Original Article

EFFICIENCY ANALYSIS OF THE AUSTRALIAN WASTEWATER TREATMENT SYSTEM IN A PIG SLAUGHTERHOUSE

ANÁLISE DA EFICIÊNCIA DO SISTEMA AUSTRALIANO DE TRATAMENTO DE ÁGUAS RESIDUAIS EM UM ABATEDOURO DE SUÍNOS

Kelly Mari Pires de OLIVEIRA[1]; Péricles David dos Santos JÚLIO[2]; Max Seiji TSUNADA[1]; Renata Pires de ARAÚJO[1] Yzel Rondon SÚAREZ[3] Alexéia Barufatti GRISOLIA[1]

1. Faculdade de Ciências Biológicas e Ambientais, Universidade Federal da Grande Dourados, Dourados, MS, Brazil. kellyoliveira@ufgd.edu.br; 2. Faculdade de Ciências Exatas e Tecnologia, Universidade Federal da Grande Dourados, Dourados, MS, Brazil; 3. Universidade Estadual de Mato Grosso do Sul - UEMS, Dourados, MS, Brazil.

ABSTRACT: Pig farming is a significant economic activity in the food industry and the meat trade. However, pig slaughterhouses release their waste through effluents, which may spread pathogenic microorganisms and degrade the environment, particularly in bodies of water. The aim of the present study was to assess the efficiency of the Australian wastewater treatment system and the quality of the Effluent Treatment Station (ETS) of a pig slaughterhouse, which flows into the Laranja Azeda stream in the city of Dourados (State of Mato Grosso do Sul, Brazil). Effluentsampling was carried out in the ETS using treatment ponds (Australian system), from the input to the output, over a period of one year. Physicochemical and biological parameters were assessed to measure the effluentquality. The results showed a reduction in organic matter and microorganisms. The concentration of dissolved oxygen, pH, effluent temperature, redox potential, as well as the amount of coliforms, exhibited a significant reduction ($p<0.005$). The waste management brought by the ETS promoted the removal of pollutants from the effluent. However, these procedures were not enough to satisfy Brazilian and international parameters proposed by the WHO, which regulate the dumping of waste into water bodies.

KEYWORDS: Environmental monitoring. Microbiological parameters. Physicochemical parameters. Treatment ponds.

INTRODUCTION

In recent years, pig meat production on an industrial scale has achieved high levels of profitability, mainly due to technological innovations. However, the swine industry produces large amounts of waste and has become a highly polluting activity. The large consumption of water required for this activity leads to great volumes of released water: 80% to 90% of the water consumed during processing is discharged as effluent. The water of effluent eliminated by slaughterhouses has a high flow and high load of suspended solids, organic nitrogen, and Biochemical Oxygen Demand (BOD), which presents values of 4.200 mg L^{-1} depending on reuse or effluent treatment (UNEP, 2000; AGUILAR, 2002; DE SENA et al., 2009; PEREIRA et al., 2011; MEKONNEN; HOEKSTRA, 2012; GERBENS-LEENES et al., 2013).

Wastewater treatment must be performed for the adequate release of effluents into water bodies. The evolution of agro-industrial wastewater treatment systems has provided efficient technologies for removing organic loads (OLIVEIRA et al., 2013). After several relevant worldwide discussions, national and international official agencies have established rules that regulate the disposal and monitoring of agro-industrial waste in order to minimize their impacts to the environment. In Brazil, according to the standards recommended by a specialized agency (CONAMA – *Conselho Nacional do Meio Ambiente*), effluents produced by the swine industry should receive adequate treatment in effluent treatment stations (ETS) before being released into receiving water bodies (BRASIL, 2000; 2005; 2011).

There are several processes involved in the treatment of swine wastewater, such as physical, physicochemical and biological treatments (VIVAN et al., 2010; BUSTILLO-LECOMPTE; MEHRVAR, 2015). Each ETS should reduce organic and inorganic substances, as well as the load of pathogenic microorganisms. Thus, the treated effluent may be released into the receiving water body without causing damage to the aquatic environment health, in accordance with the physicochemical and microbiological parameters recommended by current legislation. Continuous monitoring of these quality parameters from agro-industrial effluents is essential for the efficient management of urban rivers.

The level of water pollution directly relates to the excessive increase in the amount of nutrients in the effluent, which has been assessed by measuring values of BOD and Chemical Oxygen

Received: 13/06/16
Accepted: 05/12/16

Demand (COD). Biodegradation of organic compounds in the receiving water bodies causes a decrease in the dissolved oxygen (DO) concentration in the water, deteriorating the quality of aquatic life. The monitoring of microbiological contaminants, determined by tests for *Escherichia coli* and total coliforms, can provide data about the operational efficiency of the wastewater treatment (FIORUCCI; FILHO, 2005; HUANG et al., 2012).

Stabilization ponds have been used as an alternative treatment method for swine manure in rivers and are a low cost alternative since they do not require great operating care (VIVAN et al., 2010). The Australian system consists of anaerobic and facultative ponds, responsible for the removal of organic matter and whose efficiency is assessed by BOD and COD measurements, as well as by maturation or polishing ponds, which are used to remove the remaining organic matter, nutrients and thermotolerant coliforms (VON SPERLING, 1996).

