Effects of Duration and Intensity of Aeration on Solids Decomposition in Pig Slurry for Odour Control

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A 30 day laboratory scale experiment was carried out using three different aeration rates, i.e. +35 mV oxidation–reduction potential (ORP: standard hydrogen electrode), 10, and 30 mgO2 l−1, to achieve solids decomposition and odour control in pig slurry with total solids (TS) levels from 0 to 40%. Changes during the aeration process were characterised by TS, total volatile solids (TVS), total suspended solids (TSS), and total volatile suspended solids (TVSS), all expressed as w/w. The measurement of volatile fatty acids (VFAs), expressed as w/v, was used to evaluate the potential odour generation in the aerated slurry. The TS removal efficiencies from 60 to 44.9, 18.6 to 50.3, and 42.3 to 56.4% were observed for the three different aeration levels, with reductions from 6.6 to 48.9, 26.0 to 61.1, and 57.3 to 69.9% for the slurry TVS. The ratios of TVS/TS, TSS/TS, and TVSS/TS in slurry over the experimental duration were found to increase with increased TS levels in the 30 day aeration under the three aeration intensities. Reductions in the 5 day biological oxygen demand (BOD5) reached 78.5–92.0, 79.4–96.0, and 91.2–97.0%, while reductions of VFAs reached 12.7–99.0, 71.7–99.0%, and 87.8–99.3%. The biodegradation of solids, BOD5, and VFAs was effectively enhanced when aeration time and intensity were increased. A low level of solids in slurry promoted aerobic decompositions of solids, BOD5, and VFAs. Changes of state in the solids being aerated and changes in the BOD5 levels can be used to distinctly characterise the potential of odour generation from the slurry. Batch aeration of 5–10 days under intensities of 10 to 30 mgO2 l−1 is recommended for odour control at farm level.

1. Introduction

Public complaints due to odour emission are a major concern of pig producers. Open slurry storages, such as lagoons and earthen basins, produce odorous gases and compounds due to anaerobic microbial decomposition of pig slurry. In an observational study, Gay et al. (2003) found that odour emission in odour units (OU) from pig slurry storage units reached anywhere from 1.0 to 114 OU s−1 m−2. It is well known that solids and organic materials in pig slurry are the first and foremost odour-producing matter under anaerobic microbial activity (Burton, 1992; Westerman & Zhang, 1997; Zhu, 2000).

Zhang and Westerman (1997) reviewed the characteristic of the distribution of solids in pig slurry, and found that the total solids (TS) content could be partitioned between suspended solids (SS) and dissolved solids (DS). Each fraction (TS, SS, or DS) can be further divided between volatile solids (VS) and fixed solids (FS). The corresponding volatile fractions of TS, SS, and DS are total volatile solids (TVS), volatile suspended solids (VSS), and volatile dissolved solids (VDS). The VS fraction generally represents the organic component of the total solids, which is more biodegradable than FS, which is mainly associated with the coarse material in the slurry and effectively inert in the typical aerobic treatment process (Burton, 1992). Understanding of distribution of slurry solids presents important information for design and selection of proper solid–liquid equipment for odour control (Zhang & Westerman, 1997). However, the separated liquid is still dark
in colour and odour generation depends largely on the amount of odour-producing organic substances remaining in the liquid, which may require additional treatment to ensure an odour-free storage (Chastain et al., 2001).

