Impacts caused by swine manure application and proper management proposition in a swine finishing farm

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ABSTRACT. Due to the increase in the PWW production level by the high concentration of animals per area, the intensification and concentration of pig farming in certain regions has resulted in the intensive application of swine manure (PWW) in the same terrain, which may provide the soil accumulation and the transference of elements may compromise the productive capacity of the territorial space of that region. In this sense, this work aimed to evaluate the elements concentration present in the soil and in swine waste, in relation to the values stipulated by CONAMA Resolution n. 420 (Conselho Nacional do Meio Ambiente [CONAMA], 2009) and also by CETESB n. 195/2005 (Companhia de Tecnologia Ambiental do Estado de São Paulo [CETESB], 2005), which provides for criteria and values guiding soil quality and groundwater for chemicals presence, and, based on the reference element, adapt to the technical standard P 4,231/2015 (Companhia de Tecnologia Ambiental do Estado de São Paulo [CETESB], 2015) proposed by CETESB for the dose calculation of vinasse application, in PWW application in pasture cultivation. The work accomplished at Fazenda Talhado Cinco de Março rural area - Rio Verde Municipality – Goiás state. Samples were performed to determine the soil physicochemical attributes and PWW chemical analysis of the soil, submitted to statistical analysis of Analysis of Variance and Tukey's Test 5%. The results made it possible to verify that the used management is not the most appropriate, and it is necessary to review the procedures currently adopted, such as performing more constant soil and PWW analyzes, to avoid that their continual application in a disorderly manner and with possible negative impacts on the environment.

Keywords: wastewater; fertigation; nutrients; pig farm.

Introduction

Being one of the main farming activities, pig farming operates in a concentrated manner at the producing regions, significantly rising the amount of Pig Waste Water (PWW) that ends up in the soil (Sacomori et al., 2016).

Generally, pig farming is divided into three phases: Breeding / Gestation / Maternity, Daycare and finishing. At the place under study, the piglets arrive at the property with 28 days and are taken to the nursery, where they remain until they complete approximately 10 weeks of life. They usually arrive weighing 8 Kg and leave with approximately 20 Kg. After this period, in the finishing phase, this is the final breeding phase and the animals remain there until they reach market weight. They are usually slaughtered weighing between 100 and 120 Kg, with 114 days of accommodation. This phase is further subdivided into two others: rearing, in which the nutrients absorbed aim at the growth of animals and the deposition of lean meat; and finishing, until they reach the slaughter weight. During this process, considering different batches, each animal produces an average of about 10 liters of swine manure per day.

Taking into account the high costs of chemical fertilizer that is essential to pasture management and the environment demand regarding the PWW control, it is indispensable to use the waste water nutrient content to nourish areas and also provide a final PWW disposal (Costa, Faquim, & Oliveira, 2010). As the PWW is constantly produced, its soil long-term disposal results in excessive and unbalanced dosages regarding the tilth nutrient's demand (Prior, Sampaio, Nóbrega, Dieter, & Costa, 2015). This way, the growth and concentration of pig farming in few regions results in excessive and uncontrolled PWW flush in the same area, which may negatively affect the soil productive capacity, plants, surface and ground water quality (Fernandes,

Costanzi, Feiden, Souza, & Kitamura, 2014; Herrmann, Sampaio, Castaldelli, Tsutsumi, & Prior, 2016; Rosa, Sampaio, Pereira, Mauli, & Reis, 2017).

Although there is evidence indicating a better productivity in some cultures (Menezes, Berti, Vieira Júnior, Ribeiro, & Berti, 2018), and also to the soil's chemical properties (Lourenzi et al., 2013), the use of PWW as nutrient source, when not properly handled, may cause a nutrient buildup and element transfer Cu, Zn, N, P and K. The high and successive waste water application rate may cause nutrient transfer through superficial flow, which may then cause negative impacts specifically to the water quality, such as water bodies' eutrophication (Ceretta, Durigon, Basso, Barcellos, & Vieira, 2003; Yang, Zhang, Qian, Duan, & Wang, 2017).

Considering that the PWW final disposal must follow agronomic and environmental guidelines, this paper aim is to assess the element concentration at the soil and in PWW relative to the values stated at the CONAMA N° 420 (CONAMA, 2009) and CETESB N°195 (Companhia de Tecnologia Ambiental do Estado de São Paulo [CETESB], 2005) resolution, which rises criteria and values of soil and ground water quality guidelines in regards to chemical substances presence, as well as, considering the reference element. Here it is aimed to adapt the technical standard P 4,231 (CETESB, 2015) from CETESB which defines the soil vinasse dose calculation into the PWW usage on pastures in order to ensure the right nutrient cycle and plant nutrition, minimizing the possible negative hazards from this activity.

