Original Article

TREATMENT OF CATTLE MANURES WITH AERATED TANKS IN A FREE-STALL SYSTEM

TRATAMENTO DE DEJETOS DE BOVINOS EM TANQUES AERADOS EM SISTEMA DE FREE-STALL

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ABSTRACT: The objective of this study was to assess a cattle manure treatment system in aerated tanks in a free-stall confinement system, where the recycled wastewater was used to clean the facilities and the effluent was applied to forage cultivation areas. A batch activated sludge reactor with a prolonged intermittent aeration system scaled to a 24-day hydraulic retention time was used, and the wastewater was diluted at a volume ratio of 1:1. Samples were taken at the input and interior of the aeration tanks, at the irrigation pipe exit, and from pure animal waste. The following parameters were determined: pH, temperature, oil and grease, total biochemical oxygen demand (BOD) and chemical oxygen demand (COD), total solids, total nitrogen and ammoniacal nitrogen, potassium, phosphorus, and magnesium. The results indicated that the aerobic biological treatment is effective in reducing and stabilising organic matter in wastewater.

KEYWORDS: Aerator. Dairy bovine culture. Batch activated sludge. Residues.

INTRODUCTION

Milk production in Minas Gerais State is a socially, economically, and environmentally important activity. It is responsible for providing numerous jobs and is the main source of income and work for farmers. However, milk production negatively affects the environment because of the large amount of waste that is produced daily.

Concerns regarding environmental degradation from production activities are increasing. In the case of animal confinement, waste includes manure, bedding, and food scraps, all of which are commonly improperly used or disposed of (RIBEIRO et al., 2007).

Dairy cattle housed under confined conditions generate large amounts of waste, and space for disposal is usually limited (GONÇALVES JÚNIOR et al., 2007). In addition to physical limitations for waste disposal, carbon dioxide (CO_2) and methane (CH_4) are emitted, water sources are eutrophicated, and soil is polluted, mainly from nitrogen and phosphorus accumulation (GÜNGÖR-DEMIRCI; DEMIRER, 2004; ANGONESE et al. 2006; DEMIRER; CHEN, 2005).

An efficient waste treatment that leaves the production system unhindered is necessary to solve these problems (ORRICO JÚNIOR et al., 2010). In the pursuit of sustainable development, the environmental impact caused by the improper disposal of waste generated in production systems is minimised by utilising methods of recycling wastes that promote the stabilisation of organic matter for use as compost (AMORIM et al., 2005).

Treatments based on biological processes are most widely used because they can be applied to most of the effluents generated, allowing the treatment of large volumes of wastewater by transforming toxic compounds into CO_2 and H_2O (or CH_4 and CO_2) at relatively low cost (CORDI et al., 2008).

Aerobic biological treatment is a reproduction of the biodegradation mechanisms that naturally occur in rivers. This process is achieved by biological stabilisation (biodegradation) of organic matter (VAZOLLÉR et al., 1991).

Advances in microbiology have led to the use of biological processes (both aerobic and anaerobic) to mitigate industrial effluents, most often applied using aerated lagoons or activated sludge (FERNANDO; FEDORAK, 2005), the latter being more versatile and efficient (SINGH; THAKUR, 2006; ARAUJO et al. 2010). The activated sludge strategy can be defined as an aerobic continuous fermentation process with biomass recycling, which constitutes a permanent and acclimated inoculum (VAZOLLÉR et al., 1991).

Thus, we aimed with this study to assess a cattle manure treatment system with aerated tanks in

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a “free-stall” system, where the wastewater recycling treatment system was used to clean the facility and the treated effluent was used in forage production areas.

MATERIAL AND METHODS

Experimental location

The study was conducted at the Embrapa Dairy Cattle facility, an intensive milk production system (IMPS) located in the municipality of Coronel Pacheco, Zona da Mata, Minas Gerais, Brazil. Geographically, the IMPS is located at 21°33’22” S latitude and 43°06’15” W longitude, at an altitude of 414 m. The local climate is classified as Cwa: a hot and rainy temperate region, with dry winters and hot summers, according to the classification by Koppen. The total area of the system is 40.0 ha, with undulating (5%) and flat (95%) topography.

