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Full Length Research Paper

Dewaterability of sludge digested in extended aeration plants using conventional sand drying beds

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Dewaterability of unconditioned sludge digested in full scale and lab scale experiments using either extended aeration (EA) or anaerobic digestion were compared on full and lab scale sand drying beds. Sludge digested in EA plants resulted in improvement in sludge dewaterability compared to sludge digested anaerobically. This was demonstrated by comparing capillary suction time, time to filter a specific amount of water, the sludge volume index and the dry solids content. In addition, sieve analysis results from both types of sludge after drying in sand drying beds clearly shows that the grain portions in the fine range in case of anaerobically digested sludge are more than that in case of EA sludge. This was also clear in microscopic photos of samples. The microscopic photos of EA stabilized sludge are characterized by larger colonies of flocs and more open structure than anaerobically digested sludge.

Key words: Sludge, dewaterability, digestion, sand drying beds, particle size distribution.

INTRODUCTION

Dewatering of digested sludge at wastewater treatment plants is an essential and costly part of wastewater treatment process. Dewatering reduces water content in sludge from about 95% to 25 - 30%, which reduces final volumes for better handling, storing and transportation. The selection of the dewatering system is determined by the type of sludge to be dewatered, its characteristics, space availability and the capital cost (Metcalf and Eddy, 1991). Several mechanical processes are used in developed countries for this purpose. However, in developing countries with hot climates, sand drying beds is one of the most used and most economical methods for sludge dewatering in small plants. In fact sand drying beds is the standard method used for domestic sludge dewatering in Jordan for both small and large wastewater treatment plants. The efficiency of this process depends on both the rate and extent of dewatering. In a sand drying bed, sludge is placed in a 200 – 300 mm layer and allowed to dry. The sludge is dewatered by drainage through the sludge mass and the underlying sand and gravel and by evaporation from the surface exposed to air (Metcalf and Eddy, 1991).

Experience in the existing plants in Jordan has shown that during summer time , when sand and gravel are new and the drainage layers are adequately placed, the sludge dries well but during winter times efficiency deteriorates. Experience has also shown that dewaterability varies widely from sludge to sludge and that the method of sewage sludge stabilization (whether aerobically or anaerobically) has an effect on the dewatering properties of sludge.

Anaerobic digestion is the most used method for sludge digestion in conventional activated sludge and attached growth processes. Aerobic digestion is more useful in small to medium wastewater treatment plants due to low capital cost and high energy consumption (Barbusinski and Koscielniak, 1997). Autothermal thermophilic aerobic digestion is becoming more popular. Most new and planned wastewater treatment plants in Jordan are using the extended aeration configuration with no primary treatment (Ammary, 2007). In these plants, digestion is achieved during the aeration/anoxic periods in the aeration tank. The sludge from the secondary clarifier is transferred to a holding tank before it is spread on sand drying beds. No additional separate sludge digestion step is practiced in these plants.

Both aerobic and anaerobic sludge digestions lead to deterioration in sludge dewaterability (Novak et al., 1977;

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Katsiris and Kouzeli-Katsiri, 1987; Bruss et al., 1993; Novak et al., 2003). Aerobic and anaerobic digestion resulted in a reduction in the dewatering rate of sludge measured as capillary suction time (CST) by several folders of magnitude as compared to undigested sludge (Novak et al., 2003). This has been attributed to the presence of biopolymer colloids which are released to solution as a result of digestion (Murthy et al., 2000). The extent of deterioration was related to the cation content of wastewater for aerobically digested sludge (Murthy and Novak, 1999) and to the reduction of iron concentration in anaerobically digested sludge (Bruss et al., 1993; Nielsen and Keiding, 1998). Digestion changes particle size distribution by breaking down organic debris (Karr and Keinath, 1978; Lawler, 1986; Nellenschulte and Kayser, 1997). The effects of sludge size and floc size distribution of digested sludge have been considered as two of the most important parameters that affect sludge dewaterability (Karr and Keinath, 1978; Olboter and Vogelpohl, 1993). As particle size decreases dewaterability decreases. Fines with sizes between 0.001 and 0.1 mm have the most effect (Karr and Keinath, 1978) as these tend to blind sludge cake during filtration (Karr and Keinath, 1978; Novak et al., 1988).

