ANAEROBIC DIGESTION OF SEWAGE SLUDGE USING THE ANOXIC GAS FLOTATION (AGF) PROCESS

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ABSTRACT

The AGF (Anoxic Gas Flotation) process is an improved anaerobic digestion process which increases the solids retention time (SRT) of anaerobic digesters while improving the rate of volatile solids, PCOD, and organic nitrogen conversion to soluble and gaseous products. The results of a pilot plant operated for one year at various SRT's and HRT's are presented. The substrate was a thickened, 6% solids slurry of primary and waste activated sewage sludge. The HRT's ranged from 5 to 17.5 days. PCOD loadings of 11 kg/m^3/day, and volatile solids loadings of 6.5 kg/m^3/day were maintained for prolonged periods of time. The hydrolysis rate of PCOD was less than one day in the AGF digester. SRT/HRT ratios of 3.35 were achieved. The factor limiting higher SRT/HRT ratios was the accumulation of inorganic sands and silts delivered to the digester during winter storms. The AGF process produced a thickened, well stabilized residual, having the odor of soil, while achieving a 72% volatile solids reduction.

KEYWORDS

Anaerobic digestion, contact process, gas flotation, sewage sludge, organic loading, volatile solids destruction, SRT/HRT ratio, particulate hydrolysis rates, biogas production, inorganic solids.

INTRODUCTION

In the digestion of sewage sludge, maximum digester efficiency is achieved by prethickening solids prior to digestion. Concentrated end products are produced in the anaerobic reactor as a result of prethickening. High concentrations of ammonia and hydrogen sulfide inhibit anaerobic degradation. The production of concentrated inorganic end products also leads to excessive calcite, struvite, or vivianite scale formation.

Increasing organic loading through the use of retained biomass systems has not been practiced because of the inadequacies of common separation and concentration techniques. Fixed film processes, or systems that retain biomass as aggregates, are not particularly suited for treating waste, such as sewage sludge which contain substantial concentrations of suspended solids and oil and grease. Cross flow membrane system have limited application since they are subject to oil and grease clogging, and have been demonstrated to disrupt the bacterial community (Brockmann and Seyfried, 1996).

and increasing volatile solids destruction (Burke, 1992). A number of investigators (Pfeffer, 1968; Parkin & Owen, 1986) have shown that volatile solids destruction is directly proportional to the solids retention time (SRT). Since a conventional digester has a SRT/HRT ratio of 1.0, the beneȚt of a retained biomass system can be measured by the SRT/HRT ratio obtained for a given ințuent concentration. Pfeffer (1968) demonstrated a maximum SRT/HRT ratio of 2.0, for ințuent solids greater than 5%, while using a second digester as a thickener. The low ratio resulted from the large HRT required to accomplish thickening in the second digester. Poling (1985) achieved an SRT/HRT ratio of 1.5 using a centrifuge to concentrate digested prinary sludge. No increase in volatile solids destruction accompanied the higher solids retention time.

THE AGF PROCESS

The AGF (Anoxic Gas Flotation) process is simply a liquid solids separation procedure. Since oxygen is toxic to anaerobic bacteria, anoxic gas, or gas without oxygen, is used to țoat and concentrate bacteria from the digester (Burke, 1992). Flotation is less expensive when compared to other separation processes. It is not harmful to anaerobic bacteria, nor does it disrupt the bacterial community. Since țotation does not impair the bacterial community, loadings can greatly exceed the limits experienced with disruptive devices such as cross țow membranes (Brockmann and Seyfried, 1996). Flotation is an inexpensive tranquil separation process. The AGF process is an effective separation technique since anaerobic bacteria naturally tend to țoat rather than settle. Methane gas, biogas from the digester, or any other anoxic gas can be used to accomplish the separation. Figure 1 below presents an illustration of the process.

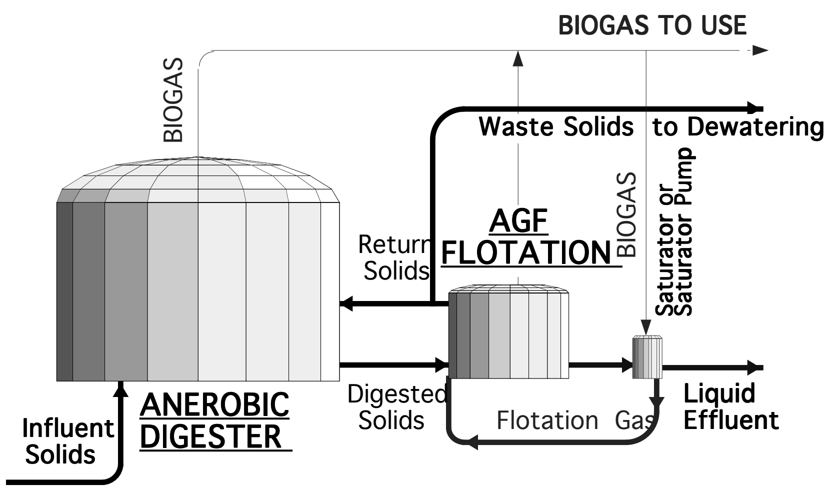

FIGURE 1. AGF Process

AGF PILOT PLANT OPERATION

An AGF pilot plant was constructed and installed at the East Division wastewater treatment plant in King County, Washington. The pilot plant was operated for 12 months. The pilot plant consisted of an AGF digester and a conventional digester which served as a control for gauging the AGF digester's performance. The conventional digester was the same size as the AGF digester (1,600 L). Both were mechanically mixed and operated at 35°C. The AGF digester incorporated a țotation separator, efțuent tank, methane saturator, and a polymer feed system. Dilution, or elutriation water was added to the efțuent tank to țush dissolved solids and inhibitory products from the system. Compressed methane gas was used as the țotation gas. Thickened primary and waste activated sludge was used as the substrate for both the conventional and AGF digesters. The

39% waste activated sludge on a volatile solids basis. The total solids content averaged 5.8% throughout the operating period. The solids were, on average, 78% volatile. The digesters were fed once a day over a 30 minute period.

