



Experimental Investigation of Dewatering of Dairy Sludge by Pressure Filter Using Geotextile and Alum, Nano Particles for Sludge Conditioning

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Abstract: This paper 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, SO₄ 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.

Keywords: Geotextile, Aluminium Sulphate, Nanoparticles, Filter Cake, Sludge Conditioning

1. Introduction

The constituents removed in sludge treatment plants include screening, grit, scum and sludge. The sludge from waste water treatment operation and process is usually in the form of a liquid or semi solid liquid that typically contains from 0.25 to 12% solids by weight, depending on the operation and processes used. The problem of dealing with sludge is complicated because of biological treatment. Only a small amount of sludge contains solid matter.

Now a days the dewatering of waste water coming from industries are directly dumped into sludge drying beds in the open air which causes several water borne diseases, bad odour, attraction of flies and land degradation. In spite of the use of sludge drying beds, here we are using geotextile, which in turn reduces the problems caused due to the use of sludge drying beds.

A Geotextile is an innovative and economical method for dewatering the digested bio-solids, dredge material sediments and industrial solid wastes, fly ash, coal ash slurry, lake and reservoir sediments, pulp and paper waste, dairy waste and sewage sludge.

Also, the addition of chemical dewatering accelerants and sludge conditioning agents like aluminium sulphate and nanoparticles can enhance the rate of dewatering significantly, and can trap contaminants within the dewatering waste.

2. Choosing Geotextile for Dewatering Sludge

After conducting several tests of geotextile by different scientists ([3, 4, 6, 7]), we could analyse that geotextile has:

1. Good Filtration Efficiency
2. Reduction in the contained volume
3. Better effluent quality
4. Chemical conditioning of dredged sediment
5. Loss of solids

Geotextile Properties

Some of the commercially available geotextile types are:

1. woven monofilament
2. woven multifilament
3. woven slit-film monofilament
4. woven slit-film multifilament
5. non-woven continuous filament heat-bonded
6. non-woven continuous filament needle-punched
7. non-woven staple needle-punched
8. non-woven resin-bonded
9. other woven and non-woven combinations

From the following above types of geotextile, for performing Pressure Filter Test, woven polyester multifilament geotextile is selected. The woven geotextile was characterized for its mechanical and hydraulic properties as discussed below;

Thickness: The thickness of the woven geotextile was determined as per the guidelines provided by ASTM D5199 and the result obtained is 0.6675mm.

Mass per unit area: The mass (gm/m^2) of the geotextile was determined as per the guidelines provided by ASTM D5261; the result obtained is 272.78 gm/m^2 for woven polyester multifilament geotextile.

Mechanical Properties

Wide Width Strip Test

The wide width tensile strength and strain of the geotextile was determined as per the guidelines provided by ASTM D4595. The result obtained for woven polyester multifilament geotextile is strength 94.65 KN/m , strain = 8% in machine direction and strength = 39.55 KN/m , strain = 10% in cross machine direction.

Puncture Strength: The puncture strength of the geotextile was determined as per the guidelines provided by ASTM D4833. The result obtained for woven polyester multifilament geotextile is 0.66 KN .

Grab Strength: The grab strength of the geotextile was determined as per the guidelines provided by ASTM D4632. The result obtained for the woven polyester multifilament geotextile is strength = 0.94 KN/m in warp direction and strength = 0.56 KN/m in weft direction.

Hydraulic Properties

Permittivity: The permittivity of the geotextile was determined as per the guidelines provided by ASTM D4491. The result obtained for the woven polyester multifilament geotextile is permittivity = 0.037 s^{-1}

Apparent Opening Size: The apparent opening size of the geotextile was determined as per the guidelines provided by ASTM D4751. The result obtained for the woven polyester multifilament geotextile is $\text{AOS} < 0.075 \text{ mm}$.

3. Aluminium Sulphate as a Sludge Conditioning Material

Aluminium sulphate is a type of chemical compound usually a hydrated double sulphate salt of aluminium with the general formula $\text{XAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$, where X is mono valent cation such as potassium or ammonium.

Aluminium sulphate was used since middle ages as a sludge conditioning material to clarify turbid and waste liquids in tanning. Coagulation is the key step in sludge treatment process and is widely used to purify piped and sludge, in medicine, for cosmetics, food preparation and cloth.