In consideration of the large number of watersheds in the state of Mato Grosso do Sul, as well as the recent increase of agro-industries, it is important to assess the quality of the effluents generated and released in local watercourses. The effectiveness of treatment systems (or simply waste stabilization pond systems), in terms of generating effluents released into the environment, can be assessed using appropriate microbial indicators and physicochemical parameters. The aim of the study was to assess the Australian system and to determine the effluent quality of a pig slaughterhouse plant for reuse purposes.

MATERIAL AND METHODS

Study area and sample collection

The slaughterhouse is located near the city of Dourados, in the state of Mato Grosso do Sul, in Midwest Brazil (geographic coordinates: 22º 13'27" S, 54º 24' 57" W). The Laranja Azeda stream is located south of the slaughterhouse and belongs to the Paraná River watershed and the Ivinhema River sub-basin. The stream receives post-treatment effluent derived from the pig slaughterhouse waste. The source of the Ivinhema River is approximately 1.0 km from where the effluent is dumped.

Approximately 1500 animals are culled daily in this slaughterhouse, representing a total of 304 tons of slaughtered animals. Approximately 2050 liters of water are used per animal during slaughter and meat processing. The average water volume consumed daily in the slaughterhouse is 3.145 m^3. The flow from the ETS to the receptor stream is 35.8 liters per second and the water retention period is 20 days.

Australian system for the Water Resource Recovery Facility from the slaughterhouse was composed of five ponds, with two anaerobic ponds (A1 and A2), two facultative ponds (F1and F2) and one polishing pond (P).

Classification of the water body

The Laranja Azeda stream has not yet been classified, according to IMASUL/Dourados/MS/Brazil. In this context, Article 40 of the law previously cited (BRASIL, 2005) states that fresh water without classification should be considered as Class 2 (Table 1).

Table 1. Classes of use of freshwater according to national parameters and their applicability

Special Class	Class 1	Class 2	Class 3	Class 4
Applicability: Supplies for human consumption with disinfection; Preservation of the natural balance of aquatic communities; Preservation of aquatic environments in conservation units with integral protection.	Applicability: Supplies for human consumption after simplified treatment; Protection of aquatic communities; Primary contact recreation such as swimming, water skiing and scuba diving, according to CONAMA resolution No. 274 (2000); Irrigation of vegetable crops that are eaten raw, and	Applicability: Supplies for human consumption, after conventional treatment; Protection of aquatic communities; Primary contact recreation such as swimming, water skiing and scuba diving, according to CONAMA resolution No. 274 (2000); Irrigation of	Applicability: Supplies for human consumption, after conventional or advanced treatment; Irrigation of tree crops, cereals and forage; Recreational fishing; Secondary contact recreation; Watering	Applicability: Navigation; Landscaped harmony

	fruits that develop closer to the ground and are eaten raw without peeling; Protection of aquatic communities in indigenous territories.	vegetable crops, fruit trees, parks, gardens and sports fields, with which the population may have direct contact; Aquaculture and fishing activity.	livestock

*Adapted from CONAMA resolution No. 357/05

Water samples

Water samples were collected in 500 mL glass bottles from each of the five ponds (A1, A2, F1, F2 and P), near the transferring duct, at a depth of 10 centimeters from the surface, on 16 different days during one year. Intotal, 80 samples were collected.

Physicochemical analysis

The parameters related to Dissolved Oxygen (DO), pH, temperature, electrical conductivity, total dissolved solids and oxi-reduction potential were measured using a multi-parameter probe (Hana HI 9828) during the water sampling. BOD and COD assessments were performed at the time when the effluent was released into the receiving water body. These parameters were determined by the respirometric method for BOD and the closed efflux colorimetric method for COD, as described by the American Public Health Association (EATON et al., 2005). The time gap between sampling and analysis was always less than 4 hours.

Microbiological Analysis

The quantifications of total coliforms (TC) and thermotolerant coliforms (TTC) were performed using the multiple-tube technique (EATON et al., 2005). Three tubes per dilution were used to determine the most probable number (MPN) of TC per mL of each sample (TC mL^{-1}). The number of TC and TTC was calculated using specific tables and the results were expressed in MPN/100 mL^{-1}.

Statistical analysis

The correlation between the physicochemical parameters and the treatment efficiency of the ponds was assessed by analysis of variance (ANOVA). When the normality and homogeneity assumptions of variances were not satisfied, the Kruskal-Wallis test was utilized. The parameter of DO was converted into log for the analysis of variance. The Mantel test was used to correlate the principal components analysis (PCA) for the physicochemical parameters with the PCA for the microbiological parameters of the effluent. The null hypothesis (H_0) formulated considered no relationship between the physicochemical and microbiological parameters. The analysis was performed using Past (version 1.81), Systat (version 12) and R softwares.

RESULTS AND DISCUSSION

Laranja Azeda stream has been classified as class 2 according to the Brazilian resolution, which classifies water bodies into classes (BRASIL, 2000). The regional classification of water bodies should be in accordance with the legislation determined by IMASUL (*Instituto de Meio Ambiente de Mato Grosso do Sul*).

