Effects of Particle Size and Time of Slurry Storage on Odorous Compound Production of Cow Dung.

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ABSTRACT

Fresh cow feces were collected from an abattoir and separated into five different liquid portions with particle size ranges of <2.0, <1.0, <0.5, <0.25, and <0.063mm, respectively. Separation was achieved by consecutive sieving of the fresh cow manure through a series of five Canadian Standard wire screen sieves with openings of 2.0, 1.0, 0.5, 0.25, and 0.063mm. The separated manure fractions were stored at an ambient temperature of approximately 25^{o}C in PVC columns (100 cm deep and 15 cm in diameter) to simulate storage in under-floor or in other types of holding pits. The results indicated that although solid liquid separation was found to reduce production of volatile fatty acids (VFAs) and 5-day biochemical oxygen demand (BOD_5) regarded as odor precursors, this technique might not significantly reduce odor nuisances from facilities unless particles smaller than 0.063mm are separated from the liquids. Linear correlations (R^2=0.82) were observed between BOD_5 and VFAs and therefore their respective levels could be used to quantify the potential of odor nuisances in cow manure.

(Keywords: volatile fatty acids (VFAs), Biochemical Oxygen Demand (BOD_5), time, particle size, cow dung, manure, farm wastes, odor)

INTRODUCTION

In the last decades, a number of countries have reported an increase in complaints due to agriculture and food processing industry related odors (Both, 2001; Philips, 1997; Shukla, 1991; Mahin, 2001). There are a number of reasons for the increase in complaints including:

(a) the increase in the size and the number of livestock and food production facilities,

(b) the increase in residential development near traditionally agricultural and food industrial areas, and

(c) the increase in sensitivity and demand of the general public for a clean and pleasant environment (Both, 2001; Mahin, 2001).

Regardless of whether a state has specific regulations for odor control or plans to implement such regulations, there are two basic principles for controlling odors:

1. reduction of odors at the generation sources, and

2. removal of odors from collected gaseous streams before the odors are discharged into the atmosphere. Source control is always the first choice for odor control.

The process of odor control generally starts with source characterization, which means:

1. identifying the sources emitting odorous compounds;

2. measuring the odor fluxes and ranking the sources according to this parameter in order to define treatment priorities; and

3. identifying the type of odorous compounds in order to select the best-suited odor abatement technology (Ramel and Nomine, 2000; Shukla, 1991).

The sugar metabolism under anaerobic conditions is represented by the following equation (Miller and Wolin, 1979):

$$34:5C_6H_{12}O_6 \rightarrow 64VFA + 23:75CH_4 + 34:25CO_2 + 10:5H_2O \qquad \textbf{(1)}$$

Sugar fermentation usually yields short and straight chain fatty acids (acetic, propionic, lactic, succinic, formic, and butyric acids). However, in the presence of oxygen, pyruvate is oxidized to acetyl-CoA and then entered the TCA cycle and the electron transport chain to produce energy. Because no fermentation process occurs under aerobic conditions, no organic acids, especially VFAs, are produced. This fact partially explains why aeration can effectively reduce malodor production (Zhu et al., 1999).

Some remarkable studies have been conducted to relate chemical characteristics to odor intensities and offensiveness of excreta (Bell, 1970; Barth et al., 1974; Spoelstra, 1980; Williams, 1984). From the above studies, it appears that the VFAs and BOD_5 contents can be used as valid indicators of odor and their concentration as valid quantifiers of odor intensities.

Ndegwa et al. (2002) working with solid-liquid separated stored pig slurry observed that solid-liquid separation resulted in reduced production of both volatile fatty acids (VFAs) and 5-day biochemical oxygen demand (BOD_5) in stored pig manure during the first 30 days of storage.

Moreover, that most of the VFAs and BOD_5 therefore appeared to be contained in a particles smaller than 0.075mm and that it appears that solid-liquid separation may only significantly mitigate odor problems in separated manure if the separation process can remove this fine fraction of the solid manure.

Abattoir Wastes

Wastes from abattoir typically contain fat, grease, hair, feathers, flesh, manure, grit and undigested feed, blood, bones, and process water which are characterized with high organic levels (Bull et al., 1982; Coker et al., 2001; Nafamda et al., 2006). The total amount of waste produced per animal slaughtered is approximately 35% its body weight (World Bank, 1998).

In an earlier study, Verheijen et al., (1996) found out that, for every 1,000 kg of carcass weight, a slaughtered cow produces 5.5 kg of manure (excluding rumen contents or stockyard manure) and 100 kg of paunch manure (partially digested food). The volume of water required for meat rendering or processing ranged between 1.5 and $10m^3t^{-1}$ of product for hogs, 2.5 and $40m^3t^{-1}$ of product for cattle and 6 and $30m3t^{-1}$ product for poultry (Gannon et al., 2004).

