ea engenharia agrícola
Journal of the Brazilian Association of Agricultural Engineering
ISSN: 1809-4430 (on-line)

PERCOLATE QUALITY IN SOIL CULTIVATED WITH APPLICATION OF WASTEWATER FROM SWINE SLAUGHTERHOUSE AND DAIRY PRODUCTS

Doi:http://dx.doi.org/10.1590/1809-4430-Eng.Agric.v37n6p1222-1235/2017

JACINEUMO F. DE OLIVEIRA[1*], FERNANDO N. RODRIGUES[2], RONALDO FIA[2], DAYANA C. B. MAFRA[2], DANIELA V. LANDIM[2]

[1*]Corresponding author. Universidade Federal de Lavras/ Lavras - MG, Brasil. E-mail: jacineumo@gmail.com

ABSTRACT: The objective of this study was to evaluate the quality of the percolate in soil columns cultivated with Tiffon-grass 85 under different wastewater rates from swine slaughterhouse and dairy. The experiment was conducted at the Department of Engineering at the Federal University of Lavras, in PVC columns with 0.30 m of diameter and 1.2 m deep, filled with Dark Red Latosol cultivated with Tifton-grass 85. The treatments consisted of a (A_QT_0) control with recommended chemical fertilization for Tifton-grass 85 (300 kg ha^{-1} year^{-1} of N), and four doses of SSW and DPW (100, 200, 300 and 400% of the recommendation) in a CRD with 3 replications. The samples of percolated were collected and characterized weekly. The treatments of highest dosage have obtained COD, after 120 days, of 47.7 mg L^{-1} (A_AT_3) and 38.6 mg L^{-1} (A_AT_4). Although nitrate concentrations were elevated on the earlier months, the greater assimilation of nutrients by the Tifton-grass 85 and the reduction of the mineralization of organic material resulted in lower nitrate concentrations of 10 mg L^{-1}.

KEYWORDS: water reuse, wastewater, leaching, soil disposal, agroindustry wastewaters.

INTRODUCTION

With the increase in water demand for agricultural production processes, the practice of the reuse of agroindustrial wastewater stands out due to the need of preservation and maintenance of environmental quality.

The slaughterhouse and dairy products wastewater are characterized by high nutritional content and organic matter, originating from their production processes, and, therefore their previous treatment is necessary before their final destination (Tocchi et al., 2013). In this sense, the disposal of wastewater in the soil as an alternative of final destination, as well as a source of water, provides nutrients for crop development, reducing production costs (Cabral et al., 2011).

However, due to the high polluting potential, soil disposal of agro-industrial wastewater without proper management practices, can have undesirable consequences on plants, soils, and groundwater. Thebaldi et al. (2011) observed contamination of rivers with bovine slaughterhouse wastewater; while Bolzani et al. (2012) and Pinto et al. (2013) in soils and groundwater, respectively, by wastewater from swine breeding farm.

According to Barros et al. (2010), when using fertirrigation, whether through conventional chemical fertilization or wastewater, it is important to monitor the dynamics and distribution of nutrients in the soil profile, since this allows establishing qualitative and quantitative criteria for the evaluation of possible environmental impacts. In this sense, some studies of reuse of agriculture show the capacity of nutrient displacement in the soil profile, as Maggi et al. (2011) who observed an increase in the potassium concentration with an increase in the rate of application of swine wastewater (SWW), and Bebé et al. (2010), who observed increments in electrical conductivity and sodium in solutions percolated through the soil submitted to coffee wastewater.

Doblinski et al. (2010) were evaluating with nitrogen, phosphorus and potassium leaching in soil cultivated with beans and fetirrigated with swine wastewater (SWW), verified that the mobility in the soil profile is higher for potassium, followed by nitrogen and phosphorus. Prior et al. (2015)

[2] Universidade Federal de Lavras/ Lavras - MG, Brasil.
Received in: 1-31-2017
Accepted in: 6-13-2017

observed an increase in the concentration of phosphorus, copper and zinc when swine wastewater was applied. Already Rodrigues et al. (2011) observed an increase of 5.25 mg kg^{-1} of nitrate in the soil solution at a depth of 0.2 to 0.4 m, 32 days after fertirrigation with dairy wastewater.

Thus, due to what is known about the consequences of incorrect management of wastewater, this study had the objective of evaluating the quality of the percolate in columns of soils cultivated with Tifton-grass 85 and under different rates of wastewater of swine slaughterhouse and dairy products.

MATERIAL AND METHODS

The experiment was conducted at the Federal University of Lavras, in Lavras, Minas Gerais, latitude 21°13'45"S, longitude 44°58'31"W, average altitude of 918 m and Cwa climate, (mesothermal or tropical altitude), with dry winter and rainy summer, according to the classification of Köppen (Sá Júnior et al., 2012).

The soil used in the experiment was classified as Dark Red Latosol (EMBRAPA, 2013), on Table 1 are presented the chemical and physical characteristics of the soil before the application of the treatments.

