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USE OF EFFLUENTS AND COMPOSTED SEWAGE SLUDGE ON THE BIOAVAILABILITY OF HEAVY METALS IN A TROPICAL SOIL

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1 ABSTRACT

The objective of this study was to evaluate the impacts of irrigation with treated effluent of domestic origin (EET) and different doses of composted sewage sludge (CSS) on soil chemical attributes and heavy metals bioavailability after five years of application. The experimental design was completely randomized, in an arrangement of subdivided plots, with ten replications. The plots contain two types of water for irrigation (EET - treated domestic effluent and AP- potable water) and in subplots doses of organic compound (CSS - 50, 100, 150, 200 and 250%), whose fertilizer quantities were based on the nitrogen fertilization required for the cultures, as reference. Results showed that levels of heavy metals As, Ba, Cd, Cr, Cu, Hg, Pb, Ni, Se and Zn did not exceed the limits and the maximum permissible content in the soil. Fertilization with composted sewage sludge associated with effluent irrigation positively impacted soil chemical quality in organic matter content, pH, bases sum (SB), base saturation (V%) and CEC. Responses obtained in this study showed a direct relationship between the type of water for irrigation and doses of compound in all evaluated parameters.

Keywords: reuse, wastewater, biosolids, sustainability.

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UTILIZAÇÃO DE EFLUENTE E LODO DE ESGOTO COMPOSTADO NA BIODISPONIBILIDADE DE METAIS PESADOS EM UM SOLO TROPICAL

2 RESUMO

Objetivou-se avaliar os impactos da irrigação com o efluente de esgoto tratado (EET) e diferentes doses de lodo de esgoto compostado (CSS) nos atributos químicos do solo e na biodisponibilidade de metais pesados após cinco anos de aplicação. O delineamento experimental foi inteiramente casualizado, em arranjo de parcelas subdivididas, com dez repetições. As parcelas contêm dois tipos de água para irrigação (EET - efluente doméstico

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tratado e AP - água potável) e nas subparcelas as doses do composto orgânico (CSS - 50, 100, 150, 200 e 250%), cujas quantidades do fertilizante foram baseadas na exigência da adubação nitrogenada para as culturas, como referência. Os resultados mostraram que os teores de metais pesados: As, Ba, Cd, Cr, Cu, Hg, Pb, Ni, Se e Zn não ultrapassaram os limites e o teor máximo permissível no solo. A adubação com lodo de esgoto compostado associado à irrigação do efluente impactou positivamente a qualidade química do solo (teor de matéria orgânica), soma base (SB), saturação por bases (V%) e CTC. As respostas obtidas neste estudo mostraram que houve relação direta entre o tipo de água para irrigação com as doses do composto sobre todos os parâmetros avaliados.

Palavras-chave: reuso, água residuária, biossólido, sustentabilidade.

3 INTRODUCTION

The use of sewage sludge and its source effluent as a form of recycling appears as an alternative to use, to control the high daily quantities produced and released into the environment. As for the first case, for the use of sewage sludge, composting is known as an important procedure for its treatment before being supplied to the soil for agricultural purposes (SILVA et al., 2013, GONÇALVES et al., 2014; ARAÚJO et al., 2015).

However, the long-term effects of the use of these urban waste as a source of organic matter for soils and wastewater for irrigation are still insipient, especially in tropical climates (ARAÚJO et al., 2016).

For the Intergovernmental Panel on Climate Change (IPCC), agricultural soils have lost more than half of organic matter in recent centuries, which is even more alarming for the tropics. Therefore, the use of these materials can be a good recovery option, as well as for the sustainable management of these wastes. Soriano-Disla et al. (2011) states that the beginning of the recovery process starts from the carbon return contained in the material that can improve soil and crop quality by reducing the free carbon in the atmosphere. However, it is possible to drag nutrients accumulated in the soil as a result of poorly calculated irrigations and natural events. the main cause refers to the loss of these by runoff or leaching, which, even in modest quantities, can boost the process of eutrophication of springs and aquifers.

For the environmental management departments, the main concern of the use of sewage sludge, even with the planned management, focuses on the potential of this in presenting some potentially harmful elements in its composition, such as heavy metals, thus limiting its use in agricultural soils and crops that can be absorbed from the soil by plants and inserted into the food chain (ROIG et al., 2012; BRAMRYD, 2013). The availability of basic elements in wastewater can be a resource for maintaining soil pH, and possibly controlling the release of heavy metals.