In Nsukka, Enugu State Nigeria, the abattoir is located centrally at a market called Ogige Market. Cows are slaughtered daily throughout the year. The manure slurry generated flows directly into an open channel or drainage system without treatments therefore crating odor nuisance at the whole market. The activities of this Abattoir remain unregulated, due to this the present study therefore aimed at assessing the abattoir cow manure slurry for odorous compounds production.

The specific objectives of this study are:(1) to investigate the effects of particle size on the potential of odor production during the storage of cow dung from abattoir waste in under-slat pits, or in other types of manure-holding pits using BOD5 and VFAs as odor indicators (2) to determine the relationship between BOD_5 and VFAs. Data obtained could be helpful in defining future technology for odor reduction and waste management practices in the Abattoir.

The problem of abattoir wastes in Enugu State is not restricted to Nsukka Urban market alone. Enugu urban markets at Ogbete, Artisan Quarters, and Gariki Awkunanu all have abattoir waste problems. It is therefore believed that the findings and recommendations of this study will also surely be useful to Environmental Sanitation Agencies, Public Health Departments, and many municipal waste managers in Nigeria.

MATERIALS AND METHODS

Construction of Simulation PVC Columns

In other to simulate manure storage pit, five PVC columns each measuring 16cm diameter and 100cm height were constructed according to Zhu et al. 1997. Each has a cover and a sampling point at 10cm from the base (Figure 1).

Figure 1: Constucted PVC Simulation Colums, Sampling Cans, Five Canadian Standard Wire Screen Sieves, Thermometers and 250mL Beaker.

Manure Collection and Experimental Procedure

Fresh cow feces were collected from Nsukka abattoir buildings and were diluted according to procedures outlined according to Zhu (2000). The diluted feces were separated into five different liquid portions with particle size ranges of <2.0mm, <1.0mm, <0.5mm, <0.25mm, and <0.063mm, respectively. Separation was effected by manual sieving of the fresh cow manure (rumen content) through a series of five Canadian Standard wire screen sieves with openings of 2.0, 1.0, 0.5, 0.25, and 0.063mm as shown in Figure 2.

The slurry which passes through each of these sieves was collected and stored in the five constructed storage pit simulation PVC columns, respectively. Each of the five simulation PVC columns (100cm deep and 16cm diameter) was filled up leaving approximately 10cm head space or freeboard. Once all the columns had been filled, each column (total of five) was thoroughly stirred using a motorized paddle stirrer (Janke & Kenkel; *Chem. Pys. Appar. and Machin*. TYp RM14;Nr.17047) and a sample was drawn from the homogenized slurry from a tap attached at 10cm height from the base of each column.

This sampling technique was continued for the first 30 days of storage at 5-day intervals. The five columns were each covered at the top and stored in a dark room to simulate the condition in the storage pits. The room's ambient temperature was between 24 and 25^{o}C throughout the storage period.

Laboratory Analysis

The VFAs was determined using AOAC Official Method 925.41 Acids (Volatile) in Oils and Fats (Reichert-Meissl and Polenske Values) Titrimetric Method (Horwitz and Latimor (eds.), 2005). All volatile acids were reported as their equivalent mgL^{-1} acetic acid (Hach Company, 1993). To determine BOD$_5$ a 300ml airtight BOD bottle was half-filled with aerated dilution water, 2ml of the supernatant was pipetted into the bottle and the bottle filled to overflowing with the aerated dilution water. Initial dissolved oxygen (DO$_1$) was determined using a dissolved oxygen (DO) meter (HANNA Instruments Model HI 9142).

The samples were then incubated for 5 days at 20^{O}C and dissolved oxygen remaining in day five (DO$_5$) determined. The BOD$_5$ was computed as the difference between DO_1 and DO_5 after correcting for dilution.

Experimental Design and Statistical Analysis

The manure samples were separated into five different size ranges and the change with time of storage in the manure was investigated in terms of Volatile Fatty Acids (VFAs) and 5-Day Biochemical Oxygen Demand (BOD_5). This fits the classical two factor (solids particle size ranges and time) experimental design for the manure sample with responses being VFAs and BOD_5. A two way analysis of variances (no blocking) was therefore performed on the responses to determine their respective variations with time and with particle size ranges in the respective manure fractions. Pair-wise comparisons was performed using the Least Significant Difference method (LSD) whenever necessary. All analysis of variance was performed using GenStat Realease 7.2 DE(PC/Windows) software. All graphical representations were done using Microsoft Excel 2007 while the Correlation analysis was done using SPSS 16.0 software. A probability level of α of 0.05 was used except were otherwise stated.

