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Anaerobic digestion of waste from a slaughterhouse

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ABSTRACT

This paper investigates the effects of variation in the inoculum to waste ratio on the anaerobic treatment of slaughterhouse waste, and proposes a low cost anaerobic treatment system. The work was carried out using a laboratory scale packed anaerobic digester with a gas collecting chamber. The inoculum used for seeding the reactors was septic tank sludge. The operating temperature ranged from 28 to 37 °C. The experimental results indicated chemical oxygen demand (COD) removal efficiencies ranged from 60 to 90% and increased with increasing inoculum to waste ratio beyond (1:1). The decrease in the temperature (from 37 to 28 °C) reduced the COD removal efficiency from 90 to 75%. The system did not show any sign of destabilization under intermittent mode of operation of the reactors.

Introduction

Slaughterhouse waste is a biodegradable waste and consists of blood, manure, offal and paunch contents. These waste materials are produced during the slaughtering process involving different steps such as killing the animals, removal of the carcass, cleaning the stomach and intestines [1]. The bloodstream produced as a result of the slaughtering process is more concentrated and has a high BOD and COD level [2] as compared to the wash water stream produced by washing of the site after slaughtering of animals.

The typical levels of COD for slaughterhouse waste range from 18,000 mg/l to 43,000 mg/l [3]. However, it has been observed that the COD can reach levels as high as 100,000 mg/l, depending on the composition and dilution of the waste. If the waste consists of blood and the paunch contents then the COD levels are high. However, if the waste is collected from the drains leaving from the slaughterhouses then it mostly consists of blood diluted with the water flowing in the drains. Both these cases are observed in this study.

There are more than 20,000 slaughterhouses in Pakistan. In addition to these slaughterhouses, the butcher shops in which the animals are slaughtered on a small scale and the slaughtering of poultry animals also add to highly contaminating waste discharged into water bodies without prior treatment.

Anaerobic digestion is known to be a useful method for a variety of wastes including municipal waste, industrial waste and slaughterhouse waste. Anaerobic digestion may be defined as the decomposition of the organic and inorganic material by micro-organisms in the absence of oxygen forming different end products including carbon dioxide and methane [4]. Different types of anaerobic reactors have been used for the treatment of slaughterhouse waste such as the anaerobic contact reactor, upflow anaerobic sludge blanket (UASB) reactor and anaerobic filter [5].

The major advantage of anaerobic digestion is that it does not require energy input if the anaerobic digestion process is carried out in mesophilic temperature range (30–40 °C). This temperature range is easily maintained most of the year in countries having hotter climate such as Pakistan. The amount of the biological sludge produced during the anaerobic digestion is significantly lesser compared to the aerobic digestion [6]. As a result there is a significant reduction in the costs associated with the sludge processing and disposal. Bio-gas produced during the anaerobic digestion consists of about 60% methane, the remaining 40% being CO_2, H_2S and some other trace gases [7]. The sludge remaining at the end of the anaerobic digestion is also a useful by product as it can be used as a soil conditioner or a fertilizer because it is rich in nutrients such as the potassium, ammonia and other trace elements [8].

Anaerobic digestion processes are prone to biological upsets and operational problems. The process may be inhibited due to the accumulation of toxic substances for the anaerobic micro-organisms such as ammonia and volatile fatty acids (VFAs). Problems such as odour production and corrosion of the digester caused by gases produced during the process also arise during anaerobic digestion [4]. All these problems may be solved by proper process design and operation. For

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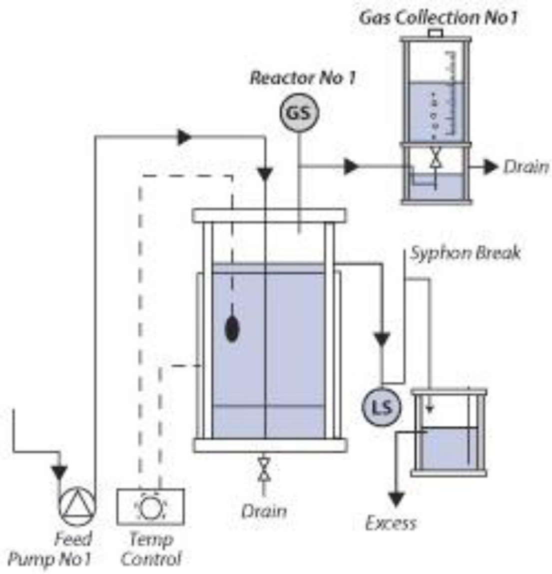

Fig. 1. Schematic diagram of anaerobic digester (http://www.discoverarmfield.co.uk).

example, start-up performance and improvement of process control was investigated for anaerobic digestion of waste water from a paper mill [9]. In most of previous studies anaerobic treatment is selected for the treatment of slaughterhouse waste [1–3,10]. In this work anaerobic digestion is employed for the treatment of slaughterhouse waste under mesophilic conditions, to determine maximum COD reduction possible for a slaughterhouse in Peshawar, Pakistan.

