ISSN 1808-3765

NITROGEN TRANSPORT DUE TO WATER REUSE APPICATION AND IRRIGATION RATES[1]

TALITA DANTAS PEDROSA[2]; ROSELENE MARIA SCHNEIDER[3]; GABRIELE WOLF[4]; ADILSON PACHECO DE SOUZA[3]; WILLIAN HENRIQUE DA SILVA LIMA[3] E EDNALDO ANTÔNIO DE ANDRADE[3]

[1] Trabalho oriundo da dissertação de mestrado da primeira autora.
[2] Centro de Ciências Exatas e Tecnologias, Universidade Federal do Maranhão, UFMA Campi São Luís, Avenida dos Portugueses, 1966, Vila Bacanga, 65.080-805, São Luís - MA, Brasil. E-mail: tdpedrosa2@yahoo.com.br
[3] Instituto de Ciências Agrárias e Ambientais, Universidade Federal de Mato Grosso, UFMT Campi Sinop, Avenida Alexandre Ferronato, 1200, Setor Industrial, 78550.728, Sinop - MT, Brasil. E-mail: roselenems@yahoo.com.br, pachecoufmt@gmail.com, willian.henriquelima27@gmail.com, ednaldo@ufmt.br
[4] Faculdade de Sinop, FASIPE Campi Sinop, Av. Magda de C. Pissinatti, 69 - Residencial Florença, 78.550-000, Sinop – MT, Brasil. E-mail: wolf_gabriele@yahoo.com.br

1 ABSTRACT

The waste application of swine activities is a common practice in many regions; however, there are uncertainties about the risks associated with applications for agriculture. This study presents the assimilable nitrogen transport in lysimeters submitted to reuse water rates and irrigation rates, with cauliflower crop (*Brassica oleracea* L.), Verona CMS variety from August to October 2014. Three swine water reuse rates were applied (0, 50 and 150 m^3 ha^{-1}) and three irrigation rates (100%, 125% and 150% of potential evapotranspiration of culture - ETc) with three repetitions. Leached samples were collected at 10, 20, 30 and 40 days after the application of reuse water (DAAR). The total Kjeldahl nitrogen (TKN) leaching increased with increasing irrigation rates in the lysimeters without water reuse, with averages of 7.84 to 22.78 mg L^{-1}. Other forms of nitrogen as nitrite (NO_2^-) and nitrate (NO_3^-) showed a higher concentration to 40 DAAR. However, there was a reduction in the leaching of these elements with increasing irrigation rates. The irrigation rates 125 and 150% and the rate 150 m^3 h^{-1} transported NO_3^- in lower concentrations.

Keywords: evapotranspiration, swine waste, cauliflower.

PEDROSA, T. D.; SCHNEIDER, R. M.; WOLF, G.; SOUZA, A. P.; LIMA, W. H. S.; ANDRADE, E. A.
TRANSPORTE DE NITROGÊNIO EM FUNÇÃO DA APLICAÇÃO DE ÁGUA DE REUSO E LÂMINAS DE IRRIGAÇÃO

2 RESUMO

A aplicação de resíduos de atividades suinícolas é uma prática que vem ganhando espaço em alguns países, todavia, persistem incertezas quanto aos riscos associados a aplicações com fins agrícolas. Neste trabalho apresenta-se o transporte de nitrogênio assimilável em lisímetros submetidos a taxas de água de reuso e lâminas de irrigação, com cultivo de couve-flor (*Brassica Oleracea* L.) variedade Verona CMS no período de agosto a outubro de 2014. Foram aplicadas

Recebido em 08/02/2017 e aprovado para publicação em 31/10/2018
DOI: http://dx.doi.org/10.15809/irriga.2018v23n4p637-648

três taxas de água de reuso da suinocultura (0, 50 e 150 m^3 ha^{-1}) e três lâminas de irrigação (100%, 125% e 150% da evapotranspiração potencial da cultura – ETc), com três repetições. Foram coletadas amostras do lixiviado aos 10, 20, 30 e 40 dias após a aplicação da água de reuso (DAAR). A lixiviação de nitrogênio total Kjeldahl (NTK) foi crescente com o aumento da lâmina de irrigação nos lisímetros sem água de reuso, com médias de 7,84 para 22,78 mg L^{-1}. As demais formas de nitrogênio, como nitrito (NO_2^-) e nitrato (NO_3^-), apresentaram maiores concentrações aos 40 DAAR, porém, houve redução na lixiviação desses elementos com o aumento da lâmina de irrigação. As lâminas 125 e 150% da ETc e a taxa 150 m^3 ha^{-1} transportaram NO_3^- em menor concentração.