RESULTS AND DISCUSSION

Mean

The mean distribution of both VFAs and BOD_5 during the first 30 days of manure storage for the different particle size fractions is as shown in Figures 2 and 3, respectively. It is evident from these figures that the highest VFAs and BOD_5 were recorded on Day 25 and at the Particle size fraction, P<0.25mm. Figures 4 and 5 demonstrate the histogram of this distribution with respect to the consolidated values of the total of 105 observations made for both VFAs and BOD_5 over the 30 days of manure storage. The grand means are 1505.49 mg/l (VFAs) and 28382.1mg/l (BOD_5). The standard deviations are 146.77mg/l (VFAs) and 12462.715mg/l (BOD_5).

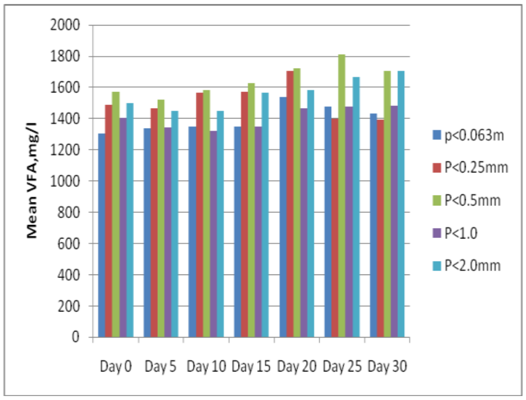

Figure 2: Mean Distribution of VFA.

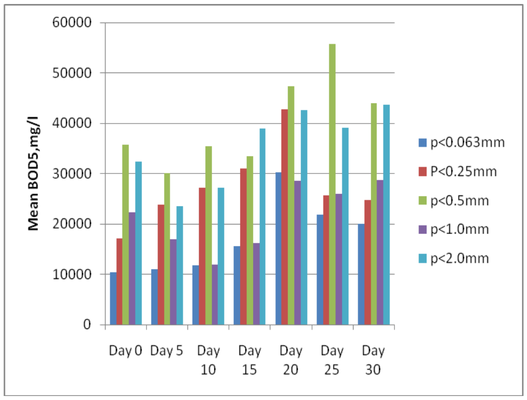

Figure 3: Mean Distribution of BOD_5.

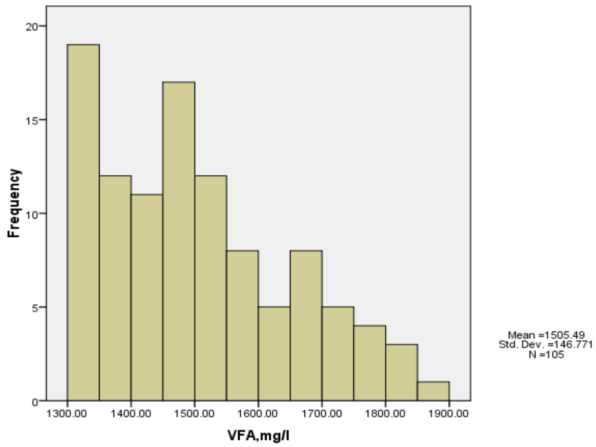

Figure 4: Histogram of Mean Distribution of VFAs.

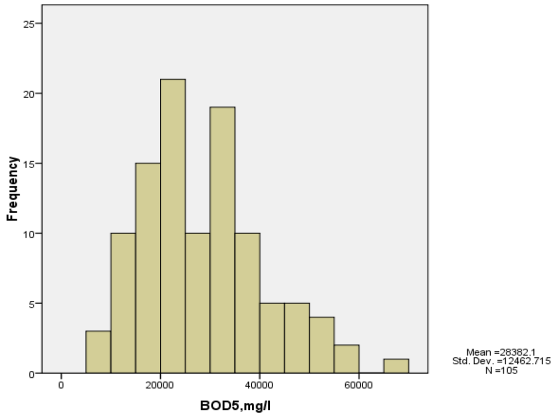

Figure 5: Histogram of Mean Distribution of BOD_5.

Effects of Particle Sizes

The ANOVA results showed that particle size has significant effect on both VFAs and BOD_5 at 5% probability levels. These effects are demonstrated in the form of bar charts and histograms, respectively (Figures 6, 7, 8, and 9). It is clear from Figure 6 that the particle size fraction P<0.5mm has the highest concentration of VFAs.

Concentration of VFA was greatly reduced in P<0.063mm and P<1.0mm but the concentration of P<0.063mm is significantly lower than others ($LSD_{0.05}$ = 51.60). The concentration of BOD_5 (Figure 8) in the particle size fractions follow the same trend with the concentration of P<0.063mm significantly lower than others ($LSD_{0.05}$= 4096.9). These seem to suggest that a removal of the fraction P<0.063mm will mitigate odor nuisance.