OPERATING RESULTS

The AGF separator removed 97.5% of the suspended solids. The total solids, volatile solids, fixed solids, volatile acids, PCOD, and organic nitrogen were thickened by 30% in the separator. Soluble COD, ammonia, alkalinity, and dissolved solids were elutriated, or flushed from the system through the separation process. As a result of solids recycle, the solids content of the AGF digester was 2.3 times the concentration of the conventional digester. During the winter months the fixed solids in the AGF digester increased from 20,000 mg/L to 36,000 mg/L. The buildup of fixed solids was the limiting factor in achieving the maximum SRT/HRT ratio. In response to the fixed solids build-up, the total solids increased to a maximum concentration of 75,000 mg/L. During the last five months of operation the particulate COD remained constant at approximately 65,000 mg/L.

The TKN concentration in the AGF digester was only 1.3 times the concentration of the conventional digester (4,000 mg/L vs. 3,000 mg/L). Ammonia nitrogen was flushed from the AGF digester resulting in lower TKN values. The ammonia concentration of the AGF digester was directly related to the combined flow volume (influent plus recycled solids) flushed through the digester. The average ammonia concentration of the AGF digester was 1,100 mg/L. The conventional digester had an average concentration of 1,800 mg/L.

The biogas quality from both the AGF and conventional digesters was similar (61% methane). After feeding, gas production would rise sharply and then decrease throughout the remainder of the day. Over 90% of the influent COD, that was degraded, was converted to gas in 24 hours or less. The hydrolysis rate of particulate matter in the AGF digester was very rapid.

MASS BALANCE

At 35°C the theoretical methane gas production rate is 395 Liters of methane per Kg of COD removed. Table 1 below, presents COD reductions from the water chemistry mass balance and the gas production values.

TABLE 1. COD REDUCTIONS AND METHANE PRODUCTION

DIGESTER / PERIOD	**HRT (days)**	**SRT/HRT Ratio**	**COD Load-ing (Kg / m^3/ day)**	**COD Reduc-tion from Water Mass Balance**	**COD Reduc-tion From Methane Gas Production**
Conventional Digester	*18.8*	*1.0*	*3.8*	*57%*	*57%*
AGF Digester, I	12.5	5.9	5.44	82%	77%
AGF Digester, III	9.1	3.18	7.32	66%	69%
AGF Digester, IV	17.4	3.35	4.53	72%	75%
AGF Digester, V	6.1	3.1	11.03	64%	67%

The AGF pilot plant was operated successfully for 12 months treating concentrated primary and waste activated sludge. The AGF pilot plant produced a well stabilized biosolid material which was odorless. Use of a much smaller digester was demonstrated by successfully operating the pilot plant at an average hydraulic retention time (HRT) of 6 days as compared to a normal value of 20 days. The pilot plant was operated at a 5 day HRT for an extended period of time.

An SRT/HRT ratio of 3.35 was demonstrated during the pilot operation. The limiting factor preventing a greater SRT/HRT ratio was the accumulation of inorganic solids, sand, and silt within the digester. Removal of sand and silt with currently available technology will greatly improve the SRT/HRT ratios attained by the AGF process. Ratios exceeding 3.75 at moderate digester concentrations are expected.

The AGF digester achieved greater solids reductions at hydraulic retention times equivalent to the conventional digester. A 33% reduction in the quantity of solids requiring disposal was demonstrated. Under properly controlled conditions, a 50% reduction in the quantity of solids can be expected at long solid retention times.

Greater gas production was demonstrated with the AGF process. Increased methane gas production was directly related to increased COD reductions. Observed gas production rates confirmed that the hydrolysis and degradation of organic solids was substantially complete in 24 hours. This fact indicates that hydraulic retention times can be reduced to as little one day provided sufficient biomass to food ratios are maintained. Sufficient biomass can be provided from a biomass storage reactor. Providing a separate source of biomass will further reduce the digester volume required. This arrangement also offers the benefit of eliminating prethickening of raw sludge prior to digestion (Burke, 1996).

Elutriation was found to be beneficial in removing the end products of digestion, especially ammonia. Increased degradation of protein may be directly related to the elutriation of ammonia. Elutriation can be accomplished by using a dilute influent feed or by adding dilution water to the flotation gas stream.

Polymer use was found to be directly proportional to the recycle solids concentration. The polymer requirement for dewatering waste solids from the AGF digester was less than 10% of the polymer requirement for dewatering solids from the conventional digester. Solids from the AGF process were charge neutralized. The polymer savings in dewatering waste solids more than compensated for the polymer use in the AGF process. If prethickening, with it's associated polymer consumption, is eliminated substantial reductions in chemical use can be achieved.

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