Accumulation and percolation of phosphorus in the soil due to the application of wastewater from swine farming in maize culture (*Zea mays* L.)

Maritane Prior; Adriana Smanhotto; Silvio César Sampaio; Lucia Helena Pereira Nobrega, Miguel Angel Uribe Opazo; Jhonatan Dieter.

Summary

The swine culture is considered by environmental agencies as an activity potentially causing environmental degradation. In recent years, in the western region of Paraná, has increased the use of wastewater from pig farming (ARS) in fertigation of crops, which improves soil conditions due to the supply of nutrients, in addition to cost savings associated with fertilizer and water. One of the elements of the ARS is the phosphorus which, when in excess, can compromise the quality of the environment, as a contaminant of water. This study aimed to evaluate the best blade of ARS, used for fertigation, which cause less contamination by phosphorus, of the percolating soil and water to the groundwater. We evaluated five blades of ARS (0, 112.5, 225, 337.5 and 450 m3 ha-1 per cycle), combined with two fertilization of soil (50 and 75%) in Latossolo Vermelho distroférrico cultivated with maize. It was observed that the higher blades of ARS show greater accumulation of phosphorus in the soil. For the percolate, the indices of phosphorus found do not present risk of contamination to the water.

Key words: effluent, irrigation, reuse.

Introduction

The swine in Brazil, mainly in the west of Parana, is a predominant activity in small rural properties, of great economic and social importance, serving especially as a tool for setting the man to the field. However, the wastewater from swine activities, if improperly managed, can cause environmental degradation. The wastewater from swine culture (ARS) has considerable amount of dissolved nutrients that are lost or discarded when released in water, making it undesirable. An alternative to this practice is the use of effluent for irrigation, applied to the soil as a source of water and fertilizer, allowing the deployment of culture.

In a swine farm, the daily amount of wastewater produced depends on the number and age of animals, the amount of water used in cleaning the stalls and drinking fountains, waste feed, hair, dust and other materials arising the rearing process, among other factors (CÔRREA e CÔRREA, 2003; OLIVEIRA et al., 2000). These factors, combined, determine the concentration of solids in the wastewater, the costs with treatment facilities or storage and the need of area for receiving these waters, as an organic fertilizer, if this is the way chosen for wastewater disposal (OLIVEIRA et al., 2000).

Phosphorus is one of the elements that integrate the composition of the ARS, and in high doses, can cause contamination of soil and surface and groundwater. Oliveira (1993), stressed the fact that the accumulation of phosphorus in several decades of application can cause imbalance of nutrients.

Approximately two thirds of P in the slurry of pigs is a form not soluble in water, part of organic structures (BARCELLOS, 1992), which provide a residual effect of manure. Successive applications of manure can cause accumulation of phosphorus in the soil, as observed Pratt (1979). A greater presence in the surface layer of soil phosphorus is undesirable because it promotes the loss by runoff, which, together with its movement in the soil profile, can cause eutrofização of water, as Giusquiani et al. (1998). This fact was demonstrated by Hountin et al. (2000), who found increments of 16, 26, 33 and 50% in all forms of phosphorus to a depth of 1 m after application of 30, 60, 90 and 120 m3 ha-1 of wastewater from swine culture, respectively.

Freitas et al. (2004), with the addition of wastewaters from swine culture observed that small amounts of phosphorus presented low concentration of the nutrient in leachate from lysimeters due to its low mobility in soil and being largely retained in the layer from 0 to 50 cm depth .

The phosphorus can follow four paths after the application of ARS soil: fixation by the particles, uptake by plants, percolation through the soil profile and precipitation (SCALOPPI and BAPTISTELLA, 1986). Freitas (2001), using wastewater of swine culture in irrigation of corn, observed that concentrations of phosphorus in the leachate were in the range of 0.69, 0.84 and 0.58 mg L-1 and being largely retained in the layer soil from 0 to 50 cm deep. The objective of this study was to evaluate the use of ARS as a source of nutrients, observing the problem of contamination of phosphorus, to define appropriate management to reduce the impact to the environment.

