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EFFECT OF BIOSOLIDS ON THE PHYSICOCHEMICAL PROPERTIES OF AN INCEPTISOL OF THE MUNICIPALITY OF PUEBLA, MEXICO

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Abstract

Biosolids are an option for improving the physical characteristics and chemical of soils of low fertility since they can incorporate organic matter and nutrients. Therefore, the objectives of this study were to assess how modify the properties of fertility and also to determine if biosolids application represents an environmental hazard. Biosolids increased the content of organic matter, nitrogen, phosphorus and exchangeable bases of soil, potassium and magnesium; while sodium and calcium decreased, the textural class was modified by sandy clay loam to loam due to the incorporation of smaller particles. It was concluded that the biosolids are materials capable of application to agricultural soils to improve their physical and chemical properties if adequated evaluations are carried out to ensure the safety of soils and the trophic network. However, it is necessary to monitor the soils that are incorporated since there is a risk of contamination by a high concentration of nutrients and heavy metals.

Key words: macronutrients, soil texture, soil monitoring.

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Introduction

Biosolids are muds that have undergone processes of stabilization and due to its content of organic matter, nutrients and properties acquired after its stabilization, may be susceptible to exploitation; one of these applications is in agriculture (Gagnon *et al.*, 2010).

Biosolids are rich in organic matter, nitrogen and phosphorus which make them potentially useful as fertilizer. They also improve the physical and chemical soil properties such as bulk density, structure, porosity retention of water, pH, cation exchange capacity, among others soil properties; all of which can be reflected in an increase in crops yield (Mahady *et al.*, 2009).

Today has increased the need to cover the benefits of the use of solids waste as biosolids and to leave of consider these by-products as "waste"(Reza, 2009).

Countries from all continents have legislation and studies for the final disposal of biosolids on agricultural soils; which stress the importance of their management and re-use. In Mexico its use it is regulated by the NOM-004-SEMARNAT-2002 (SEMARNAT, 2002).

Treatment of waste water and the management of produced solids are a global issue, with increasing challenges that must involving managers and operators, regulators, politicians, generators of waste water, public in general and the scientific community.

So it is important to achieve quality standards for biosolids which are applied on agricultural soils to avoid that these soils suffering from irreversible changes. The search for alternatives to the minimization and reuse of various waste generated are the new challenges that the man has to face for a sustainable future. Application of biosolids to degraded agro-ecosystems modifies directly its physical, chemical, and biological properties so they have a key role in the recovery of the quality of these type of ecosystems. The efficiency of these biosolids as fertilizer depends on several factors, among which are the type of soil and crop, the quality of the biosolids and environmental factors that will directly affect the processes of mineralization and the availability of nutrients for the plant (Postisek *et al.*, 2010).

The municipality of Puebla, Mexico, produces around 140 t of biosolids daily in various wastewater treatment plants and these biosolids can be used for fertilizing and to reduce the erosion of agricultural soils dedicated to corn production in the south of the municipality and thus to achieve and increase in the productivity of crops and to growth the local economy (Oumet *et al*., 2015).

The application of biosolids as soil amendment can incorporate, in addition to nutrients, some heavy metals which in high concentrations can cause damage to human health and natural resources, it is thus necessary to monitor the quantities of these both in soil and in plant tissue.

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The content of heavy metals may be a limiting factor for the application of biosolids to agricultural soils (Alleman *et al.*, 1990). The most common heavy metals found include Cr, Ni, Cu, Zn, Cd, and Pb. Some of them such as Cu and Zn are essential elements for the plant and its deficiency may cause problems in crops, whereas if they are in excess they imply risks of toxicity. The others have no recognized physiological functions and its presence on soil will always be a potential risk, either for plants or for consumers (Shober *et al.*, 2003). Therefore all countries using biosolids as organic amendment has legislated its use to not overpass limits of chemical elements which are a risk to health and, this way, to prevent an environmental damage (Wichelns and Manzoor , 2015).

The objectives of this study were to measure the physical and chemical properties of the soils which are modified when biosolids were applied.