Water from any pollution source cannot be deposited in a receiving water body if its quality features are in disagreement with the previously established specific parameters. According to legislation, effluents should not exceed the quality standards and conditions of its respective classes, in terms of reference flow or volume available (BRASIL, 2005). Furthermore, it is important to consider other conditions of effluent discharge in accordance with CONAMA resolution No. 430/11(BRASIL, 2011).

Physicochemical parameters

BOD and COD are the main physicochemical parameters used to assess the organic load in wastewater. Figure 1 are displayed the mean variation of BOD and COD measured in the effluent in the anaerobic (A1) and polishing (P) ponds.

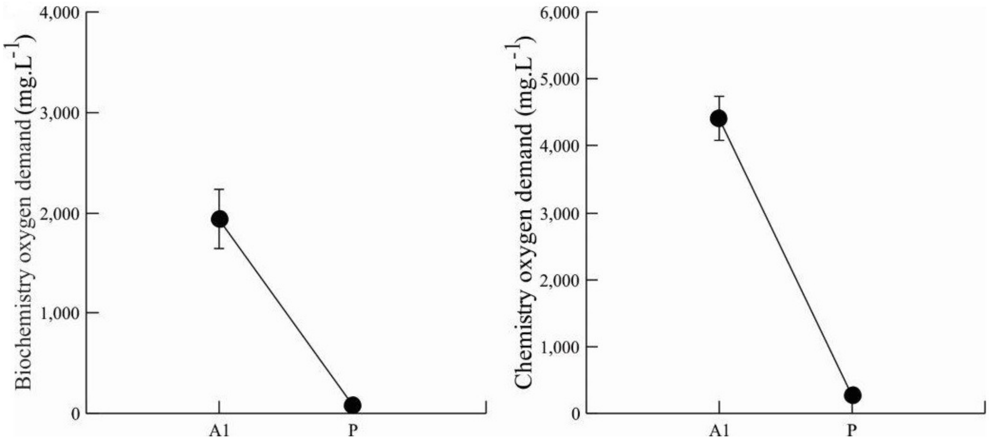

Figure 1. Mean variation of BOD (a) and COD (b) in the effluent measured in the anaerobic pond (A1) and polishing pond (P).

The Brazilian reference parameters established for BOD a minimal removal of 60% (BRASIL, 2011). The Australian water treatment system removed 97.3% and 95% of BOD and COD, respectively, which indicates high efficiency in the reduction of organic load. Pacheco and Wolff (2004) analyzed the efficiency of ETS from slaughterhouses and obtained BOD removal of 91%. Similarly, Sousa (2007) monitored the domestic wastewater treatment using the Australian stabilization system and found values of 93.90% and 79.14% for BOD and COD, respectively (Figure 1). In South Africa, legislation that regulates effluent disposal in water bodies determines 30 mg L^{-1} of COD, whereas the World Health Organization level is 20 mg L^{-1} for BOD (EAF, 1984; WHO, 1996). The COD values for the samples collected at the end of treatment varied from 127 mg L^{-1} to 553 mg L^{-1}, whereas BOD values ranged from 26 mg L^{-1} to 197 mg L^{-1} . Based on these values, the effluent did not satisfy international parameters. Organic and inorganic matter contributed to the increase of COD and BOD levels, particularly nitrate, an important product of oxidized organic matter (IGBINOSA; OKOH, 2009).

Significant differences were found in pH, effluent temperature, redox potential and DO parameters, between the beginning (anaerobic pond 1) and end (polishing pond) of the effluent treatment (Figure 2). However, no significant difference was found in total dissolved solids and electrical conductivity parameters between the beginning and end of the Australian treatment system (Table 2).

Gemmell and Schmidt (2013) assessed the water quality in the Msunduzi River (South Africa) and reported a pH variation ranging from 6.5 to 8.5. The WHO (2003) determines a pH value range from 4 to 11, whereas Brazilian legislation determines pH 5 and 9 as the minimum and maximum, respectively (BRASIL, 2011). In this case, the effluent satisfies the characteristics previously established by national and international standards (Figure 2).

Therefore, the pH water of effluent cannot cause harm to the soil, crops, or people. Park et al. (2011) stated that the pH variation in treatment ponds is related to algae proliferation, which consumes carbon dioxide and releases bicarbonates during the photosynthesis process, thereby causing alkalinity. Figure 1 displays the pH increase in the facultative pond. In the effluent treatment process, temperature can influence the ionic balance, pH, gas solubility (CO_2 and O_2) and the metabolic activity of the algae. Temperature decreased by about 5 ºC while passing through the ETS, ranging from 27 ºC to 22 ºC. This parameter is in agreement with the Brazilian resolution, which states that the effluent temperature at discharges hould be lower than 40 ºC (BRASIL, 2011).

The DO concentration for water potability should be higher than 6 mg L^{-1}, considering that a concentration lower than 5 mg L^{-1} is not adequate for the maintenance of aquatic life (DFID, 1999). There was a slight increase of DO in the water while passing through the ETS, with a final concentration of 1 mg L^{-1} in the polishing pond. Nevertheless, DO values were lower than 5 mg L^{-1}, which is the national reference (BRASIL, 2005). According to Holenda et al. (2007), oxygen loss is related to temperature alterations that lead to a metabolic rate increase in heterotrophic bacteria, which consume O_2 for organic matter degradation.

