PERFORMANCE OF GEOTEXTILE TUBES WITH AND WITHOUT CHEMICAL AMENDMENTS TO DEWATER DAIRY LAGOON SOLIDS

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ABSTRACT. *Geotextile filtration tubes were used to dewater lagoon solids from a first stage dairy lagoon. Slurry was pumped from the lagoon into the tube with filtered liquid seeping from the tube and returning to the lagoon. Three tubes were filled with no chemical amendments, and three were filled using a combination of aluminum sulfate and a polymer to improve separation efficiency. Each tube was filled five to six times and then allowed to dewater before sampling and spreading. Chemical amendment significantly increased dewatering rate and improved separation efficiency from 79% to 99% for phosphorus and from 92% to 100% for organic nitrogen. Cost for the tube was approximately \$10/m^3 with no chemical amendment and cost including the chemicals was approximately \$14/ m^3.*

Keywords. *Lagoon sludge, geotextile, solids separation, polymer, alum, animal waste*

INTRODUCTION

One of the challenging aspects of managing an anaerobic lagoon is dealing with the non-soluble solids, often called “sludge”, that collect at the bottom of the lagoon. If sludge is not removed periodically, the capacity of the lagoon to act as a treatment system is compromised because the effective volume is reduced. Lagoons are often agitated before pumping in an attempt to suspend solids into the liquid mixture, but most lagoons are too large to effectively agitate the entire contents. A concern with land applying sludge is that it is typically high in organic nitrogen and phosphorus, and application fields around a lagoon that are set up to receive waste often cannot effectively utilize the large quantities of phosphorus and/or nitrogen in the sludge.

An alternative that is often used is pumping the sludge into a tanker truck or trailer and hauling it to application fields that are farther from the lagoon. This is an expensive process because of the large amount of water that must be transported. Also to make this method practical, all or most of the liquid effluent must be pumped off of the sludge before it is pumped into the tanker so that the liquid in the sludge is minimized, and this process adds to the cost, especially if it has to be done more than once.

GEO-TEXTILE TUBES. An alternative method has been proposed for the removal of solids from animal waste lagoons that utilizes a geo-textile fabric tube as a filtering device. The tube retains a high percentage of the solids and allows the liquid to be returned to the lagoon. Advantages of this method include the ability to handle the waste as a solid, and thus more easily transport it to remote locations, and the ability to schedule waste applications at a later date when crops can effectively utilize the nutrients (The waste can be safely stored for a year or more in the tube.)

Geo-textile tubes are available commercially in circumferences from 9 to 27 m (30 to 90 ft) and virtually any length. Sludge is pumped into the tube through fill ports until it reaches a safe height limit prescribed by the manufacturer. For example, a 14 m (45 ft) circumference tube can safely be filled to a height of approximately 1.5 m (5 ft). As the tube dewaters, additional sludge can be pumped in. This process of filling and dewatering is repeated until the tube is filled with solids. Then, the tube is allowed to dewater until its contents can be handled as a solid.

Geo-textile tubes were tested by Baker et al. (2002) to determine separation efficiencies for swine and dairy lagoon sludge. They used small (approx. 1 m circumference by 1 m high) hanging bags for the pilot scale test and achieved separation efficiencies of approximately 88% for total solids, 58% for Total Ammonium Nitrogen, 88% for organic nitrogen, and 88% for total phosphorus. These values were approximately the same for both species (swine and dairy.) In a full-scale test, Worley et al. (2004) found separation efficiencies of 97% for total solids, 92% for organic nitrogen, and 79% for phosphorus. It has been suggested that the addition of chemical amendments might improve separation efficiencies and increase the speed of the dewatering process. Through preliminary trials, it appears that a combination of aluminum sulfate (alum) and a polymer provide a cost-effective amendment to improve the separation efficiency of geo-textile tubes.

Objectives. The objectives of the project were as follows:

- Determine separation efficiencies for total solids, nitrogen, phosphorus, and potassium when dairy lagoon sludge is filtered through a geo-textile fabric tube with and without chemical amendments.
- Compare the two methods based on efficiency and economics.