Material and methods

This research was developed at Fazenda Talho Cinco de Março located at Rodovia GO 174 km 54, Rural Area – county Rio Verde - GO. Following the Köppen and Geiger Classification, the region climate is AW (Tropical with summer rain), 23.3°C average temperature and 1,663 mm annual precipitation rate (Instituto Nacional de Meteorologia [INMET], 2019). The region ground is a typical Ortic Quartzarenic Neossol (Santos, 2018).

The region is part of the hydrographic basin of the Paranaíba River, in southwest Goiás, where the water bodies of the Doce, Talhada and Lata rivers are present. The total study area is 91 hectares, of which 70 hectares are subdivided into 18 paddocks destined for grazing (Cynodon nlemfuensis), exploited for intensive livestock like in Figure 1. At this place there are three pig farming cells with vertical termination system, capacity of 450 pig heads each, which generates an average volume of 4500 liters of swine manure per day in each farm. For the treatment of PWW there are three anaerobic lagoons and two anaerobic digesters.

In order to select a proper number of sample units, the critical number of the t student distribution for a given trust level, standard deviation and acceptable uncertainty level was used (Equation 1).

$$n = \left(\frac{t * S}{U}\right)^2 \qquad (1)$$

where:
n= sample number;
t = t student distribution according to value α;
S = standard deviation;
U = acceptable uncertainty level.

The samples gather frequency was divided into two rounds: the dry season and rain season, executed in May and November, respectively. Over each round 18 soil samples were collected, summing up 36 samples at 20-40 cm deep. The following physic–chemical attribute was measured: pH in CaCl2, phosphor (P), potassium (K), cooper (Cu), iron (Fe), manganese (Mn), zinc (Zn) extracted via Melhich's solution, calcium (Ca), magnesium (Mg) into KCl, Total Organic Carbon, aluminum (Al), boron (B), sulfur (S), organic matter (M.O), soil texture (sand, silt, clay), potential acidity (H+Al), sum of bases (S), cation exchange capacity (CEC), base saturation (V), aluminum saturation (m) following Donagema, Campos, Calderano, Teixeira and Viana (2011) methodology.

Regarding the PWW, 10 samples were collected in each round, totaling 20 samples. The measured technical features in regard to the nutrient content were: pH, nitrogen (N), phosphor (P), sulfur (S), calcium (Ca), magnesium (Mg), zinc (Zn) and organic matter (M.O). All these were evaluated according to Standard Methods for the Examination of Water and Wastewater methodology (Rice, Baird, & Eaton, 2017).

The statistical outline was block to case, Analysis of Variance technic ANOVA was applied and average 5% Tuckey significance test evaluated. The soil analysis outline was two treatments with 18 repetitions for each parameter and the PWW analysis was 2 treatments with 10 repetitions for each parameter.
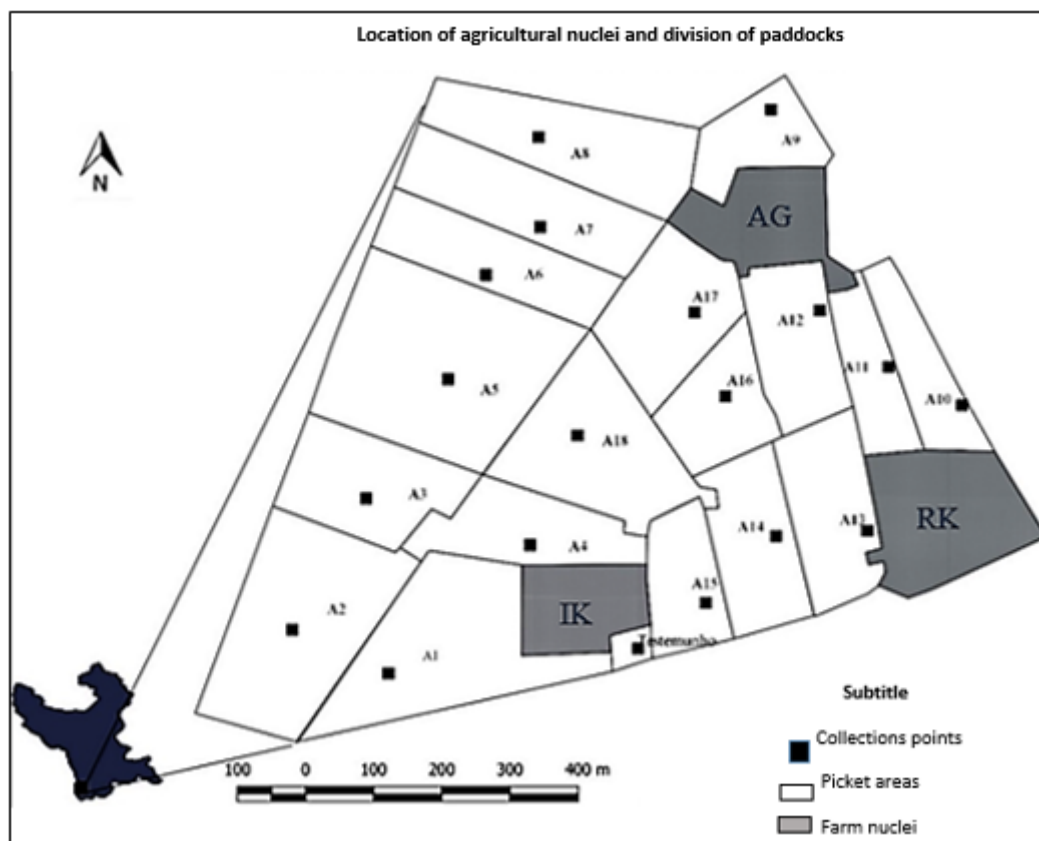
Figure 1. Map of the location and divisions of the paddocks in their respective areas and on IK (Ivan Klein), RK (Ricardo Klein) and AG (Farming) Farms, in the southwest of Goiás.

