evaluating the efficiency of double layer geotextile container systems. In system is a double layer system the author has taken permittivity of system is a combination of the nonwoven and woven geotextile permittivity's. Assuming the flow rate is constant during the permittivity test and that the total head loss across the two-layer system is the sum of the head losses across each geotextile, an equivalent permittivity defined by author as

$$\Psi_{eq} = \frac{1}{(\Psi_{nonwoven})^{-1} + (\Psi_{woven})^{-1}}$$

Where Ψ_{woven} and $\Psi_{nonwoven}$ is permittivity of woven and nonwoven geotextile combination PFTs and HBTs were conducted to dewater fly ash and the fly ash slurries where tested at water contents of 80%, 200%, and 500% and dredged sediments were tested at water content of 500% and 1600%. Piping and dewatering efficiency were used to compare relative performance.
This study found that
1) The use of double layer nonwoven / woven geotextile rather than single woven geotextile significantly increased the retention performance of geotextile container.
2) Geotextile hydraulic properties such as permittivity and AOS had little effect on dewatering efficiency.
3) Higher slurry water content and fines resulted in greater piping.
4) The filter cake was found to promote retention and limit piping.
The study recommended parametric studies to investigate the compatibility of geotextile pore size and the particle size of the material to be dewatered, under site specific conditions. Thus concludes that the geotextile use must be selected based on empirical methods developed by researchers rather than available filter criteria.

2.6.Huang and Koerner (2005) Geotextile geotube when use for pollutants bearing sediments and sludge's two major problem which reduces the effectiveness of use of geotextile geotube are 1) the inability to retain organic and inorganic pollutants that are dissolved in the water phase and 2) the slow dewatering process due to rapid formation of a filter cake by colloidal particles on the inside of the fabric.
In this study in order to overcome the above mentioned problem they are adding reactive materials like activated carbon, charcoal (~ 100um diameter) for immobilizing organic pollutants and phosphoric rock for precipitating heavy metals.
The calculated aqueous phase concentrations of the target chemicals before and after adding charcoal was assessed.
The study addresses the addition of activated carbon, charcoal and phosphoric rock to contaminated sediments and slurries for the purpose of decontamination along with cost effectiveness.
Author addresses that there is lots of scope for further study as the research is in progress and many details need to address.

2.7.Koerner and Koerner (2005) they have studied three different field application of geotextile
1) Shoreline protection using a sand infill.
2) Dewatering of dredged harbour sediment and
3) Dewatering of lagooned industrial ash.
The performance of geotextile was tested by Hanging bag test and Pressure filtration test as comparative method. The pressure filtration test is an extension of work by Young, et al. (2002). Set up used is as shown in figure

Figure 4: Pressure filter set

They concluded that designer must evaluate the potential behaviour between infill soil and geotextile type based on above mentioned test. These tests are tools that the designer needs so as to answer site specific questions about fabric to infill material compatibility. Also stated that there is still much work to be done on refinement of both of these laboratory methods.

2.8.Koerner and Koerner (2006) The paper reported 12 HBT with three different case history and used four different fabrics(Woven polyester diamond, Woven polypropylene twill, Woven polypropylene basket, Woven polypropylene bias) .The proposed hanging bag test method is an extension of one proposed by Flower et al.(1994) for the US Army Corps of engineers at Vicksburg, Mississippi.

The physical concept remains the same, while the measurement method is quite different. HBT is used to determine the flow rate of water passing through the fabric as well as any sediment passing through over a specific time period.

At the same time it is also used to evaluate the properties of the dewatered infill material as well as examine the nature of the filter cake.

They summarize that good predication of performance of geotextile fabric is an integral part of designing and selecting the fabric for geotextile geotubes for both shore line protection and dewatering.