PROCEDURE

The tests were done on the first stage lagoon at the University of Georgia research dairy in Athens. This dairy uses sawdust for bedding. Sludge was pumped from the bottom of the lagoon using a floating pump with an adjustable boom. The level from which pumping occurred was adjusted to pump as much solids as possible without overloading the pump. For the non-amended test, 14-m circumference by 30.5-m long (45 by 100 ft) geo-textile tubes (Figure 1) manufactured by T.C. Mirafi[1]

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[1] Mention of a brand name does not imply endorsement

were placed on a pad with a 1% slope from one end to the other along the long axis.

Figure 1. Geotextile Tube on Lined Pad

The pad was lined with 6-mil polyethylene plastic sheeting and located at a point elevated above the lagoon. Effluent was returned to the lagoon by diverting it to an existing manhole and drain pipe. The test was repeated three times in May, September, and December, 2003.

The test using chemical amendment was done with three 10.7-m circumference by 24.4-m long (35 by 80-ft) tubes which were all placed on similar pads. This test was done during November, 2004. Liquid aluminum sulfate (alum) was injected into the sludge at a point where the pipe left the lagoon. Polymer (Hyper-Lyte 5874, General Chemical Corporation[1]) was mixed with water to provide a 0.5% solution which was injected using a variable-speed pump at a point approximately 35 meters downstream from the alum injection port. The injection site provided contact time for the alum to react with the sludge before adding polymer. The sludge then passed through a series of 45° elbows (Figure 2) to mix the solution before being introduced into the tube.

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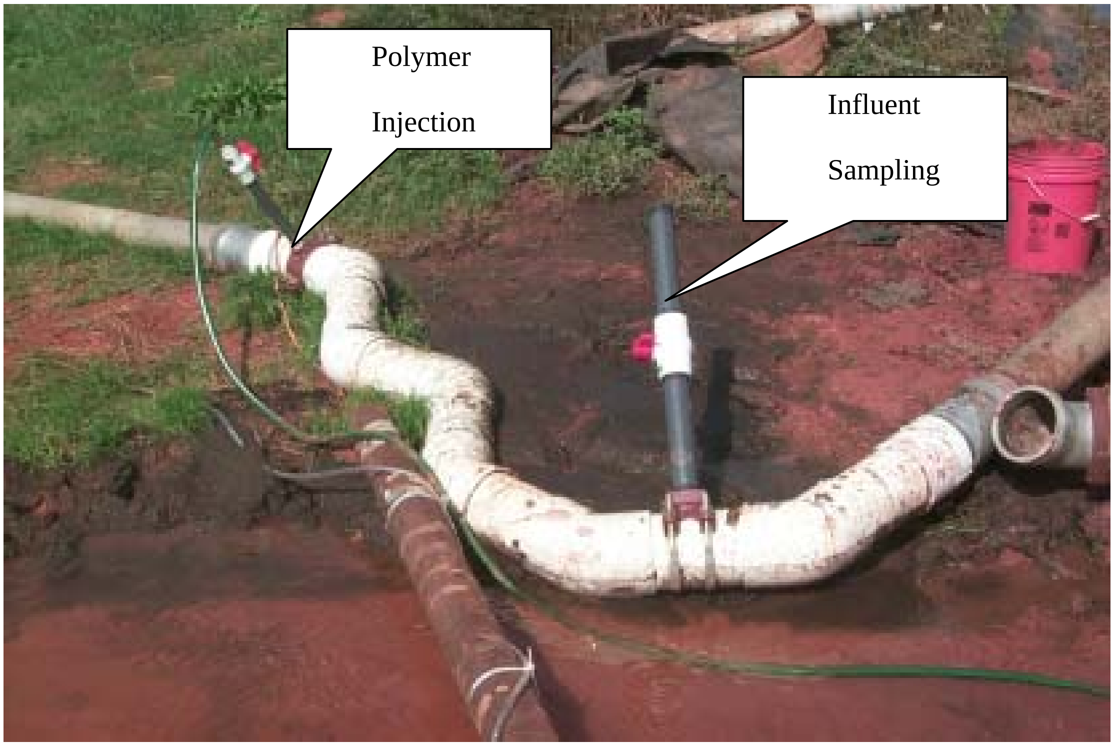

Figure 2. Piping to mix polymer

Dosing rate for alum and polymer were adjusted periodically by visual inspection of beakers of amended sludge. As flow rates varied and solids content of influent varied, it was necessary to vary the amendment rate in order to achieve adequate flocculation. Adequate flocculation was evaluated by visual inspection of samples pulled from the sampling port (Figure 2). It was observed that dosing rate was closely tied to total solids flow rate rather than total liquid flow rate. Because of equipment limitations, adjustment of alum flow rate was very limited, so alum was added at higher than the optimal rate for much of the test. Liquid alum dosing rate varied from 0.5% to 1.5% depending on sludge flow rate, and averaged approximately 1%. Dosing rate for the 0.5% solution of polymer started at 0.5%, but with experience, the rate was reduced to 0.1% to 0.2%. Average dosing rate was approximately 0.15%.