In water purification, aluminium sulphate causes suspended impurities to coagulate into larger particles and then settle to the bottom of the container.

When dissolved in large amounts of slightly alkaline or neutral water, aluminium sulphate produces a gelatinous precipitate of aluminium hydroxide, $\text{Al}(\text{OH})_3$. The effectiveness of aluminium coagulants arises principally from their ability to form multi-charged polynuclear complexes with enhanced adsorption characteristics. The nature of complexes formed could be controlled by the pH of the system.

More specifically, aluminium sulphate works by neutralising the negative charge on suspended and colloidal particles to produce compact flocs suitable for easy removal by either settlement or flotation processes and promotes more efficient sludge digestion and dewatering.

4. Nanoparticles for Dewatering

Nanoparticles are sub-nanosized colloidal structures composed of synthetic or semi-synthetic polymers. Nano particles are particles between 1 and 100 nanometres in size with a surrounding interfacial layer (interior part of nano scale matter), fundamentally affecting all its properties. Nano filtration has low operating, energy costs and it increases the dewatering rate. It helps in the reduction of TDS, pesticides, VOC's, heavy metals, nitrates, sulphates, colour and turbidity.

Addition of nanoparticles modifies the structure of the sludge and provides benefits in terms of dewatering rate. The waste water samples dosed with nanoparticles exhibits faster water removal, a more permeable filter cake and hence more permeable sludge. A concentration of 2-4% of nanoparticles is required to achieve a noticeable change.

Polymers for nanoparticles:

1. Natural hydrophilic polymers:
 - a) Proteins:-Gelatin, albumin, lectins, legumin.
 - b) Polysaccharides:- alginate, dextran, chitosan, agarose
2. Synthetic hydrophobic polymers:
 - c) Pre-polymerized polymers: - Poly (ε-caprolactone) (PECL), poly (lactic acid) (PLA), polystyrene.
 - d) Polymerized in process polymers: - Poly (isobutyl cyanoacrylates ((PICA), poly (butyl cyano acrylates).



Figure 1. Nanoparticles.

5. Application of Pressure

Application of pressure increases the dewatering rate to a considerable level. Using a metal piston coated with synthetic rubber weighing roughly around 1.48kgs and additional weight of 1kg is applied.

Total pressure applied on the waste water:

$$P = F/A$$

$$\text{Force} = 23.324 \text{ N}$$

$$\text{Area} = 0.0176 \text{ m}^2$$

$$P = 23.324/0.0176$$

$$= 1.32 \text{ KN/m}^2$$



Figure 2. Metal piston coated with synthetic rubber.

6. Selection of Dosages of Aluminium Sulphate and Nanoparticles

The jar test has been widely used to determine the optimum coagulant dosage for removing turbidity by chemical pre-treatment. In this mixing apparatus was used to ensure identical mixing conditions in all tests.

For Aluminium Sulphate:

Selection of dosages of aluminium sulphate was done through jar test, following dosages were used (in 500ml waste water):

1- 550mg/l

2- 600mg/l

3- 650mg/l

For 2 minutes, fast mixing was done, for 20 minutes, slow mixing was done, further it was kept for settlement for 20 minutes.

Turbidity obtained for the following dosages:

1- 550mg/l: 15.0 NTU

2- 600mg/l: 13.1 NTU

3- 650mg/l: 14.3 NTU

Optimum turbidity obtained using Aluminium sulphate = 13.1 NTU in 500ml sample.

Therefore selected dosage of Aluminium sulphate: 600mg/l (for 500 ml sample): 6000mg/l (for 5 litres of waste water)



Figure 3. Jar test apparatus.

For Nanoparticles:

Similarly, for the selection of dosages of nanoparticles was done through jar test, following dosages were used:

1- 50mg/l

2- 60mg/l

3- 70mg/l

For 2 minutes, fast mixing was done, for 20 minutes, slow mixing was done, further it was kept for settlement for 20 minutes.

Turbidity obtained for the following dosages:

1- 50mg/l: 12.2 NTU

2- 60mg/l: 12.8 NTU

3- 70mg/l: 11.8 NTU

Optimum turbidity obtained using Nanoparticles = 12.2 NTU in 50ml sample

Therefore selected dosage of nanoparticles: 50mg/l (for 500 ml sample):

500mg/l (for 5 litres of waste water)

7. Imhoff's Cone Analysis

The Imhoff settling cone and rack is used to determine the volume of settleable solids from a known volume of waste. The sample may be fresh or saline water, or domestic or industrial waste water.