The herd consisted of 60 lactating Holstein purebreds that were housed in "free-stall" barns under total confinement. The basic diet offered to cows consisted of corn silage, grass and legume hay, chopped green grass, and pastures of elephant grass and Setaria, with concentrated mineral supplementation.

Manure management

The confinement barns were cleaned daily after each milking, and the wastewater (manure diluted in water) was pumped from the floors. The water returned to the aeration tanks and was homogenised through channels. After homogenisation, stabilisation, and reaching the hydraulic retention time (24 days), the slurry was carried by PVC pipes to the forage production areas via irrigation infiltration.

Two tanks, each with a 300-m^3 capacity, were used to treat and store the liquid manure. These tanks were constructed of concrete with a circular section close to the confinement barns and received the influent by gravity. Each tank was equipped with an aeration and homogenisation system. A 60-m^3 h^{-1} capacity centrifugal pump was installed at the base of the two tanks. The pump transported liquid manure from the confinement barns and distributed the water to clean the floors. The aeration and stabilisation tanks were scaled to a 24-day hydraulic retention time, where the manure (faeces + urine) was diluted in water at a 1:1 ratio, with waste production of approximately 42 kg^{-1}UA day^{-1}.

A Tornado-5 submersible aerator-mixer three-phase motor with 5.0 hp (3.68 kW) was installed in each tank to promote the oxidation and homogenisation of the liquid mass. Each aerator operated at a maximum rated capacity of 400 m^3 of liquid mass. Homogenisation was performed by blenders, pulse transmitted with little turbulence by the propeller. Aeration was conducted with accentuated turbulence and cavitation, causing the diffusion of atmospheric air and introducing it into the liquid mass. The aerators were regulated for prolonged, intermittent periods of aeration (18 minutes of aeration and 30 minutes of rest) to reduce the system energy costs.

The cleaning water system for the barn floor consisted of a motor pump set, with a three-phase 12.5 hp motor with 1,750 rpm and an open rotor pump (model-KSB ANS 0-50-200) with a flow of 60 m^3 h^{-1} for a total head of 12 mwc and a 101.60 mm outlet pipe. A raised 101.60-mm-diameter galvanised iron pipe was used as the discharge piping from the pump. Weldable PVC was buried under the barn corridors, where the pipes were reduced by three to four 76.20 mm ejectors, for uniform distribution of the cleaning water used in the corridors. The confinement barn corridors had concrete floors, beaded in the longitudinal direction, with little slope, giving access to channels with iron railings to collect the manure. The channels were built in the concrete, with a slight slope, driving the liquid manure to the tanks by gravity.

The pumping system consisted of a submersible three-phase 36-kg 20T Piranha motor-pump located inside of each tank, with a flow of 10 m^3 h^{-1} for a total head of 12 mwc, a 31.75-mm exit diameter, 1.6 kW (2.2 hp) power, and a speed of 3,450 rpm. The piping network from the tanks to the cultivation areas consisted of 2-in diameter PVC tubing, buried 0.30 m deep. Either aluminium or PVC quick-coupling pipes were used to deliver the treated manure to the soil.

Effluent characterisation

The IMPS effluent was composed of cattle manure (faeces + urine), facility cleaning water, trough leakage, leftover rations, and bedding material. The total dilution ratio of the treatment system was 1:1 water to total waste.

The sampling for effluent characterisation was performed as follows:

1) Treatment station effluent input (TSEI) composite samples were collected. These samples composed of five 1.0-L aliquots collected every five minutes throughout the facility cleaning process; this occurred twice daily.

2) Inside the aeration tank (IAT) composite samples were collected. These samples were of

treated liquid manure at one meter below the surface of the aeration tank after two hours of decanting.

3) Irrigation pipe output composite samples were collected. These samples were composed of irrigation effluent (IE) collected during the reactor discharge period, taken at 15-minute intervals.

4) Pure waste (PW) composite samples were collected. Two samples of faeces and urine were taken immediately after excretion by the animals.

