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# Production of volatile fatty acids from wastewater screenings using a leach-bed reactor

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ABSTRACT

Screenings recovered from the inlet works of wastewater treatment plants were digested without pre-treatment or dilution using a lab-scale, leach-bed reactor. Variations in recirculation ratio of the leachate of 4 and 8 $l/l_{reactor}$/day and pH values of 5 and 6 were evaluated in order to determine the optimal operating conditions for maximum total volatile fatty acids (VFA) production. By increasing the recirculation ratio of the leachate from 4 to 8 $l/l_{reactor}$/day it was possible to increase VFA production (11%) and soluble COD (17%) and thus generate up to 264 g VFA/kg-dry screenings. These VFA were predominantly acetic acid with some propionic and butyric acid. The optimum pH for VFA production was 6.0, when the methanogenic phase was inhibited. Below pH 5.0, acid-producing fermentation was inhibited and some alcohols were produced. Ammonia release during the hydrolysis of screenings provided adequate alkalinity; consequently, a digestion process without pH adjustment could be recommended. The leach-bed reactor was able to achieve rapid rates of screenings degradation with the production of valuable end-products that will reduce the carbon footprint associated with current screenings disposal techniques.


## 1. Introduction

Screens are used in wastewater treatment plants (WWTP) to remove large materials from the influent and thus protect downstream unit processes. In the UK, 6 mm screens are commonly used prior to primary settlement, but smaller screens as low as 1 mm may be used to protect other, more sensitive unit processes, such as biological aerated filters or membrane bioreactors. The daily production of screenings in the UK is between 488 and 1464 wet-tonnes and the organic fraction is around 90% on a dry basis (Cadavid and Horan, 2012). This material is unpleasant to handle and typically disposed of to landfill. However, due to the high organic content, its GHG potential is high when disposed of via this route.

Screenings will readily digest anaerobically with methane yields of around 0.3 $m^3$ $CH_4$/kg $VS_{applied}$ (Le Hyaric et al., 2010; Cadavid and Horan, 2012). Nevertheless, given its heterogeneity and high content of sanitary items, it is an unsuitable feedstock for conventional mesophilic anaerobic digestion (MAD), a process commonly used at wastewater treatment plants, where it would cause solids accumulation, stratification and foaming (Le Hyaric et al., 2010).

To make anaerobic treatment feasible, an alternative approach would be to utilize an optimised and flexible two-stage process with the first-stage generating a VFA rich

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stream. This could then be fed to existing on-site MAD assets for methane production or alternatively utilized directly in the wastewater treatment for biological phosphorus or nitrogen removal (Cadavid-Rodríguez and Horan, 2013). A dry process in a leach bed reactor (LBR) appears to offer an attractive option as the first stage, since that would overcome the operational problems associated with solids and reduce the need for pre-treatment.

The LBR has been employed to digest organic materials with a high solids concentration and a large fraction of contaminants (Dogan et al., 2008). It is operated to optimize the reactions of hydrolysis in which particulate organic matter is hydrolysed to smaller, soluble compounds. These are then reduced to VFA by the reactions of acidogenesis and acetogenesis. The resultant VFA-rich liquid stream, largely free from particulate material, can then be passed forward to a more conventional methanogenic reactor for the production of methane. This technique has proven to be effective for the digestion of the Organic Fraction of Municipal Solid Waste (OFMSW) (Chugh et al., 1999; Vieitez et al., 2000), fruit and vegetables waste (Mtz-Viturtia et al., 1995), food waste (Xu et al., 2011), animal manure (Demirer and Chen, 2008), as well as biohydrogen production from food waste (Shin and Youn, 2005).