TABLE 1. Physical and chemical characterization of the soil used to fill the columns.

pH	N	P (Mehlich 1)	K (Mehlich 1)	Na	Ca+Mg	Al	H+Al	BS	CEC_p	O.M.
	--g kg^{-1}--	-- mg kg^{-1} --	----g kg^{-1}----	----------------$cmol_c$ dm^{-3}--------------						-- g kg^{-1}--
5.6	0.2	3.21	0.02	-	0.92	0	2.32	0.98	3.3	16.4
Soil classification			Clay		Silt	Sand	Sand (Thick)			Sand (Thin)
			---------------------------dag kg^{-1}--------------------------							
Dark Red Latosol			60		24	-	8			8

pH in water; Al, H + Al, Ca + Mg extracted with KCl (1 mol L^{-1}) and volumetric determination with NaOH and complexiometry, respectively: P and K extracted with Mehlich 1 extractor and spectrophotometry and photometry determination of the flame, respectively; N quantified using the method: semi-micro Kjeldahl; CECp calculated from the sum of the exchangeable cations and exchangeable acidity; O.M. quantified using the volumetric method for potassium bichromate.

The experimental system consisted of 27 soil columns constructed in PVC with a diameter of 0.30 m (area of 0.07 m^2) and 1.20 m height. The columns were filled, from the base, with 0.05 m of gravel number zero, 0.05 m of washed thick sand and 1.05 m of Dark Red Latosol. The soil columns were cultivated with seedlings of Tifton-grass 85 (*Cynodon* spp.), which were transplanted with 0.15 to 0.25m in length and three to four buds, after 15 days of collection, with a period of adaptation of 5 days in the soil columns, as shown in Figure 1. The monitoring of the culture conditions in the columns was carried out daily, aiming at the removal of weeds possibly present, in order to avoid nutritional competition and influence on the vegetative performance of the crop. During the cultivation period, three cuts of Tifton-grass 85 were made, always at a height of 5cm, at 60, 90 and 120 days after transplanting. The soil liming was performed in the superficial 0.30 m of all 27 columns, with the use of calcium carbonate ($CaCO_3$), reaching 60% of base saturation (CFSEMG, 1999).

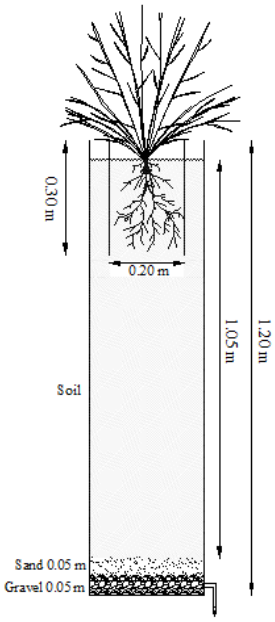

FIGURA 1. Schematic configuration of the profile of the soil columns used in the experiment.

The different treatments included the application of swine slaughterhouse wastewater (SSW), after preliminary treatment with grating and static sieving, and dairy products wastewater (DPW), collected after preliminary treatment consisting of grating followed by flotation and equalization tank, from two agroindustries in Lavras-MG. In the soil columns, four different loads were applied, while another received only conventional chemical fertilization (A_QT_0), being characterized as a control treatment, in which was applied 300, 310 and 200 kg ha^{-1}year^{-1} of N (Urea), P (Single superphosphate with 18% P_2O_5) and K (KCl), respectively. The applications of the treatments occurred once a month, between August and December 2015, following the recommendation of 300 kg ha^{-1}year^{-1} of nitrogen, recommended for grazing by the Soil Fertility Commission of the State of Minas Gerais - CFSEMG (1999). Adopting the A_QT_0 standard as recommended dosage of N, the N loads were tested via wastewater at the following dosages: 100, 200, 300 and 400% of the recommendation for SSW and DPW treatments. Thus, the doses of 979, 1958, 2937 and 3916 m^3 ha^{-1} were applied in the A_AT_1, A_AT_2, A_AT_3 and A_AT_4 treatments, respectively, while 1801, 3602, 5403 and 7204 m^3 ha^{-1} were applied in the treatments A_LT_1, A_LT_2, A_LT_3 and A_LT_4, respectively.

The SSW and DPW characterizations were fulfilled monthly in the Laboratory of Analysis of Wastewater of the Nucleus of Environmental and Sanitary Engineering of the Department of Engineering of UFLA, following the methodologies proposed by APHA; AWWA; WEF (2012). The results of these characterizations are shown in Table 2.

TABLE 2. Characterization of swine slaughterhouse (SSW) and dairy products (DPW) wastewater after preliminary treatment, applied during the experiment.

Parameters	DPW				SSW			
	Ave + SD	Min	Max	CV (%)	Ave + SD	Min	Max	CV (%)
pH	7.8 ± 0.3	5.2	10.5	31.3	7.7 ± 0.3	7.4	8.1	3.4
EC (dS m^{-1})	3.2 ± 0.5	3.1	4.1	14.7	1.2 ± 0.11	0.4	1.6	8.7
COD (mg L^{-1})	7,176 ± 4631	3,367	13,966	64.5	5,813 ± 3007	2,700	10,731	51.7
BOD (mg L^{-1})	2,429 ± 1304	1,245	3,766	53.7	2,360 ± 1139	1,245	3,766	48.3
P (mg L^{-1})	16.1 ± 7.6	7.3	23	47.7	11.9± 9.61	1.2	22.08	80.7
N (mg L^{-1})	84.8 ± 12.8	70	105	15.1	157.5 ± 27.00	115	188	17.2
O&G (mg L^{-1})	2.695 ± 2180	614	5,696	80.9	2,403 ± 1896	386	4,765	78.9
Ca (mg L^{-1})	83.1 ± 29.4	39.2	117.9	35.5	65.0 ± 38.1	24.1	103.4	58.7
Mg (mg L^{-1})	30.7 ± 10.9	14.5	43.6	35.5	89.0 ± 52.22	16.7	33.0	141.0
Na (mg L^{-1})	134 ± 21.7	116.7	164.5	16.2	21.5 ± 3.60	16.7	25.7	16.7
K (mg L^{-1})	16.3 ± 7.6	9.3	28.8	46.6	12.6 ± 5.00	8.1	19.8	39.7
SAR (mmol $L)^{-0,5}$	5.9 ± 1.0	5.2	7.5	16.1	1.3 ± 0.4	1.0	1.8	8.5