Palavras-chave: evapotranspiração, resíduos de suinocultura, couve-flor.

3 INTRODUCTION

Among the various demands of agriculture, water reuse is a practice that has been gaining ground in some countries and could be many times, the only source of nutrients for the soil and crops. In Brazil, the United States and some European countries, the reuse of water disposal in the soil has been widely used because it enables the reduction of the cost of final disposal of the waste, and providing nutrients that offer the improvement of soil fertility (FREITAS et al., 2010; ZANUZO et al., 2013; PEDROSA et al., 2017).

Although the use and disposal of organic waste have grown and gained prominence in the national and international scene, it is essential to analyze potential contamination of the soil, groundwater and surface water. In general, these problems may arise from the applied volume, the biosorption capacity, permeability and porosity of the soil (ABREU NETO e OLIVEIRA, 2009).

The use of recycled water in agriculture can cause the movement of chemical elements, especially nitrogen (N). The excessive applications of bio-fertilizers result in low efficiencies of using N and entail high losses by leaching, runoff, volatilization, denitrification, among other processes (KIRD, DERICI, SCHEPERS, 2001). Matos, Lemos, Barros (2004) state that the nitrate (NO_3^-) and ammonium (NH^{4+}) occur naturally in the soil as mineralization products of organic material.

The leaching of nitrate (NO_3^-) depends on nitrogenous fertilizer application rates or organic compounds, but the irrigation excess may also promote the leaching of nitrates in the soil profile, thereby making them unavailable to the plant (ZHU et al., 2005). This unavailability may be a concern from the agricultural point of view, as NO_3^- is the main form of nitrogen absorption by plants, and also one of the forms of N more easily leached into the soil, with the potential for groundwater contamination.

In this sense, it was aimed to evaluate the nitrogen transport (total Kjeldahl nitrogen, nitrite and nitrate - TKN) in lysimeters, after the application of different rates of swine reuse water and irrigation rates, to support the integrity of natural resources by search of water reuse rates and irrigation rates that promoted minor movements of these elements in the soil, making them available in higher concentration for the plants.

4 MATERIAL AND METHODS

The research was conducted in the Federal University of Mato Grosso, Sinop University *Campus*, located in 11º 51’ S and 55º 29’ W, from August to October 2014. Precipitations occurred during the experiment. The soil of the experimental area was classified as red-yellow Latosol.

Twenty-seven lysimeters were built for the study of leaching, arranged in plot, and inserted into trenches of 1.20 m deep and 0.30 m in diameter. The structure of the lysimeters was hard PVC filled with soil, maintaining the same sequence as the original profile. Before completing the lysimeters, a chemical, and physical soil was performed at two depths 0 – 20 cm and 20 – 40 cm. For filling of the lysimeters, an isolated trench was opened with about 1.0 m deep. From this trench, the depths of 0-10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-70 and 70-80 cm, were marked to take samples from soil to determine soil density. It was sought to reconstitute the soil profile in the lysimeter through certain densities. The lysimeter was provided with a collection system (funnel and bottle) in the bottom of the trench, where the leachate was stored for later collection.

In the chemical analysis of the soil of layer 0-20 cm, concentrations of 2.46 and 32.00 mg dm^{-3} for phosphorus and potassium were obtained; 2.03 and 1.72 cmol dm^{-3} for calcium and magnesium; 3.90 and 0.59 mg dm^{-3} for zinc and copper; zero concentration of Aluminum; pH (H_2O) 5.4; cation exchange capacity (CEC - pH 7.0) of 6.98 cmol dm^{-3} and organic matter content in 38.22 g dm^{-3}. The physical analysis identified 462, 250 and 288 g dm^{-3} for the clay, silt and sand contents, respectively. Consequently, 4.61 and 55.00 mg dm^{-3} for phosphorus and potassium were obtained in the layer of 20-40 cm; and 3.75 and 1.30 cmol dm^{-3} for calcium and magnesium; zero concentration of aluminum; and 4.85 to 0.84 mg dm^{-3} for zinc and copper; pH (H_2O) of 5.9; cation exchange capacity (CEC – pH 7.0) of 8.01 cmol dm^{-3} and organic matter content in 43.00 g dm^{-3}. In the physical analysis, the clay, silt, and sand contents were 483, 167 and 350 g dm^{-3}, respectively.

