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Effects of Different Rates of Liquid Sewage Sludge Amendment on Nutrient Content of the Soil in Rabat, Morocco †

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Abstract: The objective of this study was to evaluate different rates of the liquid sewage sludge fertilizer developed by a treatment plant in Skhirat, Rabat, Morocco on improving soil fertility indicators. The results revealed that the application of liquid sludge on the soil increased soil pH from 7.3 to 7.7, electrical conductivity from 227.1 to 416.21 $\mu S.cm^{-1}$, and other nutrients such as soil organic matter from 9.0 to 21.4%, Kjeldahl nitrogen (TKN) from 0.1 to 0.7%, and total organic carbon (TOC) from 2.4 to 16.5%; the phosphorus ranged 79.1 to 127.8 $mg.kg^{-1}$ in a dose-dependent manner in amended soil compared to untreated controls. However, the results also showed increase in heavy metal content in the following order: Zn > Cu > Pb > Ni > Cd, (Zn = 136.69 $mg.kg^{-1}$, Cu = 69.05 $mg.kg^{-1}$, Pb = 17.91 $mg.kg^{-1}$, Ni = 4.73 $mg.kg^{-1}$, Cd = 0.03 $mg.kg^{-1}$); nevertheless, we noticed that their concentrations were lower than the critical values established by the European Union for the agronomic use of the soil.

Keywords: soil; sludge; electrical conductivity; agriculture

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1. Introduction

Management and disposal of sewage sludge from municipal wastewater treatment plants is a growing concern, especially with the increase in the world's population [1]. Sewage sludge is the waste product of wastewater treatment plants, produced by the primary (physical and/or chemical), secondary (biological) and tertiary (complementary to secondary) treatment of wastewater [2]. The amount of sludge generated and its composition depend on the properties of the influent and the wastewater treatment process used [3], type of land where sewage sludge is used for soil amendment, and lead improvement in soil structure, fertility, and soil porosity. It also provides an effective means of recycling organic matter and other plant nutrients, including nitrogen and phosphorus [4]. The organic carbon (OC) content in soil amended with sludge can be higher than that of soils amended by inorganic fertilizers [5], while the electrical conductivity (EC) of the soil (with or without lime) increases due to the presence of higher levels of salts [6]. Despite several benefits, sludge application could also increase the accumulation of toxic metals in receiving soils [7]. Sludge may contains trace metals from domestic, commercial industrial, and surface water runoff [8]. In areas of high urbanization and industrialization, sludge can contain high levels of potentially toxic metals, for example, Hg, Ni, Pb, Cd, Cr, Cu, and Zn [9]. Trace metal content in sludge is one of the limiting factors for its application on a bigger scale as a soil amendment. The soil threshold level (content) of metals such as Hg, Ni, Pb, Cd, Cr, Cu, and Zn have been established by European legislation (European Directive 86/278/EEC) to regulates the application, and maintaining these elements at lower levels than the threshold when using sewage sludge for agricultural purposes [10].

The aim of this study was to investigate the liquid sludge sourced from the wastewater treatment plant of the activated sludge lagoon type, located in the city of Skhirat, Rabat, Morocco for its suitability to apply as an amendment for agriculture. It is believed that soil application of liquid sludge can improve soil properties and enhance crop growth and yield.

2. Materials and Methods

Experimental Design and Physico-Chemical Investigation

This experiment was designed to determine the effect of different proportions of liquid sludge (generated by the WWTP Skhirat Morocco) mixed with the soil. Different mixtures of sludge with clay soil were prepared in plastic pots and experimentally monitored for two years. The physicochemical parameters of the sludge and the soil were analyzed and compared with a control soil. The experiment was carried out in plastic pots with a capacity of 5 L. Five treatments were evaluated in a randomized complete block design. The treatments comprised: (1) 20% liquid sludge and 80% soil, (2) 40% liquid sludge and 60% soil, (3) 60% liquid sludge and 40% soil, (4) 80% liquid sludge and 20% soil, (5) 100% soil (control); the texture of soil was determined according to [11]. pH (1:2 w/v soil water) and electrical conductivity (EC) (1:4 w/v soil water) were performed using a multiparameter Type HACHLANG/Model: sensi ON + MM374. The chloride (Cl^-) was determined by titration with AgNO3 [12]. Available phosphorus (P) was measured by NaHCO3-ascorbic acid method [13]. Total Khjeldal nitrogen (TKN) was determined using the Kjeldahl method (Bremner 1996) [14] and total organic carbon (TOC) was determined using titration [15]. Heavy metals such as Cu, Ni, Zn, Pb, and Cd were extracted with acids and determined using a microwave plasma atomic emission spectrometry: MP-AES 4210, at the National Laboratory of Studies and Surveillance of Pollution Rabat Morocco.