Material and methods

The experiment was conducted in the Experimental Center of Agricultural Engineering of the State University of West of Paraná (UNIOESTE), Cascavel, PR, in Latossolo Vermelho distroférrico.

It was constructed 24 lysimeters, spaced 0.40 x 0.50 m with 1.20 m depth. The methodology used for construction of the lysimeters was described by FAO (1986). Each lysimeter was an equal volume of 1 m3, with depth of 1.10 m diameter 1.43 m, total area of 1.60 m2.

The soil samples were taken at depth of 0-60 cm, one before the implementation of ARS and seeding, at 60 and 120 DAS, the latter, after removal of the culture. The soil samples were analyzed in the laboratory of the Department of Natural Resources - Soil Science, UNESP / Botucatu-SP to assess the levels of phosphorus in the soil according to et RAIJ al. (2001).

The maize hybrid used was CD 705, sown on March 23rd 2006, with seeding density of 45,000 plants ha-1, keeping one plant per hole. In the sowing all treatments received fertilizer with 600 kg ha-1 of the 5-20-20 formulation. The control of weeds was done by hand weeding, and Spodoptera frugiperda with deltamethrin (Desis) at a concentration of 0.2 L ha-1, 30 days after sowing, using backpack sprayer. The ARS used was collected in a farm for the production of pigs in the finishing phase, in the city of Cascavel-PR, which was already in the pond of discharge for 40 days. The ARS was taken to the experiment site and placed in sealed tanks for 150 days during the development of culture. The ARS rates were estimated by the quantity of available nitrogen found in the physical-chemical analysis (Table 1).

The demand of N by the corn was also considerate, as Fancelli e Dourado Neto (2000), of 80 kg N ha-1, splitted in doses of 30 kg ha-1 at sowing and 50 kg ha-1 in fertilization coverage. Thus, the fertilizers at sowing was of 30 kg N ha-1, and the fertilization of coverage relates to 80 kg N ha-1, were distributed throughout the development of culture. Based on the amount of N present in the ARS, the applications resulted in rates that were 100, 200, 300 and 400 kg N ha-1, established from the fertilization of coverage (50 kg N ha-1). The doses of fertilizer were 15 and 22.5 kg N ha -1, referring to 50 and 75% of fertilizer used at sowing (30 kg N ha -1). The

Table 1. Physical-chemistry characterization of the wastewater used during the experiment.

Parameters	Results
pH	7.7
DBO	2046 mg L^{-1}
DQO	3048 mg L^{-1}
Nitrate	35 mg L^{-1}
Nitrite	2.78 mg L^{-1}
Ammonia	1073mg l^{-1}
Total phosphorus	171 mg L^{-1}

Note: Analysis performed at the Laboratory Solanálise according to the method of APHA (1995).

combination of factors ARS, AD and DAS resulted in ten treatments, described in Table 2.

The same quantities of ARS were used in all treatments throughout the period of application, as it was found that there were no significant changes in the concentration of nitrogen in their wastewater. The applications of ARS were performed in biweekly intervals, alternated with irrigation, i.e., seven days after the applications of ARS the irrigation was applied, according to historical averages of rainfall in the region, assessed by Longo et al. (2006). The experimental design was performed in randomized blocks with trifatorial in a split plot in a randomized block design with three replicates and subplots in time, i.e., were used five ARS rates (0, 112.5, 225, 337.5 and 450 m3 ha-1 cycle), two levels of fertilization (50 and 75%), and periods of collection, with five samples to soil and seven samples for the leachate. The soil samples were taken one before the implementation of an ARS, one after the harvest and the other at intervals of 30 days for the development of culture. For the leachate samples were performed in accordance with the application of ARS, with three replicates each, totalizing 24 plots. There was analysis of data normality, while for those who did not show normality was submitted to changes suggested by Banzatto and Kronka (1989). The data were submitted to analysis of variance to test their significance, and in the significant interactions the split took place and average test. The averages were compared among themselves by Tukey test at 5% probability. (STORCK, ESTEFANEL and GARCIA, 1995) five samples of the leachate (87, 102, 117, 132, 147 DAS) were assessed throughout the experiment, the determination of phosphorus, according to the methodology described by Tedesco et al. (1995).