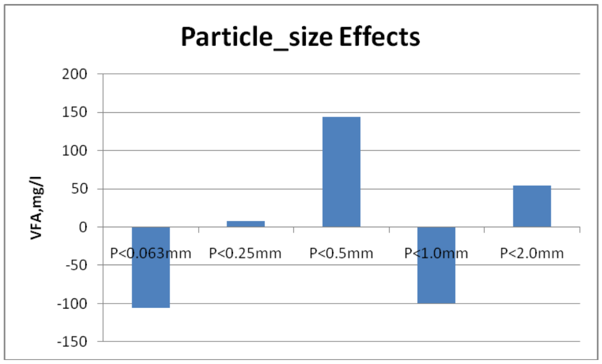

Figure 6: Effects of Particle Size on VFAs.

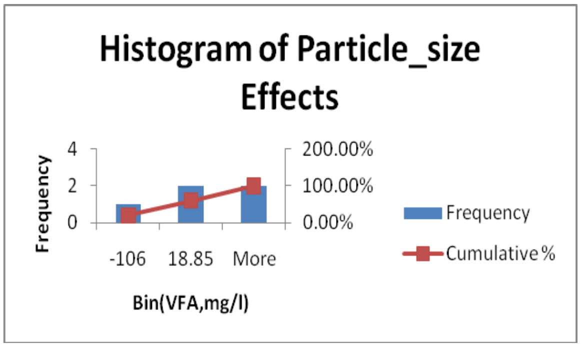

Figure 7: Histogram of Effects of Particle Size on VFA Concentrations.

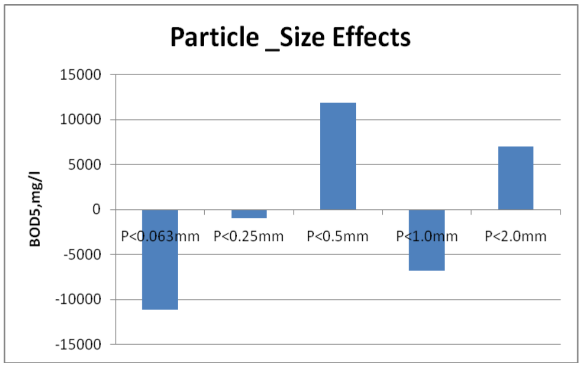

Figure 8: Effects of Particle Size on BOD_5.

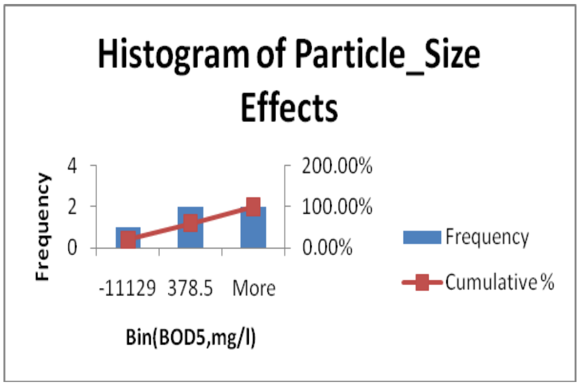

Figure 9: Histogram of Effects of Particle Size on BOD_5 Concentrations.

Effects of Time

The ANOVA results showed that Time has significant effect on both VFAs and BOD_5 at 5% probability levels. These effects are demonstrated in the form of bar charts and histograms respectively (Figures 10 – 13). It is clear from Figure 10 that VFAs concentrations are generally reduced during the 30 days of manure storage. However, it is obvious that this reduction of VFAs concentration is higher on Day 20 and this is significantly different from other days ($LSD_{0.05}$ = 61.05). Similarly, concentration of BOD_5 (Figure 12) is significantly lower than other days ($LSD_{0.05}$ = 4847.5).

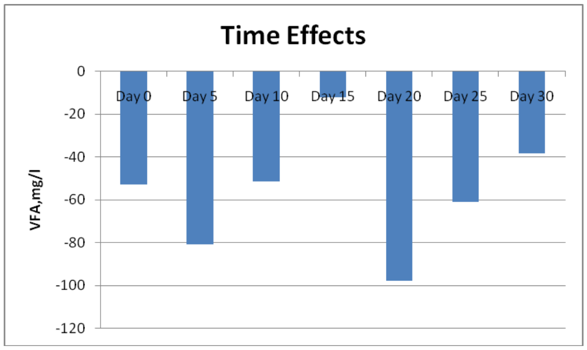

Figure 10: Effects of Time on VFAs Concentrations.

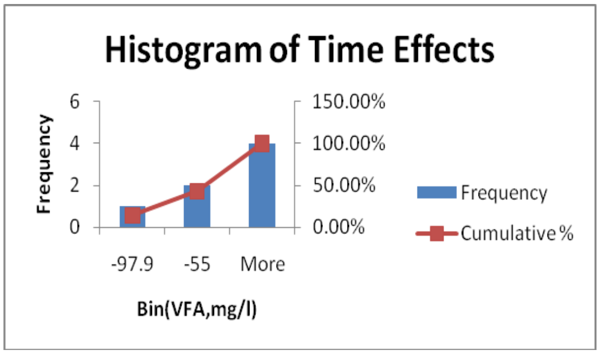

Figure 11: Histogram of Effects of Time on VFAs Concentrations.