At sample points 1, 2, and 3, the following parameters were analysed: pH, air temperature, sample temperature, oil and grease, total biochemical oxygen demand (BOD) and chemical oxygen demand (COD), total solids, total volatile solids, total fixed solids, total suspended solids, fixed suspended solids, volatile suspended solids, carbon, total nitrogen and ammoniacal nitrogen, potassium, phosphorus, calcium and magnesium. At point 4, the following parameters were analysed: total BOD and COD, total solids, carbon, and pH. The temperature at each point was obtained in the field.

Analyses were performed according to the established analytical methods of the American Public Health Association (APHA; 2005).

System operation

A batch activated sludge (BAS) process with prolonged intermittent aeration was chosen for the system operation. The operating cycle periods for the BAS process (Table 1) were determined according to the method of Campos et al. (2002).

Table 1. Operating cycle phases of the adopted BAS

	Period (days)	
Operating cycle phases	Reactor 1	Reactor 2
Filling and reaction	24	24
Draining and reaction	3	3
Rest	21	21
Total/cycle/reactor	48	48

For every 24-day filling period, the draining period was initiated in reactor 1 and the filling period in reactor 2, resulting in a 21-day rest period for each reactor. This rest period provided greater flexibility in system management, for example in controlling the effluent disposal operations to the ground based on the varied stages of forage crops, removing decanted coarse solid (sand) from the reactor, and maintaining machinery and equipment.

RESULTS AND DISCUSSION

The decanted effluent (DE) and IE samples were obtained from the tanks after two hours of decanting and at the irrigation pipe output, respectively. The influent was obtained at the treatment station input.

Table 2 shows high concentrations of total BOD and COD, total solids, and total carbon found in the pure waste. Highly concentrated organic and mineral residues are pollutants when released into rivers and lakes without proper treatment. It is specially important due cattle manure pollution potential, that is much higher than human waste. Wastewater produced by dairy cows generates a BOD 4 to 14 times greater than that of urban sewage (Matos, 2004) as we can see in Table 2. Usually, the BOD generated by the urban sewage presents the average concentration of 400 mg L^{-1}.

Nutrient accumulation can cause eutrophication in natural waters with adverse effects, such as algal blooms, decreased dissolved oxygen, toxin formation, odour problems, fish kills, harmful effects to human health, and the hindering of self-purification in the receiving body of water (KUMMER et al., 2011). Thus, the removal of organic matter and nutrients are prioritised in the environmental requirements on agro-industrial effluent quality and in currently used biological and physiochemical treatments.

Table 2. Mean values of some parameters obtained in pure manure characterisation (faeces + urine) of confined animals

Parameters	Result
Total BOD (mg L^{-1})	21,791.45
Total COD (mg L^{-1})	84,397.80
Total solids (TS) (mg L^{-1})	109,872.00

Total carbon (mg L^{-1})	8,400.00
Air temperature (ºC)	19.0
pH	8.20

The objective for the IMPS is to reuse cattle manure in a sustainable agricultural system. An aerobic biological treatment was used to achieve this goal, a solution also found by Campos et al. (2002), Oliveira et al. (2009), Silva and Roston (2010).

The results that characterise the raw influent at the TSEI relative to the IE are shown in Table 3. The BOD reductions were 59.05% and 48.16% for the IE and DE, respectively. The COD reductions were 42.79% and 3.79% for the IE and DE, respectively. The smaller COD reductions (42.79% and 3.79%), as compared to the BOD (59.05% and 48.16%), can be explained by the high COD/BOD ratio of the influent (3.51) and COD/BOD ratio of the irrigation effluent (4.90), shown in Table 3. According to Braile and Cavalcanti (1993), a residue is easily biodegradable when its chemical and biochemical oxygen demands have a COD/BOD ratio less than 2. Because this ratio is greater than 3 for the influent and irrigation effluent, there will be further reduction of the BOD relative to the COD because the waste is non-biodegradable organic matter (OM).

The reduction of total solids (TS) for the IE was 50.35% (Table 3); for the DE, it was 34.34% (Table 4). The reduction of organic matter (TVS) for the IE was 39.13% (Table 3) and was 30.43% for the DE (Table 4). In absolute numbers, the TS concentration is still above that recommended. Greater efficiency in solid removal can be obtained using specific equipment for this purpose as a supplementary aid in the treatment system.