After the chemical and physical soil characterization, the supplement chemical fertilizer was determined, following the technical recommendations of Zanuzo et al. (2013) for cv. Verona cauliflower. In this context, the planting fertilizer corresponded to the addition of 10 g of urea, 15 g of potassium chloride, 20 g of simple superphosphate and 12.5 g of dolomite limestone in the surface of each of the lysimeters before transplanting the seedlings.

Swine reuse water was collected on a farm in the municipality of Vera/Mato Grosso, after treatment in bio-digesters. The residue (reuse water) has been chemically and physically characterized, with pH 6.85, turbidity of 4.970 NTU, electrical conductivity of 1.1 S m^{-1}, total dissolved solids concentration of 7.0 g L^{-1}, biochemical oxygen demand (BOD) of 283.3, TKN of 308.7, 154.7 of NO_2^-, 811.36 of NO_3^-, P total of 150.29, zinc (Zn) of 35,90 and copper (Cu) concentration of 10.88 mg L^{-1}. The application of reuse water was performed only once on the surface of the lysimeters, before transplanting the seedlings in three application rates, 0.50 and 150 m^3 ha^{-1} yr^{-1}. Surrounds plants, as well as plants that were on the surface of the lysimeters, also received effluent reuse water in the same application above rates.

The transplanting of cauliflower seedlings was performed (*Brassica oleracea* L.) Verona CMS variety, manually in each lysimeters on 3rd August 2014. The spacing was set at 0.50 x 0.50 m (between plants and between lines), indicating that the distance between lysimeters was 0.50 m. After transplanting, the dripping irrigation system was installed, with daily watering, for 40 days through the use of dripping polyethylene hose, with spacing between drippings of 25 cm, flow rate of 7.5 L h^{-1} m^{-1} and 10 meters of water column operating pressure (m.c.a).

The evaluated irrigation rates were 100, 125 and 150% of potential evapotranspiration of culture (ETc), given by multiplying the reference evapotranspiration (ET_0) and crop coefficient (Kc). The rates were determined according to the daily reference evapotranspiration (ET_0), obtained by the Class A Tank method, employed the recommendations of Souza et al. (2015) with tank coefficient "Kp" of 0.7795. It also employed the crop coefficient Kc of 0.65 (ALLEN et al., 1998).

Four leached samplings were performed (10, 20, 30 and 40) DAAR along the experiment. The evaluated chemical elements were TKN, NO_2^-, NO_3^-, following the methodology described in Standard Methods of Water and Wastewater (APHA, 2012).

The experimental design was adopted in randomized blocks in a subdivided plot with factorial on plot 3 x 3 x 4, wastewater application rates, irrigation rates and collected over time respectively, and three replications.

5 RESULTS AND DISCUSSION

5.1 Water Volume Applied in the Irrigation

Table 1 shows the amount of water applied through irrigation on the surface of the lysimeters and the total volume applied during the experiment. The total volume of water applied was crescent with increasing ETc (totaling 179.73, 224.67, 269.61 liters for increments of 0.25 and 50% ETc). However, it was observed a reduction trend of daily volume applied throughout the experimental time for all rates due to the reduction of ET_0.

Table 1. Applied volume irrigation (L) in different irrigation rates and leachate collection times in lysimeters with red-yellow Latosol and cultivated with cauliflower cv. Verona.

Time (DAAR)*	Irrigation rates (% ETc)**		
	100	125	150
10	59.85 Ca	74.81 Ba	89.78 Aa
20	55.18 Cb	68.98 Bb	82.77 Ab
30	30.91 Cd	38.64 Bd	46.37 Ad
40	33.79 Cc	42.24 Bc	50.69 Ac
Total (L)	179.73	224.67	269.61

*DAAR – days after application of reuse water; **Means followed by the same lowercase letter in columns and a capital letter in rows do not differ by the Scott Knott test at 5% probability

It is essential to know the amount of water required by the crop for an efficient irrigation water management, for a certain period, not restricting its growth and production, in the local climate conditions (BERNARDO, SOARES, MANTOVANI, 2006). Thus, the use of crop coefficient (Kc) to determine in ETc, indicates that the culture will not be submitted to water deficiency (SILVA, MEZA, VARAS, 2010).

Providing 100% ETc is considered sufficient to meet the demand for water by crops; however, Lima, Custódio, Gomes, (2008) evaluated different irrigation rates and observed that the increase of the rates significantly contributed to increasing productivity. It is emphasized that this assumption is not valid for all cultures, since the replacement of ETc indicates that the losses by percolation and evaporation will be minimized, and also that each culture will present a response function of the applied water quantity, dependent on the amount and frequency of irrigation, application method of water, development stage, soil variability, climate conditions, cultural practices, among other factors.