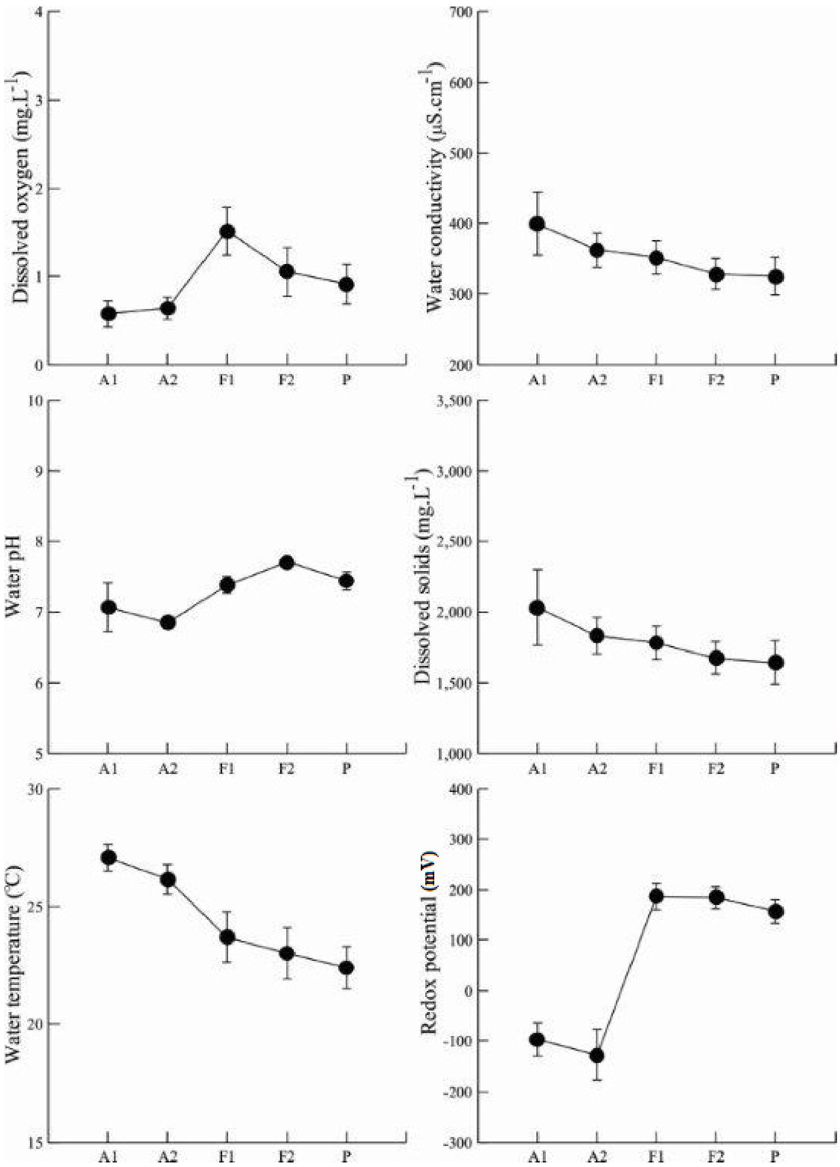

Figure 2. Means and standard error of the physicochemical parameters assessed in water from treatment ponds (A1 – Anaerobic pond 1; A2 – Anaerobic pond 2; F1 – Facultative pond 1; F2 – Facultative pond 2; P – Polishing pond)

Table 2. ANOVA and Kruskal-Wallis test of the physicochemical and microbiological variables according to the ponds

Parameters	**r^2**	**F**	**P**
Dissolved Oxygen (log)	0.248	3.302	0.020
Electrical Conductivity	0.108	1.210	0.322
		K	**P**
pH	-	24.540	<0.001
Water Temperature	-	19.763	0.001
Total Dissolved Solids	-	2.902	0.574
Salinity	-	3.132	0.536
Oxide-reduction Potential	-	29.386	<0.001

r^2 - determination coefficient; **F -** Cumulative frequency; **P-** chance or probability effect; **K –** number of classes;

The oxidation reaction of a compound, or a mixture of compounds, rearranges chemical substances, altering the chemical structure and creating toxic products. The main natural agents of oxidation and reduction reactions in effluent are microorganisms that degrade organic matter, which can involve partial oxidation (producing compounds of reduced toxicity) or total oxidation (complete mineralization of organic matter). Low oxidation reduction (ORP) values indicate the presence of reducing agents (e.g. ammonium, nitrites, organic substances), whereas high ORP values indicate the presence of oxidizing agents (e.g. Cr (VI), Mn (VII), oxygen gas, chlorine gas or products of its hydrolysis) (GONCHARUK et al., 2010). The ORP variation observed in the treatment ponds may be associated with biochemical reactions related to microorganisms and algae. The increase of ORP observed in facultative pond 1 (200 mV) (Figure 1) indicated formation of free oxygen in the effluent from photosynthetic activity. There are no standards for this parameter in Brazil, although it was possible to infer that the recycling of organic and inorganic compounds present in the effluent happened while passing through the treatment ponds, which resulted in the increased ORP.

