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Long-term application of swine manure can increase Cu and Zn contents in the pasture soils

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Abstract

The intensive disposal of swine manure can promote accumulation of those low mobile nutrients in the soil surface, such as P, Cu and Zn, which can enhance their transference by runoff. The aim of this study was to evaluate the long-term effect of swine manure as fertilizer on chemical attributes of soil in pasture areas. Soil samples were collected from countryside areas in the southwest of Goiás state, where used swine manure as fertilizer from two breeding systems: Piglet production system (SPL) and finishing vertical system (SVT). The sandy and clayey soils received swine manure up to 10 years and over 10 years. Soil samples were also collected from native forest and permanent preservation areas as control. The samples were collected at 0-20cm, 20-40cm and 40-60cm depths to determine the contents of copper (Cu) and zinc (Zn), using Mehlich-1 as extractor. The t-test was used to evaluate the contrasts significance. The results showed that liquid swine manure of the SPL applied in sandy soils and the manure of the SVT in clayey soils for more than 10 years changed the contents of Cu in the soil up to 60 cm depth. Application of manure of the SPL in sandy soil affected Cu contents up to 60 cm depth. The liquid swine manure, continuously applied in clayey soils for up to 10 years did not modify the contents of Zn compared to the control soil.

Keywords: Environmental monitoring, organic manure, soil fertility, successive applications, trace elements.
Abbreviations: SPL_ Piglet production system; SVT_ Finishing Vertical System; Cu_copper; Zn_ zinc.

Introduction

Pig farming activity began in the middle of 2000, with the arrival of meat agribusiness in the southwest of Goiás state. The intensive pig farming is characterized by confined breeding of animals and high quantities of effluents, such as liquid swine manure (DLS) are generated in this Region. Currently, there are 42 piglets farms (SPL) installed, with 1,000 sows each and 162 fattening piglets farms (termination - SVT), with 4,000 animals each, producing around three million cubic meters of manure per year (Menezes, 2012).
The swine manure undergoes to treatment process in anaerobic lagoons and later, obligatorily, used in crops fertigation (Law of the State of Goiás, No. 8,544, 1978 and Administrative Rule GM / nº. 124 of August 20, 1980). Manure application must comply the following minimum distances: 200m (two hundred meters) from watercourse, nature trail and downstream mines and sources, 100m (one hundred meters) from legal reserves and 400m (four hundred meters) from upstream mines and sources. Manure application in the soil cannot exceed 180 m^3 ha^{-1} per year, according to the technical requirements of the competent environmental agency.

Swine manure is a good source of nutrients, especially in N, P and K (Scherer, 1996; Prando, 2007) used for crops fertigation. However, it can be a negative factor with environmental impact when improperly used, mainly for soil and water contamination with amount of nutrients above those allowed by current laws (Law 12,305 of 2010, Decree 7,404 of December 23, 2012, Law 4771 of 1965 amendments of the Brazilian Forest Code, Resolution of CONAMA 237/1997, Resolution of CONAMA 420/2009, ISSO 14001 of 2006 and new Forest Code, 12.651 / 2012).

Excessive disposal of swine manure may promote accumulation of nutrients in the soil surface, mainly low mobile elements such as Cu and Zn (Konzen 2000; Ceretta et al., 2003; Gräber et al., 2005; Scherer et al., 2007). It may enhance Cu and Zn transference by surface runoff and cause eutrophication of aquatic systems (Gesel et al., 2004; Basso et al., 2005; Berwanger, 2006; Gatiboni et al., 2015).

The presence of elements such as Cu and Zn in high concentrations in swine manure is a consequence of adding excessive amounts of Cu and Zn in the swine food, to prevent diseases, improve the digestion and promote the growth. This fact, coupled with successive manure applications, tends to cause accumulations of Cu and Zn in soils, making manure a polluting source with high potential for environmental contamination (Jondreville et al., 2003 and Girotto, 2007).

The soils from southwest of Goiás state have different textures. Most of the farms are established in sandy soils, which may cause leaching and/or runoff of nutrients towards surface water and groundwater. To know the dynamics of nutrients in the soils, treated with swine manure as fertilizer, may help to establish strategies to correct distortions in the production systems, aiming greater environmental sustainability.