pH - hydrogenation potential; EC - electrical conductivity; COD - chemical oxygen demand; BOD - biochemical oxygen demand; P - total phosphorus; N - total nitrogen kjeldahl; O&G - oils and greases; Ca - calcium; Mg-magnesium; Na-sodium; K-potassium; SAR - sodium adsorption ratio; Ave - arithmetic average; SD - standard deviation; Min - minor value; Max - maximum value; CV - coefficient of variation.

During the productive cycles of Tifton-grass 85, part of the required water was supplied by the application of SSW and DPW, applied once a month, and another part came from the irrigation management with water from the UFLA supply system. The climatic data needed to estimate the reference evapotranspiration (ETo) by the Penman-Monteith equation (Allen et al., 2006; Carvalho et al., 2011) were obtained at the Conventional Meteorological Station installed in the university campus under monitoring of the National Institute of Meteorology. It was adopted a cultivation coefficient (kc) of 0.8 proposed by Drumond et al., (2006).

The water layer, applied individually in each soil column using a volumetric beaker, was determined based on the water deficit obtained by the difference between crop evapotranspiration (ETc), precipitation and wastewater layers applied, with irrigation shift of 2 days. It should be noted that the applications of DPW and SSW doses were defined to meet the N demand established for each treatment, and that, therefore, when the wastewater layer (DPW and SSW) were higher than the evapotranspirometric demand of Tifton-grass 85 and precipitation, irrigation water supplementation was not performed, but if the DPW and SSW layer were inferior to the culture water requirement, it was supplemented with irrigation water up to its maximum value for the application day, as presented in Figure 2.

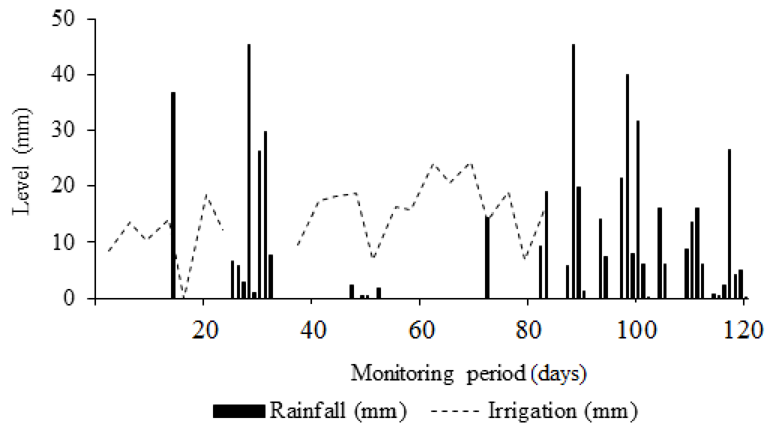

FIGURE 2. Distribution of rainfall and irrigation layer occurred during the experiment.

The experiment was set up in a completely randomized design (CRD) with two wastewater (SSW and DPW), with four treatments and three replicates, and one control treatment using conventional chemical fertilizer with three replicates. It was carried out preliminary analyzes of the treatments with residual water, separately, before the applications in the soil columns, regarding the pH, EC, BOD, COD, N, P_T, K, Na^+, Ca^{+2}, Mg^{+2} and SAR. The percolated data were submitted to analysis of variance using F Test, and the average compared to each other using the Tukey Test at 5%. For the ANOVA, it was considered the total nutrient losses (total mass loss in function of the volume collected in the percolates and their concentrations) during 120 days of monitoring. In the statistical analysis, the Sisvar 5.1 software was used (Ferreira, 2011).

RESULTS AND DISCUSSION

Table 3 summarized the analyzes of variances of the average values of nutrients NTK, NO_3^-, P_T and K that percolated during 120 days of monitoring.

TABLE 3. Average values and variance analysis of total losses of percolated nutrients during 120 days of monitoring (kg ha^{-1}) in soil columns fertirrigated with swine slaughterhouse (SSW) and dairy products (DPW) wastewater.