The total dissolved solids (TDS) concentration is an important parameter of the water quality in agriculture, since the productivity and quality of plants depend on the soil salinity levels, which may be determined by irrigation. TDS directly relates to the electrical conductivity that measures the ionizable constituents in water. TDS levels and electrical conductivity of the effluent did not decrease while being treated in the ETS, with values higher than 1500 mg L^{-1} and 300 μS/cm, respectively, and a low significance value ($p<0.005$) was recorded. In Brazil, there are no reference values for these parameters e for the effluent deposition in the environment, making it difficult to monitor the ETS effectiveness. Igbinosa and Ohok (2009) assessed the effectiveness of an ETS in South Africa, considering a limit of 0 to 450 mg L^{-1} for treated effluent, as stipulated by South African Water Quality and the Department of Environmental Affairs and Tourism guidelines for TDS (DWAF, 1996; DEAT, 2000). The same authors considered electrical conductivity values below 250 $\mu S.cm^{-1}$ as an indicator of safety to freshwater aquatic communities. Based on these values, the effluent released into the Laranja Azeda stream exhibited high levels of salinity and conductivity. High concentrations of TDS and conductivity are toxic to the freshwater environment and may affect the osmoregulation ability of aquatic organisms, thereby reducing the local biodiversity. In this context, the incorporation of a pond with aquatic macrophytes after polishing could contribute to an increase in the ETS effectiveness. This procedure may enable the adsorption of salts by plant roots, resulting in the reduction of remaining total solids and conductivity in the treated effluent.

The Mantel test found a significant correlation between the physicochemical and microbiological characteristics of the ponds ($r = 0.27$; $p = 0.013$). Thus, changes in physicochemical conditions occurred throughout the effluent treatment process, influencing the microbiological characteristics this water significantly.

Microbiological parameters

Microbiological parameters analysis of the slaughterhouse effluent indicated the efficiency of the treatment system in terms of reducing total and thermotolerant coliforms. Analysis of the ETS efficiency in terms of microbiological parameters in the polishing pond indicated that 75% of the samples (12/16) exhibited TTC levels ≤1000 $TTC.mL^{-1}$, and 37.5% of the samples (6/16) exhibited TC levels higher than 2200 TC.100 mL^{-1} during the collection period. The results showed a reduction of up to three orders of magnitude in the log, representing a decrease of more than 99%. Significant difference ($p<0.005$) was found in the microbiological parameters assessed by the Kruskal-Wallis test (Figure 3).

Brazilian legislation indicates a limit of 1000 thermotolerant coliforms per 100 milliliters in 80% of samples of water river collected during one year (BRASIL, 2005). Despite the considerable reduction of microorganisms during the effluent treatment, only 75% of the samples presented permissible TTC values. Thus, the quality of the effluent was not in accordance with the parameters described by Brazilian legislation.

World Health Organization (2006) indicates a limit of 1000 $TTC.100m.L^{-1}$/sample for the use of wastewater in unrestricted irrigation. Since the thermotolerant coliforms levels in the effluent exceeded the limit, this wastewater must not be used for forage, fruit trees, industrial crops and pastures. According to Keraita et al. (2007), vegetable irrigation with wastewater is widespread, providing important nutrients for vegetables, and is considered a profitable alternative for farmers. However, it is important to highlight that water with pathogens levels above the established limits (calculated from the number of total and thermotolerant coliforms) may cause diseases in people and animals (SCHAAR et al.; 2013).

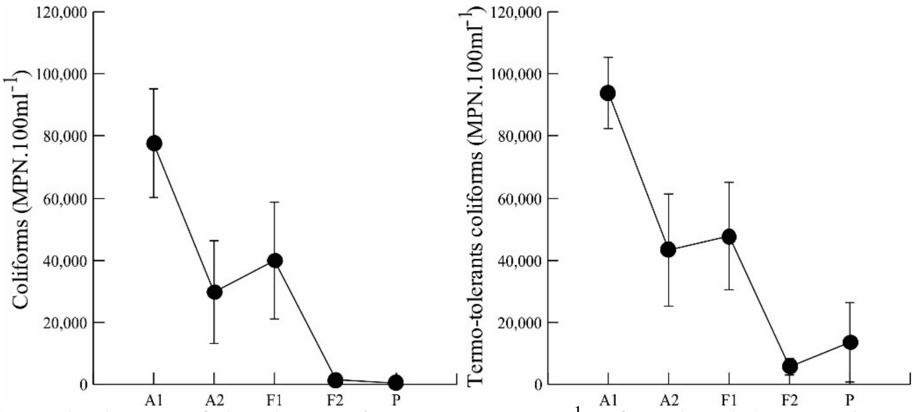

Figure 3. Means and standard error of the changes in MNP (100 mL^{-1}) of total and thermotolerant coliforms in the five treatment ponds (A1 – Anaerobic pond 1; A2 – Anaerobic pond 2; F1 – Facultative pond 1; F2 – Facultative pond 2; P – Polishing pond)

TTC is used to analyze river water quality but it does not represent a reliable indicator of fecal contamination (WHO, 2011). The Canadian Council of Ministers of the Environment and the California and Colorado Government established a limit of 2.2 TC 100 mL^{-1} for irrigation of food to be consumed raw (GEMMELL; SCHMIDT, 2013). In the present study, only 62.5% of the samples were in accordance with this limit during the sampling period, indicating a high level of contaminants in the effluent after treatment.