In short, water supply in rates higher than the ETc demanded by Cauliflower cv. Verona (125 and 150% ETc) may provide greater formation of leachate (water percolation in the soil profile). In this sense, when considering that the rainfall in the region is approximately 2.000 mm yr^{-1}, concentrated in seven months (SOUZA et al., 2013), there may be periods with natural recharge of water (rainfall) higher than ETc daily average.

Therefore, the joint evaluation between applied volume and collected volume may be an assessment indicative for nitrogen transport in the soil, when used via reuse water in crops in the rainy season. It is noteworthy that despite the irrigation rates and reuse of water application rates have been set in order to seek an increase in cauliflower productivity, the components of the agronomic performance of cultivation have not been evaluated.

5.2 Volume Collected Water

The volume of water collected after irrigation showed significant interaction between irrigation rates and time and between wastewater rate and irrigaton rate (Table 2). The reduction of the collected volume was observed for the rates 125 and 150% ETc at collection time. This reduction can be explained by irrigation since the excess water promotes the incidence of translocation of solid particles from the soil (mainly clays), which in turn favors the process of soil storage within the lysimeters, reducing its permeability over the time (IMHOFF et al., 2001).

Table 2. Collected volume (L) in different irrigation rates and leachate collection times in lysimeters with red-yellow Latosol and cultivated with cauliflower cv. Verona.

Time (DAAR)*	Irrigation rates (% ETc)**		
	100	125	150
10	5.14 Ca	8.19 Ba	11.96 Aa
20	3.61 Ca	5.87 Bb	8.51 Ab
30	3.50 Ba	4.89 Bb	6.89 Ac
40	3.68 Ba	5.14 Bb	6.94 Ac
Total (L)	15.93	24.09	34.30

Irrigation rates (% ETc)	Reuse water rates (m^3 ha^{-1})**			
	0	50	150	Total (L)
100	3.80 Ac	4.10 Ac	4.10 Ab	12.00
125	5.56 Ab	6.06 Ab	6.45 Aa	18.07
150	10.34 Aa	8.59 Ba	6.79 Ca	25.72

*DAAR – days after application of reuse water; **Means followed by the same lowercase letter in the columns and a capital letter in rows do not differ by the Scott Knott test at 5% probability.

On the 100% ETc rate, it was also observed the generation of leachate, not an expected behavior because the water supply to the culture is based on the same evaporation, resulting in providing the entire water content recommended to the culture. However, the determination of ET_0 by the class A tank method tends to provide overestimate, even considering tank coefficient values (Kp) regionally calibrated (BARROS et al., 2009). However, this method is an interesting alternative in the irrigation management, for its simplicity of operation and low cost. The total collected volume was 8.86; 10.72 and 12.72% of the volume applied to the 100, 125 and 150% ETc rates.

In the interaction between reuse water rates and irrigations rates the table show the volume average values collected, and in this development, the leached volume increased concomitantly with the increase of the irrigation rates, regardless of wastewater rates. The higher leach volume was observed in the 150 rate with 0 water reuse rate.

The unfolding rate within rates was only significant in the 150% ETc rate since the volume was decreased with applied increased residual rate. It was observed that the total collected volume was also higher for a higher rate, with an average of 25.72 L. The balance between the total quantity of water applied by irrigation and collected indicates that the remaining water content is demanded by the atmosphere by evaporation and/or was stored in the soil pores.

5.3 Kjeldahl Total Nitrogen Assessment

Total Kjeldahl nitrogen (TKN) leaching was influenced by all treatments, presenting significant triple interaction (time, water reuse rate and irrigation rate). Table 3 shows the unfolding time in water reuse rate and irrigation rate lines as well as the unfolding water reuse rate in time and columns irrigation rates and unfolding of the irrigation rates in time and water reuse rate in the columns.

Table 3. Total Kjeldahl nitrogen concentration (mg L^{-1}) in different irrigation rates, water reuse application rates and collection times in lysimeters with red-yellow Latosol and cultivated with cauliflower cv. Verona.