In view of the above, the objective of this work was to evaluate the impacts on chemical attributes and the bioavailability of heavy metals in soils under management of composted sewage sludge associated to the irrigation of treated effluents after five years of application.

4 MATERIAL AND METHODS

The experimental test was installed in greenhouse type environment located at coordinates 22 ° 52'55 "S and 48 ° 26'22" W at 786 m altitude. The climate of the region is Cwa, according to the classification of Köppen as altitude tropical, hot and humid summer with high precipitation and dryness in the winter (KOPPEN, 1936; SANTOS; ESCOBEDO, 2016).

For the experiment, containers of high density polyethylene (HDPE) with 60 cm depth and a useful volume of 100 liters were used. The soil used is classified as Dystrophic Red Latosol according to EMBRAPA (2006), also defined as Oxisol Udox by USDA (2014). The experimental design was completely randomized in arrangement of plots subdivided with fourteen treatments and ten replications, totaling 140 experimental units. The plots consisted of two types of irrigation water (EET - domestic effluent treated and AP-Potable water) and the subplots by the doses of composted sewage sludge (CSS - 50, 100, 150, 200 and 250%), the chemical composition of the soil used before the experiment is presented in Table 1.

Table 1. Chemical composition of the soil before the installation of the experiments

Soil Atributes	**Layer (cm)**	**Soil Atributes**	**Layer (cm)**
	0 – 40		**0 – 40**
pH ($CaCl_2$)	4.1	As (mg kg^{-1})	ND
O.M (g dm^{-3})	13	Ba (mg kg^{-1})	25.72
P_{Resine} (mg dm^{-3})	3	Cd (mg kg^{-1})	ND
Al^{+3} ($mmol_c$ dm^{-3})	13	Cu (mg kg^{-1})	1.1
H+Al ($mmol_c$ dm^3)	65	Cr (mg kg^{-1})	ND
SB ($mmol_c$ dm^{-3})	3.3	Hg (mg kg^{-1})	ND
CTC ($mmol_c$ dm^3)	68	Ni (mg kg^{-1})	ND
V%	6.0	Pb (mg kg^{-1})	ND
		Se (mg kg^{-1})	ND

ND – not detectable by atomic emission spectrometry with inductive plasma (Levels below of: As= 0.86; Cd= 0.24; Cr= 0.4; Hg= 6.0; Ni= 0.56; Pb= 2.2; Se= 9.4, mg kg^{-1}). **Source:** Laboratory of Fertilizer and Corrective of the Department of Soils and Environmental Resources/ FCA-UNESP. Botucatu-SP, 2010.

In this same research structure, two cycles of wheat and soybean were cultivated in May and November 2011 and 2012, and a cycle of sunflower, crambe and beans in September 2013, July 2014 and, December 2015 and 2016, totaling seven cycles in five consecutive years.

For each crop, the amounts of composted sewage sludge were provided based on the recommendation of nitrogen fertilization, emphasizing that the conditions were the same with the present study, both in fertilizer doses and in water types for irrigation.

As described, the amount of composted sewage sludge (CSS) used was based on the replacement of the conventional nitrogen fertilizer by culture. For this, the material mineralization rate of 30%, adjusted for regions with tropical climate was adopted, since the rate of 10% is adopted for temperate climates (ANDRADE, 2010) and the amount of N% detected (that is, in 100 kg of sludge contained 1.5 kg of N) as found in Table 2.

At the end of the calculation, the amount of 223 g $vase^{-1}$ of composted sewage sludge corresponding to 100% of the nitrogen requirement for the beans was obtained. From this result, the other quantities were proportionally calculated at the doses of 50, 150, 200 and 250% of composted sewage sludge (Table 3). The equation used was:

N *availability* = **N** *total x (**NMF** ÷100).* (CONAMA, 2006) (Eq. 01)

Legend of the equation:
N availability = available nitrogen
N total = nitrogen detected in the sewage sludge
NMF = nitrogen mineralization factor

Table 2. Chemical composition of composted sewage sludge.