Variables (kg ha^{-1})	Treatments					RAM	F
	A_QT_0	A_AT_1	A_AT_2	A_AT_3	A_AT_4		
NTK	9.4b	15.6ab	25.9a	18.3ab	24.5a	27.1	4.9*
NO_3^-	2.,2b	24.0b	58.6a	59.7a	47.6a	35.9	4.5*
P_T	0.2bc	0.1c	0.3a	0.2abc	0.3ab	0.01	7.8**
K	23.6a	23.2a	42.3a	43.0a	28.1a	105.8	2.7^{ns}
Variables (kg ha^{-1})	A_QT_0	A_LT_1	A_LT_2	A_LT_3	A_LT_4	RAM	F
NTK	9.4b	19.1a	18.3a	14.7ab	18.5a	8.4	5.8*
NO_3^-	26.2b	32.9b	39.7ab	38.3b	59.5a	199.4	8.2**
P_T	0.2b	0.3ab	0.3ab	0.2b	0.5a	0.01	6.9**
K	23.6c	49.3ab	41.3b	41.8b	59.0a	42.6	13.2**

NTK - nitrogen total kjeldahl; NO_3- nitrate; PT - total phosphorus; K-potassium; RAM - residue average square; F - test of variance; Averages followed by the same letter in the lines, within each parameter studied, do not differ between them, by Tukey Test, at 5%; * Significant at 5%; ** Significant at 1%.

Significant differences were observed for NTK and P_T removed in percolates for SSW and DPW treatments compared to treatment with conventional chemical fertilization (A_QT_0), with the highest concentrations of 25.9 and 19.1 kg ha^{-1} of NTK in the columns that received the treatments with A_AT_2 and A_LT_1, respectively, in relation to the 9.4 kg ha^{-1} of NTK obtained in the percolated of the columns after receiving A_QT_0. However, although the effects of fertirrigation with the A_AT_1, A_AT_3 and A_LT_3 treatments have provided higher amounts of NTK removed from the percolated, there were no significant differences in relation to the control (Table 3). This situation may be related to the variations in NTK concentrations in the percolated due to the oscillations in the nitrification process that is influenced by the precipitation during the long experimental period and the possibility formation of preferential paths in the soil columns. In relation to P_T, the highest significant losses were 0.3 and 0.5 kg ha^{-1} in A_AT_2 and A_LT_4 treatments, respectively, in relation to the 0.2 kg ha^{-1} in the A_QT_0 treatment.

The low concentrations of NTK in the percolate, compared to the 300 kg ha^{-1} that were applied, are due to the mineralization of this nutrient (Guo et al., 2017) and also to the extracting capacity of the nitrogen of the Tifton-grass 85, as highlighted by Prado (2008). Ceretta et al. (2005) observed 9.5 kg ha^{-1} of NTK in percolated dystrophic red Argisoil cultivated with corn (*Zea mays*), after 2 years of swine manure application, representing, therefore, a reduction of 74% of NTK in relation to the concentration of the initial application.

Although the applications of wastewater treatment were based on the recommended nitrogen dosage (300 kg ha^{-1}), therefore, there was no adequate supply of P_T to the Tifton-grass 85 crop, factors such as soil adsorption of P_T and the own absorption by the culture, influence P_T losses, as highlighted by Canga et al. (2016) and Machado et al. (2017). According to Haynes (1984) another factor that interferes in the availability of phosphorus to the soil solution, and thus being susceptible of absorption by the culture or percolation, is the pH, as its increase causes the surface charge of soil particles to become even more negative, increasing the repulsion (lower adsorption) between phosphate and adsorbent surface and decreasing the electrostatic potential of the adsorption plan.

The higher dosages applied and the effect of nitrogen mineralization on the soil columns provided significant concentrations of NO_3^- in the percolate (Table 3). Statistical differences were observed for NO_3^- percolates that received the A_AT_3 and A_LT_4 treatments, respectively, with concentrations of 59.7 kg ha^{-1} and 59.5 kg ha^{-1} of NO_3^-, when compared to the effects of the A_QT_0 treatment, which presented inferiors of 26.2 kg ha^{-1}. However, the lower dosages of SSW (A_AT_1) and DPW (A_LT_1), which represent 100% of the N recommendation, did not present significant NO_3 removals in the percolate compared to the control, which may be related to the same amount of N applied, in which were subject to similar conditions of nitrification and nutrient absorption by Tifton-grass 85, as highlighted by Sampaio et al. (2010). Gollany et al. (2004) studying doses of N in clayey soils, found average values of NO_3^- percolated of up to 78 kg ha^{-1}, when 20 and 200 kg ha^{-1} doses of N were applied in the maize crop. High values such as those found by Gollany et al. (2004) and those obtained in the present study show that the percolation of NO_3^- in the soil are quite variable, which makes it difficult to compare the results obtained at different sites.

Although there were no significant differences by the Tukey's test for potassium (K) for the treatments that received SSW, in the others showed changes as a function of the different doses of DPW application (Table 3). The maximal concentration of K in the percolated was 59.0 kg ha^{-1} (A_LT_4), presenting a significant effect when compared to the 23.6 kg ha^{-1} removed in the percolate after application of the A_QT_0 treatment. These results were superior to those found by Brito et al. (2005), in which were observed concentrations of 15.1 kg ha^{-1} of K in the percolation of soil columns submitted to 700 m^3 ha^{-1} of vinasse, and Maggi et al. (2013) that observed the presence of 4.7 kg ha^{-1} of K in percolate of 27 lysimeters submitted to dosages of 300 m^3 ha^{-1} of swine wastewater (SSW).

