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Soils irrigated with treated wastewater: aspects of salinization and agricultural production with biosolids

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Highlights:

- The use of wastewater in soil is an environmentally friendly option to alleviate water scarcity
- The combined use of biosolids and treated wastewater increase soil nutrients and can replace synthetic fertilizers with low risk of salinization process.
- Biosolids + wastewater reuse in corn cultivation generates high production without negative-affecting plants and soil.

Keywords: reuse; salinity; biosolids.

INTRODUCTION

The global demand for water and nutrients and the risks of insecurity in accessing these inputs reinforce the importance of the practice of wastewater reuse. On the other hand, this solution can result in risks to the soil, such as salinization and changes in its characteristics, as observed by Khanpae (2020). However, treatment systems that generate effluents with low concentrations of salts can promote the increase of nutrients without causing salinity, such as wetland systems (Silva, 2018). The presence of plants helps the leaching process of salts accumulated by simulated rainfall events and this reduced the salinization process (Magalhães Filho et al., 2017).

According to Miranda (2011), when there is salinity, one of the correction techniques used in soils is the use of organic fertilizers. Therefore, an alternative is the use of biosolids, an organic compound rich in organic matter and nutrients, also from the wastewater treatment. One of the main problems with its use is the addition of heavy metals to the soil, which can also be absorbed by plants.

Thus, the objective of the work was to investigate the salinization process of soils irrigated with wastewater in relation to agricultural soil and evaluate the associated use of biosolids in agricultural production, by analyzing the chemical characteristics and potential for accumulation of heavy metals; and by the production of corn grown in these types of soils with different doses of biosolids.

METHODOLOGY

The experiment was conducted in a greenhouse in the city of Campo Grande – MS. To define the initial salinity, samples were collected from two soils irrigated with treated sewage and one agricultural soil for analysis of chemical characteristics. For the maize cultivation 2 types of soils were used: soil irrigated with wastewater for ten years, coming from local WWTP (0,44 $L.s^{-1}$; pH: 7,20; DBO: 59,8 $mg.L^{-1}$; EC: 320,9 $\mu S.cm^{-1}$; TP: 5,9 $mg.L^{-1}$), and common agricultural soil, prepared to receive planting. The experiment was conducted in a completely randomized design, with 12 treatments (Table 3), two of which were controls, two with NPK and four different doses of biosolids, as per the table, defined by the need for Nitrogen for the maize crop, separated between the two types of soil used, with 3 repetitions each, totaling 36 units (Figure 1). The experiment was carried out over a period of 120 days, with 93 days of maize cycle, from planting to harvesting, with 47 days of vegetative stage (V) and 40 days of reproductive stage (R). After the experimental period, samples of soil, corresponding to each treatment, and corn plants were sent to the laboratory for analysis of chemical parameters and heavy metals, according to the Embrapa Soil Analysis Methods Manual (2011), as detailed by Paulino (2022).

Figure 1: Experimental Design – Start and end of experiment.

RESULTS AND CONCLUSIONS

Irrigation with wastewater adds nutrients, organic matter and provides benefits to the soil, however, the characteristics of the water are important to define the changes. It was observed that domestic sewage improved the soil, adding more nutrients, due to the high concentrations coming from WWTPs. Soil salinity parameters presented EC values ranging from 0,349 $mS.cm^{-1}$ to 0,164 $mS.cm^{-1}$ and PST from 6.89% to 4.98%, falling outside the saline classification (Table 1). Parameters such as organic matter and electrical conductivity showed an increase in nutrients, and are detailed by Paulino (2022).

Table 1: Salt-affected soil classification.

Classification	Electrical Conductivity ($mS.cm^{-1}$)	Exchangeable Sodium Percentage
Saline	> 4,0	< 15
Sodic	< 4,0	> 15
Saline-Sodic	> 4,0	> 15

Source: Richards (1954).

It was also observed that the biosolids increased nutrients and organic matter in the soil, without significant changes in salinity, for an initial application (Table 2). The nutrients available with the application of biosolids brought benefits to corn cultivation, with growth and high production of up to 10.63 ton.ha^{-1}, above the state average of 5.5 ton.ha^{-1} (Table 3), leaving the soil with fertility and in conditions to be used for agricultural purposes. Thus, its use as organic fertilizer brings benefits to the producer and the environment, combining high production with sustainable agriculture, adding value to the waste.