The present study compares the efficiency of sand drying beds to dewater sludge digested anaerobically against sludge digested in the aerobic/anoxic stages in extended aeration (EA) plants. The establishment of a trend between sludge dewaterability and the stabilization method opens up the possibility to modify the treatment processes in order to suite existing facilities and to suggest sludge drying options depending on existing or planned treatment systems.

MATERIALS AND METHODS

A range of activated digested sludge samples were collected from two different full scale municipal wastewater treatment plants, one using aerobic/anoxic stabilization in EA plants and the other using anaerobic stabilization. The dewaterability of both types of sludge was comparatively investigated without the addition of conditioning agents. The biological unit of Central Irbid wastewater treatment plant consists of a trickling filter followed by a conventional activated sludge process. The detention time in this stage is about 10 to 12 h. Primary and secondary sludge was then diverted together into the air-tight digester to be anaerobically stabilized. The biological stage at the extended aeration plant at Ramtha wastewater treatment plant consists of two aeration tanks that are separated into four zones designed to help achieve biological nutrient removal and provide semi-plug flow conditions to reduce short circuiting. Each extended aeration tank is equipped with 6 surface aerators for oxygenation of wastewater. Three submersible mixers hold the mixed liquor in suspension and maintain the circulation of flow. The minimum hydraulic detention time in the tank exceeds 24 h and at the time of this study was about 3 days. The sludge age is calculated to exceed 25 days. The excess sludge from the secondary clarifiers is stored in a holding tank before being applied into sand drying beds. No separate digestion of sludge was practiced and there was no primary sludge in the plant as no primary sedimentation tank was present.

In addition, the digested sludge from two lab scale digestion tanks, one using aerobic/anoxic digestion in EA mode and the other using anaerobic digestion, were compared in various ways. Samples were compared after 30 days of digestion. The digesters had 10 liters volume each and were operated at room temperature. Dissolved oxygen content in the EA lab scale plant ranged from 0 during the air off period to about 2 mg/L during the air on period. The alteration between the air on period to the air off period was intended to resemble the aeration scheme in the extended aeration plants for nitrogen removal. The air off period was set at 10 min every 50 min of aeration. Sludge dewatering rate was determined using the Capillary Suction Time (CST) test, according to Standard Methods (APHA, 2000) test 2710 G. Each measurement was conducted in triplicate and the average is presented here. Sludge drainability from lab scale experiments was determined using two identical lab scale sand filter boxes. The galvanized steel boxes (60 cm x 40 cm x 10 cm) were prepared and filled with 5 cm depth sand having a diameter of 3 - 10 mm, followed by 3 cm depth sand with a diameter of less than 2 mm (the same sequence is used in full scale sand drying beds). A volume of 5 L of both aerobically and anaerobically digested sludge were applied to each sand filter box and the infiltrate collected in a graduated measuring cylinder. The volume of filtrate was measured and recorded at specific time intervals. Each drainability test was conducted three times and the results averaged.

Particle size distribution of the digested sludge was evaluated using sieve analysis of the dried digested sludge. In addition, microscopic photos of the sludge were taken. Total solids, volatile solids, suspended solids and Sludge Volume Index (SVI) were all determined in accordance with Standard Methods (APHA, 2000).

RESULTS

Anaerobic digestion of sludge from both the full scale and lab scale digestion tanks resulted in an average reduction of volatile solids (VS) by about 30 to 40%. On the other hand, EA digested sludge resulted in about 50 to 60% average reduction in VS (Figure 1).

Sludge volume index

The sludge volume index for both EA digested sludge and anaerobically digested sludge was low, with lower values for EA digested sludge (Figure 2) suggesting better settleability than anaerobically digested sludge.

Capillary suction time

The dewatering rate of anaerobically digested sludge measured as CST was about 600 to 800 s compared to 100 to 200 s for EA digested sludge (Figure 3).

Filtered volume

The sludge drainability results indicate that it is easier and faster for water in EA digested sludge to be filtered under gravity through sand drying beds than anaerobically digested sludge (Figure 4). Out of 5 liters of EA digested sludge, about 2000 ml were filtered in about