3. Results and Discussion

The physicochemical properties and heavy metals of the soil after the experiments in pots are presented in Table 1. Soil pH is one of the most important and widely measured chemical properties of soil that directly influence plant growth. It is a major factor affecting the availability of elements for plant uptake. In the present work, the pH of the liquid sludge applied amended to the soil was within the threshold level for plant growth and ranged from 7.32 to 7.75. Similar results were obtained by other researchers and they also noticed an increase in soil pH after sludge application [16]. With regard to salinity, the measured electrical conductivity (EC) (Table 1) showed that application of the liquid sludge, did not lead to soil salinization, and EC values remained generally in the accepted range of $\geq$4000 µS cm^{-1} according to Cantrell and Linderman, 2001 [17]. The concentrations of macronutrients K, Na+, and P were increased with sludge treatments (20% liquid sludge +80% soil) (Table 1). With the application of sludge, TOC increased from 0.64% (soil control) to 25.34% in 80% liquid and sludge and 20% soil. TOC is directly related to soil fertility and agricultural productivity potential [18]. Most of the sludge treatments decreased C/N ratio, indicating favorable mineralization of sludge. The trace metal content in sludge is one of the limiting factors for its use as a soil amendment. The threshold limits for Cd, Cr, Cu, Hg, Ni, Pb, and Zn have been set by European legislation (European Directive 86/278/EEC). The liquid sludge added to the soil resulted in an increase in heavy metals content in the receiving soil. However, this was mainly a dose-dependent increase (highest increase in the highest proportion of sludge). For the heavy metal content from the 80% sludge treatment, the average values recorded in the treatments was in the following order

Zn > Cu > Pb > Ni > Cd (Table 1). Their concentration in all treatments with sludge was not higher than the critical values defined by the European Union for agronomy.

Table 1. Physio-chemical properties of experimental soils and liquid sludge from the treatment plant in Skhirat, Rabat, Morocco.

Parameter	LS	LS 1/S1	LS2/S2	LS3/S3	LS4/S4	CS	Limits of Heavy Metal Concentrations in Soil
Clay %	-	-	-	-	-	56.12	
Sand %	-	-	-	-	-	12.03	
Silts %	-	-	-	-	-	31.85	
pH	7.86	7.32	7.58	7.69	7.75	7.24	
EC (µS cm^{-1})	3091.08	227.1	249.84	294.15	416.21	213.52	
Moisture (%)	95.14	16.24	38.64	48.98	69.78	14.98	
OM (%)	83.78	9.03	16.78	19.10	21.43	0.71	
TOC (%)	41.71	2.45	4.29	9.12	25.34	0.64	
TKN (%)	1.23	0.19	0.31	0.49	0.73	0.082	
C/N ratio	33.91	12.89	13.83	18.61	22.6	7.8	
P Olsen (mg kg^{-1})	189.47	79,10	86.78	113.29	127.89	26.03	
K+ (mg kg^{-1})	56.47	21,85	29.69	35.90	38.07	4.92	
Na+ (mg kg^{-1})	46.09	13.56	19.37	24.83	27.17	2.4	
Cl- (mg kg^{-1})	2149.16	143.71	194.26	234.51	678.47	8.13	
Zn (mg kg^{-1})	289.84	19.04	26.75	37.11	136.69	7.71	150–300
Pb (mg kg^{-1})	59.03	9.58	11.14	14.98	17.91	4.11	750–1200
Ni (mg kg^{-1})	8.45	2.8	3.1	3.89	4.73	0.4	300–400
Cd (mg kg^{-1})	<0.003	0.001	0.001	0.002	0.03	0.001	1–3
Cu (mg kg^{-1})	116.64	25.49	32.18	43.98	69.05	9.68	1000–1750

LS; liquid sludge, LS1/S1: 20% liquid sludge +80% soil, LS2/S2:40% liquid sludge +60% soil, LS3/S3: 60% liquid sludge+40% soil, LS4/S4: 80% liquid sludge +20 soil, CS: control soil.

4. Conclusions

The potential use of liquid sludge as a soil amendment was evaluated by mixing in different proportions with soil. The highest concentrations of organic matter and macro- and micronutrients (NPK) in the treatments with sludge application indicate its potential to replace mineral fertilizers. The nutrient and heavy metal parameters (trace metals) determined are below the European limits, which indicates it is possible and suitable to apply as a soil amendment. However, a future study on thorough microbial study is suggested to prevent its possible negative effect on human and environmental health.