The use of water for bathing is regulated by CONAMA resolution No. 274, which established the conditions for recreation of primary contact, classifying them as proper or improper (BRASIL, 2000). At least 80% of the samples collected in the same place must exhibit a maximum of 1000 thermotolerant coliforms 100 mL^{-1} (thermotolerant). Considering that the effluent did not satisfy the microbiological parameters provided for the receiving water body, it appears the Laranja Azeda stream is inappropriate for diving activities due to its proximity to locations of imbalance between the effluent components and the water body. Future ecotoxicological studies should be performed to analyze the mortality of aquatic organisms in the Laranja Azeda stream, as well as to diagnose the impacts caused by the microbiological contaminants and levels of conductivity, salt and DO from the effluent.

CONCLUSIONS

Despite the considerable improvement in the physicochemical and microbiological parameters assessed in the effluent while being treated in the ETS, the effluent did not fully comply with national and international parameters that regulate the discharge of effluents into water bodies. This finding may imply deleterious effects on the receiving environment and prohibit the reuse of the wastewater.

This research indicates the need to analyze other ETS in order to assess the contamination level in water bodies that comprise the regional watershed, as well as the need adjusting the necessary parameters for greater efficiency in the elimination of pathogens as a form of environmental health control of ecosystems in these sources.

ACKNOWLEDGMENTS

The authors are grateful to the *Fundação de Apoio ao Desenvolvimento do Ensino, Ciência e Tecnologia do Estado de Mato Grosso do Sul* (FUNDECT) and the *Universidade Federal da Grande Dourados* (UFGD) for financial and logistic support, respectively.

RESUMO: A suinocultura é uma atividade econômica que ocupa posição de destaque no cenário mundial alimentício vinculado ao comércio da carne. No entanto, abatedouros de suínos geram resíduos que são liberados pelos efluentes e podem disseminar microrganismos patogênicos e degradar o meio ambiente, especialmente em corpos hídricos. O objetivo do estudo foi avaliar a eficiência do sistema australiano e qualidade do efluente proveniente da Estação de Tratamento de Efluente (ETE) de um abatedouro de suínos liberada no Córrego Laranja Azeda localizado na cidade de Dourados (Estado do Mato Grosso do Sul, Brazil). As coletas das amostras de efluentes na ETE foram realizadas nas lagoas de tratamento (sistema australiano) desde a sua entrada até a saída durante o período de um ano. Para mensuração da qualidade de água foram avaliados parâmetros físico-químicos e biológicos. Parâmetros referentes à Demanda Bioquímica de Oxigênio e a Demanda Química de Oxigênio foram aferidos de acordo com a American Public Health Association e, além destes foram mensurados quantidade de oxigênio dissolvido, pH, temperatura, condutividade elétrica, sólidos totais dissolvidos e potencial de oxi-redução do efluente. A técnica dos tubos múltiplos foi utilizada para quantificação de coliformes totais (CT) e coliformes termotolerantes (CTT). Os resultados apontaram a redução de matéria orgânica e microrganismos. As médias dos parâmetros avaliados apresentaram redução significativa (p<0,005) para a concentração de oxigênio dissolvido, pH, temperatura da água, potencial de oxi-redução, quantidade de coliformes presentes na água. O manejo dos resíduos gerados pela ETE acarretou na remoção de poluentes do efluente, mas não foi eficiente em atender os parâmetros legais brasileiros e internacionais que normatizam o seu despejo em corpos de água. Considera-se necessária maior fiscalização das condições referentes a qualidade de água do efluente lançado neste córrego, pois o resultado indica risco de saúde para a comunidade ribeirinha que faz uso dessa água para banhos, dessedentação de animais, irrigação e outras atividades domésticas.

PALAVRAS-CHAVES: Monitoramento ambiental. Parâmetros microbiológicos. Parâmetros físico-químicos. Lagoas de tratamento.

REFERENCES

AGUILAR, M. I. Nutrient removal and sludge production in the coagulation-flocculation process. **Water Research,** Unite Kingdom, v. 36, n. 11, p. 2910-2919, Jun. 2002. http://dx.doi.org/10.1016/S0043-1354(01)00508-5

BRASIL. CONSELHO NACIONAL DO MEIO AMBIENTE. Resolução CONAMA no. 357/2005, de 17 março de 2005. Dispõe sobre a classificação das águas doces, salobras e salinas do território nacional. **Diário Oficial da União** n° 053, 18 de março de 2005, p.58-63. Poder Executivo Brasília, DF. 2005. Available:http://www.mma.gov.br/port/conama/res/res05/res35705.pdf. Access: Aug. 2015.