Generally, insoluble organic substances or organic particulates in various wastewaters can be converted into soluble organic matter through hydrolysis, which depends on extracellular enzymes secreted by endogenic microbes (Grady et al., 1999). Some of the soluble organic matter is consumed by microbes to support their own metabolism, while the death, and the subsequent decay of microorganisms, increases insoluble organic materials. The convertible organic matter is transformed into methane, carbon dioxide, water, and other odourless products under the restrictive and controlled anaerobic digestion system (Chynoweth et al., 1999; Magbanua et al., 2001; Kataoka et al., 2002). A variety of odorous compounds, however, such as volatile fatty acids (VFAs), aldehydes, alcohols, volatile amines, mercaptans, indoles, and skatols, classified as the intermediate products of anaerobic metabolism, are produced abundantly under the uncontrolled anaerobic condition (Westerman & Zhang, 1997; Hobbs et al., 1998; Zhu, 2000). When the oxygen supply to wastewaters is maintained, organic decomposition is achieved by the activity of aerobic microorganisms, with no apparent accumulation of odorous compounds (Zhang et al., 1997; Yang & Wang, 1999; Zhu, 2000). Moreover, both the growth in the population of aerobic microorganisms and the subsequent biodegradation rate of organic matter are accelerated rapidly in the aerobic system compared to non-controlled anaerobic systems (Burton, 1992). Whilst previous studies have found that the concentration of solids in slurry can be used as an indicator of organic particulates hydrolysis, microorganism metabolism, aerobic decomposition of soluble organic substance, and biomass production when aeration technique is adopted, few have reported on the role of solids in odour control during the aeration process, particularly in relation to different solids fractions. As a matter of fact, the total amount of solids and fractions, such as VS, SS and DS, changes due to particulate hydrolysis, microorganism activity (assimilation and decay), and breakdown of soluble organic matter during the aerobic process.

Aeration offers an effective way of treating animal slurry to achieve solids decomposition and odour control, but the relatively high cost of the required energy has hampered the broad application of this method. Ample research has been conducted in both improving the efficiency of aeration (Cumby, 1987; Yang & Wang, 1999) and reducing the duration and intensity of aeration (Phillips & Bulley, 1980; Zhang et al., 1997). A level of 1–2 mg[O2] l−1 maintained in the wastewater ensures adequate oxygen transfer into the biomass solids and provides mixing, so that the aerobic environment can be kept consistent throughout the treatment vessel (Wang & Pereira, 1986). A study by Williams et al. (1989) showed that odour offensiveness could be controlled if the oxidation–reduction potential (ORP) was maintained at above +13 mV (expressed as the value of standard hydrogen electrode, E0) in slurry. If the ORP was controlled at +133 mV, the odour intensity ranged between ‘very faint’ and ‘faint’ (Burton et al., 1998). Another study showed that once the ORP in the liquid exceeded +100 mV (E0), the liquid environment was said to be aerobic with detectable dissolved oxygen present and prevalent aerobic respiration (Charpentier et al., 1989). In a previous study of bacterial counts corresponding to the ORP, it was suggested that, for odour control, the slurry ORP should be maintained at +35 mV (E0) or higher to effectively support aerobic growth and simultaneously hinder anaerobic activity (Zhu et al., 2002). To date, the characteristics of solids decomposition under different aeration durations and intensities for slurry odour control using batch operation is not fully understood.

Since complete stabilisation of livestock slurry by aerobic treatment is normally not economically justifiable, low levels of aeration have been recommended for partial odour control (Westerman & Zhang, 1997). In this study, a 30 day, laboratory scale batch experiment with three different aeration levels, i.e. +35 mV[ORP] (E0), 1.0 mg[O2] l−1, and 3.0 mg[O2] l−1, was designed to treat pig slurry with TS concentrations from 0.5 to 4.0% in order to shed light on odour control and aerobic decomposition of solids. The changing characteristics of solids during the aeration process were evaluated by TS, TVS, total suspended solids (TSS), and total volatile suspended solids (TVSS). The values of the 5 day biochemical oxygen demand (BOD5) in the slurries were measured to show the extent of organic matter decomposition and to indicate the efficiency of the various aeration regimes. Although the measurement and quantification of odour have been widely debated over the development of strategies toward odour issues, VFAs are considered appropriate in evaluating the potential odour generation in slurry (Williams, 1984; Burton, 1992). The level of VFAs was often reported to quantify pig slurry odour reduction (Burton et al., 1998; Zhang et al., 1997, 2000; Zhu et al., 2001). The potential odour generation during the course of aerobic decomposition is also investigated by using VFAs in this study in order to develop strategies for odour control.
2. Materials and methods

2.1. Slurry collection and experimental procedure

Raw slurry for this study was collected from a reception pit of a finishing barn at the University of Minnesota Southern Research and Outreach Center, where fresh slurry in a shallow pit inside the barn was flushed out weekly. The pigs at the sampling site were fed with corn and soyabean. Prior to loading the batch reactors (Fig. 1), the collected slurry was passed through a sieve with 2 mm openings. Four sub-samples of the screened slurry were then diluted with tap water to achieve respective TS concentrations of 0.5, 1.0, 2.0, and 4.0%. The characteristics of the sieved liquid slurry before dilution are shown in Table 1.

