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Technical note

Gamma radiation induced effects on slaughterhouse wastewater treatment

Rita Melo[a,*], Sandra Cabo Verde[a], Joaquim Branco[b], M. Luisa Botelho[a]

[a]*Departamento de Física, Instituto Tecnológico e Nuclear, Estrada Nacional 10, Apartado 21, 2686-953 Sacavém, Portugal*
[b]*Departamento de Química, Instituto Tecnológico e Nuclear, Estrada Nacional 10, Apartado 21, 2686-953 Sacavém, Portugal*

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Abstract

A preliminary study using gamma radiation on slaughterhouse wastewater samples was carried out. Chemical oxygen demand (COD), biochemical oxygen demand (BOD) and total suspended solids (TSS) results were obtained at a dose rate of 0.9 kGy h^{-1}. A decrease of COD, BOD and colour was observed after irradiation at high absorbed doses. The microbiological results, following irradiation in the same conditions, correlated with the BOD results. The results obtained highlight the potential of this technology for wastewater treatment.

Keywords: Slaughterhouse wastewater; Gamma radiation; COD; BOD; TSS; Colour; Microbiological response

1. Introduction

It was reported that ionizing radiation induces both the degradation of numerous compounds and the inactivation of microorganisms depending on the type of energy, dose rate and absorbed dose (Drzewicz et al., 2005; Casimiro et al., 2005; Cabo Verde et al., 2004; Becker, 2002; Duarte et al., 2002; Botelho et al., 1993). As described by Getoff (1996), powerful oxidizing and reducing species (e.g., OH, e^-_{aq}, H) and molecular products (e.g. H_2, H_2O_2) are produced due to the interaction between gamma radiation and water, so these chain reactions lead to the phenomena described before.

Slaughterhouses generate large wastewater volumes and are frequently inefficient users of water (Massé and Masse, 2000). Therefore, for slaughterhouses, not only the consequences of wastewater are critical for the environment, but water is also critically wasted. Furthermore, the potential for pollution is great due to the high quantity of waste produced in line production, namely organic matter such as blood, which degrades with difficulty. Therefore, due to strict legislation and control to protect health and the environment, new approaches should be taken to overcome this situation, including remediation and the reuse of water.

In this work, the impact of gamma radiation, at a low dose rate, on slaughterhouse wastewater was undertaken. Herein, we report preliminary results where the gamma radiation effect was accessed through the measurement of some relevant legislated parameters, such as TSS, COD and BOD. Microbiological results are also presented and correlated with BOD under the same conditions. From a practical point of view, the colour parameter was also considered as an indicator of the concentration of pollutants, namely blood, in the wastewater.

2. Experimental

2.1. Sample preparation and gamma irradiation

The effluent used for the study was untreated slaughterhouse wastewater, which was submitted to mechanical pre-treatment screening only. The sampling was punctual, and during the slaughter period taking into account the worst case.

*Corresponding author. Tel.: +351 21 994 6080; fax: +351 21 994 1525.
E-mail address: ritamelo@itn.pt (R. Melo).

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Samples in a 0.5 l beaker were irradiated at γ-ray, dose rate 0.9 kGy h^{-1} (January 2004). The irradiation doses were established from 7 up to 25 kGy and were measured by routine dosimeters (Harwell Red Perspex, Batch HA Type 4034; and Gammachrome YR), with nominal uncertainty limits of about 5% (McLaughlin et al., 1989).

2.2. Analytical methods

BOD (Method 5210 B, Aqualytic BOD-OxiDirect), COD (Tritimetric Method 5220 C, Merck Thermoreactor TR300) and TSS (Method 2540 B) were measured according to Standard Methods for the Examination of Water and Wastewater (American Public Health Association, 1998). COD was measured after filtration with membrane pore size 1.2 μm. All values are the average of three replicates.

The impact of gamma radiation on the mesophilic wastewater natural contaminants was determined by means of total counts before and after irradiation. The method was based on the Spread Plate Method (9215 C) as described in the Standard Methods for the Examination of Water and Wastewater (American Public Health Association, 1998). For each sample, two dilutions were performed and three replicas of each dilution were plated in Tryptic Soy Agar (TSA, Oxoid, UK). The growth conditions were aerobic incubation at 30 °C for 14 days. Colony forming units (cfu) were counted after 24, 48 and 72 h after 7 and 14 days.

UV–vis–NIR spectrophotometric measurements (Cary 5G Spectrophotometer) were used to access the impact of gamma radiation on the persistent red colour of the slaughterhouse wastewater. A standard solution of oxyhemoglobin (Oxoid, UK) with a concentration of about 0.2% was used as reference. All samples were previously filtrated through a membrane pore size of 1.2 μm.

3. Results and discussion

The COD value at 7 kGy (3860 ± 234 mgO_2/l) is higher that the non-irradiated sample (2368 ± 221 mgO_2/l), whereas at 10–15 kGy, the COD value reverts to the non-irradiated value and decreases at 25 kGy (1600 ± 222 mgO_2/l) which is comparable to that reported by the slaughterhouse following anaerobic lagoon treatment.

The effectiveness of using ionizing radiation to remove toxic organic chemicals from aqueous solutions has been already reported by Kurucz et al. (2002) and Bao et al. (2002).