Table 3. Concentration variation of some influent parameters in relation to values obtained from irrigation effluent (IE)

Parameters	Influent	Irrigation effluent	Reduction (%)
Total BOD (mg L^{-1})	7,560.09	3,096.09	59.05
Total COD (mg L^{-1})	26,503.08	15,161.53	42.79
Ammoniacal nitrogen (mg L^{-1})	126.42	165.2	-
Total nitrogen (mg L^{-1})	557.20	201.20	63.89
Calcium (mg L^{-1})	293.46	164.82	43.84
Phosphorus Total (mg L^{-1})	144.00	93.20	35.28
Magnesium (mg L^{-1})	75.71	63.5	16.13
Potassium (mg L^{-1})	385.00	237.01	38.44
Total solids (TS) (mg L^{-1})	10,748.00	5,337.00	50.35
Total volatile solids OM (TVS) (mg L^{-1})	7,958.00	4,844.00	39.13
Total fixed solids (TFS) (mg L^{-1})	2,790.00	493.00	82.33
Total suspended solids (TSS) (mg L^{-1})	-	2,258.00	-
Fixed suspended solids (FSS) (mg L^{-1})	-	778.00	-
Volatile suspended solids (VSS) (mg L^{-1})	-	1,480.00	-
Total carbon (C) (mg L^{-1})	4,600.00	2,800.00	39.13
Carbon/nitrogen ratio (C/N)	8.26	13.92	-
BOD/N ratio	13.57	-	-
COD/BOD ratio	3.51	4.89	-
pH	6.74	7.10	-

The results of physical-chemical parameters analysed in effluent from the BAS process with prolonged intermittent aeration are presented in Table 4. This effluent is formed from stabilised biological sludge in the reactor, characterised by a prolonged aeration process with 24-day-old sludge (average cell retention time), where the effluent supernatant forms a homogeneous product.

Table 4. Concentration variation of some influent parameters in relation to decanted effluent (DE), supernatant in the aeration tank, after a two-hour decanting period

Parameters	Influent	Decanted effluent	Reduction (%)
Total BOD (mg L^{-1})	7,560.09	3,919.05	48.16
Total COD (mg L^{-1})	26,503.08	25,498.50	3.79
Ammoniacal nitrogen (mg L^{-1})	126.42	156.80	-
Total nitrogen (mg L^{-1})	557.20	270.60	51.44
Calcium (mg L^{-1})	293.46	269.34	8.22
Phosphorus Total (mg L^{-1})	144.00	132.00	8.33
Magnesium (mg L^{-1})	75.71	65.94	12.90
Potassium (mg L^{-1})	385.00	355.00	7.79
Total solids (TS) (mg L^{-1})	10,748.00	7,057.00	34.34
Total volatile solids OM (TVS) (mg L^{-1})	7,95800	5,536.00	30.43
Total fixed solids (TFS) (mg L^{-1})	2,790.00	1,521.00	45.48
Total suspended solids (TSS) (mg L^{-1})	-	4,530.00	-
Fixed suspended solids (FSS) (mg L^{-1})	-	550.00	-
Volatile suspended solids (VSS) (mg L^{-1})	-	3,980.00	-
Total carbon (C) (mg L^{-1})	4,600.00	3,200.00	30.44
Carbon/nitrogen ration (C/N)	8.26	11.83	-
pH	6.74	6.77	-

We found a reduction in total BOD and COD for the IE and DE (Table 3 and 4). According to Repula and Quináia (2009) and Mendes et al. (2006), the COD is useful to determine effluent biodegradability when used in conjunction with the BOD. When the BOD value approaches the COD, it means that the effluent is more readily biodegradable. In contrast, when the difference between these two parameters is very high, it means that the non-biodegradable fraction of the matter is much larger than the biodegradable fraction.

Zhang et al. (2006), using swine wastewater with a total suspended solids (TSS) value of 1.86 g L^{-1} in a sequential batch reactor with an 8-hour cycle (divided into anaerobic, anoxic/aerobic, and sedimentation stages) and 3.3-day hydraulic retention times, achieved 90% TSS removal efficiency, higher than those observed in this study. These differences may be due to the generated wastewater type and the system management adopted.