The prepared liquid slurry was concurrently placed in 12 columns, made of PVC materials, 916 mm in height and 153 mm in internal diameter, simulating batch reactors (Fig. 1). The slurry level in each column was 763 mm, giving a 153 mm headspace. Air was pumped through a bubble stone located at the bottom of each column. Four aeration durations (5, 10, 20, and 30 day) and three aeration levels (+35 mV[ORP], 1, 0, and 0 mV[ORP]) were tested. The aeration intensities were maintained by controlling the airflow rates according to the ORP and dissolved oxygen (DO) readings taken three times a day. The ORP was converted to standard hydrogen electrode $E_h$ in mV by a formula

$$E_h = E_{cal} + 241$$

where $E_{cal}$ in mV (calomel reference electrode) was measured by an ORP meter (DIGI-SENSE, Model 407510). The DO in the liquid was measured using an oxygen meter (Extech, Model 407510). The actual ORP or DO in the aerated slurries had fluctuated around the set values, which were recorded as $+35 \pm 25$ mV[ORP], 1.0 ± 1.2, and $3.0 \pm 2.1$ mgO$_2$ l$^{-1}$. All columns were housed under constant room temperature at 17 ± 0.5 °C.

2.2. Sampling and analyses

After sieving, one mixed slurry sample was collected for analysis of the initial characteristics. During aeration, liquid slurry samples from all columns were collected on days 5, 10, 20, and 30. All slurry samples, including the initial sample, were drawn from the well-mixed slurry at approximately the mid-depth of each column (or container) during agitation using a motorised paddle-stirrer (Tline laboratory stirrer, Model 102). All the samples were stored at −20 °C immediately after collection, and thawed and allowed to reach room temperature only prior to analysis.

American Public and Health Association Standard methods were used to run the liquid slurry sample analysis for TS, TVS, TSS, TVSS, and BOD$_s$ (APHA et al., 1998). According to Hach (1993), the VFA measurement is based on esterification of the carboxylic acids present in the sample. Calorimetric determination of the esters follows a ferric hydroxamate reaction. The
concentration of VFAs was measured at a wavelength of 495 nm using a DR/3000 spectrophotometer. All volatile acids are reported as their equivalent concentration of acetic acid. The removal efficiency, in terms of solids in different forms, BOD5, and VFAs, is calculated by dividing the difference between the treatment and the concurrent control by the concurrent control, and then multiplying by 100.

3. Results and discussion

3.1. Changes of total solids and total volatile solids

Figure 2 presents the changes of TS levels in slurry treated by the 30 day aeration process. For the treatment under ORP of +35 mV, there is some decrease in TS levels for all slurry columns when aeration time increases from 5 to 20 days, compared to the control. However, the TS levels apparently decrease when the aeration process lasts 30 days, particularly for slurry with initial TS levels lower than 4-0%. With few exceptions, the TS levels in non-aerated columns decrease slightly (Fig. 2). Analysis of the TS removal efficiency reveals that 1-6–11-1% is removed by day 5 for columns initially filled with slurry with TS levels of 0-5–4-0%. As the aeration treatment approaches 30 days, the removal efficiencies reach 6-0–44-9%. When the aeration intensity is raised to 3-0 mg[O2]l⁻¹, the trend of decrease in TS levels and increase in TS removal efficiencies become pronounced as the aeration time increases (Fig. 2). TS removal efficiencies are enhanced from 8-4 to 30-5% by day 5 and between 42-3 and 56-4% by day 30. The effectiveness of TS removal under the aeration intensity of 1-0 mg[O2]l⁻¹ is found to be 1-7 to 4-2% by day 5 and 18-6–50-3% by day 30.

The changes of TVS levels in slurry under the three aeration intensities are shown in Fig. 3. Similar to TS, the TVS levels in slurry columns are decreasing during the process of aeration. The overall TVS removal efficiencies under the aeration intensity of +35 mV[ORP] achieve 0-8–17-2% by day 5 and 6-6–48-9% by day 30. The TS removal under 1-0 mg[O2]l⁻¹ increases from 2-9 to 21-8% by day 5 to 26-0–61-1% by day 30, while from 18-2 to 35-7% by day 5 to 57-3–69-9% by day 30 under 3-0 mg[O2]l⁻¹.