Results and discussion

Table 3 presents the values of variance analysis for the levels of phosphorus in soil and leachate. It can be observed from the Table 3 that the F values were significant for the cause of variation in the leachate and soil. Observing the values of variation coefficients, it can be observed that the data of leachate were homogeneous, according to the low coefficient of variation, below 20% (GOMES, 1987). For the data of phosphorus in the soil, it is noted that the F values were significant for the factor DAS, of the interaction of AD x DAS and ARS x DAS. Regarding the homogeneity of data, it is observed that for phosphorus data in the soil, they presented low homogeneity, according to the intervals suggested by Gomes (1987).

Table 4 presents the average values of phosphorus (mg L - 1) determined in the leachate material collected during the development of the corn crop in lysimeters under treatment with ARS. Observe that the highest average was found to 135 DAS, which differ not only the average observed at 150 DAS. The lowest average were observed at 75 and 105 of which were statistically equal, and differed from the others. It can be observed that from the Table 4 that the leaching of phosphorous in the soil profile after application of wastewater is small. Eghball et al. (1997), applying 60 kg ha-1 of phosphorus in bands and observed that the decrease of phosphorus was only 4 cm in three different soil types. However, the movement in depth of the element may be greater when combining high doses of mineral fertilization with the addition of organic waste. Some studies indicate that the leaching of phosphorus from the application of fertilizers and organic waste, has

Table 2. Treatments applied in experiment

Treatment	Fertilization		Application rate of ARS
	Chemistry (kgha^{-1})	ARS (m^3 ha^{-1})	(L lysimeters^{-1} application^{-1})
T1	15	112,5	3
T2	22,5	112,5	3
T3	15	225	6
T4	22,5	225	6
T5	15	337,5	9
T6	22,5	337,5	9
T7	15	450	12
T8	22,5	450	12
T9	15	-	-
T10	22,5	-	-

Table 3. Summary of variance analysis of phosphorus in soil and leachate

Variation causes	Phosphorus leachate		Phosphorus soil	
	Gl	F	Gl	F
Block	2	3,20 ns	2	3,91 ns
ARS	3	0,84 ns	4	1,91 ns
Error I	6		8	
AD	1	0,14 ns	1	3,04 ns
ARS x AD	3	1,08 ns	4	1,75 ns
Error II	8		10	
DAS	6	8,06*	4	16,02*
ARS x DAS	18	1,27 ns	16	2,68*
AD x DAS	6	1,74 ns	4	3,68*
ARSx ADxDAS	18	1,11 ns	16	1,54 ns
Block x DAS	84	3,65*	8	1,66 ns
Error III	12		72	
Total	167		149	
CV (%)		16,18		47,92
CV II (%)		15,02		36,97
CV III (%)		4,99		27,07

*DAS: days after sowing; ARS: wastewater from swine culture, CV: coefficient of variation, * significant effect at 5% level of significance, ns: not significant at 5% level of significance.*

increased mobility of phosphorus in the soil in organic form. The levels of phosphorus found in the leachate indicate higher concentration of the element at the end of the period analyzed. The concentrations of phosphorus in leachate material were low, indicating no problems with this element in the leachate, as all doses of ARS presented concentrations below to those indicated by CONAMA (2005), which is 0,025 mg L-1 to surface waters. Low concentrations of phosphorus in wastewater due to the low mobility of this nutrient in the soil, which is probably adsorbed by soil particles, absorbed by plants and the remaining precipitated (BASSO, 2003).