BRASIL. CONSELHO NACIONAL DO MEIO AMBIENTE. Resolução CONAMA nº 274/2000, de 29 de novembro de 2000. Revisa os critérios de Balneabilidade em Águas Brasileiras e Revoga os artigos 26 a 34 da Resolução CONAMA no 20/86**. Diário Oficial da União** n°18, 25 de janeiro de 2001, p. 70-71. Poder Executivo Brasília, DF. 2000. Available:http://www.mma.gov.br/port/conama/legislacao/CONAMA_RES_CONS_2000_274.pdf Access: Aug. 2015.

BRASIL. CONSELHO NACIONAL DO MEIO AMBIENTE. Resolução CONAMA nº 430/2011 de 13 de maio de 2011. Dispõe sobre as condições e padrões de lançamentos de efluentes, complementa e altera a Resolução nº 357/05. **Diário Oficial da União n°92**, de 16 de maio de 2011, p.89. Poder Executivo Brasília, DF.2011. Available: http://www.mma.gov.br/port/conama/legiabre.cfm?codlegi=646. Access: Aug. 2015.

BUSTILLO-LECOMPTE, C. F.; MEHRVAR, M. Slaughterhouse wastewater characteristics, treatment, and management in the meat processing industry: A review on trends and advances. **Journal of Environmental Management,** United States, v. 161, p. 287-302, Set. 2015. http://dx.doi.org/10.1016/j.jenvman.2015.07.008

DE SENA, R. F.; MOREIRA, R. F. P. M.; JOSE, H. J. Comparison of coagulants and coagulation aids for treatment of meat processing wastewater by column flotation. **Bioresource Technology,** Unite Kingdom, v. 99, n. 17, p. 8221-8225, Nov. 2008. http://dx.doi.org/10.1016/j.biortech.2008.03.014.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM GUIDELINES - DEAT. **White paper on integrated pollution and waste management for South Africa: A policy on pollution prevention, Waste minimization, impact management and remediation**. Pretoria, Department of Environmental Affairs and Tourism 80. 17 March 2000. Available: http://cer.org.za/wp-content/uploads/2013/02/integrated_pollutionand_wastemanagement_0.pdf. Access: Aug. 2015.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY - DWAF. **South African Water Quality Guidelines**, (Volume 2), Recreational Water Use (2nd Ed.). 1996. Pretoria, Available: https://www.capetown.gov.za/en/CSRM/Documents/Recreational_Guidelines.pdf. Access: Aug. 2015.

EATON, A. D.; CLESCERI, L. S.; RICE, E. W.; GREENBERG, A. E.; FRANSON, M. A. H. Standard methods for the examination of water and wastewater: Centennial edition. Washington, D.C.: **American Public Health Association**, 2005.1368 p.

FIORUCCI, A. R.; FILHO, E. B. A. Importância do oxigênio dissolvido em ecossistemas aquáticos. **Revista Química Nova na Escola,** São Paulo, v. 22, p. 10-16, Nov. 2005.

GEMMELL, M. E.; SCHMIDT, S. Is the microbiological quality of the Msunduzi River (KwaZulu-Natal, South Africa) suitable for domestic, recreational, and agricultural purposes? **Environmental Science and Pollution Research,** Berlin*,* v. 20 n. 9, p.6551–6562, 2013. http://dx.doi.org/10.1007/s11356-013-1710-1

GERBENS-LEENES, P. W.; MEKONNEN, M. M.; HOEKSTRA, A. Y. The water footprint of poultry, pork and beef: a comparative study in different countries and production systems. **Water Resources and Industry,** Netherlands, v. 1-2, p. 25-36, 2013. http://dx.doi.org/10.1016/j.wri. 2013.03.001.

GONCHARUK, V. V.; BAGRII, V. A.; MEL'NIK, L. A.; CHEBOTAREVA, R. D.; BASHTAN, S. Y. U. The use of redox potential in water treatment processes. **Journal of Water Chemistry and Technology**, United States, v. 32, n. 1, p. 1-9. http://dx.doi.org/10.3103/S1063455X10010017

MINISTRY OF ENVIRONMENTAL AFFAIRS AND FISHERIES – EAF. Requirements for the purification of waste water or effluent. *Government Gazette* No. 9225, Regulation 991. Pretoria, South Africa.1984. Available: https://www.dwa.gov.za/Dir_WQM/docs/Leg_General_and_Special_Standards.pdf Access: Aug. 2015.

HOLENDA, B.; DOMOKOS, E.; RE'DEY, A.; FAZAKAS, J. Dissolved oxygen control of the activated sludge wastewater treatment process using model predictive control. **Computers and Chemical Engineering,** Unite Kingdom, v. 32, p. 1270–1278, Jun. 2008. http://dx.doi.org/10.1016/j.compchemeng.2007.06.008

HUANG, S.; HSU, B.; SU, Y.; JI, D.; LIN, W.; CHEN, J.; SHIH, F.; KAO, P.; CHIU, Y. Occurrence of diarrheagenic *Escherichia coli* genes in raw water of water treatment plants. **Environmental Science and Pollution Research,** Germany,v. 19; n. 7, p. 2776–2783, Ago. 2012. http://dx.doi.org/10.1007/s11356-012-0777-4. PMID:22327641

IGBINOSA, E. O.; OHOK, A. I. Impact of discharge wastewater effluents on the physico-chemical qualities of a receiving watershed in a typical rural community. **International Journal of Environmental Science and Technology,** Iran, v. 6, n. 2, p. 175-182, Mar. 2009.