The changes in potassium (K) concentrations in soil and percolated profiles, as observed in the present study, were influenced by the variations in the existing concentrations of SSW and DPW, 12.6 and 16.3 mg L^{-1} respectively (Table 2), according to Neves et al. (2009) and Rosolem & Calonego (2013) also vary according to soil type, texture, cation exchange capacity (CEC) and nutrient source solubility. Mielniczuk (2005) points out that although the presence of high soil moisture provides nutrient movement conditions in the profile, the plants and soil CEC present an important role in reducing losses of K in percolates, especially in soils that have or are supplied of organic matter and under crops with high extraction potential, such as Tifton-grass 85 (Fia et al., 2014).

In Figure 3A, 3B, 3C and 3D are represented the box-plot of the pH values and COD concentrations, respectively, in the percolates after applications of the treatments with conventional chemical fertilization (A_QT_0), dairy products wastewater (DPW) and swine slaughterhouse wastewater (SSW), in soil columns.

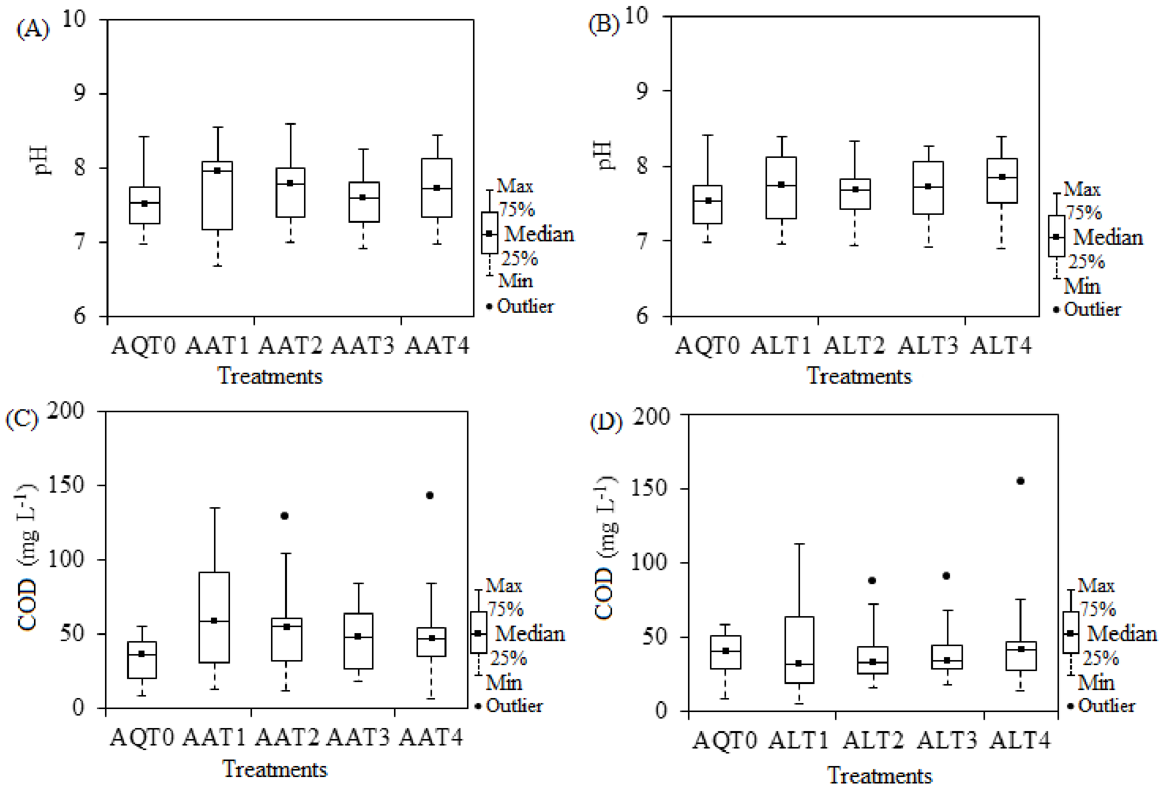

FIGURE 3. Box-plot of pH and COD concentrations in the percolated in function of slaughterhouse wastewater (A and C) and dairy products doses (B and D), respectively.

The pH values in the percolates presented medians varying between 7.0 and 8.0 in function of all the dosages. The maximum pH values occurred with the A_AT_1 (Figure 3A) and A_QT_0 (Figure 3B) treatments, being 8.5 and 8.4, respectively. The variations observed between the first and third quartiles show that the percolated pH did not undergo major alterations, a result that corroborates with those obtained by Maggi et al. (2011) who obtained fluctuations between 7.0 and 7.3 pH in percolates after maximum application of 300 m^3 ha^{-1} of swine wastewater (SSW) and Trevisan et al. (2013) who studied the quality of the percolate with the application of swine wastewater (SSW) do not finding differences in the percolated pH between the doses of 150 and 600 kg ha^{-1} of nitrogen. However, Bolzani et al. (2012) evaluated the percolated in Argisol fertirrigated with SSW, they observed an increase of the percolated pH in function of the application rates, mainly after application of 150 m^3 ha^{-1}.