The application of wastewater increased the levels of phosphorus in the soil, however in small quantities. This probably occurred because the wastewater from swine culture is rich in nutrients, combined with low mobility of phosphorus in the soil. Furthermore, organic matter helps keeping the nutrients available in the exchangeable form. Similar results were found by Chateaubriand (1988), Oliveira Parizotto (1994) and Campelo (1999) in studies with the swine culture wastewater.

Table 5 presents the unfolding of the interaction rates of application of ARS x collection periods for the values of P (mgL-1) determined in the collected soil during the development of the corn crop in lysimeters under treatment with ARS.

In Table 5, it is shown an increase in the phosphorus concentrations in soil depending on the period, but without providing any statistical difference. For the rate of 0 m3ha-1, no changes occurred over time, i.e. the average showed no significant difference throughout the study. For the rate of 112.5 m3 ha-1 it is noted that the highest average was observed at 95 DAS, which differed from the others. For all periods in function of the layer of application, no statistical differences were observed. For the rate of 225 m3 ha-1 the major averages were observed at 95 and 200 DAS, which did not differ from others. The rate of 337.5 m3 ha-1 presented the highest average at 95 DAS, not differing statistically

Table 4. Average values of phosphorus (mg L-1) determined in the leachate material collected during the development of the maize culture, in lysimeters on treatment of swine wastewater.

Parameter	Period (DAS)							Average
	60	75	90	105	120	135	150	
P	0,00236c	0,00058d	0,00233c	0,00078d	0,03317b	0,05346a	0,04453ab	0,01960

Averages followed by the same letter in the line do not differ by Tukey test at 5% level of significance. For the analysis of variance was used for data processing $\sqrt{x+1}$

Table 5. Unfolding of the interaction rates of application of ARS x periods of collection to the values of phosphorus (mg L-1) determined in the collected soil during the development of the culture of corn crop in lysimeters on treatment of ARS.

Fees ($m^3 ha^{-1}$)	Periods (DAS)					Averages
	BS	40 DAS	70 DAS	95 DAS	200 DAS	
0	14,62aAB	14,66aA	14,79aA	14,06aC	14,26aB	14,47
112,5	13,40bB	13,89bA	13,93bA	21,98aB	14,38bB	15,51
225	16,85bA	16,27bA	17,03bA	26,24aAB	22,64aA	19,80
337,5	11,22bB	13,99bA	17,43abA	24,63aAB	17,05abAB	16,86
450	13,57bAB	15,83bA	19,22bA	29,70aA	16,73bAB	18,95
Averages	13,93	14,93	16,48	23,32	17,01	

BS = Before sowing, DAS = Days after sowing. Averages followed by the same letter in the row and capital letter column do not differ by Tukey test at 5% level of significance. For the analysis of variance was used for data processing $\sqrt{x+1}$.

of the averages presented at 70 and 200 DAS. For greater dosage for the application of ARS (450 m3 ha-1), the averages were higher at 90 DAS, which differed from the others. The other periods presented no significant differences averages.

For periods, it is observed that for the witness, the highest average was found for the rate of 225 m3 ha-1, which differed from other means. At 40 and 70 there were no significant differences in the rates of application. For the period of 90 DAS, the lowest average was observed for the rate of 0 m3 ha-1, which differed from the others, and higher for the rate of 450 m3 ha-1, which differed in the rate of 112.5 m3 ha-1. At 200 DAS, the highest dose was observed for the rate of 225 m3ha-1, which did not differ statistically from levels of 337.5 and 450 m3 ha-1. The lowest doses were found for the rates of 0 and 112.5 m3 ha-1.