Pig manure generation and nutrient concentration are basic information in order to establish the best way to handle these residues. The methodology used to estimate the vinasse soil application mimics the technical standard P 4,231/2015 from Companhia de Tecnologia Ambiental do Estado de São Paulo (CETESB, 2015), which defines the criteria and procedures to store, transport and apply vinasse in the soil in the state of São Paulo.

According to CETESB (2015), the selection and dosage of vinasse for agriculture soil enrichment are calculated considering the vinasse's potassium, its average extraction rate by sugar cane, the depth, soil fertility, with special remark that the maximum soil potassium build up should not exceed 5% of the soil's CEC (Elia Neto et al., 2010). Once this limit is reached the vinasse application is restricted to this element sugar cane average extraction rate which is 185 Kg of K_2O per hectare per share, according to Equation 2.

$$\text{m}^3 \text{ vinasse ha}^{-1} = \frac{[(0{,}05 \text{ x CEC} - \text{Ks}) \text{x } 3744 + 185]}{\text{kvi}} \tag{2}$$

where:
Ks = refers to potassium concentration in the soil cmolc.dm^{-3} at a depth of 0 to 0.80 m;
Kvi = refers to the concentration of potassium in vinasse, expressed in Kg of K_2O m^{-3};

The value of 3744 is the constant for transforming fertility analysis results, expressed in cmolc dm^{-3}, to Kg of potassium in a volume of 01 (one) hectare per 0.80 meters deep.

Although nitrogen is the most abundant element in most analyses, the microorganism uses most of it in its biological process (Zordan, Saléh, & Mendonça, 2008). On top of that it is in its ammoniacal form, which easily volatizes at high temperatures. Therefore, the potassium stays as the nutrient with highest concentration present in PWW.

Another main factor regarding the potassium soil's concentration is that in Cerrado this paper's study's region biome, Ronquim (2010) states that the cation exchange capacity (CEC) must not exceed 3% because the Cerrado's soils have a low CEC and a high-water percolation degree, which may easily cause nutrient leaching.

In order to convert the fertility analysis results expressed in cmolc.dm^{-3} into potassium Kg in a hectare at 0.40 meters deep, it was used the constant 2439,22. This constant is from the multiplication of the potassium equivalent mass times the soil density is 1.56 Kg dm^{-3} (Table 1) times the soils volume in a hectare at 0,40 meters deep as shows Equation 3.

$$0,3909(\text{cmolc.dm}^{-3} - g.\text{dm}^{-3}) \, x \, 1,56(\text{Kg.d}m^{-3} - \text{Kg K ha}^{-1}) x \, 10.000(\text{ha} - \text{m}^2) x \, 0,40 = 2439,22 \quad (3)$$

Table 1. Density of typical Ortic Quartzarenic Neossol in pasture.