The estimation of organic matter, expressed by COD of percolate (Figures 3C and 3D), in the SSW and DPW treatments presented maximum concentrations of 143.1 and 111.3 mg L^{-1}, after application in the dosages of 3916 (A_AT_4) and 7204 m^3 ha^{-1} (A_LT_4), respectively, evidencing, in relation to the entrance of wastewater in the columns, removal efficiencies of 97.5 and 98.4% in the A_AT_4 and A_LT_4 treatments, respectively. These results were superior to the 58.9 mg L^{-1} obtained in the A_QT_0 treatment, which sources of organic matter were residues already existing in the dark red Latosol and those coming from the straw of the Tifton-grass 85.

Corroborating with this study, Brito et al. (2007) the behavior of vinasse doses in yellow dystrophic Argisol, in which they obtained statistical differences in the COD of the percolates in the treatments that received 350 m^3 ha^{-1} and 700 m^3 ha^{-1} of vinasse, obtaining concentrations in percolates of 100 and 125 mg L^{-1} for the respective dosages, thus evidencing COD reduction efficiencies above 81% when compared to the control (water supply) treatment. The authors also report that although the vinasse doses are low, there were periods of 30 days of rest followed by the applications of the leach layers based on the volume of the pores, generating percolated and being possible to evaluate the COD behavior in the treatments.

It was observed that the increase in the dosages of the SSW and DPW treatments applied in the soil columns did not provide large changes between the first and third quartiles of the COD concentrations (Figure 3C and 3D), which according to Von Sperling (2014) it is related to the ability of the soil to assimilate complex organic compounds and to the temperature of the environment. For Bolzani et al. (2012), the soils treated with organic compounds, such as those present in wastewater, have mineralization of organic matter highly dependent on their composition, such as the relation C / N, besides the physical, chemical and microbiological characteristics that exist in the effluents, that in a way, corroborate to the increase of the microbial activity in the soil, reflecting, therefore, the concentrations of COD in the percolated.

The concentrations of Nitrogen Total Kjeldahl (NTK) and nitrate (NO^-_3) in the box-plots of Figures 4A, 4B, 4C and 4D for the treatments with A_AT_0, SSW and DPW presented variable amplitudes between maximum and minimum, which according to Zhao et al. (2014) may be related to the dynamics of nitrification and denitrification in the soil.

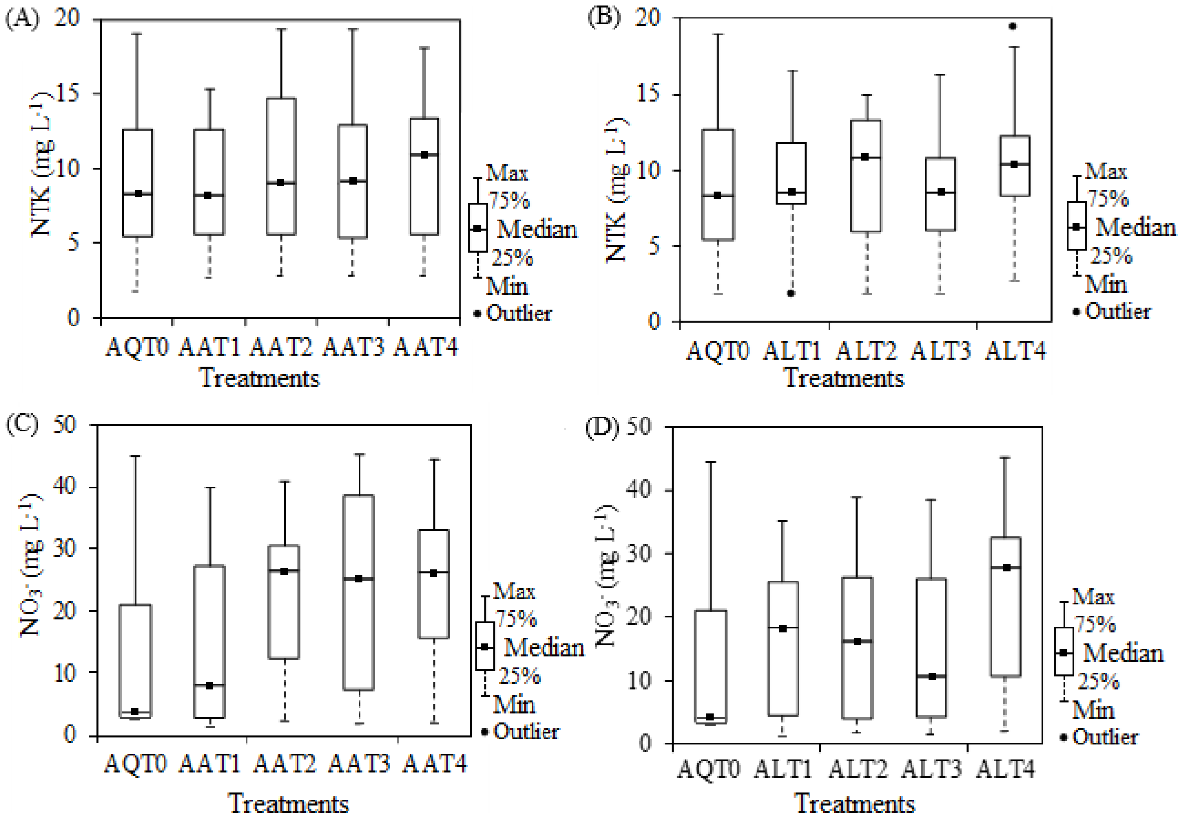

FIGURE 4. Box-plot of concentrations of NTK and NO_3^- in the percolated as a function of the wastewater from swine slaughterhouses (A and C) and dairy products doses (B and D), respectively.