			MAV(2)	
Parameters	**Unit(1)**	**Concentration**	**Brazil**	**USA**
pH	-	6.1	-	-
Humidity	%	24	-	-
C/N ratio	-	9	-	-
Organic matter	%	58	-	-
Organic carbon	%	32	-	--
Nitrogen	%	1.5	-	-
Phosphor	g kg^{-1}	10	-	-
Potassium	g kg^{-1}	6	-	-
Calcium	g kg^{-1}	19	-	-
Magnesium	g kg^{-1}	5	-	-
Sulfur	g kg^{-1}	5	-	-
Arsenic	mg kg^{-1}	2.1	41.0	75.0
Barium	mg kg^{-1}	225.6	1300.0	-
Boron	mg kg^{-1}	64.0	-	-
Cadmium	mg kg^{-1}	3.7	39.0	85.0
Lead	mg kg^{-1}	14.7	300.0	840.0
Copper	mg kg^{-1}	100	1500.0	4300.0
Cobalt	mg kg^{-1}	2.6	-	-
Chrome	mg kg^{-1}	39.05	1000.0	3000.0
Iron	mg kg^{-1}	1504	-	-
Manganese	mg kg^{-1}	316	-	-
Mercury	mg kg^{-1}	< 1.25	1.0	57.0
Nickel	mg kg^{-1}	13.56	420.0	320.0
Selenium	mg kg^{-1}	< 2.5	100.0	100.0
Zinc	mg kg^{-1}	244	2800.0	7500.0

(1)Expressed results based on dry mass. (2)MAV- Maximum Allowed Values to Brazil: maximum admissible concentration in sewage sludge and by-products according to CONAMA National Environmental Council (375/2006) and USA: maximum concentration of heavy metals allowed in composted sewage sludge according to the United States Environmental Protection Agency (USEPA, CFR Part 503, 1993). **Source:** Laboratory of Fertilizer and Corrective of the Department of Soils and Environmental Resources/ FCA-UNESP.. Botucatu-SP, 2016.

Table 3. Dose of organic compound applied per treatment.

Treatments	Composted sewage sludge							
	2011 and 2012		2013		2014		2015 and 2016	
	(1)	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
T0	-	-	-	-	-	-	-	-
T1	-	-	-	-	-	-	-	-
T2	153	12	125	10	392	3.1	111.5	8.9
T3	305	24	250	20	785	6.2	223	17.8
T4	458	36	375	30	1177.5	9.3	334.5	26.7
T5	610	48	500	40	1570	12.5	446	35.5
T6	763	60	625	50	1962.5	15.6	557.5	44.4

Source: **(1)** Actual amount applied (g vase^{-1}); **(2)** Dose equivalent (Mg ha^{-1}). The treatments T0 (control) and T1 did not receive composted sewage sludge. Botucatu-SP, 2016.

The nitrogen fertilization in the subplots T1 and T2 was based on the recommended rate for each crop, according to Boletim 100-IAC (RAIJ, 1997). In treatments that received CSS, fertilization rates were partial (50%), total (100%) and above the dose (150, 200 and 250%) recommended by the nitrogen equivalent present in the compound, as shown in Table 3. Thus , the treatments applied to each subplot were: T0 = no fertilizer (control); T1 = 100% mineral fertilizer (80 kg N ha^{-1} of urea); T2 = 50% mineral fertilizer + 50% CSS application (80 kg ha^{-1} of N); T3 = 100% CSS (80 kg kg ha^{-1} of N); T4 = 150% CSS (120 kg ha^{-1} N); T5 = 200% CSS (160 kg ha^{-1} N); and T6 = 250% CSS (200 kg ha^{-1} N). It is noteworthy that the amounts of the organic compound applied were the same according to the nutritional requirements of cultivated crops in the years 2014 (crambe), 2015 and 2016 (bean).

The irrigation depth applied daily with drip irrigation was determined by the Class A pan for estimating evaporation, being corrected by the crop coefficient (Kc) adjusted to the plant development stage, according to Allen et al. (1998), considering 95% efficiency of the system, percentage obtained by tests performed according to the methodology proposed by Keller; Bliesner (1990).