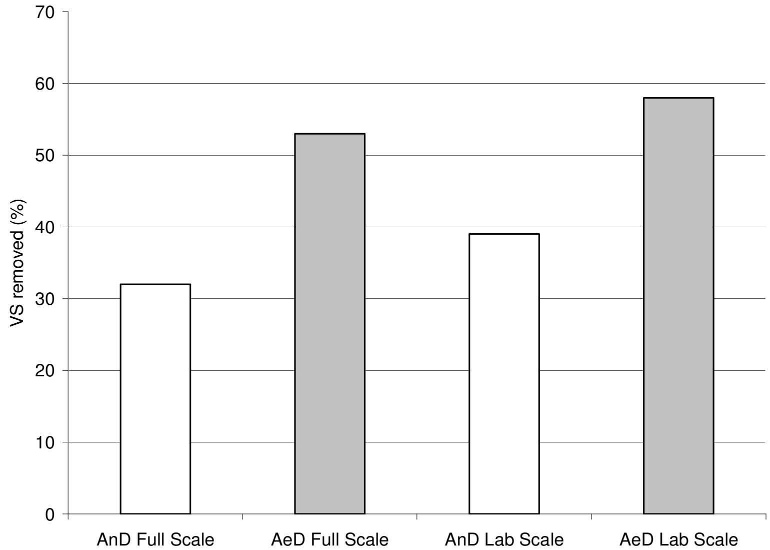


Figure 1. Percent of volatile solids removed during aerobically digested (AeD) and anaerobically digested (AnD) sludge for both full and lab scale experiments.

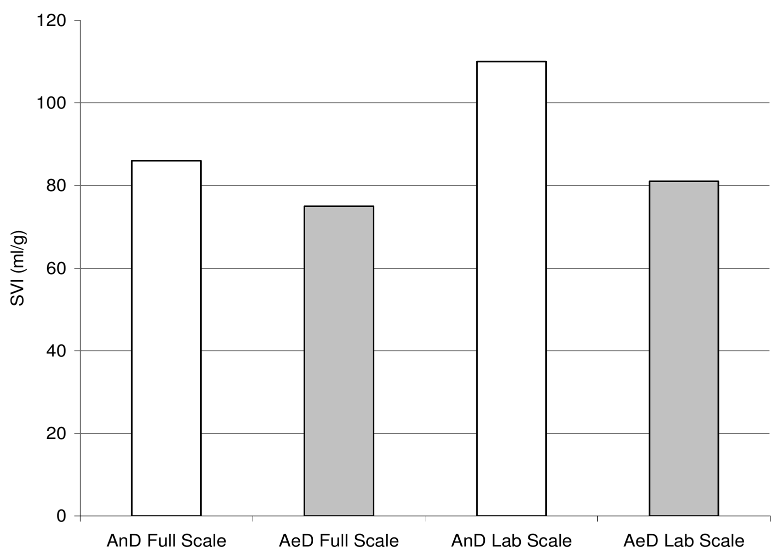


Figure 2. Sludge volume index (SVI) of digested sludge.

4 h, while only 1700 ml of anaerobically digested sludge were filtered in the same period. The rate of filtration decreased substantially after about 40 min of filtration for both digestion methods.

Floc sizes

Sizes of floc particles affect the total particle surface area and the porosity formed from these particles, which therefore has significant effect on dewaterability. To examine the floc sizes of different types of sludges, sieve analysis of dried digested sludge and microscopic photos were taken. The sieve analysis of sludge samples show clearly that the grain portions in the fine range in case of anaerobically digested sludge are more than in the EA digested sludge (Figure 5).

Microscopic photos of flocs that have been stabilized in EA plants are characterized by an open structure of large colonies of particles that have been flocculated giving them a good settling character. On the other hand, anaerobically digested sludge has small discrete flocs

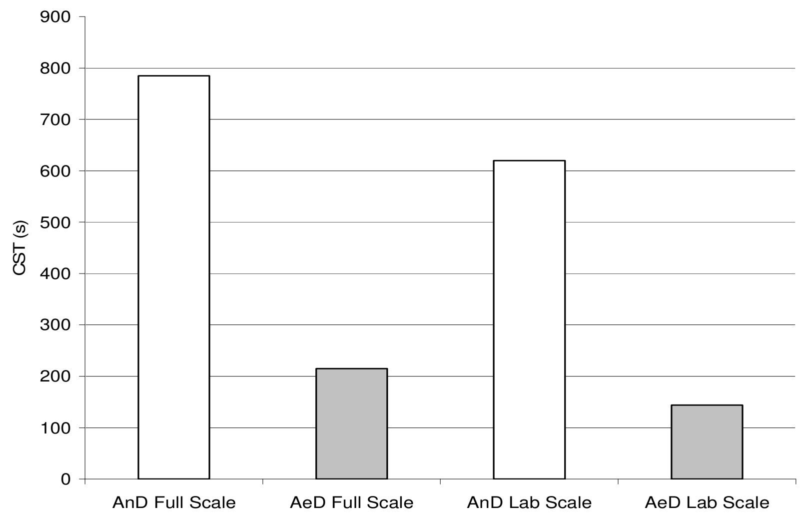


Figure 3. Capillary Suction Time (CST) for aerobically digested (AeD) and anaerobically digested (AnD) sludge for both full and lab scale experiments.