We observed increasing medians of NTK concentrations with the increasing of SSW dosages (Figure 4A), with values of 14.3 mg L^{-1} in the third quartile (A_AT_2) and 5.4 mg L^{-1} in the first quartile (A_AT_0). In the percolates of the treatments that received DPW, there were higher oscillations in NTK concentrations in function of the applied rates, especially the A_LT_2 treatment, which presented a median of 10.8 mg L^{-1}, higher than the other treatments, and the highest concentration of NTK of 14.8mg L^{-1}. These results differ from those obtained by Maggi et al. (2011), who did not observed increases in NTK in the percolated of soil cultivated with soybean after applications of 300 m^3 ha^{-1} rates of swine wastewater.

The proximity of the median of the first and third quartiles indicates that the concentrations of NTK found in the percolated samples presented lower amplitudes in the box-plots in function of the applied treatments, and may be related to the formation of preferential paths, due to the increase in roots activities in the soil, which may have contributed to the reduction of the exposure to nitrification conditions of organic nitrogen (N_{org}) and assimilation of Tifton-grass 85, as observed by Phillips & Burton (2005) when finding NH_4^+ increments in the percolated after the formation of preference paths in pine forests. In addition, there was probably a reduction in the aerobic microbial activity of the soil resulting from the increase of water content in the soil due to the increase in precipitation (Figure 2).

The box-plot of nitrate concentrations in all treatments (Figures 4C and 4D) showed maximum values of 45.2 and 45.1 mg L^{-1} for A_AT_3 and A_LT_4, respectively, although lower at 44.9 mg L^{-1} found in the A_QT_0 treatment, using urea as a nitrogen source. These results are justified by the fact that nitrate ion (NO_3^-) presents high mobility in the soil profile in function of negative charges in its molecule and, therefore, is not retained in the soil (Paramashivam et al., 2016). Other factors responsible for NO_3^- mobility are texture, amount of fertilizer applied, type of fertilization, quantity and frequency of rainfall, irrigation management, drainage conditions and dynamics of N transformations such as: mineralization, immobilization, denitrification and N absorption by plants (Campbell et al., 1993; Jadoski et al., 2010).

The lowest concentrations of NO_3^-, represented by the lower dashed line of box-plots, presented results below 3.0 mg L^{-1}, being lower than the 14.6 mg L^{-1} found by Santos et al. (2014) after application of 137.1 kg ha^{-1} of nitrogen, derived from swine wastewater, in soils columns; and from 12.6 mg L^{-1} obtained by Bolzani et al. (2012) after dosing of 67.2 kg ha^{-1} of nitrogen applied through swine wastewater (SSW). Esterhuizen et al. (2012) evaluated groundwater from 75 dairy farms in Mangaung, South Africa, and found that 49.3% of the wells had NO_3^- concentrations higher than 10 mg L^{-1}, which, according to the authors, are consequences of poor management practices in the disposal of wastewater in the soils of the region.

Although, at the end of the monitoring, we observed concentrations of NO_3^- less than 10 mg L^{-1}, established by the Resolution of the National Environmental Council No. 396 (Brasil, 2008) as groundwater quality criteria, it was observed high concentrations of NO_3^- over the months of the percolated evaluation, and, therefore, it is necessary to implement more appropriate management practices due to the potential contamination of surface and ground waters (Kanthle et al., 2016).

For the total phosphorus (P_T), it was observed that there were small variations between the first and third quartiles (Figure 5A and 5B), while potassium (K) presented higher interquartile oscillations depending on the dosages of the treatments, as observed in the Figures 5C and 5D.