To obtain the results concerning soil chemical attributes after 5 years of application of sewage sludge and water types for irrigation, soil samples were collected from all pots at 40 cm from the soil surface, being separated by treatment and homogenized to obtain a representative sample of each treatment. Subsequently, the composite samples were analyzed separately by the Fertilizer and Corrective Laboratory of the Department of Soils and Environmental Resources of the Faculty of Agronomic Sciences of Botucatu, SP. The chemical attributes pH, Orgânic matter (OM), Bases sum (SB), Cation exchange capacity (CEC), bases saturation (V%) and Phosphorus (P) of the soil were determined by Raij et al. (2001) and heavy metals as Arsenic (As), Barium (Ba), Cadmium (Cd), Chrome (Cr), Copper (Cu), Mercury (Hg), Lead (Pb), Nickel (Ni), Selenium (Se) and Zinc (Zn) by ICP-AES: atomic emission spectrometry with inductive plasma (MONTASER; GOLIGHTLY, 1987).

Statistical analyses were performed in SAS software version 9.3 and submitted to analysis of variance with 5% probability, the means being compared by the Tukey test at ≤ 0.05 of significance. The results were later subjected to regression analysis, allowing to construct graphs that demonstrate the behavior of each parameter studied as a function of increasing doses of the composted sewage sludge and water types, with the optimum point determined from the SAS break point for the regressions.

5 RESULTS AND DISCUSSION

Table 4 shows the average levels of heavy metals in the soil in relation to sewage sludge doses and the type of water used in irrigation.

It was observed that the Zn content increased significantly as the sewage sludge application rate increased (CSS) in relation to Cu and Ba. The initial Zn content in the soil was 0.5 mg kg-1 before the application of the organic compound and, with the doses of 8.9, 17.8, 26.7, 35.5 and 44.4 Mg ha^{-1} of sewage sludge, equivalent to 50, 100, 150 , 200 and 250%, the mean contents increased to 43.68, 45.76, 45.46, 47.91 and 47.71 mg kg^{-1}, respectively.

With these results, even after five years of application of sewage sludge, the Zn contents did not exceed the maximum allowable load and did not present contamination risks according to the CONAMA (2009) resolution. It is noteworthy that the use of the effluent increased the bioavailability of Zn, the same behavior was observed for Cu. For Ba, the use of the effluent with the sludge doses decreased its bioavailability in the soil. The levels are also within the limits established by the legislation.

Table 4. Average results of Cu, Zn and Ba in the soil.

Typer of water	Treatments(1)							
	T0	T1	T2	T3	T4	T5	T6	Mean
				Copper (mg kg^{-1})				
EET	7.12 aAB	6.17 aB	7.39 aA	6.79 aAB	6.68 aAB	6.95 aAB	7.70 aA	6.97 A
AP	6.04 bAB	6.76 aA	5.84 bABC	5.08 bBCD	4.45 bD	4.88 bCD	5.31 bBCD	5.48 B
Means	6.58 a	6.46 a	6.61 a	5.93 ab	5.56 b	5.91 ab	6.51 a	–
CV$_1$%				9.97				
CV$_2$%				7.94				
MAV				200.0				
				Zinc (mg kg^{-1})				
EET	29.93 aD	35.63 aC	47.38 aB	48.53 aAB	52.63 aA	50.33 aAB	52.03 aA	45.21 A
AP	30.18 aD	32.33 bD	39.98 bBC	42.98 bAB	38.28 bC	45.48 bA	52.78 bABC	38.86 B
Means	30.06 d	33.98 c	43.68 b	45.76 ab	45.46 ab	47.91 a	47.71 a	–
CV$_1$%				4.94				
CV$_2$%				4.89				
MAV				450.0				
				Barium (mg kg^{-1})				
EET	33.18	33.31	32.66	22.43	32.10	21.85	31.15	29.53 B
AP	33.41	35.73	35.73	33.94	33.03	23.34	31.87	31.42 A
Means	33.27 abc	34.52 a	34.20 ab	28.18 abc	32.57 bc	22.60 bc	31.51 c	–
CV$_1$%				60.79				
CV$_2$%				38.90				
MAV				300.0				

(1)T0 = no nitrogen fertilization; T1 = 80.0 kg ha^{-1} of urea; T2 = 40 kg ha^{-1} of urea + 8.9 Mg ha^{-1} of composted sewage sludge as source of N; T3, T4, T5 and T6 refer to 17.8, 26.7, 35.5 and 44 Mg ha^{-1} of composted sewage sludge as the source of N, respectively. EET = treated sewage effluent;AP = potable water. CV1 = coefficient of variation of plot; CV2 = coefficient of variation of the subplot; * Means followed by the same letters, upper case in the column and lowercase in the line, do not differ among themselves by the Tukey test at 5% of probability. MAV - Maximum allowed value to CONAMA (420/2009). **Source:** Laboratory of Fertilizer and Corrective of the Department of Soils and Environmental Resources/ FCA-UNESP. Botucatu-SP, 2016.