Thus it is hoped that their work will lead to development of a standard test method that can be used by engineers to select fabrics for optimal geotextile geotube field performance. The apparatus used for this test are shown in figure

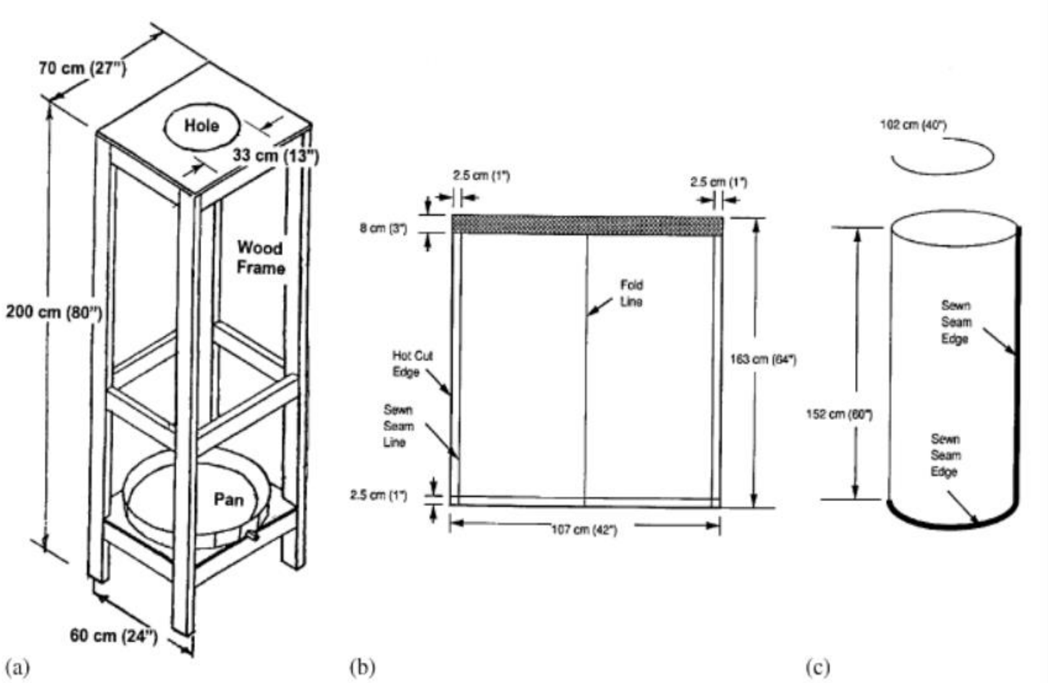


Figure 5: Hanging bag test apparatus and geotextile after and before fabrication

The two critical findings from this study are

1. The flow rates for all the tests were directly proportional to the permeability of the soil contained within the tube. Thus concludes that HBT results adequately predicted the field performance in all three case histories.
2. Also the performance of the geotextile bags was not dependent on any conventional parameters, including the fabric AOS values.

2.9.Muthukumaran and Ilamparuthi (2006) Conducted 42 filtration test (FHT) in the laboratory the experimental set used is shown figure 2.18 on two materials (fly ash and harbour sediment) and four different geotextiles .At water content ranging from 80% to 320% with eight primary combinations of two waste material and four geotextiles.

From the observations it is seen that the FE and DE were equal at particular water content; this water content is termed as the critical water content and the corresponding efficiency is the optimum efficiency.

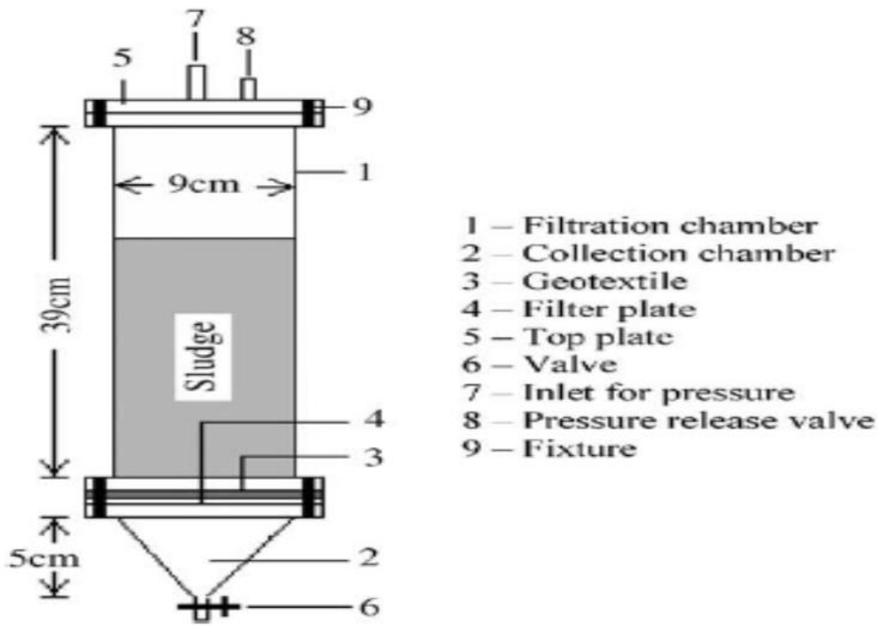


Figure 6: Filtration test set up (FHT)