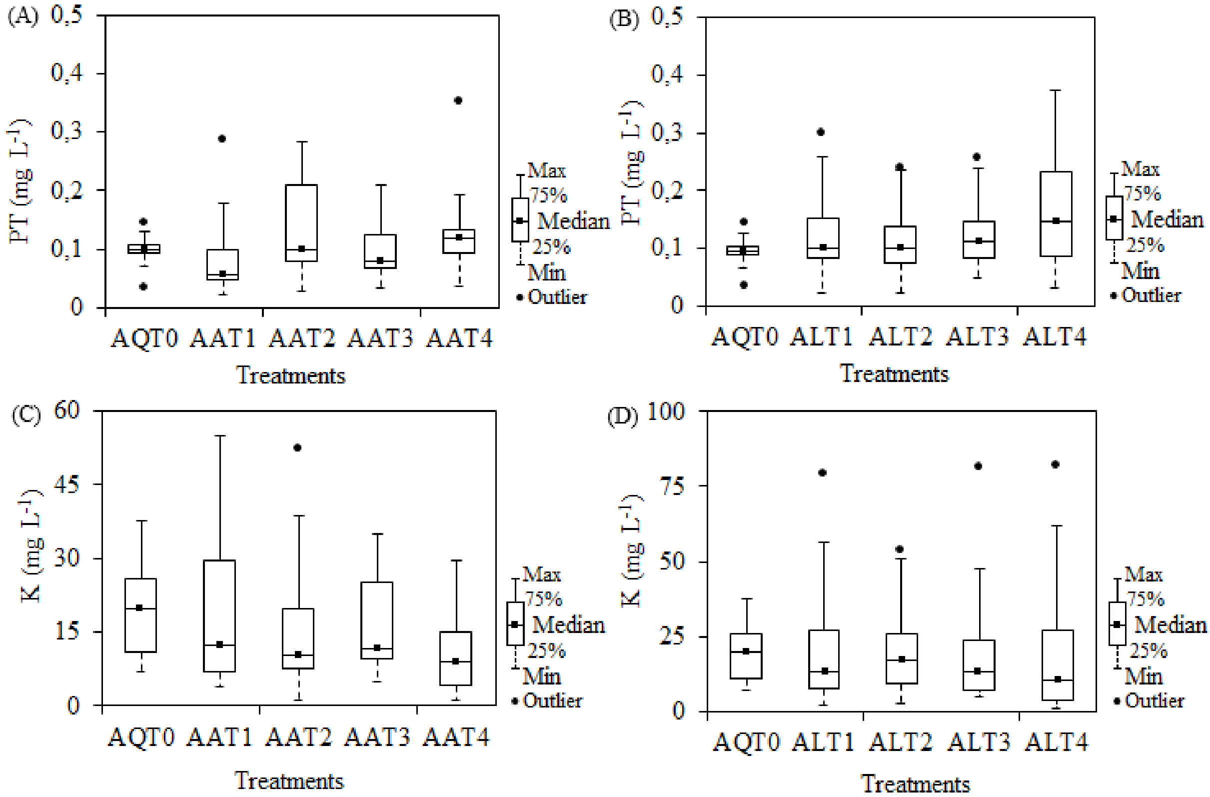

FIGURE 5. Box-plot of P_T and K concentrations in the percolated in function of the wastewater from swine slaughterhouses (A and C) and dairy products doses (B and D), respectively.

It was observed that the concentrations of P_T in DPW percolates presented increasing medians as a result of increased dosages (Figure 5B), with maximum values 0.37mg L^{-1} (A_LT_4), unlike the SSW treatments that presented a higher concentration of 0.26 mg L^{-1} in the A_AT_2 treatment (Figure 5A). The phosphorus supplied in the treatments with conventional chemical fertilization (single superphosphate with 18% of P_2O_5), SSW and DPW was largely adsorbed to the soil matrix due to the low solubility of the super simple, as well as absorbed by the Tifton-grass 85, being justified by the application of the effluents have been based on the nitrogen requirement of the Tifton-grass 85, not providing, therefore, the need of 310 kg ha^{-1} of the crop, and consequently, resulting in low concentrations in the percolate. According to Novais et al. (2007) and Rajput et al. (2014) the low concentrations of phosphorus in percolates are related to several factors, some related to soil physics, such as the structure and presence of clays, and others concerning to the chemistry interaction soil-water, such as pH.

In studies with wastewater from the processing of tomato in soil columns, Chahal et al. (2011) observed concentrations of 1.5 mg $L^{-1}$of total phosphorus after application of 170 m^3 ha^{-1} of effluent with 30 days of monitoring, while Bolzani et al. (2012) found 0.34 mg L^{-1} of total phosphorus after applying 50 m^3 ha^{-1} of swine wastewater.

It is observed in Figures 5C that the potassium (K) concentration had a greater oscillation of the medians in function of the treatments, highlighting the effect of A_AT_2 that provided 29.6 mg L^{-1} of K in the third quartile, representing 75% of the data evaluated, a maximum of 55.6 mg L^{-1} and a median of 12.4 mg L^{-1}, as the median being lower, therefore, 21.2 mg L^{-1} in the A_QT_0 treatment.

In the DPW dosages presented in Figure 5D, we observed interquartile variations (relation between first and third quartiles) between 5 and 25.4 mg L^{-1}, demonstrating that increasing dosages of DPW were not sufficient to provide increased concentrations of K, although was observed during the monitoring peaks of 57.2 mg L^{-1} of K in the higher dosage treatment (A_LT_4). Results close to those obtained in this study were found by Maggi et al. (2011) in which they observed 75 mg L^{-1} of

K in percolated soils cultivated with soybean after application of 100 m^3 ha^{-1} of swine wastewater (SSW) and Chahal et al. (2011) found 15.1 mg L^{-1} of K in percolate after application of 170 m^3 ha^{-1} of tomato processing residues.

The oscillations of K average values were below 25 mg L^{-1} (Figures 5C and 5D) after application of all the experimental treatments, fact that evidence that this nutrient presents intermediate mobility in the soil profile (Alcarde et al., 2000) between nitrate and phosphorus, and, in parts, being absorbed by Tifton-grass 85 as a nutritional requirement for its vegetative development.

CONCLUSIONS

The system composed of soil and Tifton-grass 85 provided efficient mineralization of the organic contribution in the soil after the DPW and SSW application rates expressed as COD and NTK in the percolate.

The higher dosages of wastewater from swine slaughterhouses and dairy products contributed to the increase in nitrogen and phosphorus mass in percolates.

The assimilation of nitrate by the crop and reduction of nitrification in the soil were responsible for the reduction of concentration levels at the end of the monitoring, with values below 10 mg L^{-1}.

ACKNOWLEDGMENTS

To CAPES and FAMEPIG for the availability of research grants and resources for the development of the project.

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