Concerning OM stabilisation, the C/N ratio for the IE was 13.92 (Table 3); for the DE, it was 11.83 (Table 4). These results indicate that the IE is stabilised and the DE is humified. According to Kiehl (1985), when the C/N ratio of a biologically treated compound is at or below 12, it is humified; when it is equal or lower than 17, the compound is stabilised; and when it is above 30, the MO is in raw form.

By measuring the pH, the IE was found to exhibit humidified characteristics, as its value was greater than 7.0 (Kiehl, 1985), as shown in Table 3. The humidification of OM is the desired final stage of the biological treatment. Thus, the effluent can be recycled, improving the physical, chemical, and biological properties of the soil wherever it is added. The values fall within the standards for discharge into bodies of water (CONAMA, 2005), with a pH between 5 and 9.

Reductions of N, P, and K by 63.89%, 35.28%, and 38.44% for IE and 51.44%, 8.33%, and 7.79% for DE, respectively were found (Table 3 and Table 4). These results are consistent with the typical characteristic values for N and P removal in sewage treatment, as cited by Von Sperling (1994), for the prolonged aeration of activated sludge and intermittent flow of activated sludge processes.

According to Araujo et al. (2010), nitrogen is one of the main nutrients that wastewater treatment seeks to remove to avoid the pollution of surface waters. Biological nitrogen removal is usually performed by combining the autotrophic nitrification and heterotrophic denitrification processes. In the wastewater, the biggest fraction of nitrogen is found in the ammoniacal form, which is a very important element in the transformations´ process suffered by the fraction of nitrogen in the soil. The quantity of nitrate (NO_3^-) in the soil depends on the nitrification reaction velocity suffered by the ammonia. The excess of nitrate in the soil may cause an accumulation of this form of nitrogen in plants. So it can compromise the human and animal consumption due to quality of the plant. For these reasons, the nitrogen´s concentrations in NO_3^- e NH_4^+ forms are controlled by the legislation, to ensure the water quality.

Phosphorus and nitrogen are directly involved in the eutrophication process. Phosphorus is considered limiting in most aquatic environments because nitrogen can be fixed from atmospheric N_2 by symbiotic algae (Mori et al., 2009). Therefore, strategies to control eutrophication have focused on control of P sources in soil and its transport from these sources to bodies of water.

Treating dairy wastewater in wetlands, Smith et al. (2006) demonstrated a total phosphorus removal efficiency of approximately 91%. The concentration for the influent in this present work was 44.4 mg L^{-1} on average, and the effluent concentration was 4.0 mg L^{-1}. Silva and Roston (2010) reported an average phosphorus removal of approximately 83%. The average concentration for the final effluent was 2.30 mg L^{-1}, which is sufficient for the final effluent to be released into shallow bodies of water. Using an Inhoff tank and wetlands with a subsurface flow for the wastewater treatment of a cattle dairy parlour, Mantovi et al. (2003) obtained a phosphorus reduction of approximately 60.6%, decreasing from 12.8 mg L^{-1} to 5.0 mg L^{-1} of phosphorus. Thus, the assessed system satisfactorily reduces phosphorus, which is one of the main nutrients responsible for eutrophication in bodies of water. However, the objective of the works cited was to maximise N and P removal from effluent so that it could be later released into bodies of water, preventing the eutrophication of rivers and lakes. Instead, this study was focused on OM stabilisation, allowing for more appropriate management of the manure to be used as bio-fertiliser in the soil. The disposal of wastewater into the soil-plant system can bring benefits when properly planned, such as providing a nutrient and water source for plants, reducing fertiliser use, and reducing the pollution potential (ERTHAL et al., 2010).

In Brazil, the movement of nutrients from soil to water is a concern, especially when considering the application of animal manure to the soil (SHIGAKI et al., 2006; MORI et al., 2009). Therefore, nutrient removal from the effluent is not important, as it will not be released into rivers or lakes, but to the ground, allowing the recycling of nutrients and OM that were removed by crops and improving soil fertility and productivity. The agricultural use of wastewater is an important contribution to mitigate pollution because it reduces the release of wastewater into the watershed and provides an economic alternative for rural properties without compromising environmental quality (SOUZA et al., 2005).