Influent material was sampled through a port in the pipe filling the tube (Figure 2.) Subsamples were taken periodically throughout each pumping event. Effluent was sampled as it flowed from the tube at several locations. Retained solids (the material left inside the tube) were sampled after they had dewatered sufficiently to be handled as a solid. Retained solids samples were taken at three locations along the length of each tube. At each location, samples were pulled from near the top, middle, and bottom of the tube. Each sample type was respectively combined, thoroughly mixed and sub-sampled for analysis per event.

Quantity and flow rate of liquid pumped into the tube was measured using a Greyline Instruments PDFM 4 Doppler meter[1] (Figure 3).

Figure 3. Doppler Flow Meter

The University of Georgia Agricultural and Environmental Services Laboratories tested all samples for Percent Moisture, Total Kjeldahl Nitrogen (TKN), Ammonium Nitrogen (AN), Nitrate Nitrogen, total Phosphorus, and total Potassium, as well as other minor minerals. Percent Total Solids were calculated as 100 – percent moisture. Total organic nitrogen was calculated as TKN – AN. Phosphorus was given as P_2O_5 equivalent, and potassium was given as K_2O equivalent.

Moisture was determined gravimetrically by drying at 135^{o} C for 2 hours (AOAC, 1996). Total Kjeldahl nitrogen was determined by a digestion with concentrated sulfuric acid and catalyst salts of potassium sulfate, copper sulfate, and titanium oxide at approximately 385 C until digests were clear. Total nitrogen was determined in the manure digest by Kjeldahl distillation into boric acid and back titration of the boric acid to determine ammonium equivalence (Clesceri et. al, 1997). Ammonium and

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nitrate nitrogen were determined separately by consecutive steam distillations using magnesium oxide, without and with Devarda alloy, respectively (Bremner, J. M., 1965). Phosphorus, potassium, and other mineral fractions were determined by inductively coupled plasma emission spectroscopy following a microwave digestion with concentrated nitric acid (Maxfield and Mindak, 1985).

RESULTS

Sludge for the first series of tests (non-amended) was pumped from an area of the lagoon just west of the input pipe. By the end of these tests, much of the solids had been removed from this area; therefore the pump was relocated for the second series to a point just east of the input pipe. Solids content of the lagoon at this new location was very high (sludge layer reached almost to the top of the water), however, as will be demonstrated in these results, the characteristics of the solids turned out to be different. Specifically, the solids from the first location were denser, containing a higher percentage of sand, while the solids from the second location contained a higher percentage of partially decomposed sawdust. Caution must be taken, therefore in comparing the results of the two trials.

Densities and solids content of the influent and the dewatered solids are shown in Table 1. In both trials, attempts were made to pump sludge with as high solids content as possible. The 30-Hp pump was working at capacity, and flow rate would drop dramatically, if solids content got too high. Solids content (% by weight) in the second test was much lower than in the first, although the thickness and viscosity were similar as measured by the ability of the pump to move the sludge. After inspecting the data, it was found that the density of the two sludge streams was different (because of the different pumping location.) Further evidence of the difference in solids is the fact that the dewatered solids from the second test were higher in moisture (% by weight), but had a lower density. Also, if the density of dewatered solids is compared to that of water (1000 kg/m3), solids from the first test were denser than water, while solids from the second test were less dense. The reason for this difference was the presence of more sand in the solids in the first test. Most of the solids in the second test were partially decomposed sawdust - a difference confirmed by visual assessment. Soluble solids were measured and recorded for the second phase of the test, but not for the first, so no comparison could be made based on that criterion.