The detected metals are not necessarily considered a threat, since the international concern is focused on the elements As, Cd, Pb and Ni from the assumption that plants can accumulate them and present them to the food chain (USEPA, 1993).

The heavy metals As, Cd, Cr, Hg, Pb, Ni and Se in the soil were not detected by the analytical method used in any of the evaluated treatments. These results are in agreement with the low concentration of metals in the compound and even with the increase of the doses, there was no tendency for the average contents of these elements to raise in the soil.

The possible reason that metal concentrations became undetectable after sewage sludge application probably occurred due to possible changes in the chemical form of the elements after composting, increasing the interaction with the soil particles.

According to McBride (1989), the concentration of metals in the solution may be 1 to 1000 μg dm^{-3} or be less than 1 μg dm^{-3} in some cases. Under these circumstances, the chemical form of the element may remain immobile in the soil by adsorption, especially in non-exchangeable form.

The most plausible explanation is that the bioavailability of the heavy metals has been affected by the organic matter in the material. According to Pan; Xing (2012), the availability of metals to plants depends on the nature of the chemical association between the metal and the organic matter in the organic compound.

These associations are dependent on interactions with pH and inorganic and organic binders such as humic, fulvic and root exudates. The existence of functional groups such as the carboxylic and phenolic groups actually perform the organic-metal-organic interactions and, therefore, make OM a natural multiligant (SMITH, 2009; VIOLANTE, 2010).

These results corroborate with the findings by Roig et al (2012). According to the authors, the analysis of the pollutant content is not enough to interpret a realistic scenario, since it must be applied in combination with the chemicals attributes of the soil, for that, these attributes were evaluated in the present experiment.

The application of sewage sludge doses, irrespective of the source of irrigation water, provided significant increases in all variables. Table 5 shows the mean values of pH in funcion of the treatments. It is verified that the use of the effluent at the dose from 150% increased the initial pH from 4.1 to 6.08, considered suitable for the plants. In the plot irrigated with potable water, it is possible to observe that the doses of sewage sludge possibly provided the increase of the pH of the soil. It is noteworthy that liming was not performed in any of the treatments, in order to verify the effects of treatments on pH.

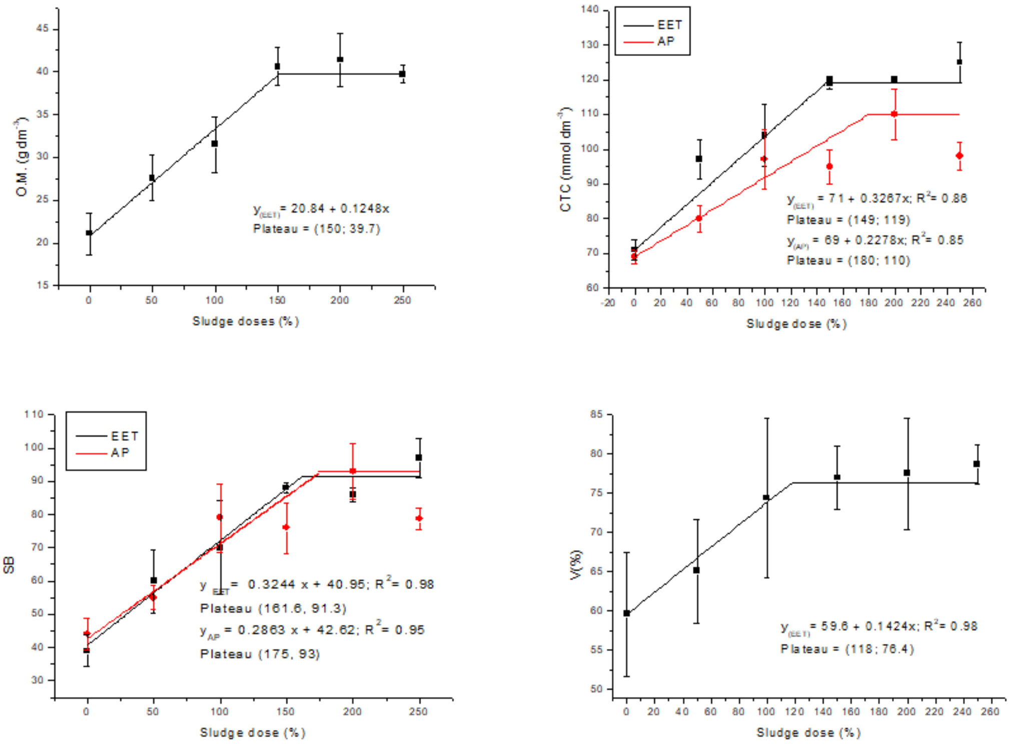
Table 5. Average results of pH in the soil.