According to Tchobanoglous (1979), nitrifying organisms are present in most aerobic biological treatment processes; however, the number of these organisms is usually limited. The nitrification ability of various activated sludge samples is correlated to the BOD/N ratio of the influent. If this ratio is greater than 5, the process can be classified as a combined nitrification and carbon oxidation process. If the ratio is less than 3, it can be classified as a separate nitrification stage. The higher the BOD/N ratio, the smaller the nitrification fraction; thus, the N and P removal from the influent residue must be greater due to denitrification.

In this study, a BOD/N ratio of 13.57 was obtained (Table 3). Thus, the process can be classified as a combination of nitrification and carbon oxidation. These stages occur simultaneously, and the N and P removal was partitioned. However, according to the propositions of this study, the removals were consistent because the goal was to achieve an effluent rich in nutrients for soil recycling.

Using the recycling system for facility cleaning led to a reduction in water consumption, benefiting the IMPS because its economy is directly linked to energy management, demonstrating the importance of recycling processes that use wastewater for cleaning facilities.

CONCLUSIONS

A large number of confined cattle generate a high volume of manure, leading to increased pollution and environmental degradation.

The aerobic biological treatment system applied at the Embrapa Dairy Cattle IMPS was efficient in reducing and stabilising organic matter in liquid cattle effluent.

Large reductions were observed in the total BOD and COD for irrigation effluents and decanted effluent.

The aerobic treatment system used was effective in stabilising the organic matter from cattle manure, turning the waste into a stabilised and humidified liquid effluent with recycled waste, contributing to the improvement of the physical, chemical, and biological characteristics of the soil.

RESUMO: Objetivou-se com o presente trabalho avaliar um sistema de tratamento de dejetos de bovinos com tanques aerados em sistema de confinamento free-stall, com reciclagem do efluente para a limpeza das instalações e posterior utilização em áreas de cultivo de forragens. Utilizou-se um reator, operado pelo processo de lodo ativado por batelada, com sistema de aeração prolongada e intermitente, dimensionado para um tempo de retenção hidráulico de 24 dias, com diluição dos dejetos em água na proporção de volume 1:1. Foram realizadas amostragens na entrada e no interior dos tanques de aeração, na saída da tubulação de irrigação e dos dejetos puros dos animais. Determinou-se os parâmetros: pH, temperatura, óleos e graxas, demandas bioquímica de oxigênio (DBO) e química de oxigênio (DQO) totais, sólidos totais, nitrogênio total e nitrogênio amoniacal, potássio, fósforo e magnésio. Por meio dos resultados obtidos, concluiu-se que o tratamento biológico aeróbio foi eficiente para reduzir e estabilizar a matéria orgânica do efluente líquido.

PALAVRAS-CHAVE: Aerador. Bovinocultura de leite. Lodo ativado por batelada. Resíduos.

REFERENCES

American Public Health Association (APHA). Eaton, A. D., Clesceri, L. S., Rice, E.W., Greenberg, A.E (eds), **Standard methods for the examination of water and wastewater**. 21st ed, American Water Works Association; Water Pollution Control Federation, Washington, D.C., 1368p, 2005.

AMORIM, A. C., LUCAS JÚNIOR, J. de., RESENDE, K. T. de., Composting and vermicomposting of caprine manure: seasonal effects. **Engenharia Agrícola**, Jaboticabal, v. 25, n. 1, p. 57-66, 2005.

ANGONESE, A. R., CAMPOS, A. T., CUNHA, F., MATSUO, M. S., ZACARIM, C. E., Energy efficiency of swine production system with waste treatment in biodigester. Revista Brasileira de **Engenharia Agrícola Ambiental**, Campina Grande, v. 10, n. 3, p. 745-750, 2006.

