Original Article

MINERAL NITROGEN IN SOIL LEACHATE AFTER PIG SLURRY APPLICATION

NITROGÊNIO MINERAL EM PERCOLADO DE SOLOS APÓS APLICAÇÕES DE DEJETOS LÍQUIDOS DE SUÍNOS

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ABSTRACT: Pig slurry is used as a fertilizer in agricultural soil. The intensification of swine breeding, along with high concentration of animals in small properties, generates great volumes of manure. Pig slurry has high nitrate content, which may contaminate surface and subsurface waters. This study aims to evaluate the environmental impact of pig slurry application in Ultisol and Alfisol samples. For this purpose, pig slurry doses obtained from distinct production systems (farrowing and finishing units) were applied in the following amounts: 0 $m^3.ha^{-1}$ (Control Treatment), 75 $m^3.ha^{-1}$ (T2), 150 $m^3.ha^{-1}$ (T3) and 300 $m^3.ha^{-1}$ (T4). Results showed presence of $N\text{-}NO_3^-$ + $N\text{-}NO_2^-$ in Alfisol and Ultisol leachates, and the pig slurry originated from farrowing units showed lower concentration of $N\text{-}NO_3^-$ + $N\text{-}NO_2^-$ for both soil leachates. The higher concentration of $N\text{-}NO_3^-$+ $N\text{-}NO_2^-$ in the leachate for both soils was at 19 days after the pig slurry application. Before using pig slurry as a fertilizer it is mandatory to establish criteria for the elaboration of management and provision strategies, in order to reduce environmental and health impacts.

KEYWORDS: Concentration. Environmental. Health impacts.

INTRODUCTION

The worry about environment preservation, especially regarding water quality, has been covered in international meetings, in which agriculture is pointed as a significant source of the contamination, along with animal production. It may contribute for water contamination in the following ways: through surface drainage after application of pig slurry in fields, leaching of compounds resulted from excessive applications, or leakage in storage tanks with inappropriate covering (BASSO, 2003).

Normally nitrogen is the element with higher concentration in pig slurry, and a potential environmental contaminant. Among all existing elements in the soil-plant-atmosphere system, nitrogen stands out due to the numbers of biochemical transformations in soil (MOREIRA; SIQUEIRA, 2006).

Usually pig slurry application occurs before sowing, during the initial phase of development, and during plant growth, initial phase nitrogen demand is low. The speed of nitrification of slurry ammonium (NH_4^+) by specific microorganisms, after the application, determines the amount of nitrate (NO_3^-) in soil. With high nitrification rates, the NO_3^- concentration rapidly increases, and such increase may occur when nitrogen demand in cultures is low. With intense precipitation, NO_3^- leaching may occur, since it is water soluble and has low binding with soil colloids (WHITEWHEAD, 1995), contributing to the contamination of surface and subsurface waters.

In Europe, in 1987, when was established the concept of soil multifunctionality, the Netherlands Ministry of Housing, Spatial Planning and the Environment (VROM) published, in 1994, a proposal for the creation of soil and ground water quality index values. This was the reference used for creating the values determined by CETESB (2005), CONAMA (357/2005 Resolution) and CONAMA (420/2009 Resolution), which are Environmental Protection Agencies from São Paulo and Brazil, respectively. The use of international standards may lead to inadequate evaluations, since there are climate, technological, and pedological differences for each country, which justify the development of exclusive lists that represent local environment characteristics.

Considering the importance of the aforementioned data, this study presupposes that pig slurry application in soil increases the concentration of mineral nitrogen in leachates, which may result in the contamination of surface and subsurface waters, leading to environmental and health impact. Thus, this study aims to quantify the amount of NO_3^- + NO_2^- found in Alfisol and Ultisol leachates at 36 hours, 19 and 33 days after the application of pig slurry, which was obtained from two pig production systems (farrowing and finishing units)

MATERIAL AND METHODS

Sampling

Samples of surface layers (0-20 cm) obtained from Ultisol, (sandstone substrate) and Alfisol (basaltic substrate) were used, both registered by the Sistema Brasileiro de Classificação de Solo (EMBRAPA, 2006). This was the first such materials were collected in the area. The soil was selected according to substantial differences in organic matter and clay content, and cation exchange capacity (CEC). The samples were collected using a cutting shovel and then stored in 50kg plastic bags. After that, the soil samples were air-dried and sieved in a 4 mm sieve.

The chemical and physical characteristics of soil were determined according to Tedesco et al. (1995), as shown in Table 1.