This study aimed to evaluate changes on chemical attributes of soils, especially the contents of Cu and Zn, influenced by continued use of swine manure in pasture areas in the southwest of Goiás state.

Results and Discussion

Cu and Zn contents in soils

The effect of time of manure application in SPL system management was significant on the contents of Cu up to 60 cm depth, in sandy soils (C6) and up to 40 cm depth in clayey soils (C5) (Table 2). The content of Cu in the sandy soils with continued swine manure application of the SVT did not show significant effect, and it was similar to the control (C4, C5 and C6). In clayey soils, the content of Cu increased up to 60 cm depth (Table 2). The soil characteristics that affect the availability and mobility of Cu through the soil profile may explain the difference on downward mobility between the soils (Gräber et al., 2005). The most cited characteristics are clay content, pH, redox potential, complexation by organic ligands and soils mineralogy (Sposito, 1989).

In sandy soils, there was significant effect of time of swine manure application for both management systems (SPL and SVT), on the content of Zn up to 60 cm depth. However, in clayey soils, the contents of Zn did not increase with continued use of manure regardless of breeding system (Table 2). In sandy soil, the initial contents of Cu increased from 0.8 mg dm^{-3} to 1.5 mg dm^{-3} and 1.2 mg dm^{-3} with 10 years of DLS application in the SPL, and DLS of the SVT, respectively (Table 3).

The increase of copper was low, compared to the control soil, even a significant addition of 87.5% and 50% in manure application was applied in SPL and SVT systems for ten years, respectively. It added around 22.5 kg ha^{-1} of Cu (180 m^3 ha^{-1} of DLS x 10 years x mean content of 12.5 g m^{-3} of Cu of the DLS).

In sandy soils, after 10 years of DLS application, the Cu content in the soil increased to 1.8 g m^{-3} and 2.9 g m^{-3} at the 0-20 cm depth that received manure from SPL and SVT, respectively (Table 3). Other authors (Girotto, 2007; Scherer et al, 2010; Penha et al, 2015) also observed increases on Cu in soil with continued application of DLS.

Clayey soils showed a greater increase of Cu contents compared to sandy soils. Application of manure of the SPL and SVT, for more than 10 years at 0-20 cm depth, increased Cu contents to 4.8 mg dm^{-3} and 3.3 mg dm^{-3}, respectively (Table 3).

According to the data from CONAMA (2009), the Cu content in the soil cannot exceed 200 mg dm^{-3}. Therefore, the contents of Cu are low enough to be considered as contaminant, even with increasing contents in sandy soils with continued use of manure of the SPL, and in clayey soils with manure of the SVT up to 40-60 cm depth. In the results presented by Mattias (2006), there was low correlation between time of manure application and increase on Cu content in two soils from Santa Catarina.

Among the heavy metals, Cu is one of the less mobile in the soil due to its strong adsorption in organic and inorganic colloids of the soil. Copper is retained in the organic matter, mainly, by humic and fulvic acids forming stable complexes (Silva and Mendonça, 2007).

Zinc contents increased with DLS application of the SPL in sandy soils (Table 4). However, in clayey soils there was no response with DLS application of the SPL.

The Zn contents in sandy soils increased 200% compared to the control with DLS application of the SPL for over 10 years (Table 4). Girotto (2007), Scherer et al., (2010) and Penha (2015) observed increases on Zn contents with successive manure applications. However, the mean content found in clayey soils from Brazilian savanna for over 10 years of manure application, referring to 20.9 mg dm^{-3} of Zn is considered high for agriculture, but low as contaminant content.

According to CONAMA (2009), the Zn content in the soil cannot exceed 450 mg dm^{-3}, because it would be a contaminant value. The maximum accumulation of Zn in this experiment corresponds to only 7% of the content to have any interference in the area. Despite the large quantities of manure annually applied, Mattias (2006) found contents of heavy metals (Cu and Zn) relatively low, even with several manure applications.

The availability of these heavy metals (Cu and Zn) are relatively low in the surface layers, compared to the maximum adsorption capacity of soils from Santa Catarina region, which was 317 and 221 mg kg^{-1} for Cu and 137 and 325 mg kg^{-1} for Zn in a Cambisol and Latosol, respectively (Moreira et al., 2009). It explains, partially, the low mobility of these two elements in these soils, mainly, in the Latosol, with successive applications of swine manure.