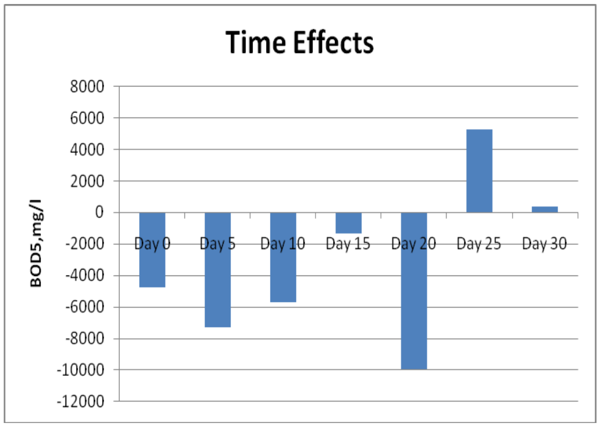

Figure 12: Effects of Time on BOD_5 Concentrations.

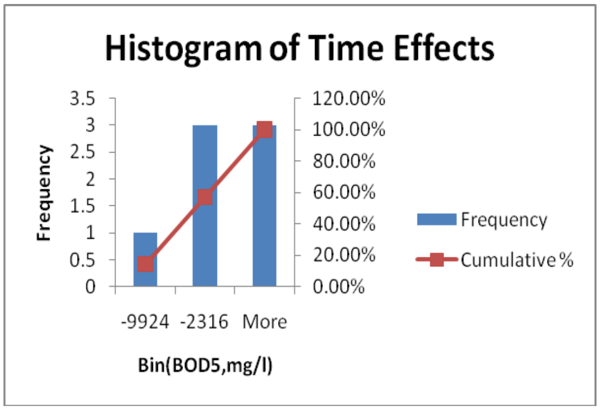

Figure 13: Histogram of Effects of Time on BOD_5 Concentrations.

Effects of Particle-Size *Time Interaction

The ANOVA results showed that particle-size*Time interaction has significant effect only on VFAs at 5% probability levels. These effects are demonstrated in the form of bar charts and histograms, respectively (Figures 14-17). These effects brought about significant reduction of concentration of VFAs on Day 25 at Particle fraction, P<0.25mm (Figure 14). Concentration of BOD_5 (Figure 16) follow a similar trend.

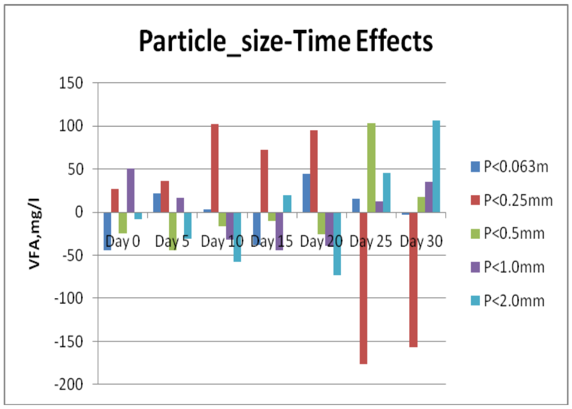

Figure 14: Effects of Particle_Size*Time Interaction onVFAs Concentrations.

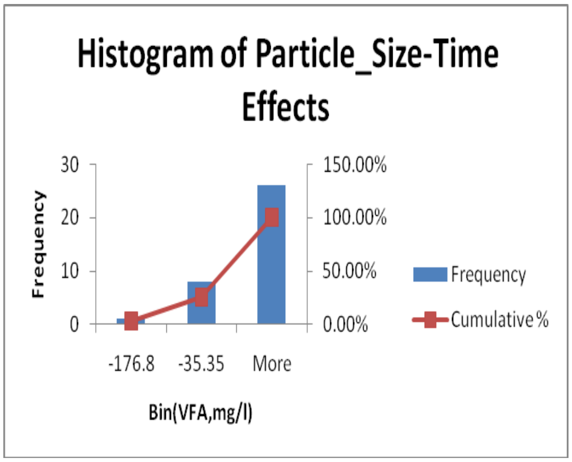

Figure 15: Histogram of Effects of Particle_Size*Time Interaction onVFAs Concentrations.