KERAITA, B.; KONRADSEN, F.; DRECHSEL, P.; ABAIDOO, R. C. Reducing microbial contamination on wastewater-irrigated lettuce by cessation of irrigation before harvesting. **Tropical Medicine and International Health**, Unite Kingdom, v. 12, n. 2, p. 8-14, dez. 2007.

MEKONNEN, M. M.; HOEKSTRA, A. Y. A global assessment of the water footprint of farm animal products. **Ecosystems**, United States, v. 15, n. 3, p. 401-415, Jan. 2012. http://dx.doi.org/10.1007/s10021-011-9517-8.

OLIVEIRA, K. M. P.; JULIO, P. D. S.; GRISOLIA, A. B. Antimicrobial susceptibility profile of Pseudomonas spp. isolated from a swine slaughterhouse in Dourados, Mato Grosso do Sul State, Brazil. **Revista Argentina de Microbiología,** Argentina, v. 45, p. 57-60. Jan- Mar. 2013. PMID:23560791

PACHECO, J. A. S.; WOLFF, D. B. Tratamento dos efluentes de um frigorífero por sistema australiano de lagoas de estabilização. **Disciplinarum Scientia Série: Ciências Naturais e Tecnológicas,** Brasil, v. 5, n. 1, p. 67-85, 2004.

PARK, J. B. K.; CRAGGS, R. J.; SHILTON, A. N. Wastewater treatment high rate algal ponds for biofuel production. **Bioresource Technology,** Unite Kingdom, v. 102, p. 35–42, Jan. 2011. http://dx.doi.org/10.1016/j.biortech.2010.06.158

PEREIRA, E. L.; CAMPOS, C. M. M.; MOTERANI, F.; NETO, A. M. O. Eficiência de um sistema de reatores no tratamento de efluentes líquidos de suinocultura. **Acta Scientiarum Technology,** Maringá, v. 33, n. 3, p. 287-293, 2011. http://dx.doi.org/10.4025/actascitechnol.v33i3.7941

SCHAAR, E.; SOMMER, R.; SCHÜRHAGL, R.; YILLIA, P.; KREUZINGER, N. Microorganism inactivation by an ozonation step optimized for micropollutant removal from tertiary effluent. **Water Science & Technology,** Unite Kingdom, v. 68, n. 2, p. 311-318, 2013. http://dx.doi.org/10.2166/wst.2013.212. PMID:23863422

SOUSA, A. C.; LÚCIO, M. M. L. M.; BEZERRA NETO, O. F.; MARCONE, G. P. S.; PEREIRA, A. F. C.; DANTAS, E. O.; FRAGOSO, W. D.; ARAUJO, M. C. U.; GALVÃO, R. K. H. A method for determination of COD in a domestic wastewater treatment plant by using near-infrared reflectance spectrometry of seston. **Analytica Chimica Acta,** Netherlands, v. 588, n. 2, p. 231-236, Abr. 2007. http://dx.doi.org/10.1016/j.aca.2007.02.022

United Nations Environment Programme - UNEP , DEPA - Danish Environmental Protection Agency, COWI-Consulting Engineers and Planners AS, Denmark. **Cleaner production assessment in meat processing.** Paris: UNEP.2000. Available: http://www.agrifood-forum.net/publications/guide/index.htm. Access: Oct. 2015.

VIVAN, M.; KUNZ, A.; STOLBERG, J.; PERDOMO, C.; TECHIO, V. H. Eficiência na interação biodigestor e lagoas de estabilização na remoção de poluentes em dejetos de suínos. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Paraiba, v. 14, n. 3, p. 320-325, Mar. 2010. http://dx.doi.org/10.1590/S1415-43662010000300013

VON SPERLING, M. **Princípios básicos do tratamento de esgotos: Princípios do Tratamento Biológico de Águas Resíduárias**. Belo Horizonte: UFMG 2, 1996. 211p.

WORLD HEALTH ORGANISATION - WHO. **Guidelines for Drinking Water Quality: Health Criteria and Other Supporting Information.** Geneva, vol. 2, 1996. Available: http://www.who.int/water_sanitation_health/dwq/2edvol2p1.pdf. Access: Oct. 2015.

WORLD HEALTH ORGANISATION - WHO. **Guidelines for safe recreational water environments.** volume 1: coastal and fresh waters**.** Geneva, 2003**.** Available: http://apps.who.int/iris/bitstream/10665/42591/1/9241545801.pdf. Access: Oct. 2015.

WORLD HEALTH ORGANISATION - WHO. **Guidelines for drinking-water quality**.4th ed. Geneva, 2011. Available: http://apps.who.int/iris/bitstream/10665/44584/1/9789241548151_eng.pdf. Access: Oct. 2015.