Table 2: Chemical parameters of agricultural and WTTP soil.

Treatments	pH	N	P	K	Na	EC	ESP	OM	OC	CEC
	H_2O	g/kg	mg/dm³	cmolc/dm³	mg/dm³	mS/cm	%	g/dm³		cmolc/dm³
Adequate	6,0	–	>15,0	>0,12	–	–	–	30,0	>20,0	>10,0
Limit	–	–	–	–	345,0	1,2	15,0	–	–	–
Agricultural soil										
Control (S)	6,1	1,38	1,6	0,26	84,2	0,24	6,1	8,0	5,0	6,0
Control (E)	5,2	1,53	26,8	0,26	148,2	0,11	7,76	31,0	18,0	8,3
NPK	5,3	1,49	34,4	0,18	131,4	0,12	6,35	23,0	13,0	9,0
25%	4,4	2,26	38,0	0,08	133,1	0,10	6,65	28,0	16,0	8,7
50%	4,2	4,28	103,9	0,08	121,5	0,20	4,48	49,0	28,0	11,8
75%	4,1	5,22	111,2	0,08	136,8	0,24	4,51	58,0	34,0	13,2
100%	4,0	6,47	117,2	0,08	137,9	0,82	3,87	68,0	39,0	15,5
WWTP soil										
Control (S)	5,8	1,84	10,5	0,45	96,3	0,35	4,98	12,0	7,0	8,4
Control (E)	5,4	1,34	7,3	0,16	132,4	0,12	7,89	18,0	10,0	7,3
NPK	5,4	1,25	6,7	0,14	125,2	0,12	7,67	16,0	9,0	7,1
25%	4,3	1,75	28,0	0,09	278,5	0,13	15,33	26,0	15,0	7,9
50%	4,2	3,01	54,9	0,07	128,7	0,14	6,08	30,0	17,0	9,2
75%	4,1	6,97	130,5	0,08	125,7	0,27	4,92	54,0	31,0	11,1
100%	4,2	1,53	129,6	0,06	144,1	0,70	4,41	63,0	37,0	14,2

N = Nitrogen; P = Phosphorus; K = Potassium; Na = Sodium; EC = Electrical Conductivity; OM = Organic Matter; OC = Organic Carbon; CEC = Cation Exchange Capacity; ESP = Exchangeable Sodium Percentage; S = Start of experiment; E = End of experiment.

Moreover, taking as a reference the new CONAMA Resolution no 498 (Brazilian legislation), there is no contamination of soils by heavy metals, without accumulation in the soil and phytotoxicity in plants, however, with different reactions for each metal. Furthermore, despite several studies pointing to heavy metals as the main risk in the use of biosolids, the application did not bring significant changes.

Therefore, considering that the flow rate of 900 L.s^{-1} of ETE effluent generates approximately 150 ton.day^{-1} of sludge, and using the highest production dose D3 (75% - 321.75 ton.ha^{-1}), in a month the sludge generated could cover 14 hectares, producing up to 201 tons of maize. In addition, the experiment confirms the concept of Circular Economy and the Nexus approach (water, energy and food) to reduce the use of synthetic fertilizers. In addition to providing adequate disposal for both sewage sludge, demonstrating smart, safe and sustainable agriculture, with benefits for the agribusiness chain and local communities.

Table 3: Treatments and productivity (t.ha^{-1}).

FERTILIZERS	**PRODUCTIVITY**			
	Agricultural soil		**WWTP soil**	
Soil Control	**T1**	7,84 Aa	**T7**	1,35 Bc
Soil + NPK	**T2**	5,57 Aa	**T8**	0,80 Bc
25% of biosolids	**T3**	8,18 Aa	**T9**	4,30 Bbc
50% of biosolids	**T4**	5,50 Ba	**T10**	10,63 Aab
75% of biosolids	**T5**	8,30 Ba	**T11**	14,41 Aa
100% of biosolids	**T6**	9,49 Aa	**T12**	8,57 Aabc

* Averages followed by the same lowercase letters for the rows and uppercase letters for the columns do not differ statistically from each other using the Tukey test at 5% probability. 25%: 107,25 ton.ha^{-1}; 50%: 214,5 ton.ha^{-1}; 75%: 321,75 ton. ha-1; 100%: 428,6 ton. ha-1.

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