

Aerobic Digestion of Tannery and Domestic Wastewater Sludge at Ambient Temperature

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Abstract: The feasibility of aerobic digestion for tannery and domestic sludge was studied to determine the best operational conditions for digestion. Sludge concentrations about 4200 mg.l⁻¹ and 12300 mg.l⁻¹ were tested with domestic and tannery waste activated sludge respectively. Temperature, dissolved oxygen, pH, mixed liquor suspended solids (MLSS), mixed liquor volatile suspended solids (MLVSS), settled sludge volume, sludge volume index (SVI), specific oxygen uptake rate (SOUR), supernatant biochemical oxygen demand (BOD₅), supernatant chemical oxygen demand (COD), sludge capillary suction time (CST), supernatant turbidity were all monitored. The reductions achieved in settled sludge volume, MLSS and MLVSS were higher for domestic than for tannery sludge. A significant improvement in domestic sludge settle ability appeared between 14 and 21 d of aerobic digestion, followed by an increase in supernatant turbidity and a decrease in sludge filterability. The aerobic digestion performance achieved was a reduction of 42.3% MLSS, 50.7% MLVSS, 95% SOUR, 78% settled sludge volume and full stabilization for domestic sludge; while for tannery sludge reductions of 15.4% MLSS, 20.0% MLVSS, and 83.3% SOUR were achieved with full stabilization.

Key words: sludge stabilization; aerobic digestion; ambient temperature; tannery wastewater

1 Introduction

Aerobic digestion of wastewater sludge is a stabilization process in which aerobic micro-organisms consume the biological degradable organic component of the sludge. ¹ Basic objective includes producing a biologically stable product while reducing both sludge mass and volume. The final product should be a mineralized sludge with good settle ability characteristics that can be easily thickened and dewatered. ²

Domestic and tannery sludge are significantly different. Domestic waste activated sludge are usually compact, strong, with a low solid content of 1500-3500 mg.l⁻¹, while tannery waste activated sludge are normally dispersed, weak with a high solid content (>5000 mg.l⁻¹). The latter sludge are often resistant to biological degradation, have poor bacterial filament development, with common pinpoint floc structure leading to poor dewater ability characteristics. In aerobic digestion, food is highly limiting, resulting in the micro-organisms consuming their own protoplasm to obtain energy for cell maintenance reactions (endogenous respiration). ³ This results in the biomass concentration continuously decreasing until the remaining portion represents such low energy content as to be considered biologically stable and suitable for disposal in the environment. ⁴ According to the US Environmental Protection Agency, sludge with a specific oxygen uptake rate (SOUR) equal to or less than 1 mg O₂.h⁻¹.g⁻¹ can be considered as being stabilized.

The aim of this study was to examine the feasibility of using aerobic digestion for tannery and domestic sludge at ambient temperature. Success in aerobic digestion was measured by the level of

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stability reached (SOUR), the reduction in settled sludge volume, mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS) achieved and the retention time needed.⁵ The feasibility of aerobic digestion is also based on its broad applicability, on the dewatering characteristics of the final product and on both foaming and odour potential.

2 Experimental

2.1 Sampling

The aim of the sludge collection was to obtain a high solid concentration, so the thickened returned domestic and tannery activated sludge were collected. A simple multiple 30-min settlement procedure was carried out on site to concentrate the sludge. After concentration, the sludge were quickly brought back to the laboratory, put into the reactors and aerated. The solids concentration of the samples represented the maximum MLSS achievable by unaided gravitational settlement alone.

2.2 Reactor design

The aerobic digestion of sludge were carried out using a batch of pilot plants composed of two sets of reactors each comprising three SBRs (one set for domestic and the other for tannery sludge). Since elevated temperatures allow a higher rate of microbial activity, leading to a shorter retention time, reactors were insulated with 5 cm wide polystyrene sheets in order to optimize the exothermic nature of the endogenous respiration. Continuous aeration ($1.5 \text{ l.air.m}^{-3}.\text{sludge.s}^{-1}$) was provided by diffusing air through the bottom of each vortex bottomed reactor, ensuring maximum aeration, mixing and the complete suspension of all sludge biomass. The experiment was carried out at ambient temperature ($\sim 18^\circ\text{C}$) for 35 d. Evaporation losses, which were generally small, were not made up in order to improve the sludge volume reduction. Solids adhering to the freeboard of each reactor were carefully returned to the mixed liquor twice a week.

2.3 Physical-chemical index

Temperature, dissolved oxygen, pH, mixed liquor suspended solids (MLSS), mixed liquor volatile suspended solids (MLVSS), settled sludge volume, sludge volume index (SVI), specific oxygen uptake rate (SOUR), supernatant biochemical oxygen demand (BOD_5), supernatant chemical oxygen demand (COD), sludge capillary suction time (CST), supernatant turbidity were all monitored.