ARAUJO, J. C. de, CAMPOS, A. P., CORREA, M. M. S., SILVA, E. C., SPERLING, M. V., CHERNICHARO, C. A. L., Enrichment of ammonia-oxidising anaerobic bacteria - anammox. **Engenharia Sanitária Ambiental**, Rio de Janeiro, v. 15, n. 2, p. 205-212, June 2010.

BRAILE, P. M.; CAVALCANTI, J. E. W. A., 1993. **Industrial wastewater treatment manual**. São Paulo: CETESB, 1993, 764 p.

CAMPOS, A. T., FERREIRA, W. A., JÚNIOR, J. L., ULBANERE, R. C., Campos, A. T., Aerobic biological treatment and recycling of cattle manure in milk production intensive system. **Ciência e Agrotecnologia**, Lavras, v. 26, n. 2, p. 426-438, 2002.

CONAMA. **National Environmental Council**. Resolution N. 357, March 17, 2005.

CORDI, L.; ASSALIN, M. R.; DIEZ, M. C.; DURAN, N. Installation, start and operation of an activated sludge system for wastewater treatment: physical-chemical and biological parameters**. Engenharia Ambiental: Pesquisa e Tecnologia**, Espírito Santo do Pinhal, v. 5, n. 1, p. 97-115, jan./abr. 2008.

DEMIRER, G. N.; CHEN, S., Two-phase anaerobic digestion of unscreened dairy manure. **Process Biochemistry**, Shanghai, v.40, n.4, p.3.542-3.549, 2005.

ERTHAL, V. J. T.; FERREIRA, P. A.; MATOS, A. T. de; PEREIRA, O. G., 2010. Physical and chemical alterations in an Ultisol by application of cattle wastewater. **Revista Brasileira de Engenharia Agrícola Ambiental**, Campina Grande, v. 14, n. 5, p. 467-477, May 2010.

FERNANDO, N. L.; FEDORAK, P. M.,Changes at an activated sludge sewage treatment plant alter the numbers of airborne aerobic microorganisms. **Water Research**, v. 39, p. 4597- 4608, 2005. http://dx.doi.org/10.1016/j.watres.2005.08.010

GONÇALVES JÚNIOR, A.; POZZA, P.; NACKE, H.; LAZZERI, D.; SELZLEIN, C.; CATILHA, L.;2007. Homogenisation and metal levels in dairy cattle manure. **Acta Scientiarum. Technology**, Maringá, v. 29, n. 2, p. 213-217, fev. 2007.

GÜNGÖR-DEMIRCI, G.; DEMIRER, G. N., 2004. Effect of initial COD concentration, nutrient addition, temperature and microbial acclimation on anaerobic treatability of broiler and cattle manure. **Bioresource Technology**, v. 93, n. 2, p. 109-117, 2004. http://dx.doi.org/10.1016/j.biortech.2003.10.019

KIEHL, E. J. Organic fertilisers. Piracicaba: **Agronômica Ceres**, 1985, 492 p.

KUMMER, A. C. B.; ANDRADE, L. ; GOMES, S. D.; FAZOLO, A.; HASAN, S. D. M.; MACHADO, F.; Treatment of tilapia slaughterhouse wastewater with the addition of manipueira during the anoxic stage. **Engenharia Agrícola**, Jaboticabal, v. 31, n. 1, fev. 2011.

MANTOVI, P.; MARMIROLI, M.; MAESTRI, E.; TAGLIAVINI, S.; PICCININI, S.; MARMIROLI, N. Application of a horizontal subsurface flow constructed wetland on treatment of dairy parlour wastewater. **Bioresource Technology**, v. 88, n. 1, p. 85-94, 2003. http://dx.doi.org/10.1016/S0960-8524(02)00291-2

MATOS, A. T. de. **Management and treatment of agro-industrial residues**, 2004, Viçosa: DEA/UFV, 120 p. (Teaching notebook n. 31).

MENDES, L. T.; COSTA, J. S.; FRANCA, E.; TEIXEIRA, R.; LOPES, D. D.; SILVA, S. M. C. P.; ALVES, J. C.; ANTONIA, L. H. D. Physical-chemical and bacteriological appearance of groundwater hydrology in the region of urban solid waste deposits, Londrina, Paraná, Brasil. **Semina: Ciênc. Exatas e Tecnológicas,** 27, 139-146.