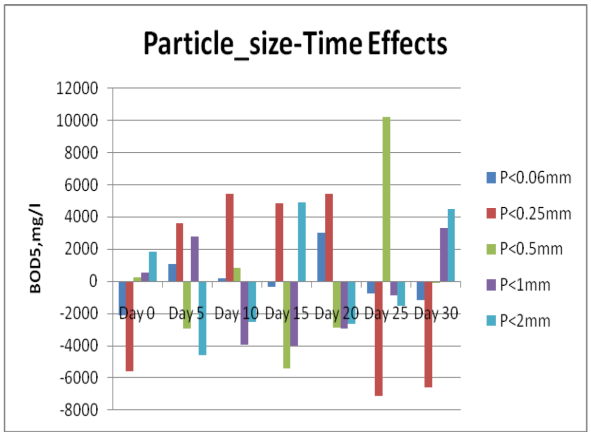

Figure 16: Effects of Particle_Size*Time Interaction on BOD5 Concentrations.

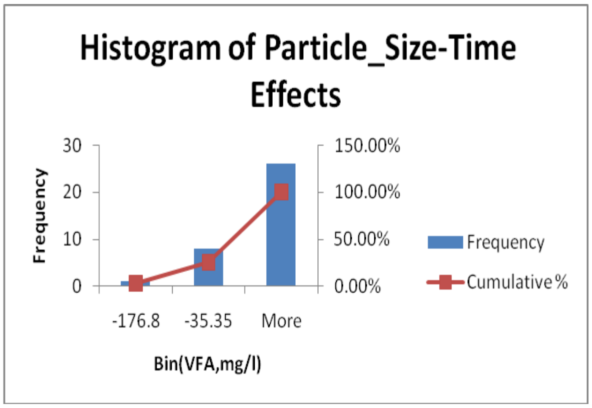

Figure 17: Histogram of Effects of Particle_Size*Time Interaction on BOD5 Concentration.

Regression Analysis

The summary of regression statistics, correlations, model summary, ANOVA, coefficients, and residual statistics result for regression analysis between concentrations of VFAs and BOD_5 are shown in Tables 1, 2, 3, 4, 5, and 6, respectively. Figures 18, 19, and 20 are histogram of regression standardized residuals, normal probability plot and actual line fit plot, respectively.

Table 1: Regression Statistics.

Multiple R	0.907465287
R Square	0.823493247
Adjusted R Square	0.821779589
Standard Error	5261.279571
Observations	105

Table 2: Correlations.

		BOD5	VFA
Pearson Correlation	BOD5	1.000	.907
	VFA	.907	1.000
Sig. (1-tailed)	BOD5	.	.000
	VFA	.000	.
N	BOD5	105	105
	VFA	105	105

Table 3: Model Summary[b].

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.907[a]	.823	.822	5261.280	.823	480.547	1	103	.000
a. Predictors: (Constant), VFA									
b. Dependent Variable: BOD5									

Table 4: ANOVA[b].

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.330E10	1	1.330E10	480.547	1.39304E-40(.000[a)]
	Residual	2.851E9	103	2.768E7		
	Total	1.615E10	104			
a. Predictors: (Constant), VFA						
b. Dependent Variable: BOD5						

Table 5: Coefficients[a].

Model		Un-standardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-87623.845	5316.758		-16.481	.000	-98168.380	-77079.309
	VFA	77.056	3.515	.907	21.921	.000	70.084	84.027
a. Dependent Variable: BOD5								

Table 6: Residual Statistics[a].

Statistics	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	12643.87	57705.93	2.84E4	11309.481	105
Residual	-1.096E4	1.213E4	.000	5235.924	105
Std. Predicted Value	-1.392	2.593	.000	1.000	105
Std. Residual	-2.082	2.306	.000	.995	105
a. Dependent Variable: BOD5					

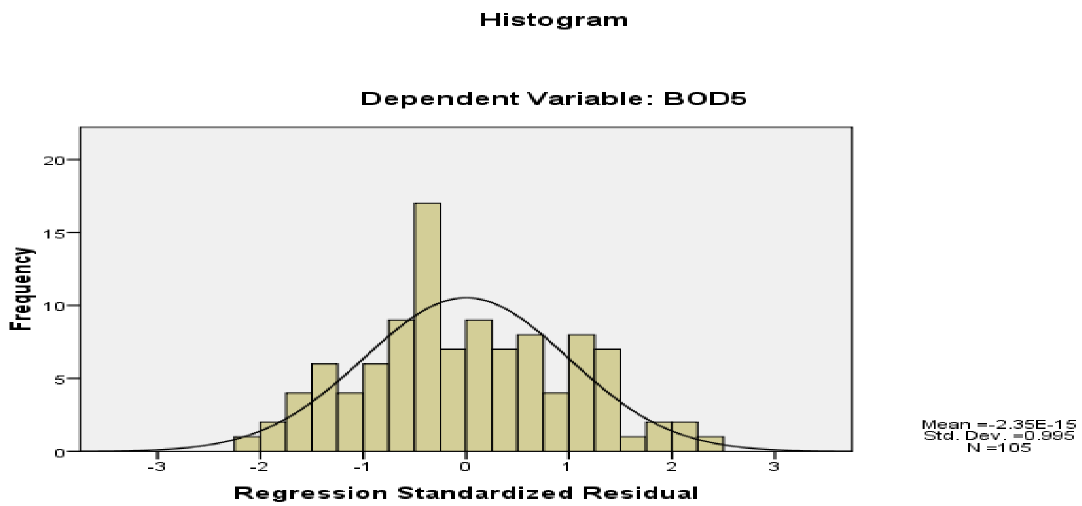

Figure 18: Histogram of Regression Standardized Residuals.