As the application of ARS was being done, the contents of the element in soil presented evidence of increase. For the rate of application of 0 m3 ha-1, and for samples taken before sowing, the rates of soil remained low. With the increasing rates of application, concentrations of phosphorus in the soil have increased, which at 95 DAS recorded the highest averages. The contents of phosphorus in the soil are within the range considered average for the soil and for the corn crop (COELHO and FRANÇA, 1995), which specified limits between 16 to 40 mg L-1. The data observed in this study are in agreement with Berwanger (2006), which verified an increase in levels of phosphorus in the soil due to the increase of application of doses of ARS. The author, using slides of 480 and 960 m3 ha-1, verified that the migration of phosphorus was observed at all depths and being more evident in the depth of 15 cm. The author also reported that applications of ARS dosage in 960 m 3ha -1, for four years, meets the need of the crop as Soil Fertility Commission - RS / SC (2004), and the exceeding quantity applied with waste accumulates in the soil. The continuity of the applications of liquid swine waste in this area probably raise more and more levels of phosphorus in the soil. Applying an accumulated amount of 560m3 ha-1, for 4 years, Ceretta et al. (2003) obtained 1664 mg L-1 of available phosphorus in the soil layer from 0 to 2.5 cm in area of natural pasture, on which Durigon et al. (2002) reported that the amount of phosphorus absorbed by plants from natural pasture is very small compared to that applied by the waste, and observed that the maximum of P accumulated in plants of natural pasture was 8.1% of total P applied to an accumulated amount of swine waste of 560 m3 ha-1, for 4 years and this would justify the accumulation in soil in this research.

The mobility of phosphorus in soil is very small, and therefore the losses by leaching in agricultural soils are considered insignificant

(BASSO, 2003; LOPES, 1995; STEFANUTTI, 1995) because of this it is observed that the low concentrations of the element in the leachate. In this way, Kao and Blanchar (1973) observed that after 82 years of continuous application of manure and fertilizers there is a significant amount of phosphorus available to a depth of 1.0 to 1.4 m. Compared to the leaching of phosphorus from the application of fertilizers and organic waste, some authors verified that phosphorus is more mobile in the soil in organic form (MOZAFFARI and SIMS, 1994, EGHBALL et al., 1996).

The soil type is an important factor that controls the vertical movement of phosphorus in the soil profile, because depending on that it can have greater interaction between soil and solution that percolates in the profile, increasing the possibility of adsorption of phosphorus.

Stefanutti et al. (1995) observed that the level of available P in soil increased significantly with the application of ARS over time. At 8.3 months of application of manure, the increase in the amount of available P in 0-10 cm layer was 242% and 580% with application of 20 and 40 m3 ha-1 respectively, at 48 months. The increase was 3.94% and 6.71% with doses of 20 and 40 m3 ha-1, respectively, reaching very high levels of available P in soil, since, for the condition of soil, levels of P above 24 mg L-1 are considered high (CQFS-RS/SC, 1995).

These results present that it must be paid attention to the polluting potential of P in the environment, avoiding the application of high doses of wastewater in small areas, and is adopting technical measures to allow greater infiltration rate of water in the soil, and systems of crops that provide the production and maintenance of high quantities of plant residues on the soil surface to reduce the runoff. Although in some cases the losses of P are small, even relatively low concentrations (0.01 mg L-1 of soluble P-3 or 0.02 mgL of total P) are sufficient to cause eutrofização (SHARPLEY and REKOLAINEN, 1997).

Doblinski et al. (2007) working with leaching of N, P and K in the culture of beans irrigated with ARS, verified that there was gradual increase of phosphorus in the more superficial layers of the profile, as the amount of wastewater applied (50, 100, 150 and 200 m3ha -1). It also noted that from the witness that quantity was increasing linearly. Table 6 presents the unfolding of the interaction rate of chemical fertilizer applied to soil x time of collection to the average values of phosphorus (mg L-1) determined in soil collected during the development of the corn crop in lysimeters under treatment with ARS.

It can be observed by Table 6 that the concentrations of phosphorus in the soil differed between sources of chemical fertilizer used. The dosage of 75% of chemical fertilizer presented higher concentration of the element to the ground without differs statistically by the dosage of 50%. For periods, the general averages show that the highest concentration of the element was observed at 90 DAS, which differed from the others. The lowest

Table 6. Unfolding of the interaction rates of chemical fertilizer applied to soil x time of collection to the average values of phosphorus (mg L-1) determined in soil collected during the development of the corn crop, in lysimeters under treatment with the rates of application of wastewater from swine culture.