3 Results and discussions

3.1 Test results

3.1.1 Temperatures

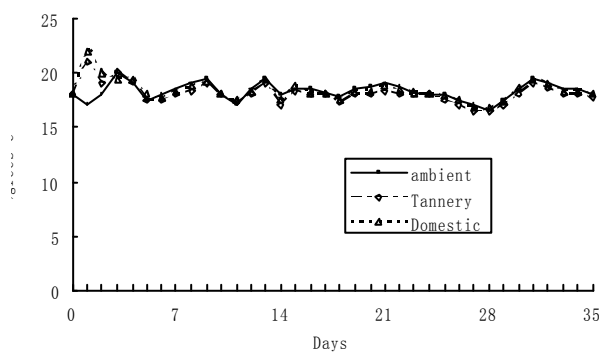


Fig. 1 Comparison of the temperatures between ambient and both reactors

Ambient temperatures varied from 16.5 to 20 °C over the experimental period. Despite a small

increase in reactor temperatures the first 2 d (Fig. 1), temperatures fluctuated according to the ambient temperature.

3.1.2 pH

The pH in all domestic sludge trials decreased due to the nitrification. The initial pH was about 8 and, without pH control, decreased down to about 5.48 after 35 d of aerobic digestion. For tannery sludge, pH evolutions remained quite constant and no reactor pH fell below 6.5.

3.1.3 MLSS and MLVSS

A continuous decrease in MLSS and MLVSS (Fig. 2) was observed for all domestic sludge, but a smaller reduction was recorded for tannery sludge. After 35 d of aerobic digestion, MLSS reductions about 42.3% and MLVSS reduction about 50.7% for the domestic sludge. For the tannery sludge, solids reduction was much less, about 15.4% for MLSS and 20.0% for MLVSS.

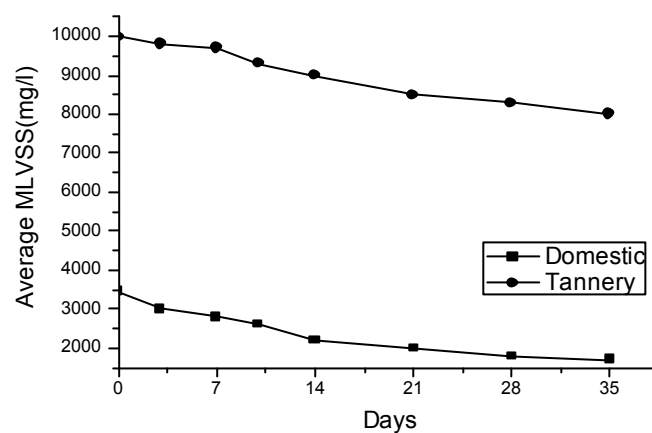


Fig. 2 Comparison of the MLVSS between domestic and tannery sludge

3.1.4 SOUR

For both domestic and tannery sludge, SOUR rapidly decreased over the first 14 d of operation and tended to level out during the following weeks (Fig. 3). After 35 d SOUR reduction was about 95% for domestic sludge and about 83.3% for tannery ones. A SOUR of less than 1 mg g⁻¹ h⁻¹, indicating full stabilization, was recorded after only 7 and 21 d of aerobic digestion for domestic and tannery sludge, respectively.

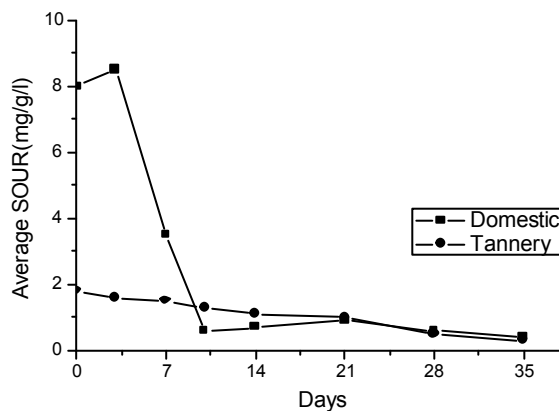


Fig. 3 Comparison of the temperatures between ambient and both reactors

3.1.5 Settleability, SVI and SSVI

A significant improvement in sludge settle ability was observed for the domestic sludge between d

14 and 21. At this period, it corresponds to about 69% settled sludge volume reductions (Fig4). SVI improved from 250 to 100 ml g⁻¹ and SSVI from 120 to 50 ml g⁻¹. No obvious settlement was observed for tannery sludge due to high solids concentrations, resulting in both the SVI and SSVI remaining quite constant throughout the experiment.