Scherer et al. (2010) observed that fertilization with swine manure affected the Zn content up to 10 cm depth, while for others soils the element mobility, such as Cu reached up to 20 cm depth in a Latosol. Girotto (2007) observed low mobility of Cu and Zn in soils that received fertilization with swine manure for seven years, reaching up to 10 and 12 cm depth, respectively in an Argisol, which is in agreement with the present study. Matos et al. (1997) did not find increases on concentrations of Cu and Zn in the soil profile subjected to the application of liquid swine manure at the doses of 0, 50, 100, 150 and 200 m^3 ha^{-1}. The application was carried out entirety at once.

According to Moraes et al. (2010) contents of Cu > 1 mg dm^{-3} and Zn > 1 mg dm^{-3} are considered high in order to evaluate the soil fertility. Scherer et al. (1996) also found significant accumulation of Cu and Zn in the surface layer of the soil under no-tillage system that may be explained by high concentrations of these metals in swine manure.

In sandy soils, fertilization with swine manure affected the contents of Cu and Zn up to 60 cm depth, while in clayey soil, it extended up to 60 cm depth and Zn content did not show significant increases. Low mobility of Cu and Zn in the soil was observed after seven years of swine manure application reaching up to 10 cm and 12 cm depth for Zn and Cu, respectively, which is not in agreement with the present study (Girotto, 2007).

An average of 10 years of liquid swine manure application in the southwest of Goiás state, it can be inferred that the concentration of heavy metals in soil did not reach the critical level yet, according to the criteria and threshold set by the Ministry of the Environment (Conama, 2009),

Table 1. Contrasts used to compare years of swine manure application in sandy and clayey soils at 0-20 cm, 20-40 cm and 40-60 cm depths and the production systems: piglets (SPL) and vertical terminator (SVT) according to the manure application time (<10 years) and (> 10 years) compared to the control soils.

Contrasts	C1	C2	C3	C4	C5	C6	C7	C8	C9
Application management									
Control (0-20 cm)	1	0	0	1	0	0	0	0	0
Control (20-40 cm)	0	1	0	0	1	0	0	0	0
Control (40-60 cm)	0	0	1	0	0	1	0	0	0
DLS < 10 years (0-20 cm)	-1	0	0	0	0	0	1	0	0
DLS < 10 years (20-40 cm)	0	-1	0	0	0	0	0	1	0
DLS < 10 years (40-60 cm)	0	0	-1	0	0	0	0	0	1
DLS > 10 years (0-20 cm)	0	0	0	-1	0	0	-1	0	0
DLS > 10 years (20-40 cm)	0	0	0	0	-1	0	0	-1	0
DLS > 10 years (40-60 cm)	0	0	0	0	0	-1	0	0	-1

Probability of the sample mean (-1) differ from the control (1), according to t test at the 1 and 5%. Control = without DLS application.

Table 2. Orthogonal contrasts used for the comparison among the years of application of swine manure in piglets production system (SPL) and vertical terminator system (SVT), in sandy and clayey soils at 0-20 cm, 20-40 cm and 40-60 cm depths.

Contrasts	C1	C2	C3	C4	C5	C6	C7	C8	C9
	Sandy soils								
Atributtes	SPL								
Cu	0.00118	0.00111	ns	0.01814	0.01749	0.05221	ns	ns	ns
Zn	ns	ns	0.00194	0.02029	0.00833	0.01033	ns	ns	ns
	SVT								
Cu	0.02551	0.03667	ns	ns	ns	ns	ns	ns	ns
Zn	0.00000	0.00002	0.00048	ns	0.02768	0.04069	ns	ns	ns
	Clay soils								
	SPL								
Cu	ns	ns	ns	0.00733	0.02589	ns	ns	ns	ns
Zn	ns	ns	ns	ns	ns	ns	ns	ns	ns
	SVT								
Cu	0.00332	0.00446	0.00657	0.00356	0.02324	0.00135	ns	ns	ns
Zn	ns	ns	ns	ns	ns	ns	ns	ns	ns

Significance in contrast at 5% by the t test and ns = not significant.

Table 3. Contents of Cu in sandy (A) and clayey soils (B) at 0-20 cm, 20-40 cm and 40-60 cm depths as function of manure application time.