MORI, H. F.; FAVARETTO, N.; PAULETTI, V.; DIECKOW, J.; SANTOS, W. L. Loss of water, soil, and phosphorus with application of liquid cattle manure in Oxisol under no-tillage and simulated rainfall. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 33, p. 189-198, fev. 2009.

OLIVEIRA, G. S. S.; ARAUJO, C. V. M.; FERNANDES, J. G. S. Microbiology of activated sludge and its relation to the treatment of industrial effluents: the experience of Cetrel. **Engenharia Sanitária e Ambiental**, Rio de Janeiro, v. 14, n. 2, 183-192, June 2009.

ORRICO JÚNIOR, M. A. P.; ORRICO, A. C. A.; LUCAS JÚNIOR, J. Influence of volume ratio: concentrated and hydraulic retention time in the anaerobic digestion of cattle manure. **Engenharia Agrícola**, Jaboticabal, v. 30, n. 3, p. 386-394, maio/jun. 2010.

REPULA, C. M. M.; QUINÁIA, S. P. Assessment of water quality in the Viaduto creek using principal component analysis. **Revista do Setor de Ciências Agrárias e Ambientais**. v. 5 n. 3, p. 433-442Set./Dez. 2009.

RIBEIRO, G. M.; SAMPAIO, A. A. M.; FERNANDES, A. R. M.; HENRIQUE, W.; SUGOHARA, A.; AMORIM, A. C. Effect of protein source and physical processing of the concentrate on termination of young confined cattle and environmental impact of manure. **Revista Brasileira Zootecnia,** Viçosa, v. 36, n. 6, p. 2082-2091, Dec. 2007.

SHIGAKI, F.; SHARPLEY, A.; PROCHNOW, L. I., Animal-based agriculture, phosphorus management and water quality in Brazil: Options for the future. **Scientia Agricola**, v. 63, n. 2, p. 194-209, 2006. http://dx.doi.org/10.1590/S0103-90162006000200013

SILVA, E. M.; ROSTON, D. M. Wastewater treatment of cattle dairy parlour effluents: followed by wetland pond stabilisation. **Engenharia Agrícola**, Jaboticabal, v. 30, n. 1, p. 67-73, feb. 2010.

SINGH, P.; THAKUR, I. S. Colour removal of anaerobically treated pulp and paper mill effluent by microorganisms in two steps bioreactor. **Bioresource Technology**, v. 97, p. 218-223, 2006. http://dx.doi.org/10.1016/j.biortech.2005.02.022

SMITH, E.; GORDON, R.; MADANI, A.; STRATTON, G. Year-round treatment of dairy wastewater by constructed wetlands in Atlantic Canada. **Wetlands**, v. 26, n. 2, p. 349-357, 2006. http://dx.doi.org/10.1672/0277-5212(2006)26[349:YTODWB]2.0.CO;2

SOUZA, J. A. R.; DENÍCULI, W.; BATISTA, R. O.; VAL, J, C. C.; MATOS, A. T. Hydraulic characterisation of microemitter applying clean water, wastewater from poultry and cattle. **Engenharia na Agricultura**, Viçosa, MG, v. 13, n. 3, p. 161-172, Jul./Set., 2005.

TCHOBANOGLOUS, G. **Wastewater engineering: treatment, disposal, reuse**. 2nd ed. McGraw-Hill Book, New York, 1979, 920p.

VAZOLLÉR, R. F., GARCIA, A. D., CONCEIÇÃO NETO, J. Microbiology of Activated Sludge – Manual Series. CETESB – Society of Environmental Sanitation Technology. São Paulo: CETESB, 1991. p. 23.

VON SPERLING, M. Criteria for selecting data for a preliminary treatment of sewage waste. **Revista Bio**, São Paulo, v. 3, n. 1, p. 7-21, 1994.

ZHANG, Z.; ZHU, J.; KING, J.; LI, W. Two-step fed SBR for treating swine manure. **Process Biochemistry**, London, v. 41, p. 892-900, 2006. http://dx.doi.org/10.1016/j.procbio.2005.11.005