3.2. Changes of total suspended solids and total volatile suspended solids

Figure 4 demonstrates the primary features of TSS change in the slurry during the aeration process under the three different intensities. For example, for slurry with low solids content, such as TS at 0-5 and 1-0%, aerated at the intensity of 1-0 mg[O2]l⁻¹, the TSS levels in the briefly aerated slurry (5 day) are similar to those
of non-aerated slurry. After 5 days, the TSS levels decrease sharply. For slurry with high solids content (2-0 and 4-0%), little change is observed in TSS levels during the first 20 days of aeration, but a significant reduction occurs by day 30. Under +35 mV[ORP], apparent decreases in TSS levels in the slurry are found only by day 30, regardless of the initial TS levels. With an aeration intensity of 3.0 mg[O2]l^{-1}, similar to TS and TVS, the TSS levels in all slurry columns decrease gradually with respect to the time of aeration. For the

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**Fig. 3.** Variation of total volatile solids (TVS) in slurry treated by 30-day aeration under: (a) +35 mV oxidation-reduction potential (ORP); (b) 1.0 mg[O2]l^{-1}; (c) 3.0 mg[O2]l^{-1}. ○ Control, slurry with TS of 0.5%; ■ control, slurry with TS of 1.0%; ●, control, slurry with TS of 2.0%; ▲ control, slurry with TS of 4.0%; ◀, aeration, slurry with TS of 0.5%; □, aeration, slurry with TS of 1.0%; ▼, aeration, slurry with TS of 2.0%; △, aeration, slurry with TS of 4.0%.

**Fig. 4.** Variation of total suspended solids (TSS) in slurry treated by 30-day aeration under: (a) +35 mV oxidation-reduction potential (ORP); (b) 1.0 mg[O2]l^{-1}; (c) 3.0 mg[O2]l^{-1}. ○ Control, slurry with TS of 0.5%; ■ control, slurry with TS of 1.0%; ● control, slurry with TS of 2.0%; ▲ control, slurry with TS of 4.0%; □, aeration, slurry with TS of 0.5%; △, aeration, slurry with TS of 1.0%; ▼, aeration, slurry with TS of 2.0%; △, aeration, slurry with TS of 4.0%.
controls, the reasons that contribute to the low levels of TSS and TVSS by day 5 and day 10, respectively, in the slurry with initial TS of 2.0% cannot be explained. The TSS levels are reduced from 4.4 to 45.8%, 18.0 to 51.9%, and 39.0 to 57.2% by day 30 among the columns with different TS contents for aeration intensities of +35 mV[ORP], 1.0, and 3.0 mg[O2]l⁻¹, respectively.

The changes of TVSS levels over time (Fig. 5) in slurry under the three aeration intensity levels are quite similar to those of TSS. A special feature is that, at all TS levels, TVSS decreases during aeration for all three aeration intensities. In the same manner, the TVSS are reduced from 7.3 to 56.8%, 27.2 to 58.2%, and 56.5 to 68.8% when aeration is run continuously for 30 days under conditions of +35 mV[ORP], 1.0, and 3.0 mg[O2]l⁻¹, respectively.

3.3. Characteristics of solids composition

The solids composition in slurry treated by the aeration process is characterised by the ratios of TVS/TS, TSS/TS, and TVSS/TS (based on the concurrent TS values in each of the aerated samples), and the changes of these ratios may reveal the relative decomposition rates of various labile substances. For the control, the ratio of TVS/TS is found to increase slightly over time in slurry with different TS levels and to increase with the increase in the levels of TS under different aeration durations, but there are no remarkable trends for the changes of ratios of TSS/TS and TVSS/TS (Table 2).

The ratios of TVS/TS, TSS/TS, and TVSS/TS in slurry are each found to increase with respect to the solids levels under the three aeration schemes within the 30 day duration. This indicates that the decompositions of TVS, TSS, and TVSS would be accelerated in slurry with low solids levels. High organic solids generally impede the oxygen transfer rate in water (Westerman & Zhang, 1997); thus, oxygen utilization should be efficient in the low-solids slurry because microorganisms are able to effectively assimilate organic compounds to support enhanced respiration.