References	Ground density
Araújo, Souza, Cremon, & Rosa (2009)	1,59 Kg dm^{-3}
Sales, Carneiro, Severiano, Oliveira, & Ferreira (2010)	1,52 Kg dm^{-3}
Carneiro, Souza, Paulino, Sales, & Vilela (2013)	1,56 Kg dm^{-3}
Souza, Carneiro, & Paulino (2005)	1,60 Kg dm^{-3}
Average value	1,56 Kg dm^{-3}

The potassium soil's content in pig farms at 20-40 cm deep is also known as Ks, which units are expressed in cmolc dm^{-3}.

The Kg of absorbed potassium in a hectare by a culture is called Kpc. In this work 469 Kg ha^{-1} is the reference values following Oliveira, Penati and Corsi (2008)'s research. The PWW potassium concentration from both the two stage analysis's average are portrayed as KPWW, which units are given in mg L^{-1}.

Thereby Equation 4 expresses the adopted PWW soil application methodology.

$$m^3 \text{ PWW } ha^{-1} = \frac{[(0,03 \ x \ CEC - Ks) \ x \ 2439,22 \ + Kpc]}{KPWW} \quad (4)$$

where:
3% CEC Cerrado's soils
Ks = refers to potassium concentration in the soil cmolc.dm-3at a depth of 20 to 0.40 m
Kpc=the Kg of absorbed potassium in a hectare by a culture is called
KPWW= The potassium concentration found in pig slurry

Among the many nutrients in PWW, nitrogen comes up as the main one. Its concentration proportion is related to its storage, breeding and sanitizing conditions (Sánchez & González, 2005).

The key parts of the nitrogen element were determined for its dosage. In anaerobic ponds there is some N build up in the ammonium form, which its oxidation into nitrate is overlooked, because it relies on O2 presence (Stevenson, 1982). According to Aita, Port and Giacomini (2006) around 40-70% of the total N is in ammoniacal form and according to Ceretta et al. (2003) the share of N in ammoniacal form in PWW is 50-60%. Hereby in this work the adopted average quantifying N ammoniacal percentage present in total N of PWW is 55%.

Referring to a methodology proposed by Matos and Matos (2017), the reference element nitrogen estimate dose is given by Equation 5 and 6.

$$N_{total} = N_{org} + N_{amon} + N_{nitrato} \quad (5)$$

$$D_{ar} = \frac{1000 \, x \left[N_{abs} - \left(T_{m1} \, x \, M_0 \, x \, \rho_s \, x \, p \, x \, 10^7 \, x \, 0,05 \, x \frac{n}{12} \right) \right]}{[T_{m2} \, x \, \frac{n}{12} \, x \, N_{org} + (N_{amoniacal} + N_{\text{nitrate}}) \, x \, PR]} \quad (6)$$

where:
D_{ar} = dose to be applied (m³ ha^{-1} year^{-1});
N_{abs} = Nitrogen absorption to obtain the desired productivity (Kg ha^{-1});
T_{m1} = Existing soil organic matter annual mineralization rate;
OM = Soil organic matter (Kg Kg^{-1});
ρ_s = soil specific mass (t m^{-3});
p = used soil depth (m);
n = number of considered months of the year;

T_{m2} = Norg mineralization Rate;

N_{total} = total nitrogen (mg L^{-1});

N_{org} = organic nitrogen (mg L^{-1});

Namon = ammoniacal nitrogen (mg L^{-1});

$N_{nitrate}$ = nitric nitrogen (mg L^{-1});

PR = Nmineral tilth recover proportion (Kg Kg^{-1} year^{-1});

1000 = unit conversion (g m^{-3});

107 = unit conversion (Kg ha^{-1});

0,05 = Nitrogen mass usually present in soil mineralized OM (Kg Kg^{-1}).

According to Oliveira, Penati and Corsi (2008), the *Cynodon nlemfuensis* N absorption is 388 Kg ha^{-1}. The recover share of Nmineral in perennial cultures is 0,5 Kg Kg^{-1} ano^{-1}.

The organic matter soil annual mineralization rate is 0,01 Kg Kg^{-1} (Matos & Matos, 2017). Still according to the above mentioned author the corresponding N_{org} mineralization rate of pig waste is 0,9 Kg Kg^{-1} year^{-1}. Through the soil physic-chemical analysis at 0,40 m deep it was set the organic matter content average values.

Results and discussion

The use of PWW as a filth fertilizer changes the chemical, physical and biological soil properties. Therefore, its use must be based on technical criteria in order to downplay the possible environmental problems and enhance the filth nutrient recycling and the soil fertility. Table 2 shows the average results for swine manure for the two phases from May to November 2018.