The real challenge for a successful operation of a LBR is to ensure optimum hydrolysis by overcoming the mass transfer limitation which appears to be the true rate-limiting process step (Martin et al., 2003). Hydrolysis is a complex process that is function of pH, type of substrate, nature of the biomass, size of particles and residual concentration of biodegradable matter (Elefsiniotis et al., 1996). It is driven by physicochemical reactions and microbial metabolism where solid–liquid mass transfer plays a key role. One parameter that can be manipulated to increase the solid–liquid mass transfer in the LBR is the recirculation ratio of the leachate. However, there are no clear criteria for selecting this parameter in the literature and therefore a wide range of values (0.2–14.4 $l/l_{reactor}$/day) can be found (Table 1).

But in addition, pH has also been reported as one of the major parameters affecting the VFA production in anaerobic acidogenesis. This parameter plays an important role in determining the type of anaerobic fermentation pathway in the acidification process. Specifically, researchers have confirmed that *Clostridium* sp. shifts its metabolism from the acid-producing to alcohol-producing by modifying pH value (Dong et al., 2010), although there are contradictory reports for the optimum pH for acidification. Whereas some authors report it in the range 5.0–6.0 (Ghosh, 1991) or even 4.0–5.0 (Chen et al., 2007) when using activated sludge as substrate; others, using pineapple waste (Babel et al., 2004) and kitchen waste (Dong et al., 2010), have found that a pH below 6 is inhibitory for the acidification process and suggested a pH between 6 and 7. It is, therefore, necessary to generate further information about the role of pH on hydrolysis/acidogenesis processes. An LBR has the potential to provide a simple, technological solution to harness the energy potential of screenings and other similar waste types. So it was the aim of this study to investigate the role of the leachate recirculation ratio and operating pH in enhancing the production of VFAs from wastewater screenings and thus evaluate its potential as a full-scale process option when retrofitted upstream of existing MAD assets.

**Table 1 – Recirculation ratio of leachate in LBR reported in literature.**

| Reference | Recirculation ratio of leachate ($l/l_{reactor}$/day) | Cycle |
|---|---|---|
| O'Keefe and Chynoweth (2000) | 12[a] | Continuously |
| Rajeshwari et al. (2001) | 7.2[a] and 14.4[a] | Continuously |
| Babel et al. (2004) | 4[a] | 1-hour-on, 5-hours-off |
| Cysneiros et al. (2008) | 0.5[a] | Continuously |
| Lehtomaki et al. (2008) | 0.75 | n.r. |
| Myint and Nirmalakhandan (2009) | 4[b] | 30-min-on, 150-min-off |
| Nizami et al. (2010) | 1[a] and 2[a] | n.r. |
| Jagadabhi et al. (2011) | 0.2[a] and 0.4[a] | n.r. |

[a] values calculated from the data reported.
[b] l/day.

## 2. Materials and methods

### 2.1. Feedstock

Screenings from a local WWTP in the Yorkshire region (UK), treating mainly domestic wastewater, were collected regularly throughout the year with an average of four samples each season, and stored at −20 °C. Representative samples were removed as required and characterised (Table 2).

### 2.2. Reactors and operation

Two lab-scale LBRs were used, each with a total volume of 5 l and a working volume of 4 l. The reactors were primed with 1.2 kg of screenings and inoculated with an acidogenic seed culture that had been taken from a reactor operating for four months with a retention time of 4 days and a pH of 5.5. The seed culture was well-mixed with the screenings at a ratio of 0.78 (w/w) inoculum:screenings. A sufficient volume of water was then added to exceed the field capacity of the waste (Vieitez et al., 2000) and reach a liquid to solids ratio (L/S) of 10 (w/w). A stainless steel 1.5 mm mesh supported the solids and

**Table 2 – Characterisation of screenings used in this research.**

| Parameter | Value | Standard deviation |
|---|---|---|
| TS (%) | 26.5 | 1.61 |
| VS (% TS) | 93.2 | 0.44 |
| C (% dry) | 50.2 | 1.92 |
| N (% dry) | 2.6 | 0.89 |
| C:N | 17.6 | 3.75 |
| Ash (%) | 1.8 | 1.61 |
| P (% dry) | 0.32 | 0.03 |

Values presented are average from triplicate analyses.