Therefore, the COD value increase at 7 kGy could be explained by the radiation-induced effect on the degradation of molecules that leads to the increase of the number of low-molecular weight substrates.

However, the hypothesis that gamma radiation is adequate to reduce the molecular weight of the organic matter in the effluent, an important goal for the slaughterhouse, is currently under study.

The TSS value decreases at 7 kGy (604 ± 30 mg/l) and is lower than the value of the non-irradiated sample (805 ± 40 mg/l). At higher dose, the TSS values are, in all cases inferior to those of the non-irradiated samples (mean 728 ± 37 mg/l). As described above, at 7 kGy the COD value increase, thus in this case solid particles and COD seem to be related accordingly to the radiation-induced degradation effect mentioned above. Nieuwenhuijzen et al. (2001) has reported that the quantity of pollutants integrated into or adsorbed onto particulate matter are non-negligible. In some cases, this is a major contribution to the wastewater COD. Further studies have to be performed to better understand the relation of the COD and TSS values.

Fig. 1 shows that BOD value increases at 7 kGy, whereas at higher doses, it decreases. The increase of BOD value at 7 kGy could be related to the radiation-induced degradation effect and the microorganisms' survival population' (approximately 5×10^3 cfu/ml). Thus, the BOD parameter, at several doses, was compared with the survival curve of the wastewater's natural contaminants. The survival curve obtained showed a linear inactivation phase (0 up to 10 kGy) followed by a stationary inactivation phase (10 up to 25 kGy) with a microorganisms' inactivation higher than 10^{-5} (inactivation efficiency of 99.999%). This inactivation curve can be interpreted by the heterogeneity of the wastewater's microbial population. A higher proportion of the less resistant cells are inactivated first, the more resistant cells (low concentration of microorganisms—cfu/ml) show a tail effect at higher doses which reflect in low constant values of the BOD at 10, 17 and 25 kGy.

Therefore at 7 kGy, the increase of BOD could be related to a radiation-induced degradation of molecules that leads to the increase of the number of low-molecular weight substrates that is easily metabolized by the survived microorganisms ($\geqslant 10^3$ cfu/ml).

Blood, oil and greases give a red colour to slaughterhouse wastewater. This parameter is one of the major problems in this kind of effluents. As shown in Fig. 2, the preliminary UV–vis–NIR spectrophotometric studies confirm that gamma

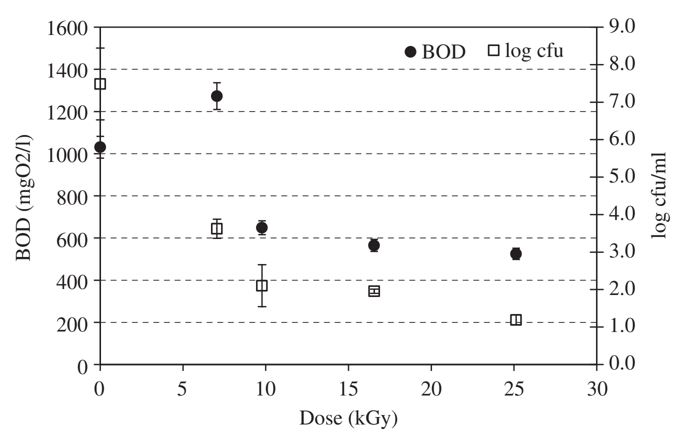

Fig. 1. BOD ($n = 10$) and inactivation curve ($n = 27$, $\alpha = 0.05$) of microorganisms versus absorbed dose.

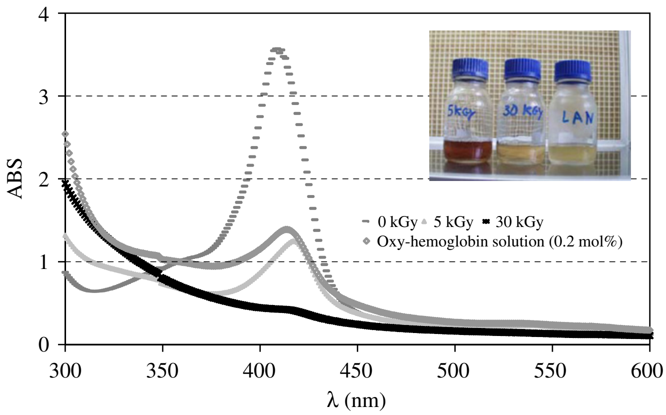

Fig. 2. Impact of nominal absorbed radiation dose on slaughterhouse wastewater colour. Legend: LAN, anaerobic lagoon.

radiation induce the degradation of potential pollutants, such as hemoglobin, turning off the red colour of the wastewater (see inserted picture) with the increase of absorbed doses, and is similar to that after anaerobic process. The concentration of aqueous hemoglobin, compared with non-irradiated wastewater, decreases about 66% and 88% at 7 and 25 kGy, respectively. These studies stress the advantages of the use of ionizing radiation for chemical and biological remediation of slaughterhouse wastewater and could reduce the wastewater residence time on the lagoons by introducing ionizing radiation step in slaughterhouses treatment facilities.

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