It is a useful method to determine the amount of solids entering a waste water treatment plant, also for estimating the amount of sludge to be expected during waste water treatment process. The total volume of solids in a sample is a combination of suspended and dissolved solids. Through Imhoff cone analysis we can only measure volume of suspended solids in a sample (in mg/l).

For Aluminium Sulphate:

Observations:

We have observed that the settlement came out to be 55 mm.

Result:

SVI = Settled sludge volume/MLSS

$$= 55 \times 1000 / 320$$

$$= 171.8 \text{ mg/l}$$

Conclusion: The sludge is of very poor quality.

For Nanoparticles:

Observations:

We have observed that settlement came out to be 78mm.

Result:

$$\text{SVI} = \text{Settled Volume} / \text{MLSS}$$

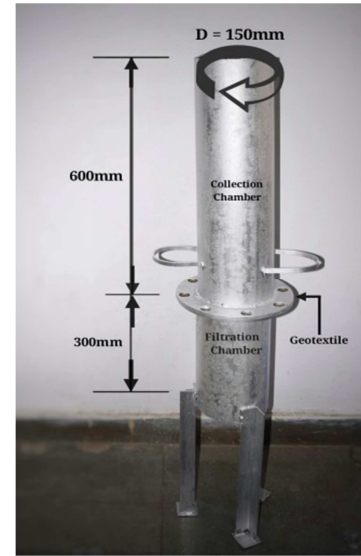
$$= 78 \times 1000 / 310$$

$$= 251.6 \text{ mg/l}$$

Conclusion: The sludge is of very poor quality.



Figure 4. Imhoff cone analysis.



(b)



(c)

Figure 5. Experimental setup.

8. Experimental Setup

Scrap material of cast iron was used for the experimental setup. One flange was welded to the collection chamber, the other to the filtration chamber.

Three legged stand (made of cast iron) was welded at the bottom for stability of the setup.

Geotextile was provided in between the two flanges and tightened with bolts. The whole setup was painted with organic paint (greyish silver), also two handles were provided for easy mobility of the setup.

Dimensions of the setup:

Cylinder Diameter: 150mm

Height of Collection Chamber: 600mm

Height of Filtration Chamber: 300mm



(a)

9. Experimental Analysis

Observation of amount of filtrate filtrated in different intervals of time:

Table 1. Through Geotextile.

| Time (min) | Quantity of sample (ml) | Discharge (m ³ /s) (10 ⁻⁶) |
|------------|-------------------------|---|
| 1 | 260 | 4.33 |
| 5 | 400 | 1.33 |
| 10 | 490 | 0.816 |
| 20 | 550 | 0.458 |
| 30 | 605 | 0.336 |
| 60 | 740 | 0.2055 |
| 90 | 810 | 0.15 |
| 24hrs | 1890 | 0.0218 |

Table 2. Using Aluminium Sulphate.

| Time (min) | Quantity of sample (ml) | Discharge (m ³ /s) (10 ⁻⁶) |
|------------|-------------------------|---|
| 1 | 410 | 6.83 |
| 5 | 525 | 1.75 |
| 10 | 650 | 1.083 |
| 20 | 750 | 0.625 |
| 30 | 845 | 0.47 |
| 60 | 1020 | 0.28 |
| 90 | 1100 | 0.203 |
| 24 hrs | 2700 | 0.0312 |

Table 3. Using nanoparticles.

| Time (min) | Quantity of sample (ml) | Discharge (m^3/s) (10^{-6}) |
|------------|-------------------------|---|
| 1 | 490 | 8.6 |
| 5 | 490 | 2.3422 |
| 10 | 670 | 1.33 |
| 20 | 800 | 0.754 |
| 30 | 905 | 0.538 |
| 60 | 970 | 0.309 |
| 90 | 1115 | 0.226 |
| 24 hrs | 1220 | 0.0416 |