Table 3 presents the results from ANOVA and Tukey's Test at 5% of significance for the soil samples.

Table 2. The average results for swine manure for the two phases from May to November 2018.

pH	N	P	K	S	Ca	Mg	Cu	Fe	Mn	Zn	Mo
-	g L^{-1}	g L^{-1}	g L^{-1}	g L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	g L^{-1}
8,0425	2,67	1,069	1,7185	7,183	37,82	21,3655	23,565	86,275	11,72	36,5015	915,61

Table 3. Results of soil samples after continuous application of PWW submitted to ANOVA and Tukey's test in May and November 2018.

Treatments	pH	CEC	K	Mg	Cu	Zn
	-	cmolc dm^{-3}	cmolc dm^{-3}	cmolc dm^{-3}	mg dm^{-3}	mg dm^{-3}
p-value	0.5900	0.0501	0.9505	0.0080	0.0015	0.2718
Overall Average	5.17	4.27	0.30	0.62	4.17	3.31
Standard deviation	0.36	0.71	0.07	0.19	1.23	1.00
CV%	6.97	16.61	24.46	30.42	29.48	30.30
1ª stage (May)	5.13 a	4.51 a	0.30 a	0.71 a	3.46 a	3.49 a
2ª stage (November)	5.20 a	4.03 a	0.30 a	0.53 b	4.88 b	3.12 a

Note: Equal letters indicate that at the 5% Tukey's test significance level there is no difference between the means.

The CEC ANOVA results point that a p-value > 0,05 so there is no difference between the sampling round. The Tuckey's test output was same letters showing that for the 5% significance level there is no difference in the mean values. The soil CEC depletion is not what was expected, bearing in mind that waste water soil application adds organic carbon and therefore rises the organic matter content and its shrinkage might be related with the change in organic matter amount and pH.

There was no treatment interference on the pH values, no significant difference, as the Tukey's Test testifies. Some researches point that there is an increase in soil pH after waste water application. This is credited as the high sodium bicarbonate in it, which can be used as a soil acidity amendment (Qilu et al., 2017). The PPW effect scale on soil acidity characteristics is also linked to the buffer effect and the applied dose, which must be usually high and in successive doses in order to observe significant changes (Cassol, Silva, Ernani, Klauberg Filho, & Lucrécio, 2011; Condé, Almeida Neto, Homem, Ferreira, & Silva, 2013).

With respect to potassium it was noticed that a p-value higher than 0,05 indicates that there is no significant difference between the value. The Tukey's Test shows similar average results and both of them are identified with a letter 'a'. The K values reduction might be related with the tilth extraction, bearing in mind that the K is in its mineral form, therefore its residual effect is brief (Ceretta et al., 2003), as well as this nutrient leaching to deeper soil layers, related to its high mobility (Silva, Lana, Lana, & Costa, 2015).

The ANOVA regarding the Mg shows there is difference between the values, since the p-value is smaller than 0.05. The Turkey's test output was different letters, indicating that at 5% there is significant difference between the mean values. Mg is usually added as a supplementary feed and around 70 to 95% are excreted (Perdomo & Cazzaré, 2001; Bertoncini, 2011), what may lead to this nutrient high concentration as it is applied to the soil. Cabral, Freitas, Rezende, Muniz, & Bertonha (2011) observed that the application rate of 99 mg ha^{-1} year^{-1} of PWW raised the soil magnesium (Mg) content from 243.1 to 449.7 mg L^{-1}. Queiroz, Matos, Pereira and Oliveira (2004) studying PWW when applied to the soil with different types of grasses found that the Mg concentration were higher at the beginning than that at the end, probably due to tilth extraction.

Mumbach et al. (2016) observed that the soil potassium availability works with a close relationship with other elements, above all the calcium and magnesium. Figure 2 expresses these elements relationship in this work.
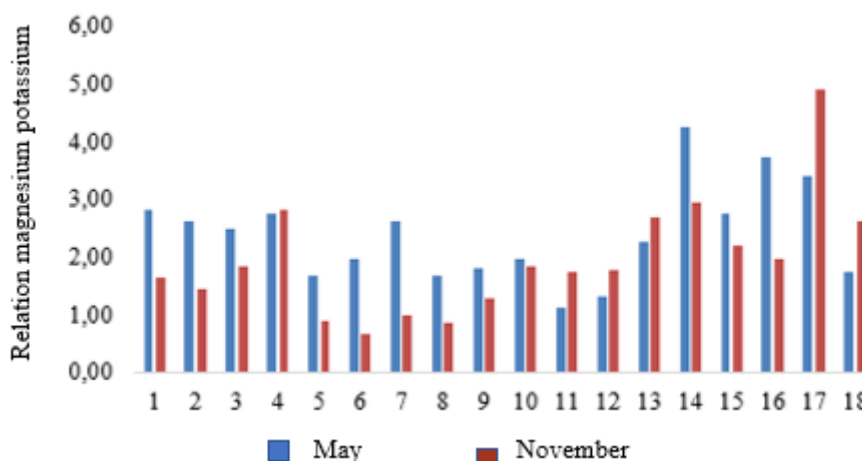