Irrigation rates (% ETc)	Water reuse rates (m^3 ha^{-1})	Time (DAAR)**			
		10	20	30	40
100	0	7.84 Aa(a)	9.64 Aa(a)	4.41 Ac(a)	3.59 Aa(a)
	50	4.65 Bb(a)	3.92 Bb(a)	22.78 Aa(a)	7.19 Ba(a)
	150	2.12 Ab(a)	1.99 Ab(a)	3.72 Ac(b)	1.44 Aa(a)
125	0	2.18 Ab(b)	4.26 Ab(a)	2.58 Ac(a)	5.59 Aa(a)
	50	2.53 Ab(a)	0.01 Ab(a)	6.94 Ab(b)	1.84 Aa(a)
	150	4.71 Ab(a)	4.22 Ab(a)	9.42 Ab(a)	5.58 Aa(a)
150	0	11.53 Aa(a)	10.26 Aa(a)	4.22 Bc(a)	0.01 Ba(a)
	50	0.01 Ab(a)	0.01 Ab(a)	0.37 Ac(c)	2.09 Aa(a)
	150	0.01 Ab(a)	0.01 Ab(a)	0.10 Ac(b)	0.01 Aa(a)

**Means followed by the same low case letter in columns and a capital letter in rows do not differ by the Scott Knott test at 5% probability. Lowercase letters in parentheses represent the unfolding of the irrigation rates in water reuse rate and time in the columns

The unfolding of water reuse rate time and irrigation rates showed significant interactions between the irrigation rate 100 and water reuse rate 50 as well as between irrigation rate 150 and 0 water reuse rate. In the interaction with the irrigation rate 100 and 50 water reuse rate, the TKN showed increasing effect with time; the highest concentration was observed at 30 DAAR of 22.78 mg L^{-1} with subsequent reduction to 40 DAAR.

In the interaction between the irrigation rate 150 and 0 water reuse rate, the leaching of the element under the effect of time reduced from 11.53 to 0.01 mg L^{-1}. The other observed treatments did not differ. The results indicated that the treatment of irrigation rate 150 and 150 water reuse rate offered no risk of loss of TKN out of the root zone along the performed collections, making it available in higher concentration to the cauliflower seedlings.

Sommer and Husted (1995) state that ammonia nitrogen suffers nitrification when applied to the soil since most of the nitrogen in swine effluents is in ammonium form when applied in the field. This decrease in TKN leaching may be associated with the intensification of the organic nitrogen mineralization processes. The unfolding of the water reuse rates interacting with time collection and irrigation rates observed in the columns showed significance in the leaching of TKN.

The water reuse rate increase caused reduction of leaching observed for the irrigation rates 100 on 10, 20 and 30 DAAR, but the irrigation rate 125 was increased by nitrogen, being leachate at 30 DAAR.

The irrigation rate 150 showed similar effect occurred in the rate 100, where the variation rates caused a reduction in the leached concentrations, but in this case only at 10 and 20 DAAR. In this context, the loss of organic nitrogen observed in lysimeters without wastewater came from the incorporation of urea to the soil (the fertilizer used as a nitrogen source) before transplanting the seedlings.

Assessing the unfolding of irrigation rates to 10 DAAR interacting with 0 water reuse rates, it was observed that the 50% increase in irrigation rate in the absence of wastewater, significantly favored the increase in nitrogen leaching, 7.84 to 11.53 mg L^{-1}. However, in this period, the irrigation rate increasing did not influence the leaching of TKN in water reuse rates of 50 and 150 m^3 ha^{-1}.

Irrigation rate effect on leaching of the TKN was also observed at 30 DAAR since the concentration of this element in the leachate, concomitantly reduced with the increase of the irrigation rate, from 22.78 to 0.37 mg L^{-1} at the water reuse rate of 50 and from 3.72 to 0.10 mg L^{-1} at water reuse rate 150, at 0 rate the TKN transport was not significant.

5.4 Nitrite Assessment

Table 4 shows the NO_2^- transport in the unfolding of the rates within the time. In general, the influence of the rates in the nitrite transport is small and is significant only in the collection made to 40 DAAR with a reduced concentration of NO_2^- with increasing rate. This reduction may have been influenced by the greater supply of water, which probably inhibited the activity of nitrobacteria during this period, leading to an NO_2^- accumulation in the soil profile.

Table 4. NO_2^- (mg L^{-1}) concentration, in different irrigation rates and lysimeters collection dates with red-yellow Latosol and cultivated with cauliflower cv. Verona.

Time (DAAR)*	Irrigation rates (% ETc)**		
	100	125	150
10	1.42 Ac	1.39 Ac	1.97 Ab
20	4.97 Ab	4.03 Ab	3.45 Ab
30	4.55 Ab	5.34 Ab	4.40 Aa
40	8.31 Aa	8.76 Aa	5.92 Ba

*DAAR – days after application of reuse water; **Means followed by the same low case letter in columns and a capital letter in rows do not differ by the Scott Knott test at 5% probability

Riley, Ortiz-Monasterio, Matson (2001) evaluating the leaching of nitrogen and nitrate, nitrite and ammonium levels in the soil, noted that the concentration of NO_2^- in the topsoil was significant during the first week at the beginning of irrigation. Mullane et al. (2015) observed that the nitrite concentration decreased significantly after the fourth irrigation.