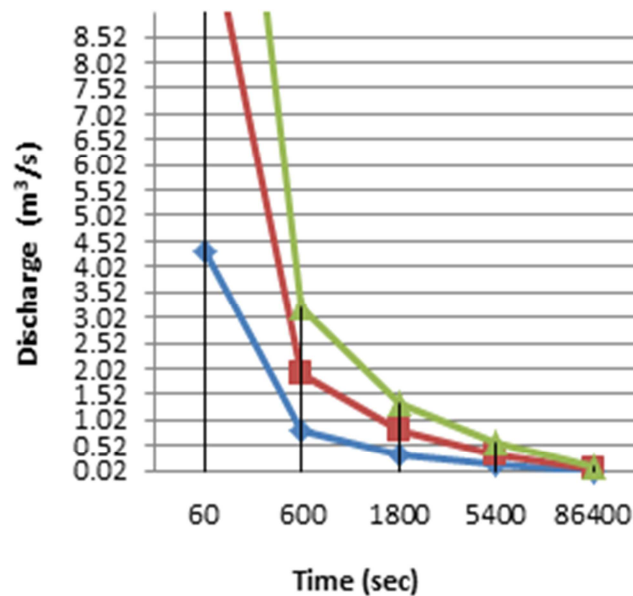


Figure 6. Discharge v/s Time graph.

- ___ Through Geotextile.
- ___ Using Aluminium sulphate.
- ___ Using Nano Particles.

The above graph demonstrates the discharge of waste water of 3 different samples in different intervals of time.

Experimental Results

First, by directly passing dairy sludge (sample 1) through geotextile, the filtrate was collected.

Further, aluminium sulphate as a conditioning agent was

added to dairy sludge (sample 2) and the filtrate was collected.

At last, nanoparticles were added to dairy sludge (sample 3) and filtrate was collected. Following are the tests conducted on dairy sludge (3 samples) with their results:

Table 4. Chemical characteristics test results.

| Sr. no | Description | Direct Sample | Using Geotextile | Using Geotextile With Aluminium Sulphate | Using Geotextile With nano-particle |
|--------|--------------------------|---------------|------------------|--|-------------------------------------|
| 1 | pH | 8.25 | 8.36 | 8.28 | 8.45 |
| 2 | TSS (mg/lit) | 1625 | 138 | 165 | 125 |
| 3 | TVS (mg/lit) | 289 | 51 | 40 | 36 |
| 4 | TS (mg/lit) | 7245 | 1612 | 1410 | 1345 |
| 5 | COD (mg/lit) | 7808 | 160 | 179.2 | 172.8 |
| 6 | BOD (mg/lit) | 3003 | 61.5 | 60.1 | 58.5 |
| 7 | SO ₄ (mg/lit) | 40 | 6.5 | 7.15 | 4.1 |
| 8 | Chlorine (mg/lit) | 0.2 | 0.1 | 0.1 | 0.1 |

Filter cake properties without adding alum:

pH = 7.8

Moisture content = 72.6%

Phosphates = 19.05 mg/l

Nitrogen = 29.96 mg/l

Specific gravity = 1.06

Dry density = 0.560

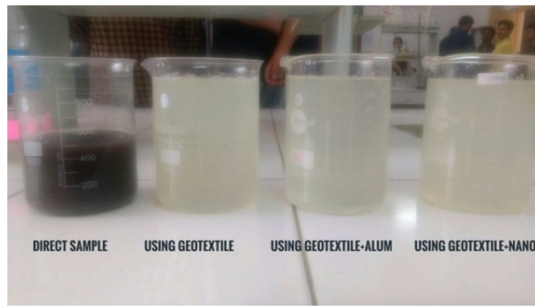


Figure 7. Comparison of different samples.

10. Conclusion

In case of woven polyester multifilament geotextile for Katraj dairy sludge with adding nano particles as sludge conditioning shows more discharge as compared to Katraj dairy sludge with addition of alum we can conclude that. Discharge rate is significantly affected due to the addition of nano material. After experimental analysis we have observed that by using Aluminium Sulphate as a conditioning agent, dewatering rate subsequently increased, also the chemical characteristics decreased, which are as TSS: 89.8%, TVS: 86.16%, TS: 80.5%, COD: 97.7%, BOD: 97.99%, SO_4 : 82.125% removal. Further we observed that, after using Nanoparticles as a coagulant, dewatering rate further increased, also the chemical characteristics further decreased, TSS: 92.4%, TVS: 87.5%, TS: 81.4%, COD: 97.8%, BOD: 98.06%, SO_4 : 86.25%. The filter cake obtained can be used as a fertilizer based on the traces of Nitrogen, Potassium Phosphate found in it, thus proving zero waste conditioning.

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