Figure 2. Magnesium / Potassium ratio of soil under study.

The soil magnesium deficiency might be related with factors such as acidity or surplus of potassium-based fertilization. Silva and Trevizam (2015) observed that higher soil K concentration might impose a lower Mg availability due to its negative feedback interaction. On top of that, soils with sandy characteristics, low pH and high leaching degrees may compromise the magnesium availability.

Sousa and Lobato (2014), points that the Mg K^{-1} level identified as suitable is around 5-15, where values below 2 are low, between 2 and 4 are average and above 15 are high. The relationship between the above mentioned ions results in levels lower than 2 in 55% of the pickets. This way the excess of PWW in the picket soil may be related with uncommon results, therefore the Mg K^{-1} levels maintenance are paramount not to occur on element build up and the other depletion.

The micronutrients Cu and Zn, are known as heavy metals. Yet the plants require them in smaller amounts, the fertilization with PWW, most of the times, rises the cooper and zinc levels (Mattias et al., 2010; Fridrich et al., 2014). Regarding cooper it was observed disparities in the average values, the p-value found was smaller than 0.05 and also the Tuckey's Test output was different letters for each mean. The continuous application of PWW resulted in cooper build up in the soil with 77.78% increase form first round of samples, held in May, set against the second round, held in November of the same year.

Taking into account CONAMA Resolution n. 420 (CONAMA, 2009) and also CETESB n. 195 (CETESB, 2005), transforming the average nutrient content Cu we obtained the value of 6.50 mg Kg^{-1}, comparing this with the prevention guiding value of 60 mg Kg^{-1}, which is lower, thus also meeting the quality reference value 35 mg Kg^{-1}.

Zinc is used in dietetic animal feed and antibiotics formulation, which raises the environment contamination risk (Scherer & Baldissera, 1994). For Zn the ANOVA indicates there is no statistical difference (p-value > 0.05), and in both treatments the Tukey's Test output is an 'a'. The PWW soil application resulted in a Zn depletion comparing May and November. Sandy soils, such as Neossol, have low PWW bearing capacity due to its low metal retention when set against loamy soils (Scherer, Nesi, & Massotti, 2010). Still about the Zn, its average value is 5,16 mg Kg^{-1}, which is under the quality reference value 86 mg Kg^{-1} established by CETESB N° 195 (CETESB, 2005), the prevention guide value 60 mg Kg^{-1} and also meets the reference prevention value 300 mg Kg^{-1} from CONAMA N° 420 (CONAMA, 2009).

The awareness of PWW specific characteristics provide a basis to establish references dose to be applied in the soil (Barros, Martinez, & Matos, 2011). Table 4 resumes PWW samples ANOVA and Tukey's test at 5% of significance.

Table 4. PWW results submitted to ANOVA and Tukey's test in May and November 2018.

Treatments	N g L^{-1}	K g L^{-1}	Cu mg L^{-1}	Zn mg L^{-1}	pH -
p-value	0.1018	0.7081	0.3929	0.0031	0.6815
Overall Average	2.67	1.69	23.57	36	8.04
Standard deviation	1.79	0.47	9.89	40.7	0.24
CV (%)	67.02	27.96	41.95	111.60	3
1ª stage (May)	1.98 a	1.73 a	25.50 a	67.59 a	8.02 a
2ª stage (November)	3.36 a	1.64 a	21.63 a	5.41 b	8.07 a

Note: Equal letters indicate that at the 5% Tukey's test significance level there is no difference between the means.