Table 1. Density and solids content for two tests

	Mean Solids Content of Influent (% by weight)	Density of Influent (kg/m^3)	Mean Solids Content of Dewatered Tube Contents (% by weight)	Density of Dewatered Tube Contents (kg/m^3)
No Chemical Amendment	5.3	1049	19.0	1054
Chemical Amendment	2.7	1000	16.0	923

Separation efficiencies for all tests are shown in Table 2 and in Figure 4. The data show significant improvement in separation efficiency using chemical amendment for phosphorus and organic nitrogen, the two elements that tend to be found in the solid partition of the waste stream. Note that separation efficiencies for potassium and ammonium nitrogen actually decrease with chemical amendment since these elements tend to stay with the liquid fraction.

Table 2. Separation Efficiencies (%) for all tubes

	Total Solids	TKN	NH_4 N	Organic Nitrogen	P_2O_5 Equivalent	K_2O Equivalent
No Chemical Amendment						
Tube 1	97	82	50	90	81	35
Tube 2	97	79	41	94	77	44
Tube 3	97	80	41	93	80	29
Average	**97**	**80**	**44**	**92**	**79**	**36**
Chemical Amendment						
Tube 1	88	86	19	101	97	14
Tube 2	90	86	20	102	99	30
Tube 3	93	86	20	102	100	29
Average	**90**	**86**	**20**	**102**	**99**	**24**

[1] Separation Efficiency calculated as [(influent mass-effluent mass)/influent mass] x100

One surprising result was that the efficiency for total solids separation went down with chemical amendment. This can be partially explained by the fact that the solids content of the influent for the second test was about half that of the first (due to differences in density), therefore if the effluent for both tests had the same solids content, the removal efficiency would be significantly lower for the second test. In addition, it was noted that on a few samples, primarily in Tube 1, the solids content of the effluent was significantly above average (average was 0.32% and two results for Tube 1 were 0.65% and 0.40%.) On further examination of the data, it was found that the solids content of the effluent was highly correlated to the aluminum content. Aluminum concentrations for these two samples were 416 and 187 ppm respectively, while values for more typical samples were 3 and 35 ppm. It is evident from these results that on these early tests, aluminum sulfate was being added at a rate too high to react with the organic solids, and it was coming out of the tube with the liquid fraction. As the dosing rates were adjusted, alum tended to stay in the tube with the solids and solids content of the effluent declined significantly. It should be noted that visually, even the early effluent looked much clearer than that from the tubes with no chemical amendment.

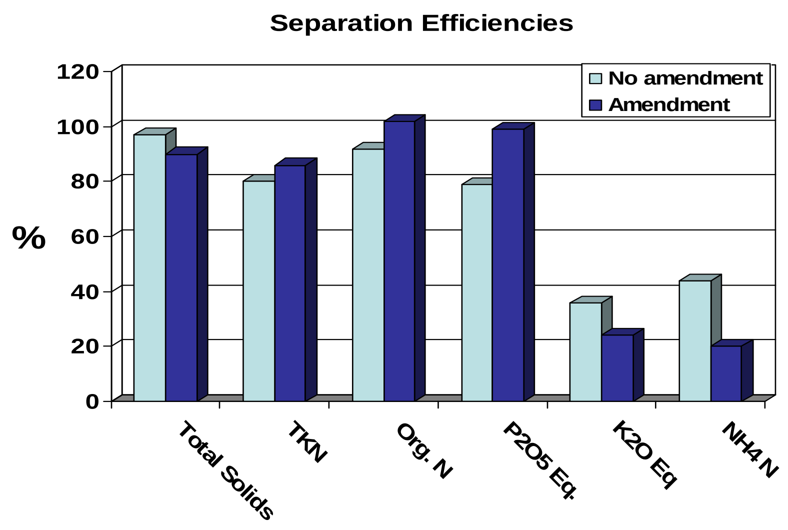

Figure 4. Percentage of Nutrients Retained in Tube with and without Chemical Amendment

DEWATERING TIME

Without chemical amendment, tubes would typically take 2 to 5 days to dewater sufficiently to warrant refilling (a minimum of 0.3 to 0.4 m below full was desired before refilling.) With chemical amendment, much more sludge was pumped into the tube before it was filled the first time since the tube was dewatering very quickly. For instance, while the smaller tubes used in the chemical amendment test only held approximately 60% as much as the non-amended tubes, an approximately equal volume (315 m^3) of sludge was pumped into each tube during the first fill cycle. Once it was full, it would typically take only 1 or sometimes 2 days before it was ready to be refilled.