There is a decreasing trend on TVS/TS ratio in slurry with different solids sampled from the three different aeration intensities when the aeration time increases from 5 days to 30 days (Table 2). In other words, the relative rate of TVS breakdown gradually increases as the time of aeration increases, compared to the breakdown of TS. Ndewga et al. (2002) found that the ratio of TVS/TS kept nearly constant in the non-treated animal slurry. The decrease in TVS/TS during aeration should reduce odour offensiveness since odorous compounds are derived from volatile solids and organics (Burton, 1992; Zhang & Westerman, 1997; Zhu, 2000). Interestingly, the TVS/TS ratios by day 5 are consistently lower than by day 10 in the slurry with initial TS of 2.0%, a relatively low value compared to those with initial TS of 1.0% by day 5. It appears that there is an optimal substrate level at 2% TS for the blooming activity of

![Fig. 5. Variation of total volatile suspended solids (TVSS) in slurry treated by 30-day aeration under: (a) +35 mV oxidation-reduction potential (ORP); (b) 1.0 mg[O2]l⁻¹; (c) 3.0 mg[O2]l⁻¹. Control, slurry with TS of 0.5%; ■, control, slurry with TS of 1.0%; •, control, slurry with TS of 2.0%; ▲, control, slurry with TS of 4.0%; ●, aeration, slurry with TS of 0.5%; ●, aeration, slurry with TS of 1.0%; ■, aeration, slurry with TS of 2.0%; ■, aeration, slurry with TS of 4.0%](image-url)
aerobic microorganisms around day 5, by which time a considerable portion of volatile organics might be consumed; this deduction needs to be verified.

For the ratio of TSS/TS, some distinct features different from that of TVS/TS are found. At the +35 mV[ORP\textsuperscript{\textdegree}], the TSS/TS tends to increase in all columns except for the initial TS of 2.0%. Under the aeration intensities of 1.0 and 3.0 mg O\textsubscript{2}[l\textsuperscript{-1}], a decreasing tendency on the ratio of TSS/TS is found in the slurry with low TS levels (0.5 and 1.0%). However, an opposite trend occurs in slurry with high TS levels (2.0 and 4.0%). Notably, the lowest TSS/TS appears in all of the columns sampled by day 10 with aeration intensity of 3.0 mg O\textsubscript{2}[l\textsuperscript{-1}], while this peculiarity is found only in the low-solids slurry (0.5 and 1.0%) for the other two aeration levels. TSS essentially consists of particulate solids and biomass (including live and decaying microbes), and the former could be decreased during aeration. Thus, the ratio of TSS/TS under +35 mV[ORP\textsuperscript{\textdegree}] might be explained by massive aerobe growth (also reported by Zhu et al., 2002). Due to abundant substrate, biomass accumulation could occur in slurry with high solids levels (Grady et al., 1999; Henze et al., 2003) when aerobe intensity is 1.0 or 3.0 mg O\textsubscript{2}[l\textsuperscript{-1}]. Biomass should decrease in slurry with low solids content.

As for the changes of TVSS/TS ratio, there is no apparent indication over the entire aeration period. But the lowest ratio is found in the slurry with low solids content (0.5 and 1.0% TS) when the aeration time reaches 10 days, regardless of the aeration intensity. The TVSS/TS ratios in slurry with a TS level of 2.0% are elevated between day 10 and day 20 under the three aeration intensities.

3.4. Change of the 5 day biochemical oxygen demand

For the controls, slight increases are found by day 10 and day 20 for BOD\textsubscript{5} for slurries with different TS levels, while for the treatments, the values of BOD\textsubscript{5} decrease after day 20 (Table 3). This phenomenon indicates that BOD\textsubscript{5} in untreated slurry could increase during a relatively short period of storage.