Materials and methods

The study was carried out in the Research Department of Agricultural Sciences of the Institute of Sciences of the Autonomous University of Puebla, located in the municipality of Puebla, Puebla, Mexico.

Study area: The study site is located in an agricultural area of the southern part of the municipality of Puebla, Pue. Mexico, within the geographical coordinates $18^o48'$ y $18^o56'$ latitude N and $98^o11'$ y $98^o17'$ longitude W (INEGI, 1999), mainly dedicated to rainfed corn and bean farming. The soils consist of lithic materials of volcanic and sedimentary nature, are shallow to moderately deep and are located in a flat to undulating topography, morphologically presented profiles of incipient formation in which stands out the presence of a cambic (B) horizon of yellowish brown hues (Soil Survey, 2010). In this area were selected 2 experimental plots of 100 m^2 each, where one of them was treated with biosolids and the other was used as a control.

Biosolids: Biosolids that were applied to the soil were obtained at the "Atoyac" wastewater treatment plant. The solids were stabilized by anaerobic digestion for 21 to 28 days and then were dried on filter in band. Biosolids does not reach the maximum limits for heavy metals and microorganisms for its use and disposal according to the NOM-004-SEMARNAT-2002.

Soil sampling: 15 individual soil samples were taken at the first 30 cm of soil depth; sampling was made by the zig-zag method, and it was made a composite sample of each soil. Samples were dried at room temperature, and in the shade. Each sample was sieved in a stainless steel sieve mesh number 10, according to NOM-021-SEMARNAT-2000.

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Physical-chemical soil analysis: The methodology was based on the NOM-021-SEMARNAT-2000 (SEMARNAT, 2000), according to the specifications of fertility and the following parameters were quantified: texture, pH, organic matter, total nitrogen, P, K^+, Ca^{++}, Mg^{++}, Na^+, and cation exchange capacity. The soil analysis was made before and after doses of biosolids were applied.
Soil labour: all farming tasks were performed according to the use of farmers in the area and were marked by the climatic conditions. Biosolids were applied in a single annual dose of 140 t ha^{-1} in wet base, using dump trucks, were scattered and homogenized with a tractor and incorporated into the soil 4 weeks prior to planting, to improve their properties and increase nutrient content. In both plots, maize was planted and the harvest was collected during the month of December 2012.

Results and discussion

Table 1 and 2 shows the characteristics of the biosolids used in this study which were provided by the system operator of drinking water from the municipality (SOAPAP). The results indicate that these biosolids do not exceed the maximum permissible limits of metals in study according to the NOM-004-SEMARNAT-2002, and correspond to type A biosolids, according to Mexican regulations these biosolids can be applied to agricultural and forest soils.

Table 1. Physical-chemical analysis of the Atoyac South WWTP biosolids (dw)

Parameter	Result
pH	7.2
% M.O.	40
% Ash	60
% Nitrogen	1.29
Cd ppm	0
Cu ppm	200
Cr ppm	110
Pb ppm	300
Zn ppm	800
Mn ppm	102

Table 2. Microbiological analysis of Atoyac South WWTP biosolids

	Fecal coliform MPN/g on a dry basis	Salmonella spp. MPN/g on a dry basis	Eggs of helminths/g on a dry basis
Atoyac	Absence	Absence	Absence

Table 3 shows the evaluated parameters in the soil treatment with biosolids and soil treatment without biosolids.

Table 3. Soil analysis

	Soils without biosolids	Soil with biosolids
% Sand	46	50
% Silt	26	42
% Clay	28	8
Textural class	sandy clay loam	Loam
% Nitrogen	1.7	4.2
% MO	3.5	7.0
CEC (cmol kg^{-1})	19.0	22.0
pH	7.1	6.3
K ppm	24.9	35.2
Na ppm	28.6	24.7
Mg ppm	28.6	34.2
Ca ppm	68.0	77.4
P ppm	22.7	38.7

The texture of the soil treated with biosolids it was modified from Sandy clay loam to loam due to the incorporation of particles of different size fractions, this being attributable to changes in the surface soil horizon generated by greater aggregation of particles of the soil system by action of the organic matter associated with sludge, thereby increasing the macroporosity. From the point of view of benefits to plants, this textural class is that which presents a better balance between their separate fractions (Rojas *et al.,* 2010).