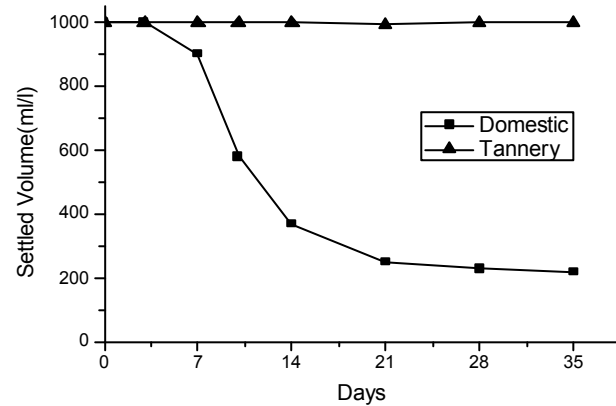


Fig. 4 Comparison of the settled sludge volume between sludge, after 30 min settlement

3.1.6 Supernatant turbidity

Supernatant turbidity increased, especially after d14, in all domestic sludge trials. For tannery sludge, the turbidity remained fairly constant throughout the experiment (Fig. 5).

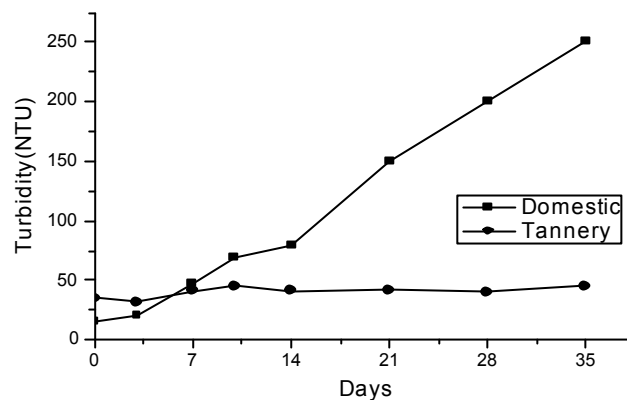


Fig. 5 Comparison of the supernatant turbidity between domestic and tannery sludge

3.1.8 CST

For all trials, CST continuously increased, especially between d 14 and 21 for domestic sludge (Fig. 6).

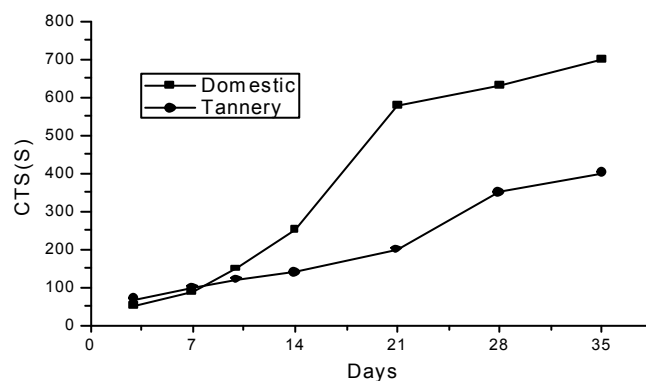


Fig.6 Comparison of the CST between domestic and tannery sludge

3.1.9 Supernatant BOD₅ and COD

Supernatant COD increased with retention time, whereas supernatant BOD₅ remained constant for domestic sludge but decreased for tannery ones. Variations in BOD₅ and COD were closely linked to turbidity, with the COD: BOD ratio increasing with time indicating continuous stabilization of sludge (Tab. 1).

Tab. 1 Supernatant COD and BOD₅

	Supernatant BOD ₅ (mg l ⁻¹)			Supernatant COD(mg l ⁻¹)			COD:BOD ratio	
	d0	d10	d35	d0	d21	d35	d0	d35
Domestic	20	30	30	135	517	656	6.8	21.9
Tannery	120	70	40	620	828	1103	5.2	27.6

3.1.10 Microscopic observations

Between d 14 and 21 of aerobic digestion, flocs became weaker and more dispersed. Little by little, flocs disintegrated and became more microstructural in nature. The filament concentration remained approximately the same or was slightly reduced during the experiment. Both domestic and tannery sludge biodiversities displayed an obvious lack of food and a long retention time indicative of successful aerobic digestion.

3.2 Discussion

3.2.1 Performance

The reductions achieved in settled sludge volume, MLSS and MLVSS were significantly greater for domestic than for tannery sludge (Tab. 2). This may be due to their higher initial metabolic activity with SOUR 6-8 mg g⁻¹ h⁻¹ for domestic sludge compared to only <1-2 mg g⁻¹ h⁻¹ for tannery sludge.