AD (%)	Periods (DAS)					Averages
	0	40	70	90	125	
50	11,39bB	14,93abA	17,50abA	22,17aA	15,46abA	16,29
75	13,87bA	14,93bA	15,46bA	24,47aA	18,57bA	17,46
Averages	12,63c	14,93b	16,48b	23,32a	17,01b	

AD = doses of chemical fertilizer. Averages followed by the same letter in the row and column capital do not differ by Tukey test at 5% level of significance. For the analysis of variance was used for data processing $\sqrt{x+1}$.

average was recorded before sowing, and also differed from other averages. The periods for 40, 70 and 125 DAS did not differ among themselves and were different from the smallest and the largest average.

For unfolding, it can be noted that the fertilization of 50% had higher average at 90 DAS, which differed from the smaller, observed at 0 DAS. For other periods the averages were statistically equal. For AD of 75%, the highest average was also observed at 90 DAS, which differed from the others. Although the lower value has been verified to the witness, statistically, the means were equal for all periods. Analysing the periods, note that only the witness presented significant difference in the averages, the largest observed for the rate of 75% of AD. In other periods differences between averages were not observed. Although they have presented these differences, note that the concentrations of the element in the soil, can be considered low when compared to values cited by Stefanuti (1995), which emphasizes that concentrations of 24 mg L-1, causes problems of contamination in soil. At 90 DAS the highest average (24.47 mg L-1) was observed, this value, according to the author, indicates problems of contamination in soil, however, at 200 DAS, when the applications of ARS were stopped these values reduced again. The equality of the means observed for the percentage of chemical fertilization, may be related to the fact that proximity of doses used, or the used interval between fertilization may have been very close, creating equality in the information.

In general, Sherer et al. (1995) working with ARS and with levels of elements in soil verified that the levels of nutrients varied as the form of storage and, for esterqueiras there is much variability of elements. The forms of phosphorus found in bioesterqueiras or esterqueiras are related to the animals' diet (SHERER et al., 1995; DOURMAD et al., 1999; KLEINMAN et al., 2005). Because of this and other factors, there is great variation in levels of nutrients found in manure and this variation may be even wthin the farm (PERDOMO et al., 2001). Therefore, it is difficult to characterize the manure of swine since the different forms solid, liquid or paste, can vary considerably, depending on the degree of dilution.

Conclusions

The continued use of ARS increased mainly the content of P in soil. The high concentration of P in the most superficial layer of soil fertilized with ARS presented that these factors may compromise the quality of the environment, especially as water contaminants. With respect to the rates of chemical fertilization, no differences were observed between applications in the proportions of 50 and 75%.

References

ABOUKHALED, A.; ALFARO, J. F.; SMITH, M. **Los lisímetros.** Roma: FAO, 1986. 60 p. (Estudos FAO: irrigação e drenagem, 39).

AMERICAN PUBLIC HEALTH ASSOCIATION. **Standard methods for the examination of water and wastewater**. 19th ed. New York, 1995. 1193 p.

BANZATTO, D. A.; KRONKA, S. N. **Experimentação agrícola**. Jaboticabal: Funep, 1992. 247 p.

BARCELLOS, L. A. R. **Avaliação do potencial fertilizante do esterco líquido de bovinos**. 1992. 108 f. Dissertação (Mestrado em Agronomia) - Universidade Federal de Santa Maria, Santa Maria, 1992.

BASSO, C. L. **Perdas de nitrogênio e fósforo com aplicação no solo de dejetos de suínos**. 2003. 125 f. Tese (Doutorado em Agronomia) - Universidade Federal de Santa Maria, Santa Maria, 2003.

BERWANGER, A. L. **Alterações e transferência de fósforo no solo para o meio aquático com o uso de dejetos líquidos de suínos.** 2006. 98 f. Dissertação (Mestrado em Agronomia/Processos Químicos e Ciclagem de Elementos) - Universidade Federal de Santa Maria, Santa Maria, 2006.