Table 1. Chemical and physical characteristics of the soil used in the experiment

Soil	Clay	pH	MOS	$CEC_{pH\ 7,0}$	Zn	Cu	Mn	P	$_{Total}N$
Layer (cm)	$g.kg^{-1}$	H_2O	$g.kg^{-1}$	$cmol_c.dm^{-3}$	-------- $mg.dm^{-3}$	---------			$g.kg^{-1}$
Alfisol									
0-20	470	5,5	26	10,6	5,3	7,1	78	5,9	1,48
20-40	390	5,5	19	9,5	5,4	6,6	55	2,9	1,24
Ultisol									
0-20	140	4,6	8	5,4	0,9	8,9	21	1,4	0,72
20-40	140	4,4	5	6,2	0,4	1,4	16	0,9	0,64

Experiment installation

The experiment was installed in vessels made of 250mm diameter and 600mm height PVC tubes. The soil samples were separated inside the vessels using 2mm silk screen and 8 µm filter paper between the 0-20cm and 21-40cm layers. The relative humidity for the soil samples of each experimental unit was kept at 80% of field capacity. Relative humidity control was carried out through weekly measurement and compensation of weight (compared to initial values) by addition of sterile distilled water.

Pig slurry samples gathering and characterization

The samples from both production systems (farrowing and finishing units) were collected in pig farms, at the same day. The anaerobic ponds were not covered and the pig slurry was homogenized before the collection of samples using wooden rods. The collection was carried out using a receptacle tied to a nylon string, both previously disinfected, which was thrown into the pond, immersed, and retrieved, resulting in a sample composed from two collections. The material was stored in disinfected plastic flasks and kept under refrigeration (approximately 4 ºC).

Pig slurry is a mixture of urine, faeces, ration remains, and excess water from drinking fountains and washing of the pigsties where the animals are raised (2.000 individuals in farrowing units and 500 individuals in finishing units).

The chemical and physical characteristics of soil were determined as described by Tedesco et al. (1995) and shown in Table 2.

Table 2. Chemical and physical characteristics of the pig slurry used in the experiment

Characteristics	Pig Slurry Origin	
	Finishing	Farrowing
Humidity %	98,6	99,6
pH	7,9	7,9
Density, $kg.m^{-3}$	986	939
N, $mg.L^{-1}$	2250	457
P, $mg.L^{-1}$	2596	125
Mn, $mg.L^{-1}$	35	3,9
Cu, $mg.L^{-1}$	72	12
Zn, $mg.L^{-1}$	63	33
Organic C, $g.L^{-1}$	16	1,4

Treatment application and leachate gathering

The experiment was conducted using full factorial design method, in triplicate. The pig slurry was applied in the surface without incorporation. Each dosage was applied three times in a 14 month period, with intervals of 60 to 80 days between them. In the end the dosage of pig slurry applied was: Control treatment (T1), 75 $m^3.ha^{-1}$ (T2), 150 $m^3.ha^{-1}$ (T3) e 300 $m^3.ha^{-1}$ (T4), respectively. Pig slurry dosage was applied in small aliquots in order to avoid flooding the soil in experimental units.

Leachate collection for analysis of mineral N and determination of $N\text{-}NO_3^-$+ $N\text{-}NO_2^-$

Leachate collection was conducted in three times: 36 hours, 19 and 33 days after the third application of pig slurry doses. By the date of the collection it was applied 30 mL of sterile distilled water in each vessel, until it was obtained approximately 150 mL of leachate. The water used for obtaining leachate from vessels was sterilized in an autoclave for 25 minutes at 120°C, and the base of the vessels was disinfected with hypochlorite 3% and alcohol 75%. Leachate collection was carried out using disposable plastic receptacles, sterile syringes and surgical gloves.

The analysis of mineral N used 20 mL aliquot collected from the leachate using sterile syringes. The content was stored in digestion flasks and immediately frozen. Mineral nitrogen concentrations were obtained by adding 0.2g magnesium oxide (MgO) in the aliquots for the determination of ammonium content ($N\text{-}NH_4$), using a semi-micro Kjeldahl distillation apparatus. Afterwards, in the same aliquot, it was added 0.2 g of Devarda's alloy for determination of nitrate-nitrite ($N\text{-}NO_3^-$+ $N\text{-}NO_2^-$). The sample's distillate was evaluated using boric acid indicator and then subjected to titration with 0.0025 mol L^{-1} acid sulfuric solution (Tedesco et al., 1995).

Determining pH and Statistical Analysis

pH determination was carried out for all leachate samples, right after collection, using a potentiometer (Digimed, DM -2) with glass electrode (Ag/AgCl).