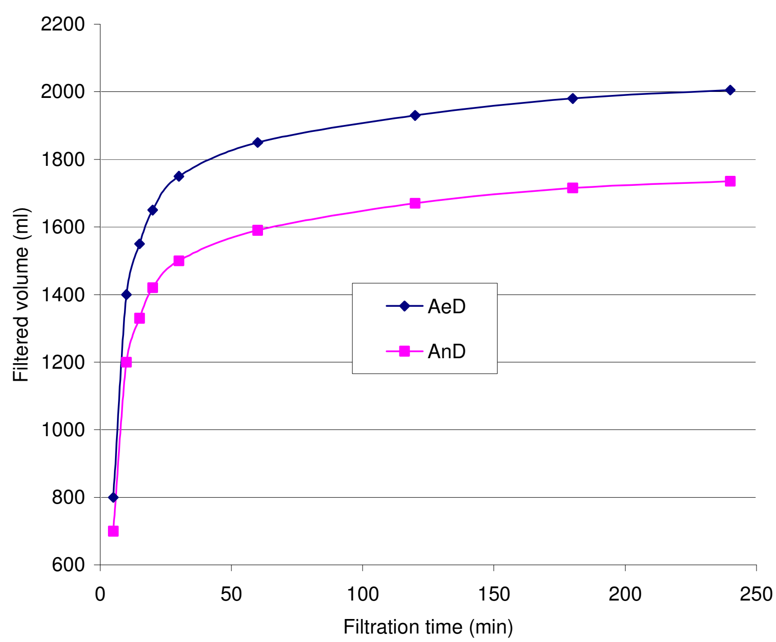


Figure 4: Filtered volume of through lab scale sand filter bed for lab scale experiments.

(Figure 6).

DISCUSSION

The main objective of sewage sludge digestion is to decompose easily degradable organic matter into inorganic materials. This results in reducing volatile solids content, reducing the unpleasant smell of the sludge and eliminating sludge putrescibility. These are usually accomplished through anaerobic mesophilic digestion and aerobic digestion at ambient conditions and recently using autothermal thermophilic aerobic digestion (Schwinning et al., 1997).

Sludge produced in extended aeration plants with high detention times and sludge ages achieves the above objectives of sludge digestion. This is true despite the fact that the EA process may not be considered a digestion process by many researchers, as usually the sludge from