Regarding nitrogen, the ANOVA and Tukey's test point out there is no significant difference (p-value > 5%). According to Rosa et al. (2017), high levels of nitrogen are expected because this is one of the nutrients with higher concentration in PWW, besides being more subjected to biological transformation and losses, either in storage and soil (Perdomo & Cazzaré, 2001). The nutrient content N shows 85% of the steps performed with values above 10,000 µg L^{-1} recommended by the groundwater standards. It's worth mentioning that these nutrient high concentration in PWW, can, on the long run, be a potential ground and surface water contaminant and pollutant (Bertoncini, 2011; Smanhotto, Sampaio, Bosco, Prior, & Soncela, 2013), because the nitrogen leaching makes it reach deeper layer soil where the tilth root system cannot absorb the nutrients.

Regarding the potassium there is a p-value > 5% consequently at 5% significance, the Tukey's test did not point out any difference in the mean values and they also all got the same letters. In a study from Dortzbach, Léis, Sartor, Comin and Belli Filho (2009), the potassium levels were affected by the fertilization with PWW, increasing the K quantity in relation to the control sample.

Cooper (Cu) plays many roles in animal metabolism, and it's supplemented in animal feed. It's estimated that around 72-80% of the ingested Cu is purged through animal excretion (Jondreville, Revey, & Dourmad, 2003). Therefore, the high cooper concentration present in PWW allied with the excessive soil application may cause this element build up in the soil, turning it into a possible pollution source (Girotto et al., 2010). The ANOVA and Tukey's test output have same letters indicating that in the same significance level there's no difference between the mean values. Regarding the soil applied PWW the average values to May and November were 22,500 and 21,630 µg L^{-1}, respectively. Bearing in mind the CONAMA N° 420 (CONAMA, 2009)'s resolution and CETESB n° 195 (CETESB, 2005) the Cu level shows itself higher in every stage related to ground water reference value 2,000 µg L^{-1}.

The excessive amount of pig waste generated, with high heavy metals concentration, such as Zinc, can happen to contaminate the soil, ground water among other environmental risks, since this nutrient animal absorbed share is minimal, and the amount to be expelled through manure is between 92-98% from the total ingestion (Girotto, 2010). Zinc depicted, at 5% significance level, a difference between the average values from the first and second round. The high variation coefficient may have a relationship with pig's housing time which coincided with the first sampling round (May), given that, Zn is added in high levels in animal fodder during the growth phase, and its concentration is significantly smaller in the termination phase which coincided with the second sampling round (November). In 25% of the analysis the Zn nutrient level were higher than CETESB n° 195's (CETESB, 2005) reference level 1,800 µg L^{-1} and according to CONAMA N° 420 (CONAMA, 2009) in 50% of the samples the values were higher than the values of ground water investigation level 1,050 µg L^{-1} indicating there is necessity to further research this in the long run.

In manure the pH is a key parameter, once, it conditions the chemical reactions in the ambient. The ANOVA results point that statistically this parameter does not show any difference. For an efficient biodigester operation the recommended pH range is between 6.0 and 8.0 (Quadros et al., 2010).

Many researches point that there is a potential in PWW usage as an input to agriculture, even though it is common ground that PWW has pollutant potential. Figure 3 shows nitrogen uniformity in pickets and the manure application rate.

The tilth K demand is linked to the production degree which is defined by the N systems source (Freire, Coelho, Viana, & Silva, 2012). According to Primavesi, Corrêa, Silva and Cantarella (2006) a potassium based fertilization increases the N efficiency use. This way the reaction of grass plant types to potassium based fertilization is affected by the N dosage the same way it's affected by the soil capacity to provide K (Coutinho, Silva, Monteiro, & Rodrigues, 2004).
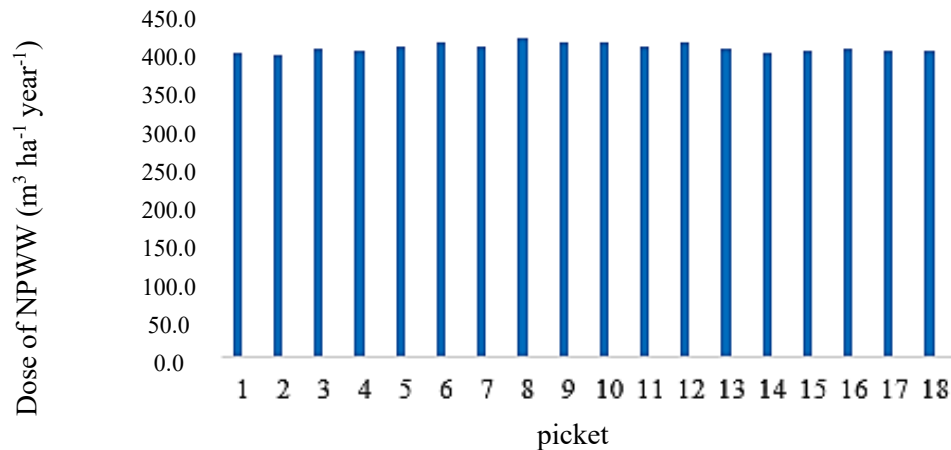
Figure 3. Amount of nitrogen to be applied (m³ ha⁻¹ year⁻¹).