Typer of water	**Treatments[(1)]**							
	T0	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**Mean**
				pH				
EET	5.64	5.59	5.69	6.08	6.32	6.33	6.07	5.96 B
AP	4.88	4.71	5.12	5.29	5.38	5.40	5.60	5.20 A
Means	5.26 cd	5.15 d	5.41 bcd	5.69 abc	5.85 ab	5.87 a	5.84 ab	–
CV_1%				2.28				
CV_2%				4.31				

(1) T0 = no nitrogen fertilization; T1 = 80.0 kg ha^{-1} of urea; T2 = 40 kg ha^{-1} of urea + 8.9 Mg ha^{-1} of composted sewage sludge as source of N; T3, T4, T5 and T6 refer to 17.8, 26.7, 35.5 and 44 Mg ha^{-1} of composted sewage sludge as the source of N, respectively. EET = treated sewage effluent; AP = potable water. CV1 = coefficient of variation of plot; CV2 = coefficient of variation of the subplot; * Means followed by the same letters, upper case in the column and lowercase in the line, do not differ among themselves by the Tukey test at 5% of probability. MAV - Maximum allowed value to CONAMA (420/2009). **Source:** Laboratory of Fertilizer and Corrective of the Department of Soils and Environmental Resources/ FCA-UNESP.. Botucatu-SP, 2016.

Figure 1 shows the behavior of the other soil chemical attributes as a function of the treatments fertilized with composted sewage sludge and water for irrigation.

Figure 1. Mean chemical attributes of organic matter (OM), sum of bases (SB), CTC and V% of the soil as a function of the doses of composted sludge (0, 50, 100, 150 and 200%) and waters used for irrigation (EET and AP), after five years, with the optimum point determined from the break point. Botucatu-SP, 2016.



For all variables, there was a quadratic adjustment. Higher averages are observed in the plot irrigated with the treated effluent, evidencing interaction between the doses and water types only for CEC and SB. With the plateau or breaking point, it is possible to observe the optimal dose of sewage sludge next to the type of irrigation water for each studied variable.

It is verified that organic matter content (OM) in the soil increased with the addition of sewage sludge, probably due to the content of the material, and a direct relation between the amount of material and the content reached can be established. The use of EET provided an evident increase in the OM content in relation to drinking water.

Considering the initial OM content in the soil, the addition of sewage sludge and irrigation with the effluent after five years, it was possible to obtain a 96% increase in the content of mineralized organic matter for the plots that received 150% of the composted material, followed by treatments T5 (200%) and T6 (250%) with 92 and 88%, respectively. Nevertheless, the averages presented a quadratic adjustment of up to 150% of the sludge, demonstrating that, with higher doses are given, the stabilization occurs followed by a decrease in OM content in the soil, which probably means that the mineralization in these treatments is occurring more slowly and more gradual.

This effect probably favored the increase of the cation exchange capacity (CEC) of the studied soil, with greater expressiveness also observed in the plots irrigated with EET.

The sum of bases (SB) also increased according to the doses of the material, possibly due to the treatment that the sewage sludge received during the composting, in which is added the virgin lime containing in its composition elements such as Calcium (Ca) and Magnesium (Mg). This increase becomes more evident with the use of the effluent. Results found by Alves (2018) corroborate with those obtained in this study, which found abundant levels of potassium, calcium and magnesium in the effluent, under conditions similar to the one used in this experiment.

The SB influences base saturation (V%). Thus, similar to that observed in SB results, the V% also increased according to the sewage sludge doses, emphasizing that for this last variable, the use of EET was more significant.

These results demonstrate the beneficial effects of sewage sludge on the recovery of soil depleted in organic matter. In addition, this study demonstrates that the use of correctly performed wastewater, over time can be an important alternative to irrigation, especially in soil quality.