BRASIL. Ministério do Meio Ambiente. Conselho Nacional do Meio Ambiente. Resolução nº 357, de 17 de março de 2005. **Diário Oficial da União**, 18 de março de 2005.

CAMPELO, R. A. et al. Influência da aplicação de águas residuárias de suinocultura na capacidade de infiltração de um solo podzólico vermelho-amarelo. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 4, n. 2, p. 263-267, 2000.

CERETTA, C. A. et al. Características químicas de solo sob aplicação de esterco líquido de suínos em pastagem natural. **Pesquisa Agropecuária Brasileira**, Brasília, DF, v. 38, n. 6, p. 729-735, jun. 2003.

CHATEAUBRIAND, A. D. **Efeito de dejetos de suínos, aplicados em irrigação por sulco, na cultura do milho (*Zea mays* L)**. 1988. 61 p. Dissertação (Mestrado em Engenharia Agrícola) - Universidade Federal de Viçosa, Viçosa, MG, 1988.

COELHO, A. M.; FRANÇA, G. E. Seja o doutor do seu milho: nutrição e adubação. **Informações Agronômicas**, Piracicaba, n. 71, set. 1995. Encarte.

COMISSÃO DE FERTILIDADE DO SOLO. **Recomendações de adubação e calagem para os estados do Rio Grande do Sul e Santa Catarina.** 3. ed. Passo Fundo: Sociedade Brasileira de Ciência do Solo, 1995, 244p.

CORRÊA, L. B.; CORRÊA, E. K. Estudo das fontes poluidoras em uma granja produtora de suínos: uma perspectiva de educação ambiental: estudo de caso. In: CONGRESSO BRASILEIRO DE VETERINÁRIOS ESPECIALIZADOS EM SUÍNOS, 11., 2003, Goiânia. **Anais**... Concórdia: EMBRAPA Suínos e Aves, 2003. p. 447-448.

DOBLINSKI, A. F. et al. Lixiviação "in situ" de nitrogênio, fósforo e potássio oriundos do uso de água residuária da suinocultura na cultura do feijão. In: CONGRESSO BRASILEIRO DE ENGENHARIA AGRICOLA, 36., 2007. Bonito. **Anais**... Bonito: Sociedade Brasileira de Engenharia Agrícola, 2007. 1 CD ROM.

DOURMAD, J. Y. et al. Nitrogen consumption, utilisation and losses in pig production in France, The Netherlands and Denmark. **Livestock Production Science**, v. 58, p. 261-264, 1999.

DURIGON, R. et al. Produção de forragem em pastagem natural com o uso de esterco líquido de suínos. **Revista Brasileira Ciência do Solo**, Viçosa, v. 26, p. 983-992, 2002.

EGHBALL, B. et al. Nutrient, carbon, and mass loss during composting of beef cattle feedlot manure. **Journal Environmental Quality l.** Madison, v. 26, n. 1, p. 189-193. 1997.

FANCELLI, A. L.; DOURADO NETO, D. **Produção de milho**. Guaíba: Agropecuária, 2000. 360 p.

FREITAS, W. da S .**Efeito da aplicação de águas residuárias de suinocultura nas características agronômicas e nutricionais do milho (*Zea Mays* L.**). 2001. 52 f. Dissertação (Mestrado em Engenharia Agrícola) - Universidade Federal de Viçosa,Viçosa, 2001.

FREITAS, W. da S. et al. Efeito da aplicação de águas residuárias da suinocultura sobre a produção de milho para silagem. **Revista de Engenharia Agrícola e Ambiental,** Campina Grande**,** v. 8, n. 1, p. 120-125. 2004.

GIUSQUIANI, P. L. et al. Fate of pig sludge liquid fraction in calcareous soil: agricultural and environmental implications. **Journal of Environmental Quality**, Madison, v. 27, p. 364-371, 1998.

GOMES, F. P. **Curso de estatística experimental**. 12. ed. Piracicaba: Nobel, 1987. 467 p.