If gradation of sludge and pore size of geotextile which are to be used are known
Then the relationship for computing critical water content is :
W_c= [-63.34(AOS)^2 + 18.161(AOS) + 59.371](d85/d50)

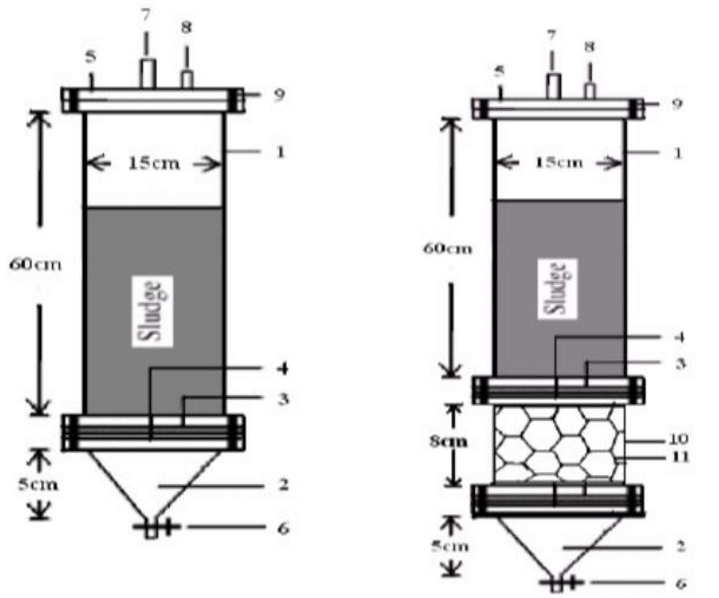
The author's noted that Filtration efficiency is less affected by water content, AOS and generation of sludge. The author says that this study is based on the test carried out on woven geotextiles of twill fabric structure and two sludge. In order to strengthen the findings more study is required for different fabric structure also recommends further study on filter cake thickness and its behaviour with time.

2.10.Shinde and Ilamparuthi (2010) Conducted filtration test (FHT) on tannery waste using two non-woven geotextile G1 and G2. Based on the experiments conducted author states that flow rate increases with increase in water content and opening size of geotextile for a given particle size distribution of sludge.

Dewatering rate increases with increasing water content and hydraulic head of sludge and filtration efficiency is less affected by water content, head of sludge, AOS and gradation of sludge.

Authors also studied sludge cake which is formed during the process of dewatering and found that particle sizes distribution of top and bottom part of filter cake doesn't show much variation with respect to varying head.

Further they added granular layer in filtration set up as shown in figure and experiments were carried out which concluded that addition of drainage layer affected flow rate as well as dewatering rate as the period of dewatering was prolonged for longer hours in case of G2.Also filtrate was tested for TSS test showed lesser TSS when drainage layer was used which indicates that sludge particles were entrapped within the drainage layer as.



(a) Filtration Set-up for stage-I (b) Filtration Set-up for stage-II
1–Filtration chamber; 2–Collection chamber; 3–Geotextile;
4–Filter plate; 5–Top plate; 6–Valve; 7–Inlet for pressure;
8–Pressure release valve; 9–Fixture; 10 – Drainage chamber;
11–Drainage layer

Figure 7: Set up for filtration and slurry geotextile drainage system

2.11.Gaffney, Chambers, Fatheringham and Munoz (2011) The authors have used geotextile geotubes to dewater dredged materials from an Acid Mine Runoff Pond and Fly ash waste with and without polymeric conditioning. The test results without polymeric conditioning indicated that the majority of the small particle size solids passed through the tube fabric and solid retention was very low. When the polymer where add during the dewatering authors observed that the dredge time was greatly reduced and more effective compared to previous years at same site, also the use of polymer to conditioning the sludge increased the solids retention and the dewatering capability of the geotextile geotubes. The polymer used was anionic flocculent. Also study shows that additional use of ferric chloride along with polymer to sequester arsenic in the dredge slurry was successfully demonstrated by laboratory test.