Materials and methods

Materials

The materials which are used in this work consist of septic tank sludge and slaughterhouse waste which includes blood, slaughterhouse wastewater and paunch contents. Anaerobic bacteria required for digesting the slaughterhouse waste were introduced in the reactor in the form of septic tank sludge. This septic tank sludge served as the inoculum. The slaughterhouse waste was obtained from the Fakirabad slaughterhouse, Peshawar, Pakistan.

Testing techniques

The COD of samples was analysed using the closed reflux method [11] while the pH was measured using a pH meter.

Experimental setup

An anaerobic digester of 5 l volume including the packing was employed as shown in Fig. 1.

A packed section having working volume of 4.3 l was available in the reactor. This packing was in the form of corrugated plastic balls and allowed the biomass to get attached, thus providing contact of the feed with the biomass. The feed was manually dumped into the reactor by removing the lid. Effluent was collected manually from the surface of the mixture in vessel. The gas produced during the process was collected in gas chamber connected. The mode of operation was intermittent as reactor was fed after every 5 days.

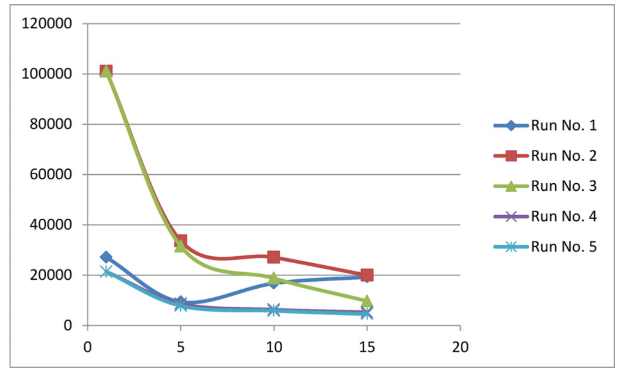

Fig. 2. Reduction in COD levels as observed during various experimental runs.

Experimental procedure

In all the five experiments sludge was first added in the reactor and left for warm up for 24 h. On the next day the slaughterhouse waste was added and then it was left for 5 days for acclimatization. Sample was collected for analysis. After the collection of sample more slaughterhouse waste was added. On the tenth day another sample was collected for analysis, followed by the addition of the slaughterhouse waste. On the fifteenth day the last sample was collected for analysis. The addition of sludge (inoculum), slaughterhouse waste, and water in each experimental run is presented (Table 1).

Results and discussion

In the first experiment the slaughterhouse waste sample had a COD level of 27,086 mg/l and the sludge sample had a COD level of 42,024 mg/l. Digestion continued for 15 days. On every 5th day the effluent was analysed for COD. The 1st reading showed that the COD level was 9360 mg/l which indicated that COD level reduced by 65%. However, subsequent readings showed that the COD level did not decrease any further but increased instead. The reason for this upset in anaerobic digestion may be attributed to sludge floatation phenomena since the feed for this experiment was not diluted. Moreover, due to the high protein and lipid content of the blood the biodegradation of the lipid content resulted in the formation of floating aggregates [12]. A similar observation has been reported previously for high organic loading rate (OLR) resulting in sludge floatation and loss of active biomass [1]. The COD level of the feed (substrate) and the change in COD levels as observed during the experiments are shown in Table 2.

In case of the 2nd experimental run the temperature conditions were the same as the first run. The temperature range was mesophilic (35–37 °C). The pH in the reactor was measured during these experiments and it was observed that it varied from 7.6 to 8 so there was no requirement for pH adjustment as, reported in a previous study [1]. In the 2nd experimental run the slaughterhouse waste sample employed had a COD level of 100,972 mg/l, the sludge sample had the same COD level of 42,024 mg/l as in the 1st run. Waste sample was sufficiently diluted in order to remove the discrepancy observed in the 1st run. The first reading, i.e. on 5th day, indicated a decrease of 67% in the COD level. The following readings indicated further decrease in COD levels to 73% and 80%. These results indicate that by increasing the amount of the inoculum the efficiency of the system in COD removal may be increased. The reduction in COD levels during experimental runs is shown in Fig. 2.

In the second experiment 210 g of bio-gas was collected on the 30th day.

The pH levels measured during the third experimental run remained in the range of 7.6–8. In the third run, the slaughterhouse