The unfolding of time in the rates observed in columns showed that the NO_2^- transport presented a linear increase over the time for all rates. Escobar et al. (2004) evaluating the effect of the application of different types of nitrogenous fertilizers in the growth of plant seedlings and nitrogen losses by leaching, observed higher losses for urea and ammonium sulfate applications over 30 days.

The NO_2^- losses due to the variation of irrigation were small, showing significance only at 40 DAAR. However, considering the unfolding of time, the concentrations were increased for any of the rates. It was found that the NO_2^- concentrations transported out of the lysimeters, were higher than the maximum set by Conama Resolution No.396 of 2008 (BRASIL, 2008), establishing that NO_2^- concentrations above 1.0 mg L^{-1} has a subterranean water potential polluter.

5.5 Nitrate Assessment

The variance analysis showed significance between irrigation rates and time for NO_3^- (Table 5). It was observed that the increase in water rate provided smaller significant losses NO_3^- at 20 and 40 DAAR, justified by dilution of NO_3^-, i.e., with a similar behavior of nitrite.

Table 5. NO_3^- concentration (mg L^{-1}) in different irrigation rates and collection dates in lysimeters with red-yellow Latosol and cultivated with cauliflower cv. Verona.

Time (DAAR)*	Irrigation rates (% ETc)**		
	100	125	150
10	19.55 Ac	12.80 Ac	12.37 Ac
20	33.42 Ab	24.03 Bb	20.21 Bc
30	32.75 Ab	38.76 Aa	40.17 Aa
40	46.43 Aa	48.48 Aa	28.29 Bb

*DAAR – days after application of reuse water; **Means followed by the same low case letter in the columns and a capital letter in a row do not differ by the Scott Knott test at 5% probability

The NO_3^- transport occurred in the above maximum allowed concentrations (10 mg L^{-1}) by Conama Resolution No.396 of 2008 (BRASIL, 2008), regardless of the irrigation rates and the collection period, representing, therefore, a subterranean water potential polluter. The NO_3^- transport through interaction between time and rates, shows a variation in leaching of nitrates over the time to all applied rates, characterizing it as a significant variation, once to four sampling, the leaching process showed an increasing trend behavior. The weather is characterized as a major factor in the process of nitrification of ammonia nitrogen in the soil.

Aita and Giacomini (2008) evaluating the accumulation and displacement of NO_3^- in the soil after the application of swine liquid waste in corn tillage, observed over three years, that the amount of NO_3^- increased rapidly in the surface layers of the soil, soon after the slurry application, accompanied by the rapid transfer of the element to the lower layers due to the high ammonia nitrogen nitrification rate of the applied slurry. Boeira (2009) evaluating the nitrogen leaching in Latosol incubated with sewage sludge, noted that increasing doses provided greater leaching of the mineralized nitrogen.

Table 6 shows the total nitrogen concentration (TKN + NO_2^- + NO_3^-) NO_3^- concentration applied and leached in lysimeters from the incorporation of reuse water before transplanting the seedlings, as well as the concentration of NO_3^- retained in ground.

Table 6. The average concentration of total nitrogen, NO_3^- applied and leached (in 4 collections) and NO_3^- average held in the soil in lysimeters with red-yellow Latosol and cultivated with cauliflower cv. Verona

Irrigation rates (% ETc)	Reuse water rates (m^3 ha^{-1})	Total nitrogen (mg)	NO_3^- applied (mg)	NO_3^- leached (mg)	NO_3^- in the soil (mg)
L100	T0	-	0,00	120.99	-
	T50	114.73	73.02	134.19	-
	T150	344.19	219.07	140.19	78.88
L125	T0	-	0.00	198.21	-
	T50	114.73	73.02	194.97	-
	T150	344.19	219.07	163.05	56.02
L150	T0	-	0.00	326.23	-
	T50	114.73	73.02	187.95	-
	T150	344.19	219.07	151.82	67.25

Li: irrigation rate; Ti: wastewater rate; NO_3^-: nitrate

The average of total nitrogen shows the potential that the waste presents indicating that the existing nitrite share in the total nitrogen can be converted to nitrate by nitrification, justifying the high concentrations found in higher element concentration applied to the soil. The highest concentration of nitrate occurred in the rate 150, and 0 rates (326.23 mg), and only 100% ETc increased wastewater rates provided higher nitrate concentrations in the leachate. For the rates 125 and 150% ETc, there was a decrease in leached nitrate concentration, concomitantly to increased applied nitrate concentration.