2.12Khachan, Barder, Bhatia and Maurer (2011) This paper introduced preliminary work comparing the dewatering performance of slurries conditioned with synthetic polymers versus slurries conditioned with natural polymers. Conducted thirteen PFT's; six using synthetic polymer, six using natural polymer, and one without any polymer. Based on the review of paper one can draw conclusion that the dewatering time decreased from 150 minutes to approximately 50 minutes because of addition of natural polymer i.e. starch-based eco-friendly polymer, and 30 minutes with addition of synthetic polymer. There is increase in water content of filter cake with increase in dose of polymer, Thus from the results authors conclude that the performance of the natural starch polymer was comparable to that of synthetic acrylamide polymer, indicating good potential for further use in geotextile tube dewatering application. Author wants to expand his study by testing a variety of natural polymers, including dual polymer system for various slurry materials.

2.13Torre and Timpson (2011) The authors describe the various dewatering test shown in figure and their accuracy in predicting full scale results. The cone test and RDT are most useful for fine-tuning polymer dosage and requires less time to perform also requires small quantity of conditioned sludge.HBT and GDT test results are more accurate in predicting full-scale results but require more time and large quantity of conditioned sludge. Author concluded that the GDT (geotextile dewatering test) is the most efficient and effective test method for predicting dewatering performance and results.

a) cone test set up

b) Rapid Dewatering test set up(RDT)

c) Geotextile dewatering test set up (GDT)

Figure 8:Various Dewatering tests

2.13.Das, Mandal and Rathanlal (2012, 2013) Performed first hanging bag test in India to study the dewatering performance by using two types of geotextile, woven polyester multifilament and woven jute geotextile for marine clay and fly ash. The environmental analysis of slurry before and after the test was done to check the efficiency. The result showed that the removal of zinc is in the range of 21% to 57%, iron 35% to 88%, calcium 17% to 37%, sodium 17% to 24% and phosphorus is in the in range of 58% to 93%. Also done finite element analysis using PLAXIS which shows the stress concentration at the bottom of geotextile geotube. Author concluded that the proper selection of the geotextile geotube material and filling material is critical factor in the installation of geotextile geotube, in terms of flow rate apart from AOS and permittivity of the geotextile, also the hanging bag test is mandatory for the design of geotextile geotube. discharge of effluents into Class 2 water bodies, as well as higher percent-solids than those obtained with mechanical dewatering technologies. This study underscores the importance of semi-performance tests to understand dewatering in geotextile tubes.

2.14.Pooja Deepak Pawar et.al (2017)

Geotextile tube is an innovative product developed by sewing permeable high strength geotextiles to form large tubes. The main application of geotextile tube is dewatering of dredge materials sediments and industrial waste slurry. The present study describes the performance of dairy sludge dewatering using hanging bag test. The effect of addition of coagulant has been studied. Alum was used as a coagulant. Dewatering was carried out for dairy sludge without addition of alum and dairy sludge mixed with alum. The environmental analysis was carried out of the sludge before and after hanging bag test to study the quality of filtrate. It was found that geotextile tube was efficient in dewatering the sludge and its efficiency increases with the addition of coagulant.

2.15.Sahil Mushtaq et.al (2018)

Study presents the results of experimental work of dewatering by pressure filter using geotextile, aluminium sulphate and nanoparticles. In the present day, industries produce a lot of sludge for which open dumping is done, this causes several water borne diseases, bad odour, attraction of flies and land degradation. Sludge is the main cause for the former problems mentioned. In order to tackle these problems, dewatering of sludge was done by applying pressure and using geotextile, aluminium sulphate (as a sludge conditioning material), of dosages 550 mg/l, 600mg/l, 650mg/l, nanoparticles (as a sludge conditioning material), of dosages 50mg/l, 60mg/l, 70mg/l. In this paper comparison is made, of filtrate by using just geotextile, aluminium sulphate (6000mg/l) plus geotextile and nanoparticles (50mg/l) plus geotextile. Results show that chemical characteristics such as TSS, TVS, TS, COD, BOD, SO_4 has been reduced to 89.8%, 86.16%, 80.5%, 97.7%, 97.99%, 82.12% respectively with aluminium sulphate and 92.4%, 87.5%, 81.4%, 97.8%, 98.06%, 98.06%, 86.25% respectively with nanoparticles, so the filtrate can be recycled and filter cake obtained after dewatering was tested for NPK, therefore it can be used as a fertilizer, thus proving zero waste conditioning.