Tab. 2 Percentage reduction achieved after 35d (C₀=initial MLSS)

	C ₀ (mg l ⁻¹)	MLSS (%)	MLVSS (%)	Sludge volume (%)	SOUR (%)
Domestic	4200	42.3	50.7	78	95
Tannery	12300	15.4	20.0	0	83.3

Domestic sludge SOUR reductions were not significantly different than tannery ones, although tannery sludge (21 d) took longer to fully stabilize than domestic ones (7 d).

3.2.2 Settlement and filterability

The sludge settleability improved between d 14 and 21 and was followed by an increase in supernatant turbidity and sludge CST. It corresponds to both a decrease in filterability and an increase in sludge density. At this period of time, floc began to disintegrate and microstructure became predominant. Smaller particles increased the sludge density and formed a blinding cake layer, which significantly reduced filterability. In addition, due to deflocculation, some matter was released in the supernatant (increasing its turbidity) and a smaller proportion of the sludge settled (reducing settlement indices).

According to the increase in the supernatant COD (chemically biodegradable) and the decrease in supernatant BOD₅ (bio-chemically biodegradable), it seems that the matter released in the supernatant was bio-chemically non-biodegradable. Therefore, when recirculated to the inlet of the treatment plant, the high turbidity supernatant would not have affected the BOD₅ loading rate.

3.2.3 Temperature and insulation

Ambient temperature varied between 16.5°C and 20°C. No parameter variation was related with the small temperature fluctuation recorded during the experiment. The first 2 d, an increase in temperature was recorded for all reactors when the microbial activity (SOUR) was at a maximum. Although very low, such an increase is consistent with a release of energy during the endogenous respiration. The insulation of the reactors may have been insufficient and the initial sludge concentration too low to achieve maximum increase in reactor temperature during the experiment

3.2.4 Retention time

For the domestic and tannery sludge examined, the SOUR was highly reduced after only 7 d of aerobic digestion. However, a minimum of 14 d was required for optimum MLSS and MLVSS reductions. The longer the retention time, the higher the reductions achieved. For domestic sludge, a high reduction in settled sludge volume was observed between d 14 and 21. Therefore, the best retention time appears to be about 17 d, just after the improvement in settle ability, at this time the filterability was still reasonable. However, the retention time should not be longer than 21 d because of the risk of foam production and the decrease in filterability. For tannery sludge, no variation in sludge settleability was observed, so the optimum retention time appears to be just before the observed decrease in filterability at about 28 d.

3.2.5 Aerobic digestion in operation

No particular odor was produced from the aerobic digesters, so long as aerobic condition was maintained. Usually about 0.33-0.67 l.m⁻³.s⁻¹ of air is required to ensure a good mixing, ¹ so the air flow rate used in the current study of 1.5 l.m⁻³.s⁻¹ may contribute to the floc disintegration observed between d 14 and 21. Decreasing the air flow rate to about 0.50 l.m⁻³.s⁻¹ may suppress foam formation; reduce floc disintegration and operational costs, while still ensuring good oxygen transfer and good mixing. However, with high sludge solids concentration the need for a separate mechanical system to supplement the turbulence caused by aeration is probable. For domestic sludge, foaming was highly linked with retention time. Foam was present from d 2 in domestic sludge and developed after 21 d of aerobic digestion. For tannery sludge, no thick foam was observed but a very light one, disappearing gradually after 14 d. In this case, no additional machinery equipment like foam controllers is required.

4 Conclusions

Microscopic observations and SOUR measurements confirmed that full stabilization had been reached for both sludge. No foam controller is required for tannery sludge. However for domestic sludge, foam appeared after 2 d of aerobic digestion and developed after 21 d of aerobic digestion. No particular odor was discernible from the aerobic reactors. A lower air flow rate to that used (e.g. about 0.50 l.m⁻³.s⁻¹) may limit foam formation, floc disintegration and operational costs, while still ensuring good oxygen transfer and mixing. The reductions in key stabilization parameters achieved were significantly higher for domestic than for tannery sludge. For domestic sludge, aerobic digestion resulted in reduction about 42.3% MLSS, 50.7% MLVSS, 95% SOUR, 78% settled sludge volume and full stabilization. For tannery sludge, reductions about 15.4% MLSS, 20.0% MLVSS and 83.3% SOUR were achieved, with no reduction in settled sludge volume but full stabilization. The optimum retention time is approximately 17 d for domestic sludge (just after the high improvement in settleability) and about 28 d for tannery ones (just before the decrease in filterability).

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