The ASSISTAT 7.5 beta (2008) software was used in the statistical analysis, with analysis of variance using the F test, and results compared through Tukey test at 5%.

RESULTS AND DISCUSSION

Soil versus dose interaction was significant (p<0,05), which indicates that manure increase in Alfisol significantly raised nitrate content in the leachate 36 hours after the application of manure, as observed when comparing to control treatment without manure application. In this soil doses equivalent to 75 and 150 m^3 per hectare resulted in similar nitrate content in soil; the highest dose showed higher nitrate content in the leachate, which was 15.16 $mg.L^{-1}$ (Table 3).

Unexpectedly, nitrate content in Ultisol for control treatment was higher than other treatments. Nitrate content for this soil in leachate was similar for 75, 150 and 300 doses, with no statistical difference between them (Table 3).

Table 3. Averages for soil versus dose interaction for nitrate content ($mg.L^{-1}$) in the leachate of both soils, 36 hours after pig slurry application.

Soil	Pig Slurry Dose Applied			
	0	75	150	300
	---------------------------- $m^3.ha^{-1}$ ----------------------------			
Alfisol	7.71 bC	12.17 aB	13.32 aAB	15.16 aA
Ultisol	16.83 aA	11.98 aB	12.09 aB	12.64 bB

DMS for columns = 1.88 (lowercase); DMS for lines = 2.50 (uppercase)

The control treatment (T1) for leachates collected 36 hours after the application of pig slurry doses showed the lowest concentration of N-NO3-+ N-NO2-, with 8.26 $mg.L^{-1}$, same value for both soils (Table 4). Alternatively, the experimental unit added with 100 $m^3.ha^{-1}$ of pig slurry from finishing units showed higher results, 15.16 $mg.L^{-1}$ of $N\text{-}NO_3^-$+ $N\text{-}NO_2^-$, as shown in the Table 4. $N\text{-}NO_3^-$+ $N\text{-}NO_2^-$ values found in the leachate for all treatments (T2, T3 and T4) were higher than the maximum value allowed by current legislation (CONAMA 357 resolution). It that enforces water bodies classification and environmental guidelines for the application of the resolution, and also establishes conditions and patterns for effluents and other measures and establishes maximum values of 10 $mg.L^{-1}$ for $N\text{-}NO_3^-$, and 1 $mg.L^{-1}$ $N\text{-}NO_2^-$.

Table 4. Concentration of $N\text{-}NO_3^-$+ $N\text{-}NO_2^-$ in Alfisol leachate 36 hours after pig slurry application

Treatments	Pig Slurry Origin	
	Finishing	Farrowing
	---------------------------- mg.L^{-1} ----------------------------	
Control Treatment	8.26 cA	8.26 bA
T2 - 75 m³	11.51 bcB	14.57 aA
T3 – 150 m³	14.84 abA	11.80 abB
T4 - 300 m³	16.24 aA	14.09 aA

DMS (Tukey 5%) for columns = 3.60 (lowercase); DMS (Tukey 5%) for lines = 2.67 (capital letter)

The pH values for collected leachates in Ultisol experimental units showed very low results, with average pH of 3.79 for units that received pig slurry from farrowing, and 3.64 for units that received pig slurry from finishing. pH values for leachates collected in Alfisol experimental units were between 5.74 (farrowing) and 5.77 (finishing). These pH values are very close to the values obtained for the water used in the experiment, which were 5.89.

After an eight-hour monitoring procedure, Gomes et al. (2004) showed that nitrification rates from nitrogen (total N) are increasingly higher for samples that showed a slight pH increase. The authors showed that the monitored sample increase was higher than 100% in comparison to the initial nitrate concentration.

Basso (2003) observed that higher concentrations of N-NO3- in the soil solution occurred in the initial stages of oats' development, in which nitrogen demand remained low, since evaluations at 102, 121, and 127 days after application did not showed N-NO3 in the solution. The author also calls the attention to the occurrence of rainfall right after pig slurry application, since NO_3^- is water soluble and might follow the waterflow into the soil, leading to irreversible damages to subsurface water resources.

The leachate collected at 19 days after the application of pig slurry showed the highest accumulated concentration of N-NO3-+ N-NO2-, a difference higher than 25.53% when compared to concentrations observed for Alfisol. Alfisol showed higher aerobic activity (nitrification), a process that might have been compromised in Ultisol, resulting in lower concentrations of free $N\text{-}NO_3^-$+ $N\text{-}NO_2^-$ in the solution (Table 5).