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References

1. Kelessidis, A.; Stasinakis, A.S. Comparative Study of the Methods Used for Treatment and Final Disposal of Sewage Sludge in European Countries. *Waste Manag.* **2012**, *32*, 1186–1195. [CrossRef] [PubMed]
2. Fytili, D.; Zabaniotou, A.Ã. Utilization of Sewage Sludge in EU Application of Old and New Methods—A Review. *Renew. Sustain. Energy Rev.* **2008**, *12*, 116–140. [CrossRef]
3. Von Sperling, M.; Gonçalves, R.F. *Sludge Characteristics and Production*; Sludge Treatment and Disposal-IWA Publishing: London, UK, 2007.
4. Heimersson, S.; Svanström, M.; Cederberg, C.; Peters, G. Improved Life Cycle Modelling of Benefits from Sewage Sludge Anaerobic Digestion and Land Application. *Resour. Conserv. Recycl.* **2017**, *122*, 126–134. [CrossRef]
5. Nyamangara, J.; Mzezewa, J. Effect of Long-Term Application of Sewage Sludge to a Grazed Grass Pasture on Organic Carbon and Nutrients of a Clay Soil in Zimbabwe. *Nutr. Cycl. Agroecosystems* **2001**, *59*, 13–18. [CrossRef]
6. Mtshali, J.S.; Tiruneh, A.T.; Fadiran, A.O. Characterization of Sewage Sludge Generated from Wastewater Treatment Plants in Swaziland in Relation to Agricultural Uses. *Resour. Environ.* **2014**, *4*, 190–199.
7. Topcuoglu, B. Chemical Speciation, Bioavailability and Environmental Pollution Risks of Heavy Metals in the Greenhouse Soil Amended with Sewage Sludge and Municipal Solid Waste Compost. *Int. J. Adv. Agric. Environ. Eng.* **2015**, *2*, 72–78.
8. Fuerhacker, M.; Haile, T.M. Treatment and Reuse of Sludge. In *Waste Water Treatment and Reuse in the Mediterranean Region*; Springer: Berlin/Heidelberg, Germany, 2010; pp. 63–92.
9. Aljerf, L. High-Efficiency Extraction of Bromocresol Purple Dye and Heavy Metals as Chromium from Industrial Effluent by Adsorption onto a Modified Surface of Zeolite: Kinetics and Equilibrium Study. *J. Environ. Manag.* **2018**, *225*, 120–132. [CrossRef] [PubMed]
10. Fuentes, A.; Lloréns, M.; Sáez, J.; Aguilar, M.I.; Ortuño, J.F.; Meseguer, V.F. Phytotoxicity and Heavy Metals Speciation of Stabilised Sewage Sludges. *J. Hazard. Mater.* **2004**, *108*, 161–169. [CrossRef] [PubMed]
11. Bouyoucos, G.J. Hydrometer Method Improved for Making Particle Size Analyses of Soils 1. *Agron. J.* **1962**, *54*, 464–465. [CrossRef]
12. Karaivazoglou, N.A.; Papakosta, D.K.; Divanidis, S. Effect of Chloride in Irrigation Water and Form of Nitrogen Fertilizer on Virginia (Flue-Cured) Tobacco. F. *Crop. Res.* **2005**, *92*, 61–74. [CrossRef]
13. Watanabe, F.S.; Olsen, S.R. Test of an Ascorbic Acid Method for Determining Phosphorus in Water and NaHCO3 Extracts from Soil. *Soil Sci. Soc. Am. J.* **1965**, *29*, 677–678. [CrossRef]
14. Bremner, J.M. Nitrogen-total. Methods soil Anal. Part 3 Chem. *Methods* **1996**, *5*, 1085–1121.
15. Walkley, A.; Black, I.A. An Examination of the Degtjareff Method for Determining Soil Organic Matter, and a Proposed Modification of the Chromic Acid Titration Method. *Soil Sci.* **1934**, *37*, 29–38. [CrossRef]
16. Zhang, S.; Wang, S.; Shan, X.; Mu, H. Influences of Lignin from Paper Mill Sludge on Soil Properties and Metal Accumulation in Wheat. *Biol. Fertil. Soils* **2004**, *40*, 237–242. [CrossRef]
17. Cantrell, I.C.; Linderman, R.G. Preinoculation of Lettuce and Onion with VA Mycorrhizal Fungi Reduces Deleterious Effects of Soil Salinity. *Plant Soil* **2001**, *233*, 269–281. [CrossRef]
18. Veeresh, H.; Tripathy, S.; Chaudhuri, D.; Ghosh, B.; Hart, B.; Powell, M. Changes in Physical and Chemical Properties of Three Soil Types in India as a Result of Amendment with Fly Ash and Sewage Sludge. *Environ. Geol.* **2003**, *43*, 513–520. [CrossRef]