2.16.Maria Alejandra Aparicio Ardila et.al (2020)

geotextile tubes as dewatering technology may significantly contribute to sustainable treatment of sludge generated in different industries, such as the water industry. This is an economical alternative for dewatering sludge from a Water Treatment Plant (WTP), which prevents sludge from being directly deposited in water bodies and makes it possible to then transfer the sludge to landfills. laboratory study and a statistical analysis, were carried out to evaluate the geotextile tube dewatering of sludge from a WTP, discussing the relation between the independent variables (initial Total Solids (TS) of the sludge and polymer dosing) and dependent variables (performance indices used in the literature) evaluated using semi-performance tests. Sludge from a WTP and three different types of geotextiles bags were used. Changes in the geotextiles' characteristics after dewatering were also evaluated, quantitatively using permittivity tests and qualitatively by Scanning Electron Microscopy (SEM).

2.17.Ümit Karadoğan G Cevikbilen, S Korkut (2022)

Study presents an efficient dewatering methodology and a beneficial alternative to store the sludge. In this scenario, the sludge of a suction-cutter dredger is transported to a pond. The beneficial use of geotextile tubes filled with the sludge at circumferential embankments of pond is evaluated. An anionic polyacrylamide (APAM) is used for conditioning the high plastic silt sludge with 10% solid content. APAM dosage is optimized by Rapid Dewatering Test (RDT) for geotextile material. Microscale SEM-EDS analyses depicted the flocculated form of the sludge. Laboratory-scale Geotextile Dewatering Test (GDT) shows improvements in the turbidity of filtrate, the quantity of solid particles retained in the tube, and the filtration efficiency, determined to be 92 NTU, 18.5% and 90.5% respectively. In accordance with the ICP-OES analysis, the discharge of the filtrate to the aquatic media is admissible. Undrained shear strength of the dewatered sludge is assessed as low, by Vane and undrained unconsolidated triaxial compression tests. Further improvements of the dewatered sludge with vacuum preloading method were projected by completion of the consolidation tests.

3.Summary

A basic understanding of geotextile geotube, dewatering and the relationships between geotextile geotube material index properties, Sediment slurry characteristics, and the variables governing the dewatering behaviour of slurred materials been subjected for considerable study for several years.

In the summary from the reviewed literature, it is evident that the relationship between geotextile material properties and dewatering performance is not well understood.(Moo-Young and Ochola-2000)Dewatering performance cannot be predicted based on geotextile or particle size characteristics,(Kutay and Aydilek 2004). Geotextile dewatering performance is independent of AOS and permittivity, (Koerner and Koerner 2006). AOS is a poor predictor of geotextile geotube dewatering performance, filtration efficiency is less affected by water content, head of sludge, AOS and gradation of sludge.(Shinde and Ilamparuthi 2010) filtration efficiency is less affected by water content, head of sludge, AOS and gradation of sludge. Almost all researchers stress a strong need for formulating design guidelines for understanding and predicting the relationship between index properties, dewatering efficiency, for choosing dosage and type of additives and above all the field performance.

4.Conclusion

From reviewed literature

- Geotextile tube dewatering technology is gaining acceptances as the preferred method for dewatering and containment.
- The relations between geotextile geotube material index properties, Sediment slurry characteristics or particle size distribution cannot be predicted accurately.
- The use of polymer conditioner provides significant improvements
- Low environmental impact (Lawson 2008) relative to other existing mechanical dewatering method**.**

5.Scope of work

In spite of extensive investigation, most researchers have failed to accurately identify the mechanism involved in the formation of the filter cake and influence of geotextile index properties on dewatering. Also accurate concluding study on various chemical coagulants and nano-coagulants which can be used to coagulate the slurry to accelerate dewatering along with (bacterial removal) disinfecting the filtrate is not found when used for various waste example sewage sludge, dairy waste, tannery waste etc. Thus raise acute need for study.

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