The effect of aeration duration and intensity on BOD\textsubscript{5} concentrations in slurry is shown in Table 3. Firstly, BOD\textsubscript{5} decreases rapidly when the duration of aeration increases under the three aeration intensities. Secondly, the higher the aeration intensity, the lower are the BOD\textsubscript{5} levels achieved. Thirdly, BOD\textsubscript{5} increases by days 10 and 20, particularly for the slurry with 4.0% TS, the main reason for which might be the increased rate of particulate hydrolysis due to the growing microbial population, leading to a release of more biodegradable materials that contribute to the temporary rise of BOD\textsubscript{5} in the treated slurry. The BOD\textsubscript{5} removal efficiencies ranges from 0.0 to 69.7%, 1.6 to 82.0%, and 25.0 to 86.4% by day 5 under the aeration intensities of

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**Table 2**

Variation in ratios of total volatile solids (TVS), total suspended solids (TSS) and total volatile suspended solids (TVSS) to total solids (TS) in slurry treated under three different levels of aeration intensities and four durations

<table>
<thead>
<tr>
<th>Total solids, %</th>
<th>Ratios for various aeration intensities and durations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
</tr>
<tr>
<td></td>
<td>5 day</td>
</tr>
<tr>
<td>TVS/TS ratio</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>0.729</td>
</tr>
<tr>
<td>1.0</td>
<td>0.727</td>
</tr>
<tr>
<td>2.0</td>
<td>0.750</td>
</tr>
<tr>
<td>4.0</td>
<td>0.777</td>
</tr>
<tr>
<td>TSS/TS ratio</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>0.497</td>
</tr>
<tr>
<td>1.0</td>
<td>0.799</td>
</tr>
<tr>
<td>2.0</td>
<td>0.480</td>
</tr>
<tr>
<td>4.0</td>
<td>0.826</td>
</tr>
<tr>
<td>TVSS/TS ratio</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>0.486</td>
</tr>
<tr>
<td>1.0</td>
<td>0.633</td>
</tr>
<tr>
<td>2.0</td>
<td>0.361</td>
</tr>
<tr>
<td>4.0</td>
<td>0.715</td>
</tr>
</tbody>
</table>

\*ORP, oxidation–reduction potential.
3.5. Characteristics on potential of odour generation

The changes of volatile fatty acids (VFAs) over time in the slurries with different TS levels under the control are quite similar to those of BOD$_5$ (Table 3). However, the removal of VFAs by the aeration treatment at different treatment durations is much more significant than removals of solids or BOD$_5$ (Table 5).

Under the three aeration intensities, the VFA levels for those columns with a TS content of 0-5% are greatly reduced by day 5 and become nearly undetectable thereafter. The VFA levels in the slurry with initial 1-0% TS gradually decrease over the length of aeration under +35 mV[ORP], but are quickly reduced to undetectable levels after 5 days under aeration intensities of both 1-0 and 3-0 mgO$_2$/l$^{-1}$. For slurry with TS levels of 2-0 and 4-0%, good removal efficiencies are also obtained for all aeration intensities, with the exception of +35 mV[ORP] for slurry with 4-0% TS. Meanwhile, some increases in VFAs are found by day 10 (e.g. 4-0%
Under an ORP (TS level in slurry), Burton of aeration intensities for a given aeration duration and removal efficiencies are usually enhanced by the increase in solids decomposition and biochemical oxygen demand regardless of aeration intensities. Moreover, the VFA removal efficiencies increase from 1-0% to 2-0% when aeration duration is longer than 5 days, and 87-7 to 99-0% by day 20 (Table 4). Continuous aeration of 5 days at 1-0 mgO₂/l⁻¹ in batch treatment is necessary for slurry with a solids level around 1-0% to ensure an economically efficient treatment. Since pig slurry after mechanical separation normally contains TS ranging from 1-0 to 2-5%, duration of 5–10 days with aeration intensities of 1-0–3-0 mgO₂/l⁻¹ is thus recommended for odour control at farm level according to this study.

### 3.6. Odour generation potential evaluated by solids and biochemical oxygen demand

Regression analysis between VFAs and solids and BOD₅ is conducted to develop the relationships for odour estimation. The linear relationships for VFAs with solids in different forms and BOD₅ throughout the process (Table 4). By this standard, 5 days of aeration will suffice to treat slurry with TS content equal to or less than 0-5%, provided that the aeration level is at least + 35 mV[ORP] (Table 4). For slurry with a TS content equal to or less than 1-0%, more than 10 days of aeration will be needed at + 35 mV[ORP] (5 days at 1-0 and 3-0 mgO₂/l⁻¹). For slurry with TS equal to or greater than 2-0%, at least 5 days of aeration is required at a level of 3-0 mgO₂/l⁻¹ (Table 4). Continuous aeration of 5 days at 1-0 mgO₂/l⁻¹ in batch treatment is necessary for slurry with a solids level around 1-0% to ensure an economically efficient treatment. Since pig slurry after mechanical separation normally contains TS ranging from 1-0 to 2-5%, duration of 5–10 days with aeration intensities of 1-0–3-0 mgO₂/l⁻¹ is thus recommended for odour control at farm level according to this study.

