Journal of Water Process Engineering 25 (2018) 157–163

Contents lists available at ScienceDirect

Journal of Water Process Engineering

journal homepage: www.elsevier.com/locate/jwpe

A combined activated sludge-filtration-ozonation process for abattoir wastewater treatment

Pello Alfonso-Muniozguren[a], Judy Lee[a,*], Madeleine Bussemaker[a], Ralph Chadeesingh[a], Caryn Jones[b], David Oakley[c], Devendra Saroj[b,*]

[a] Chemical and Process Engineering, University of Surrey, Guildford, GU27XH, United Kingdom
[b] Civil and Environmental Engineering, University of Surrey, Guildford, GU27XH, United Kingdom
[c] Worldwide Industries Pte Ltd, London, United Kingdom

ARTICLE INFO

Keywords:
Abattoir wastewater
Activated sludge
Advanced oxidation process
Organic matter
Disinfection
Ozonation

ABSTRACT

Current industrial livestock production has one of the highest consumptions of water, producing up to ten times more polluted (biological oxygen demand, BOD) wastewaters compared to domestic sewage. Additionally, livestock production grows yearly leading to an increase in the generation of wastewater that varies considerably in terms of organic content and microbial population. Therefore, suitable wastewater treatment methods are required to ensure the wastewater quality meets EU regulations before discharge. In the present study, a combined lab scale activated sludge-filtration-ozonation system was used to treat a pre-treated abattoir wastewater. A 24-h hydraulic retention time and a 13-day solid retention time were used for the activated sludge process, followed by filtration (4–7 µm) and using ozone as tertiary treatment. Average reductions of 93% and 98% were achieved for chemical oxygen demand (COD) and BOD, respectively, obtaining final values of 128 mg/L COD and 12 mg/L BOD. The total suspended solids (TSS) average reduction reached 99% in the same system, reducing the final value down to 3 mg/L. Furthermore, 98% reduction in phosphorus (P) and a complete inactivation of total coliforms (TC) was obtained after 17 min of ozonation. For total viable counts (TVC), a drastic reduction was observed after 30 min of ozonation (6 log inactivation) at an injected ozone dose of 71 mg/L. The reduction percentages reported in this study are higher than those previously reported in the literature. Overall, the combined process was sufficient to meet discharge requirements without further treatment for the measured parameters (COD, BOD, TSS, P, TC and TVC).

1. Introduction

Water pollution is becoming a worldwide concern due to new and tighter environmental regulations, and the increasing need for fresh water for the exponentially growing human population. In order to meet certain water discharge or reuse regulations, wastewater treatment usually combines primary (pre-treatment), secondary (usually biological) and tertiary (disinfection) treatments. The type and combination of processes used are governed by the wastewater quality and regulatory limits [1]. Within the European Union (EU), standards for discharge from urban wastewater treatment plants are subjected to 91/271/EEC Council Directive and are as follow: biological oxygen demand (BOD) 25 mg/L, chemical oxygen demand (COD) 125 mg/L, total suspended solids (TSS) 35 mg/L, phosphorus (P) 1–2 mg/L [2]. There are no regulations at the EU level on water reuse for agriculture irrigation, although steps are being taken to implement a common water reuse legislation [3].

The meat industry has one of the highest consumptions of water [4,5] with the global animal production requiring 2422 Gm^3 of water per year and the beef cattle sector alone accounting for almost one third of this volume [6]. With the production of animal products increasing yearly [7], so does the consumption of water. This then leads to the increase in the generation of wastewater which can vary considerably in terms of organic content and microbial population [8–11]. Therefore, suitable wastewater treatment methods are required to ensure the wastewater effluent quality meets regulations before discharge.

Activated sludge process (ASP) treatment of abattoir wastewater has proved to be effective at reducing COD, BOD and TSS, among other parameters, even for high organic load influent wastewaters [12–19]. Further treatment is then required to reduce the microbial content. Disinfection includes the use of chemicals such as chlorine, peracetic acid or hydrogen peroxide, as well as ultraviolet radiation (UV) and

* Corresponding authors.
E-mail addresses: j.y.lee@surrey.ac.uk (J. Lee), d.saroj@surrey.ac.uk (D. Saroj).

https://doi.org/10.1016/j.jwpe.2018.07.009
Received 26 February 2018; Received in revised form 21 June 2018; Accepted 24 July 2018

ozone [20,21]. Chemical usage is usually avoided to prevent the increase in effluent toxicity and bacterial regrowth [22]. UV has also been rarely utilised as a disinfection method for abattoir wastewater treatment because its performance efficiency is compromised when treating high turbidity and waters containing suspended solids [20,21]. UV also demonstrates low efficiency in the removal of organic matter [23]. Ozone, however, can remove micropollutants and inactivate microorganisms without altering or increasing the toxicity of the treated effluent [23–27] and is also an efficient virucidal agent [20,25,28–30]. This can be achieved using ozone alone or in combination with other advanced oxidation processes for the treatment of different wastewaters [31,32].

During ozonation, oxidation can occur through direct reaction involving molecular ozone and via an indirect pathway through hydroxyl radicals (OH•) formed during ozone decomposition. The former selectively attacks organic compounds while the latter, hydroxyl radicals, reacts non-selectively with many dissolved compounds (organic and inorganic contaminants) and the water matrix [20,33–36]. By oxidation of the specific cell wall components, ozone kills bacteria and disinfects water [36].