Based on the results obtained by adapting the Cetesb formulation (equation 4), it was observed that the continuous use of PWW in pastures exceeded the amount of K in the soil (K in the soil exceeds the CEC of the soil by 3%), which results in negative dosages in 45% of the paddocks (Figure 4).
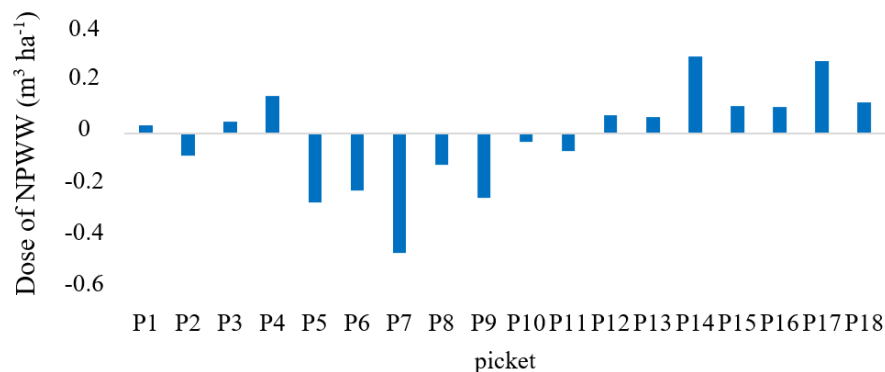

Figure 4. Quantity of PWW K to be applied (m³ ha⁻¹).

Study with the smaller dose (100 m³ ha⁻¹ year⁻¹) contributed to a higher nutrient extraction efficiency by the plants root system (Souza & Duarte, 2014). In the same manner Cabral et al. (2011), exploring different PWW dosages in Elephant Grass (*Pennisetum purpureum*), observed that with the 750 and 600 m³ ha⁻¹ year⁻¹ treatment followed a lower dry mass productivity, smaller growth, reduction of nutrient extraction and consequently higher soil left over.

Medeiros et al. (2007) observed that PWW doses of 180 m³ ha⁻¹ year⁻¹ are enough to replace the use of mineral fertilizer in a *Brachiaria brizantha* tilth. Cardoso et al. (2015) managed to get good dry and green mass productivity with increasing PWW dosages at Grass-Tifton 85.

Silva et al. (2015) working with *Brachiaria decumbens* and applying dosages of 60, 120 and 180 m³ ha⁻¹ year⁻¹, observed that the productivity remained the same, regardless of the dosage, and they concluded that the smaller dosage is more suitable bearing in mind the environmental impact. In line with Krajeski e Povaluk (2014), where it was found that the maximum amount of PWW that can be safely applied in tilth land in Santa Catarina State is 50 m³ ha⁻¹ year⁻¹.

According to CETESB (2015) if in a context it is observed that the PWW soil application is responsible for nutrient buildup above any of the reference values, the soil application must be suspended. Nutrient dosage that exceed the optimum level for a healthy plant development stop being beneficial and become potential pollution sources (Seganfredo, Bissani, & Sá, 2017).

Conclusion

Even though the PWW soil application provides essential nutrients to tilths it is important to carry out analysis more constantly in order to have a control of these components in soil and ground water. Since this

nutrient source has an unbalanced and high concentration nutrient distribution due to the many treatments it goes through (biodigester, stabilization ponds). This way the mismanagement regarding the PWW soil application for productivity enhancement may cause soil nutrient imbalances, due to the excess of elements. And lastly, the dosage applied in this study area is not properly performed.

With this study it was possible to ascertain that the reformulation of CETESB P 4,231 (CETESB, 2015) is a reasonable technical mechanism to oversee the PWW soil application using potassium (K) as the base element, bearing in mind that the former is more stable than nitrogen (N). This way the physical and chemical soil characteristics tracking as well as the waste properties are essential to avoid the environmental degradation and contamination. Therefore it is evident that this research field is important on behalf of a rural, livestock and environment sustainable development. In conclusion it is necessary that each and every pig farm has a waste water annual management plan.

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