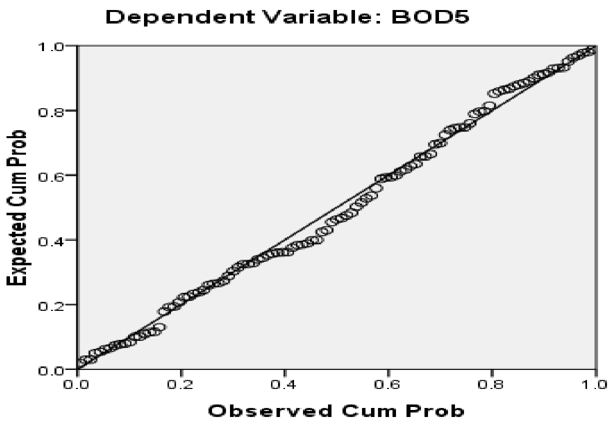

Figure 19: Normal Probability Plot (Normal P-P Plot of Regression Standardized Residuals).

The regression equation is $Y = 77.056x - 87624$. Where Y =BOD$_5$ and x= VFAs. The t-ratio tests the hypothesis that either of the model coefficient is zero. For the slope, t-ratio is 21.921, this is highly significant (P<0.0005) and for the intercept, the t-ratio is -16.481 (P<0.0005), this is highly significant. This means that the intercept is not significantly different from zero and the slope is not significantly different from unity at 5% probability, so there is strong evidence of a relationship between the predicted BOD$_5$ using the model and the actual field data.

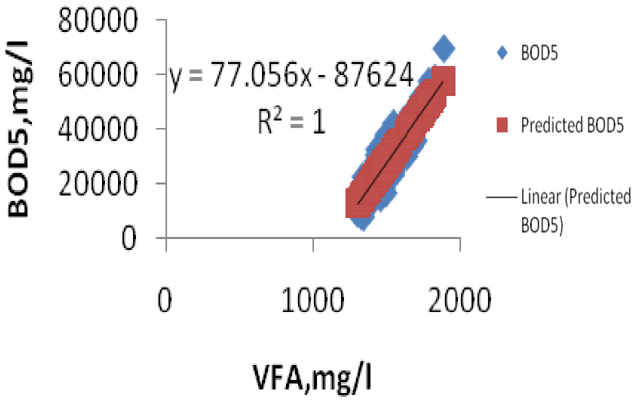

Figure 20: Actual Line Fit Plot (VFA Line Fit Plot).

The regression line has a high R^2 value of 0.82 (at 95% confidence interval) which signifies a high percentage variability in the data.

CONCLUSIONS

1. Solid-liquid separation resulted in reduced production of both volatile fatty acids (VFAs) and 5-day biochemical oxygen demand (BOD5) in stored cow manure during the first 30 days of storage. However, removal of solids larger than 0.5 mm did not have significant reductions in the levels of either BOD5 or VFAs during the 30 days of storage in this study. Most of the VFAs and BOD5

therefore appeared to be contained in particles smaller than 0.063mm . Based on the results of this study, it appears that solid-liquid separation may only significantly mitigate odor problems in separated manure if the separation process can remove this fine fraction of the solid manure.

2. On the basis of the foregoing conclusion, it is unlikely that screening as a solid-liquid separation technique for odor control is a candidate since it is extremely difficult to remove fine particles solely by screening, at least from the type of manure used in this study. Research is, however, needed using manure from diverse sources for verification of the findings of this study. More work is also needed using further separated slurries before discarding the idea of using solid-liquid separation for purposes of controlling odor.

3. A linear correlation was observed between BOD_5 and VFAs levels in stored manure. It appears that either both may be used for quantification of odor intensities in stored manure. More work is suggested using manure from different sources for the validation of this relationship. BOD_5 in manure is easy to measure than VFA since it do not require complex apparatus as VFAs and its use would naturally simplify the quantification of odor nuisances in stored cow slurries.

REFERENCES

1. Barth, C.L., D.T. Hill, and L.B. Polkowski. 1974. "Correlating Odour Intensity Index and Odorous Components in Stored Dairy Manure". *Transactions of the ASAE*. 17(4):742–744, 747.

2. Bell, R.G. 1970. "Fatty Acid Content as a Measure of the Odor Potential of Stored Liquid Poultry Manure". *Poultry Science*. 49:1126-1129.