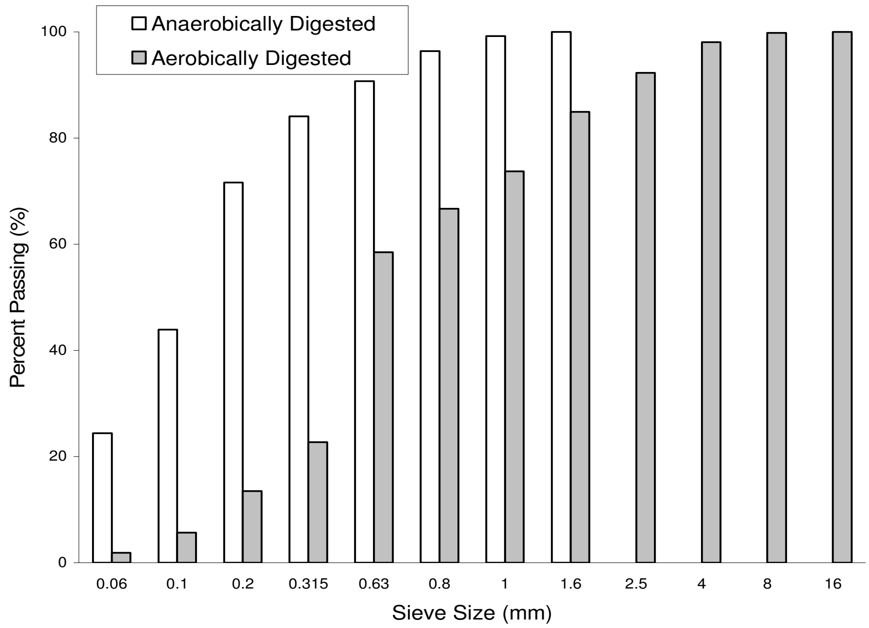
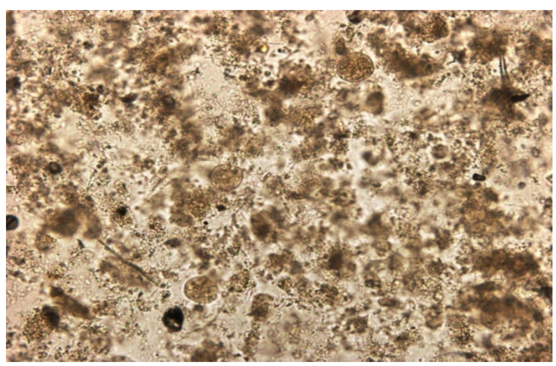
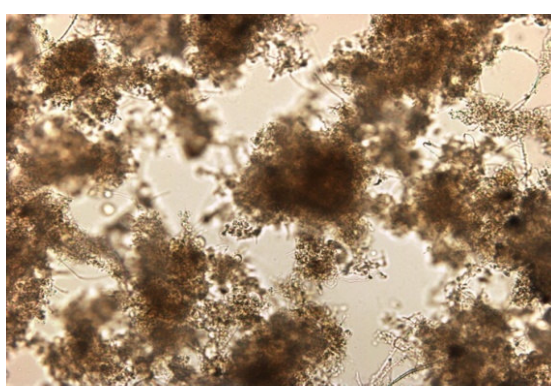


Figure 5: Particle size distribution of dry dewatered sludge from full scale plants.



(a) Anaerobically Digested Sludge



(b) Aerobically Digested Sludge

Figure 6: Sample of microscopic photos of lab scale sludge samples that have been digested either anaerobically or aerobically.

extended aeration plants is further digested either aerobically or anaerobically. However, the EA sludge produced was odorless and its putrescibility was eliminated.

The improvement of dewaterability of aerobically digested sludge over anaerobically digested sludge may be explained by the effects these types of digestion have on particle size distribution and structure. Particle size of sludge is believed to be the most important parameter that affects the dewaterability of sludge (Karr and Keinath, 1978; Olboter and Vogelpohl, 1993). As particle size increases, the filtration rate of sludge improves and the cake moisture content is reduced. The effects of various parameters on dewaterability might all be explained from effects of these factors on particle size distribution. Supercolloidal solids (1 - 100 µm) have the most significant effect due to blinding of sludge cake and filter medium by these sizes of particles (Karr and Keinath, 1978).

Sieve analysis results from both types of sludge after drying in sand drying beds clearly show that the grain portions in the fine range in case of anaerobically digested sludge are more than that in case of aerobically digested sludge. This was also clear in microscopic photos of samples. The microscopic photos of aerobically stabilized sludge were characterized by larger colonies of flocs and more open structure than anaerobically digested sludge.

As mentioned earlier, both aerobic and anaerobic sludge digestions lead to deterioration in sludge dewaterability (Novak et al., 1977; Katsiris and Kouzeli-Katsiri, 1987; Bruss et al., 1993; Novak et al., 2003) and in a reduction in the dewatering rate of sludge as compared to undigested sludge (Novak et al., 2003). Digestion changes particle size distribution by breaking down organic debris (Karr and Keinath, 1978; Lawler, 1986; Nellenschulte and Kayser, 1997). It seems that the unconventional digestion of sludge in EA plants with aeration periods and anoxic periods did not deteriorate the particle size distribution as the anaerobic digestion. The extended aeration of sludge in extended aeration plants with low food to microorganisms ratio may have produced better flocculated particles that resulted in smaller fraction of fines than anaerobically digested sludge.

Conclusion

Full and lab scale experiments have shown that aerobically digested sludge in extended aeration plants has better dewatering efficiency on sand drying beds than anaerobically digested sludge. This was shown by comparing a number of parameters that are usually used to characterize the dewaterability of wastewater sludges.

They included dry solids content, capillary suction time (CST), sludge volume index (SVI), volatile and fixed solids, particle size distribution, fraction of small particles (fines) and drainage test. It is recommended that sand drying beds be used in Jordan for extended aeration plants as these produce low volumes of sludge that has better dewatering properties than anaerobically digested sludge.

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