The increase in rate provided higher nitrate leaching, and this effect was even observed for the lysimeters treated with 0 rates. The treatment between the rate 100 and rate 150 showed the highest concentration of nitrate in the soil and therefore, available for plants. In short, the NO_3^- concentration in the leachate was higher than the concentration applied at rates 0 and 50 m^3 h^{-1} for all three evaluated rates, indicating that the nitrate was ground from different reuse water sources and lower than this concentration T150 m^3 h^{-1} for all evaluated rates, indicating that part of the nutrient was retained in the soil solution and therefore, available for the culture.

Marofi et al. (2015) found that nitrate concentrations in leachate were much higher when applied wastewater compared to treatments that did not receive any fertilizer, and also stated that the majority of the elements in wastewater are retained into the soil, causing a lower concentration of these elements in the leachate water.

6 CONCLUSIONS

1. The volume of leachate was growing according to higher increases of water for irrigation, however, decreasing the increase in swine wastewater rates.

2. The lower TKN transport occurred with the interaction of irrigation rate 150 and reuse water rate 150 to 10 DAAR, as well as the irrigation rate 150 and 150 reuse water rate to 30 DAAR, characterizing this treatment both agriculturally and environmentally, more efficient in ensuring nutrients in the root zone and protect the integrity of groundwater resources.
3. The variation of irrigation rates provided little influence on NO_2^- transport, while rates are exceeding 100% of evapotranspiration of the culture, have provided transport with smaller NO_3^- concentrations in the soil profile in lysimeters.

7 ACKNOWLEDGMENTS

To FAPEMAT (Support Research Foundation in Mato Grosso) by granting scholarship to the first author and CNPq (National Council for Scientific and Technological Development) for financial support (MCTI/CNPq No. 14/2014).

8 REFERENCES

ABREU NETO, M. S.; OLIVEIRA, R. A. Remoção de matéria orgânica, de nutrientes e de coliformes no processo anaeróbio em dois estágios (reator compartimentado seguido de reator UASB) para o tratamento de águas residuárias de suinocultura. **Engenharia Agrícola**, Jaboticabal, v. 29, n. 1, p. 148-161, 2009.

AITA, C.; GIACOMINI, S. J. Nitrato no Solo com a Aplicação de Dejetos Líquidos de Suínos no Milho em Plantio Direto. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 32, n. 5, p. 2101-2111, 2008.

ALLEN, R. G.; PEREIRA, L. S.; RAES, D.; SMITH, M. **Crop evapotranspiration:** guidelines for computing crop water requirements. Roma: FAO, 1998. 300 p. (Irrigation and Drainage Paper, 56).

APHA. **Standard methods for examination of water and wastewater**. 22. ed. Washington, DC: APHA/AWWA/WEF, 2012. 1496 p.

BARROS, V. R.; SOUZA, A. P.; FONSECA, D. C.; SILVA, L. B. D. Avaliação da evapotranspiração de referência na região de Seropédica, Rio de Janeiro, utilizando lisímetro de pesagem e modelos matemáticos. **Agrária**, Recife, v. 4, n. 2, p. 198-203, 2009.

BERNARDO, S.; SOARES, A. A.; MANTOVANI, E. C**. Manual de irrigação**. 8. ed. atual. ampl. Viçosa: UFV, 2006. 613 p.

BOEIRA, R. C. Lixiviação de nitrogênio em latossolo incubado com lodo de esgoto**. Revista Brasileira de Ciência do Solo**, Viçosa, v. 33, n. 4, p. 947-958, 2009.

BRASIL. Ministério do Meio Ambiente. Conselho Nacional de Meio Ambiente. Resolução nº 396, de 3 de abril de 2008. Dispõe sobre a classificação e diretrizes ambientais para o enquadramento das águas subterrâneas e dá outras providencias. **Diário Oficial da União**, Brasília, DF, 03 abr. 2008.

ESCOBAR, R. F.; BENLLOCH, M.; HERRERA, E.; NOVELO, J. M. G. Effect of traditional and slow-release N fertilizers on growth of olive nursery plants and N losses by leaching. **Scientia Horticulturae**, Amsterdam, v. 101, n. 1/2, p. 39-49, 2004.