HOUNTIN, J. A. et al. Use of a fractionation procedure to assess the potential for P movement in a soil profile after 14 years of liquid pig manure fertilization. **Agriculture and Ecosystems Environment**, Charlottetown, v. 78, p. 77- 84, 2000.

KAO, C. W.; BLANCHAR, R. W. Distribuition and chemistry of phosphorus in na Albaqualf soil after 82 year of phosphate fertilization. **Journal Environmental Quality.,** Madison, v. 2, n. 1, p. 237-240. 1973.

KLEINMAN, P. J. et al. Survey of water-extractable phosphorus in livestock manure. **Soil Science Society American Journal,** Madison, v. 69, p. 701-708, 2005.

LOPES, A. S. **Manual internacional de fertilidade do solo.** Piracicaba, Potafos, 1995. 176 p.

MOZAFFARI, M.; SIMS, T. S. Phosphorus availability and sorption in an Atlantic Coastal plain wastershed dominated by animal based agriculture. **Soil Science**, Baltimore, v. 157, n. 2, p. 97-107, 1994.

OLIVEIRA, E.; PARIZOTTO, M. L. V. **Características e uso fertilizante do esterco de suíno.** Londrina: IAPAR, 1994. 24 p. (Circular, 83).

OLIVEIRA, P. A. V. de. **Manual de manejo e utilização dos dejetos de suínos.** Concórdia, SC: EMBRAPA, CNPSA, 1993. 188 p. (Documento, 27).

OLIVEIRA, R. A. et al. Influência da aplicação de águas residuárias de suinocultura na capacidade de infiltração de um solo podzólico vermelho-amarelo. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 4, n. 2, p. 263-267, 2000.

PERDOMO, C. C.; LIMA, G. J. M. M. D.; NONES, K. Produção de suínos e meio ambiente. In: SEMINÁRIO NACIONAL DE DESENVOLVIMENTO DA SUINOCULTURA, 2001, Gramado. **Anais…** Gramado:, 2001. p. 17.

PRATT, P. F. Management restrictions in soil application of manure. **Journal of Animal Science**, Washington, DC, v. 48, p. 134-143, 1979.

RAIJ, B. Van. et al. (Eds.). **Análise química para avaliação da fertilidade de solos tropicais**. Campinas: Instituto Agronômico, 2001. 285 p.

SCALLOPPI, E. J.; BAPTISTELLA, J. R. Considerações sobre a aplicação de efluentes ao solo. In: CONGRESSO NACIONAL DE IRRIGAÇÃO E DRENAGEM,1986, Brasília, DF. **Anais**... Brasília, DF: ABID, 1986. v. 3, p. 1049-1066.

SHARPLEY, A. N.; REKOLAINEN, S. Phosphorus in agriculture and its environmental implications. In: TUNNEY, H.; SMYTH, T. J.; TIESSEN, H. **Phosphorus loss from soil to water**. Wallingford: CAB, 1997. p. 1-54.

SHERER, E. E.; BALDISSERA, I. T.; DIAS, L. F. X. Potencial fertilizante do esterco líquido de suínos da região oeste catarinense. **Agropecuária Catarinense**, Florianópolis, v. 8, n. 1, p. 33-39, 1995.

STEFANUTTI, R.; MALAVOLTA, E.; MURAOKA, T. Recuperação do fósforo residual do solo, derivado de um termofosfato magnesiano com diferentes granulometrias e do superfosfato simples granulado. **Scientia Agrícola**, Piracicaba, v. 2, n. 52, p. 233-238, 1995.

STORK, L.; ESTEFANEL, V.; GARCIA, D. C. **Experimentos fatoriais: modelos de análise pelos pacotes SAS, SAEG e SOC.** s. n. Santa Maria, 1995. 52 p.

TEDESCO, M. J. et al. **Análise de solo, plantas e outros materiais.** Porto Alegre: UFRGS, Departamento de Solos, 1995. 174 p.