Texture	Sandy (A)			Clayey (B)		
Depths (cm)	0-20	20-40	40-60	0-20	20-40	40-60
	---------------- mg dm^{-3} --------------					
Control	0.8	0.7	0.7	1.5	1.5	1.7
	SPL					
< 10 years	1.5	1.5	1.9	2.0	1.9	5.3
>10 years	1.8	1.2	1.0	4.8	4.9	4.9
	SVT					
< 10 years	1.2	1.2	1.1	2.3	2.2	2.4
>10 years	2.9	1.5	2.4	3.3	4.7	2.8

SPL n= 30 samples and SVT n= 80 samples.

Table 4. Mean content of Zn in sandy (A) and clayey soils (B) at 0-20 cm, 20-40 cm and 40-60 cm depth as function of manure application time.

Texture		Sandy (A)			Clayey (B)	
Depths (cm)	0-20	20-40	40-60	0-20	20-40	40-60
	---------------- mg dm^{-3} --------------					
Control	1.4	0.6	0.4	19.6	9.6	8.7
	SPL					
< 10 years	26.0	13.3	21.7	7.8	8.7	21.9
>10 years	10.8	6.6	5.0	20.9	20.2	20.2
	SVT					
< 10 years	2.7	3.4	3.7	4.6	4.0	4.6
>10 years	11.8	7.2	7.2	7.0	5.7	6.4

SPL n= 30 samples and SVT n= 80 samples.

However, there is a warning reality because the heavy metals concentrations will pile up, since the swine farm activity continues. It justifies the needs of monitoring the crop areas that apply the swine manure annually to avoid the increase of concentrations of these elements that are not well-defined and may affect the chemical and biotic components of the soil.

Materials and Methods

Study area

The physical and chemical characteristics of soils were obtained. The files information submitted to the municipal and state environmental agencies that analyze the environmental licensing of the units of swine production (farms) from southwest of Goiás region coupled with BRF company. The information were separated according to the soil texture (sandy, with clay content < 35% and clayey with clay content > 36%), years of manure application (lower or higher than 10 years of swine liquid manure application), production systems (SPL = Piglets Production System and SVT = Finishing Vertical System) and use of DLS in pasture areas of the Region.

Finishing Vertical System (SVT): the producers receive the animals when they leave the nursery and carry out the stages of growth and termination.

Piglets Production System (SPL): the cycle begins with the gestation of the female that lasts 114 days. The litter will continue until the animals reach 60 days or 22 kg.

30 properties of piglet production system (SPL) and 80 properties of vertical terminator system (SVT) were selected. The SPL consisted of 1,050 sows and SVT consisted of 4,000 fattening pigs up to 100 kg, with an annual production of 3 million of cubic meter of manure (Menezes et al., 2012).

The chemical analysis of the sandy and clayey soils was carried out at 0-20 cm; 20-40 cm e 40-60 cm depths, with lower and greater than 10 years of liquid manure application.

Furthermore, soils sample from native forest or legal reserve areas with sandy and clay soils at 0-20 cm, 20-40 cm and 40-60 cm depths were obtained to use as a control. The soil samples were chemically analyzed in a UniRV lab. Cu and Zn were extracted from the soils samples with Mehlich-1 solution (Embrapa, 1997). Cu and Zn were submitted to photometric reading by using atomic absorption spectrophotometry, according to Silva et al. (2009).

Statistical analysis

All Cu and Zn results in sandy and clayey soils at 0-20 cm, 20-40 cm and 40-60 cm depths were compared between the control soils and the soils in time of swine manure application for both systems: SPL and SVT by contrasts (Table 1) at the 5% probability of the statistical program SISVAR 5.3 (Ferreira, 2011). The use of orthogonal contrasts in the analysis of experiments is a technique that has proved quite efficient in obtaining main effects, interaction and nested effects. In general, this technique is most useful for analyzing data from an unconventional experiment, which is one that does not follow a defined structure.

Conclusion

Continued applications of manure (SPL) in sandy soils, and SVT in clayey soils caused increases of Cu contents up to 60 cm depth. Application of manure of the SPL in sandy soils increased the contents of Zn in soil up to 60 cm depth. There was no increase on Zn content in clayey soils that received continued manure fertilization for more than 10 years and the content of Cu and Zn, in soils after 10 years of liquid manure application is under the dose to be considered as contaminant.

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