FREITAS, G. A.; SANTOS, L. B.; SIEBENEICHLER, S. C.; NASCIMENTO, I. R.; SILVA, R. R.; CAPONE, A. Resíduo de efluente de frigorífico bovino como fertilizante alternativo para a produção de rúcula. **Pesquisa Aplicada & Agrotecnologia**, Guarapuava, v. 3, n. 2, p. 39-44, 2010.

IMHOFF, S.; SILVA, A. P.; DIAS JUNIOR, M. S.; TORMENA, C. A. Quantificação de pressões críticas para o crescimento das plantas. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 25, n. 1, p. 11-18, 2001.

KIRD, C.; DERICI, M. R.; SCHEPERS, J. S. Yield response and N fertiliser recovery of rainfed wheat growing in the Mediterranean region. **Field Crops Research**, Maricopa, v. 71, n. 2, p. 113-122, 2001.

LIMA, L. A.; CUSTÓDIO, A. A. P.; GOMES, N. M. Produtividade e rendimento do cafeeiro nas cinco primeiras safras irrigado por pivô central em Lavras, MG. **Ciência e Agrotecnologia**, Lavras, v. 32, n. 6, p. 1832-1842, 2008.

MAROFI, S.; SHAKARAMI, M.; RAHIMI, G.; ERSHADFATH, F. Effect of wastewater and compost on leaching nutrients of soil column under basil cultivation. **Agricultural Water Management**, Amsterdam, v. 158, p. 266-276, 2015.

MATOS, A. T.; LEMOS, A. F.; BARROS, F. M. Mobilidade de nitrato em solos de rampas de tratamento de águas residuárias por escoamento superficial. **Engenharia na Agricultura**, Viçosa, v. 12, n. 1, p. 57-65, 2004.

MULLANE, J. M.; FLURY, M.; IQBAL, H.; FREEZE, P. M.; HINMAN, C.; COGGER, C. G.; SHI, Z. Intermittent rainstorms cause pulses of nitrogen, phosphorus, and copper in leachate from compost in bioretention systems. **Science of the Total Environment**, Amsterdam, v. 537, p. 294-303, 2015.

PEDROSA, T. D.; OZIMA, H. T.; SCHNEIDER, R. M.; SOUZA, A. P.; ANDRADE, E. A.; MATTOS, L. V. Phosphorus, copper and zinc leached in lysimeters with red-yellow latosol subjected to different rates of reused swine water and irrigation water. **African Journal of Agricultural Research**, Nairobi, v. 12, p. 2902-2909, 2017.

RILEY, W. J.; ORTIZ-MONASTERIO, I.; MATSON, P. A. Nitrogen leaching and soil nitrate, nitrite, and ammonium levels under irrigated wheat in Northern Mexico. **Nutrient Cycling in Agroecosystems**, Dordrecht, v. 61, p. 223-236, 2001.

SILVA, D.; MEZA, F. J.; VARAS, E. Estimating reference evapotranspiration (ET_0) using numerical weather forecast data in central Chile. **Journal of Hydrology**, Amsterdam, v. 382, p. 64-71, 2010.

SOMMER, S. G.; HUSTED, S. The chemical buffer system in raw and digested animal slurry. **The Journal of Agricultural Science**, Cambridge, v. 124, n. 1, p. 45-53, 1995.

SOUZA, A. P.; ALMEIDA, F. T.; ARANTES, K. R.; MARTIM, C. C.; SILVA, J. O. Coeficientes de Tanque Classe A para estimativa da evapotranspiração de referência diária na região de transição Cerrado-Amazônia. **Scientia Plena**, Aracajú, v. 11, n. 5, p. 1-11, 2015.

SOUZA, A. P.; MOTA, L. L.; ZAMADEI, T.; MARTIM, C. C.; ALMEIDA, F. T.; PAULINO, J. Classificação climática e balanço hídrico climatológico no estado de Mato Grosso. **Nativa**, Sinop, v. 1, n. 1, p. 34-43, 2013.

ZANUZO, M. R.; RIBEIRO, L. M.; LANGE, A.; MACHADO, R. A. F.; MASSAROTO, J. A. Desempenho agronômico de genótipos de couve-flor nas condições edafoclimáticas de Sinop. **Horticultura Brasileira**, Brasília, v. 31, n. 2, p. 332-337, 2013.

ZHU, A. N.; ZHANG, J. B.; ZHAO, B. Z.; CHENG, Z. H.; Li, L. P. Water balance and nitrate leaching losses under intensive crop production with Ochric Aquic Cambosols in North China Plain. **Environment International**, New York, v. 31, n. 6, p. 904–912, 2005.