<table>
<thead>
<tr>
<th>Aeration intensity</th>
<th>Aeration duration, day</th>
<th>VFAs, mg l⁻¹</th>
<th>VFAs removal efficiencies, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total solids, %</td>
<td>Total solids, %</td>
</tr>
<tr>
<td></td>
<td>0-5</td>
<td>1-0</td>
<td>2-0</td>
</tr>
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<td></td>
<td>0-5</td>
<td>1-0</td>
<td>2-0</td>
</tr>
</tbody>
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*ORP, oxidation–reduction potential.
coefficients $R$ of 0.8147, 0.8224, 0.8097, and 0.8200, respectively, while that for VFAs versus BOD$_5$ reaches 0.8415. Previous studies demonstrated a similar linear correlation between BOD$_5$ and VFAs in pig slurry with no aeration treatment (Zhu et al., 2001), and in slurry during aerobic treatment (Williams, 1984). Research also showed that the VFA generation was relevant to the portion of solids in the smallest particle size range (<0.075 mm) in slurry by microbial degradation (Yasuhara et al., 1984; Zhu et al., 2001) and the odour offensiveness was linearly related to the BOD in slurry storage (Williams, 1984; Ndegwa et al., 2002). Because aeration changes the composition of the solids and biological properties of the aerated slurry (as discussed above), the correlations in this study where odour generation potential is evaluated by the changes of solids in slurry under different aeration levels are different from the previous literature. Therefore, during the course of both decomposition of solids and organic materials and biodegradation of odorous compounds, the odour generation potential in slurry treated by aeration can be distinctly characterised by changes in TS, TVS, TSS and BOD$_5$ concentrations.

4. Conclusions

(1) Data from this study indicate that under a given intensity of aeration, solids decomposition, including total solids (TS), total volatile solids (TVS), total suspended solids (TSS), and total volatile solids (TVSS), 5 day biochemical oxygen demand (BOD$_5$) reduction, and volatile fatty acids (VFAs) breakdown are improved by the duration of aeration for pig slurry with TS levels from 0.5 to 4.0%, which are enhanced with the increase of aeration intensities (i.e. +35 mV [oxidation–reduction potentials, ORP], 1.0, 3.0 mg[O$_2$] l$^{-1}$). However, slurry containing a...
higher TS level would impair the efficiencies of aeration and aeration under +35 mV[ORP] is insufficient for odour control. Aeration intensities equal to or greater than 1.0 mgO₂ l⁻¹ for slurry with TS less than 2.0% would offer an advantageous condition for solids decomposition, BOD₅ reduction, and VFA removal during the batch aeration treatment.

(2) Total solids (TS) removals with ranges from 6.0 to 44.9%, 18.6 to 50.3 and 42.3 to 56.4% are achieved by day 30 under aeration intensities of +35 mV[ORP], 1.0, 3.0 mgO₂ l⁻¹, respectively. The ratios of TVS/TS, TSS/TS, and TVSS/TS in slurry consistently increase with respect to the solids levels under the 30-day aeration process. The TVS/TS ratio in slurry decreases, however, as aeration continues from day 5 to day 30.

(3) At the end of experiment, the BOD₅ removal efficiencies range from 78.5 to 92.0%, 79.4 to 96.0% and 91.7 to 97.0% under aeration intensities of +35 mV[ORP], 1.0, 3.0 mgO₂ l⁻¹, respectively. By the standard of VFA level (below 230 mg l⁻¹) for a slurry without offensive odour, duration of 5–10 days with aeration intensities of 1.0 to 3.0 mgO₂ l⁻¹ in batch treatment is recommended for farm practice for odour control.

(5) Linear regression reveals that the odour generation potential in slurry treated by aeration can be distinctly characterised by the change in the state of solids and also by the change in BOD₅ levels.

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