To the best of the authors' knowledge, there are few reports in the literature on abattoir wastewater treatment with ozone [11,37–39]. Wu and Doan [11] used a screening system to remove particles larger than 1 mm as the only pre-treatment before ozonation, reporting a 99% inactivation of total coliforms (TC), aerobic bacteria and *Escherichia coli* after 8 min of ozonation with an applied ozone dose of 23.09 mg/min L. They also reported a reduction in COD by 10.7% and BOD by 23.6% after ozonation. Millamena [37] relied on coagulation and filtration processes as a pre-treatment method reporting a COD reduction of 57.5% after applying ozone to the pre-treated samples at a rate of 1.2 L/min and producing 0.11 g O_3/h. The highest reduction in COD was reported by Proesmans et al. [39], where they combined a biological-ozonation system for abattoir wastewater treatment, achieving a 66% COD reduction after the ozonation step.

With the limited literature reports on the potential of a combined biological-ozonation system at treating abattoir wastewater, the present study aims to bridge the literature gap by assessing the use of a combined Activated sludge-Filtration-Ozonation (AFO) process to treat a heavily polluted and highly variable quality effluent from an abattoir.

2. Materials and methods

2.1. Abattoir wastewater

Wastewater samples were taken directly from an abattoir located in the county of Surrey, UK. The wastewater contained not only animal residues (blood, fat, viscera, manure, among others), but also onsite sewage, and traces of floor cleaning products. The wastewater collected was partially treated on site by a grit removal system, followed by coagulation-flocculation where ferric chloride solution was used as a coagulant and Polygold CE662 as a flocculation agent, and processed further by dissolved air flotation. This onsite pre-treated effluent will be referred to as "raw wastewater". To account for wastewater variability, the abattoir effluent was sampled at least once per week over a two-month period and stored at 4 °C prior to use. The variation before and after storing the raw wastewater (maximum storing time was 5 days at 4 °C) was measured and found to be insignificant for the measured parameters (COD, BOD and TSS).

2.2. Experimental setup

The activated sludge-filtration-ozonation system used is shown in Fig. 1. The abattoir wastewater samples were fed at a rate of 1 L/day into an activated sludge reactor (6 L glass reactor) in a semi-batch mode with a solid retention time (SRT) of 13 days. The aeration (5 L/min) in the ASP was stopped for 30 min in order to allow the sludge to settle before removing the bio-treated effluent (from the top of the reactor), as well as the settled sludge. Once the ASP reached steady state, the effluent was filtered through a filter paper of pore size ranging between 4 and 7 µm (Whatman cellulose filters, grade 595). The purpose of the filtration system was to separate any solids/sludge coming from the ASP, and to show the possible extent of the application of a separation process as a polishing step after the ASP. Then, 400 mL of the filtrate was exposed to a fixed dose of 71 ± 17 mg O_3/L (injected ozone dose produced by an Okamizu Food Detoxifier V.2 at a rate of 2.3 L air/min), which was injected into the filtrate via an air stone diffuser placed at the bottom of a conical flask. The exhaust ozone leaving the reaction vessel was measured with Aeroqual S-200 ozone meter. Ozonation was carried out at room temperature (22 °C ± 1) and varying exposure time from 1 to 60 min. To avoid airborne contamination, ozonation experiments and subsequent sample analyses were run within a fume cabinet. The initial hydraulic retention time (HRT) of 24 h was later

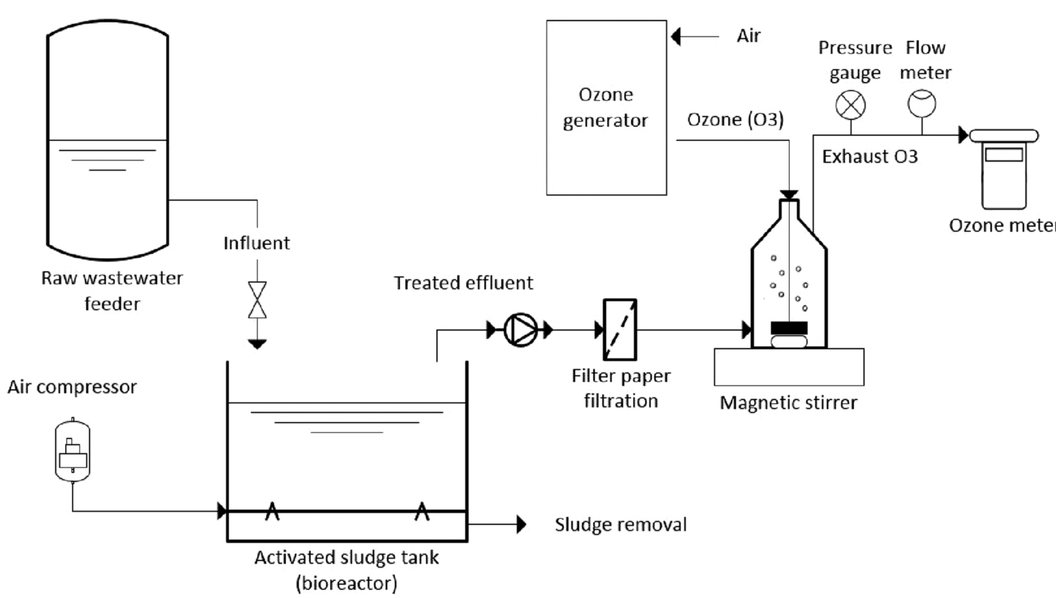

Fig. 1. A schematic of the experimental setup.