On the use of sewage sludge, similar results were found by Schiavoni et al. (2011), the authors affirmed the existence of a direct relationship between the mineralized organic matter and the other soil chemical attributes studied by the authors.

Arthur et al. (2012) in studying the effects of sludge on sandy soil concluded that, for effects to intensify, time will act as an important agent involved in chemical changes occurring both in sewage sludge and in soil, and these changes will contribute to the release of organic, substances such as carbon and nitrogen.

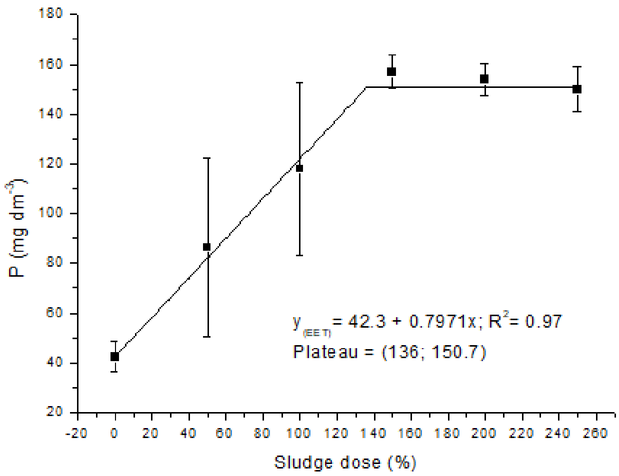
These changes, according to Bonini et al. (2015), increase the organic load of the soil and possibly alter the soil properties, the chemical properties complex, especially the CEC, the organic fraction and positively influence its physical structure.

Once the increase in soil chemical attributes were found in several studies, and considered normal when organic materials are added to the soil, these effects are important according to De Paolis; Kukkonen (1997), so that this leads to an increase in soil capacity to adsorb organic pollutants, as observed.

In addition to evaluations of the bioavailability of heavy metals and soil chemical attributes (pH, OM, SB, V% and CEC), this study evaluated the bioavailability of P in the soil with the use of sludge and effluent irrigation. The rationale for this analysis is the fact that tropical soils are commonly poor in P, in addition to the fact that the degree of weathering of these soils may hinder their availability to plants, and to meet this need, high fertilization loads are needed.

In Figure 2, it can be seen that the behavior of P was similar to OM. The 150% dose of the compound (26.7 Mg ha^{-1}) promoted an increase of 114.68 mg dm^{-3} of the nutrient compared to the control treatment, followed by treatments T5 and T6, with 111.6 and 107.6 mg dm^{-3}, respectively. Irrigation with EET promoted an increase of 14.5 mg dm^{-3} of P in relation to the use of potable water.

Figure 2. P soil content as a function of the doses of composted sludge (0, 50, 100, 150 and 200%) and water used for irrigation (EET and PA) after five years, with the optimum point determined from the break point . Botucatu-SP, 2016.



Considering the initial content of P of the soil, the increases obtained through the above mentioned treatments are data that can be considered important for the sustainability of fertilization of this nutrient. The irrigation with the effluent carried out in the present study was the differential in relation to the others cientific works.

The increase in soil OM accompanied by the increase in soil P content when using composted sewage sludge was also reported by Costa et al. (2014), studying the spatial distribution of P in non-uniformly applied biosolids treated Oxisols, verified linear increases in the available P contents. These variations were directly correlated with the OM content as a consequence of the biosolids applied to the soil.

6 CONCLUSIONS

The total concentrations of heavy metals did not exceed the legal limits in any of the evaluated treatments. In general, lower levels were obtained from the plot irrigated with the effluent treated for Ba. Some toxicity trends related to zinc levels should be taken into account.

The estimated rate of 26.7 Mg ha^{-1} of composted sewage sludge was ideal to increase all soil chemical attributes after five years of application. It is also recommended that the use of smaller doses is better than high applications, as it increases soil fertility and minimizes possible negative environmental impacts related to eutrophication.

In all variables evaluated, it was evident that the type of water has influence on the soil properties, and the use of treated effluent of domestic origin (EET) can be performed as an irrigation alternative.

The findings in this study suggest that research is needed to assess the relationship between deletion effects related to metal complexation with the compound stabilization process.

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