COST

The test with no chemical amendment was run using 14 x 30.5-m (45 x 100 ft) tubes which cost approximately $2,400 each and contain approximately 225 m^3 of solids when filled and dewatered, so the cost is approximately $11/ m^3 of dewatered solids. The tube could have been refilled additional times, increasing the volume of solids, and thus reducing the cost, but the theoretical maximum amount of solids that a tube this size could contain would be approximately 250 m^3. At this rate, the cost would be approximately $9.60/ m^3.

The tubes used in the experiment with chemical amendment were 11.5 x 24.4 m (37.5 x 80 ft) and contained approximately 130 m^3 (32,000 ft^3) of solids after filling and dewatering. The average volume of sludge pumped through the three tubes was 782 m^3. Approximately 4.4 m^3 of aluminum sulfate and 1.17 m^3 of 0.5% polymer solution were added to the influent for each tube. The approximate cost for this aluminum sulfate was $750 per tube. The cost of the polymer was approximately $21. As stated earlier, alum was being applied at a rate higher than needed because of limitations in equipment. Subsequent tests with different equipment showed that the necessary rate of alum was approximately 0.3 to 0.4%. If this dosing rate had been used, the total amount of alum needed would have been 2.7 m^3, and the cost of alum would have been approximately $460, so the total chemical cost for filling a tube this size would be approximately $500. The cost of the tube is approximately $1500, and it is not reusable, so it would cost approximately $2,000 for each tube in addition to the cost of pumping and injection equipment. The total cost for tube and chemicals would then be approximately $15/ m^3 of dewatered solids. Again, if the tube were filled additional times, the theoretical maximum capacity of the tube is 147 m^3, so the minimum cost would be approximately $13.60/ m^3.

It should be pointed out that larger diameter tubes reduce the cost per m^3, and the use of larger tubes would be more feasible with chemical amendment since the improved solid/liquid separation characteristics would aid in getting liquids to the surface of these large tubes. Tubes are available in 18.3 and 27.4 m (60 and 90-ft) circumferences as well as the smaller sizes used in these tests.

CONCLUSIONS

These experiments demonstrated that a geo-textile filtration tube was successful in dewatering lagoon solids from a first stage dairy lagoon. The dairy uses sawdust as bedding and does not utilize solids separation for the incoming waste stream. The addition of alum and a polymer improved the solid/liquid separation process allowing the tube to be refilled sooner and keeping more solids (including phosphorus and organic nitrogen) with the solid fraction retained in the tube. Improved separation of liquid components (including ammonium nitrogen and potassium) resulted in more of these nutrients being removed with the liquid waste stream. The difference in the characteristics of sludge being pumped during the two phases of the experiment (Phase 1 sludge contained more sand, and phase 2 contained more sawdust) made strict comparison of the results difficult. Some of the differences however, were clear. Removal rate of phosphorus increased from 79% to 99% and of organic nitrogen from 92% to 100% (data showed 102% which is explained by random sampling error) by adding chemical amendment to the process.

Chemical cost is primarily a function of the amount of organic solids in the sludge. Dosing rates of chemicals need to be increased as organic content increases. In order for a system to operate efficiently, sensors would need to be employed to estimate both flow rate and density of the sludge being pumped, so that chemical dosing can be properly adjusted. The cost of the process was higher with chemical amendments, so judgment is called for in deciding whether or not the additional cost is warranted by the improved characteristics of the outflow. If the tube works sufficiently well for a given lagoon and given situation without chemicals, it may not be advisable to add chemicals. In cases where the tube does not function well, but tends to clog, chemical amendment might be the only means of making tubes work.

One would expect that the use of this method (either with or without chemical amendment) to reduce solids in a lagoon would result in a more balanced and desirable fertilizer remaining in the lagoon since the liquid stream, containing ammonium nitrogen and potassium but very little phosphorus, is returned to the lagoon. This process would therefore increase the N/P ratio more closely matching the nutrient needs of most plants. The solid fraction would be higher in phosphorus and lower in available nitrogen, but this material can be transported further from the lagoon and used on land that is phosphorus deficient in order to better utilize available resources.

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