Table 5. Accumulated concentration of $N\text{-}NO_3^-$+ $N\text{-}NO_2^-$ in leachate for interaction: time after the pig slurry application x Soil

Treatment	Time after pig slurry application		
	36 hours	19 days	33 days
	------------------------------------- mg L-¹ ----------------------------------		
Ultisol	12.45 bA	16.41 aA	10.54 cA
Alfisol	12.70 bA	15.10 aB	7.86 cB

DMS (Tukey 5%) for lines = 1.22 (lowercase); DMS (Tukey 5%) for lines = 1.02 (capital letter)

The application of pig slurry as fertilizer may favor N_2O emission, since it stimulates both nitrification and denitrification (BASSO, 2003). These processes are greatly responsible for N_2O production, although it is not the main product (GIACOMINI, 2005). N_2O is a potential pollutant (GIACOMINI, 2005; MOREIRA; SIQUEIRA, 2006), as it reacts with O_3 in the stratosphere, affecting the ozone layer (DENDOOVEN et al., 1998; CHANTIGNY et al., 2004), besides leading to the formation of HNO_3 an acid rain component (CHANTIGNY et al.; 2004).

Nitrogen in ammonia form is susceptible to loss by ammonia volatilization, either in pig slurry storage sites or after field application (PORT, 2002). Thus, after pig slurry application, the availability of N in soil is mainly conditioned to ammonia fraction. Besides being conditioned to loss by volatilization, the ammonia is also susceptible to nitrification and immobilization (GIACOMINI, 2005).

Considering a larger scale, like a watershed, the management of pig slurry towards the reduction of nitrogen impact over water quality demands a holistic approach (HEATHWAITE et al., 2000). In the last decades, many of the impacts caused by phosphorus cited in international literature are related to the focus given on nitrogen in the past, which was justified by the high solubility of the nitrate, while other elements, like phosphorus, were not considered potential pollutants.

Regarding the use of pig slurry as a fertilizer, the major technical and scientific challenge is to elaborate criteria for evaluating the susceptibility of natural resources to contamination, and then define management and provision strategies, in order to reduce environmental and health impacts.

When nitrate is converted into nitrite in the human body, the results are two hazardous chemical reactions: induction of methemoglobinemia (Blue baby syndrome), specially in newborns, and potential formation of nitrosamides and nitrosamines (USEPA, 1989). High contents of NO_3^- in soil can also result in accumulated N form in the plant tissue, compromising the quality of plants for consume by humans and animals (L'HIRONDEL; L'HIRONDEL, 2002). There is strong evidence of relations between nitrate and nitrite exposition in humans and risk of cancer (WHO, 2004).

CONCLUSIONS

The evaluation of Alfisol and Ultisol leachates showed that N-NO_3^-+ N-NO_2^- was detected, as a result from the application of pig slurry in the surface.

The manure from the farrowing system showed lower concentrations of N-NO_3^-+ N-NO_2^- for both soils.

The higher concentration of N-NO_3^-+ N-NO_2^- in the leachate of both soils was at 19 days after the pig slurry application.

N-NO3-+ N-NO2 values found in the leachate for all treatments (T2, T3 and T4) were higher than the maximum value allowed by current legislation.

RESUMO: Os dejetos líquidos de suínos (DLS) são utilizados como fertilizante em solos agrícolas. A intensificação de criações de suínos com alta concentração de animais em pequenas propriedades tem gerado grande volume de dejetos. Os DLS podem conter altos teores de nitrato, podendo contaminar águas superficiais e subsuperficiais. Este estudo foi realizado para avaliar o impacto ambiental resultante da aplicação de DLS em amostras de um Argissolo Vermelho Distrófico e de um Nitossolo Vermelho Distrófico. Para tal, aplicaram-se doses equivalentes a 0 (Testemunha), 25 (T2), 50 (T3) e 100 (T4) $m^3.ha^{-1}$ de dejetos líquidos de suínos provenientes de dois sistemas de criação denominados de "creche" e "terminação". Foi detectada a presença de N-NO_3^- + N-NO_2^- no percolado do Nitossolo e do Argissolo; o dejeto líquido proveniente do sistema de criação "creche" resultou em menores concentrações de N-NO_3^- + N-NO_2^- no percolado de ambos os solos. A maior concentração de N-NO_3^- + N-NO_2^- no percolado ocorreu aos 19 dias após a aplicação dos DLS. Para a utilização dos DLS como fertilizante há necessidade que se estabeleçam critérios adequados para definir estratégias de seu manejo e disposição para reduzir seu impacto no ambiente e à saúde.

PALAVRAS CHAVE: Concentração. Meio ambiente. Impacto à saúde.

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