3. Both, R. 2001. "Directive on Odour in Ambient Air: An Established System of Odour Measurement and Odour Regulation in Germany". *Wat. Sci. Technol*. 44 (9):119–126.

4. Bull, M.N., R.M. Sterritt, and J.N. Lester. 1982. "The Treatment of Wastewaters from the Meat Industries: A Review". *Environ. Technol. Lett*. 3(33):117-126.

5. Coker, A.O., B.O. Olugasa, and A.O. Adeyemi. 2001. "Abattoir Wastewater Quality in South Western Nigeria". *Proceedings of the 27th WEDC Conference*. Lusaca, Zambia. 329-331.

6. Gannon, V.P.J., F. Hummenil, M. Rice, J. Cicmanec, L. Smith, Jr., and R. Carr. 2004. *Control of Zoonotic Pathogens in Animal Wastes, Waterborne Diseases: Identification, Causes and Control*. WHO, IWA: London, UK. 409-425.

7. Hach Company. 1993. *Procedure Manual*. P.O. Box 389, Loveland, CO. 80539-9987.

8. Horwitz, W. and G.W. Latimor (eds).2005. *Official Method of Analysis of AOAC International*,18th ed. AOAC International: Baltimore, MD.

9. Mahin, T.D. 2001. "Comparison of Different Approaches used to Regulate Odours around the World". *Wat. Sci. Tech.* 44(9):87–102.

10. Miller, T.L. and M.J. Wolin. 1979. "Fermentations by Saccharolytic Intestinal Bacteria". *Am. J. Clin. Nutr*. 32(1):164–172.

11. Nafarmda, W.D., A. Yayi, and H.I. Kubkomawa. 2006. "Impact of Abattoir Waste on Aquatic Life: A Case Study of Yola Abattoir". *Global. J. Pure. Appli. Sci.* 12(1):31-33.

12. Ndegwa, P.M., J. Zhu, and A. Luo. 2002. "Effects of Solids Separation and Time on the Production of Odorous Compounds in Stored Pig Slurry". *J. Biosysterm Engineering*. 81(1):127 – 133.

13. Patni, N.K. and P.Y. Jui. 1985. "Volatile Fatty Acids in Stored Dairy-Cattle Slurry". *Agricultural Wastes*. 13:159–178.

14. Philips, R.J. 1997. "Odor Control of Food Processing Operations by Air Cleaning Technologies (Biofiltration)". State of the Art Report: Food Manufacturing Coalition for Innovation and Technology Transfer R.J. Philips & Associates, Inc, Virginia, USA, available from: http://foodsci.unl.edu/fmc/4odors.htm

15. Ramel, M. and M. Nomine. 2000. "Physicochemical Characterization of Odours". *Analusis*. 28(3):171 – 179.

16. Shukla, N.P. 1991. "Air Pollution by Odour-Sources, Identification and Control". *Rev. Environ. Health*. 9(4):239-244.

17. Spoelstra, S.F. 1980. "Origin of Objectionable Odorous Components in Piggery Wastes and the Possibility of Applying Indicator Components for Studying Odour Development". *Agric. and Env.* 5:241-60.

18. Verheijen, L.A.H.M., D. Wiersema, L.W. Hulshoff, and J. De Wit. 1996. *Management of Wastes from*

Animal Product Processing: Livestock and Environment, Finding a Balance. International Agriculture Center: Wageningen, The Netherlands.

19. Williams, A.G. 1984. "Indicators of Piggery Slurry Odour Offensiveness". *Agricultural Wastes*. 10(1): 15-36.

20. Williams, A.G. and M.R. Evans. 1981. "Storage of Piggery Slurry". *Agricultural Wastes*. 3:311-321.

21. Williams, T.O. 1993. "Biofiltration for Control of Odorous Emissions from Composting Facilities". *Proceedings of the 3rd Annual meeting of the Composting Council of Canada*. Montreal QC, 23-24 September 1993. pp. 425-442.

22. World Bank. 1998. *Meat Processing and Rendering: Pollution Prevention and Abatement Handbook*. Environmental Department. World Bank: Washington, DC.

23. Zhu, J. 2000. "Early Separation of Fresh Swine Manure May Enhance Separation Efficiency: Minnesota/Wisconsin Engineering Notes". Summer 2000. www.bae.umn.edu/, visited January, 2002.

24. Zhu, J., G.L. Riskowski, and M. Torreomorell. 1999 "Volatile Fatty Acids as Odor Indicators in Swine Manure- A Critical Review". *Transactions of the ASAE*. 42

25. Zhu, J., D.S. Bundy, X. Li, and N. Rashid. 1997. "Controlling Odor and Volatile Substances in Liquid Hog Manure by Amendment". *Journal of Environmental Quality*. 26:740-743.

SUGGESTED CITATION

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