Soil control presented a neutral pH of 7.1 and soil amendment with biosolids presented a slightly acid pH of 6.3, this slight decrease in pH value may be due to the formation of organic acids product of the addition of organic matter to the soil (Torri, 2012), incorporating to soil with high organic matter loads provokes a reactivation of the bacteria presents in biosolids, increasing its metabolism and decreasing soil pH values (Costa *et al.*, 1987).

The percentage of organic matter in soils with biosolids treatment increase of 3.5 to 7.0, similar results were reported by Vaca *et al.*(2011), the most significant effect of the application of biosolids is the increase in organic matter content which leads to improve water retention in soils and physical properties, It is important to note that increased organic matter in soils due to biosolids also influences the soil organic carbon (SOC), so in recent years the carbon cycle in soils amended with biosolids begins to be studied (Gass, 1992). Cation exchange capacity in soil amended with biosolids application increased slightly. The percentage of total nitrogen increased from 1.7 in the soil control to 4.2 in biosolids treated soil, this is of great importance since the increase in the total nitrogen percentage represent a risk of groundwater contamination and it should be considered for the application of biosolids. Being that the consumption of nitrogen by present or future vegetation should be a key parameter to take in account when the rates of application of this element are determined (Akrivos *et al.*, 2002).

The amount of phosphorus in the soil without treatment was 22.7 ppm and presented a considerable increase in treated soils to 38.7 ppm, this suggests that P contained in biosolids suffers chemical transformations in the soil, i.e. that the organic fraction of this P is transformed by different mechanisms to mineralized forms; examples of this is the following reaction catalyzed by various fungi and bacteria (*Bacillus, Aspergillum, Penicillium*): $Ca_3(PO_4)_2 \rightarrow H_2PO_4^-$, so important in plant nutrition (Studart, 2004).

The soil bases generally increased with biosolids application, for potassium from 24.9 ppm to 35.2 ppm, for magnesium from 28.6 to 34.2 ppm; for sodium is observed a decrease of 28.6 ppm to 24.7 ppm, and for calcium there is an increase from 68.0 ppm to 77.4 ppm. Effect of biosolids on the soil bases should be monitored to avoid a possible salinization of soils due to the possible high quantities of bases that are incorporated at soil with biosolids that may represent a gradually cumulative process (Miralles *et al.*, 2007).

The results of the characterization of the soils and the influence of biosolids application on the content of some elements of agronomic interest, indicate that the application of these organic waste increases the soil content of SOC and essential elements assimilated by plants, which is an aspect of vital importance because of the role played by these in plant development, and the higher content of SOM as a gradual and important source of nutrients, primarily of nitrogen, which at the same time positively influences the soil physical and chemical properties (Jurado *et al.*, 1991; Jurado *et al.,* 2013).

Table 4. Metals content in soil (ppm)

	Without biosolids	With biosolids
Cadmium	0.0	0.0
Lead	0.6	1.4
Iron	1.6	9.6
Copper	7.3	106
Nickel	0.4	1.3
Chromium	0.01	0.01
Manganese	2.5	9.8
Zinc	5.6	71.3

The concentration of Cu, Cd, Cr, Ni, Pb, Zn, Fe, and Mn in soils treated with biosolids increased due to the incorporation of these residuals, however, the metals content are within the maximum limits for soils of agricultural use (Kabata, 1992). Results of the metals content in soils are shown in table 4.

It was quantified heavy metals content in corn plots with treatment of biosolids and untreated; the results are shown in table 5:

Table 5. Concentration of heavy metals in corn grain (ppm)

	With biosolids	Without biosolids	Kabata-Pendias, 2000
Cadmium	0.1	0.1	3
Nickel	0.7	0.5	5
Lead	2.5	2.3	10
Chromium	0.1	0.1	3
Iron	1.4	1.3	-
Manganese	0.3	0.01	26
Copper	0.5	0.03	5
Zinc	2.0	1.7	35

The effect of biosolids on the contents of metals in the grains of maize showed a slight increase in soils with biosolids, so it must be follow the monitoring, expecting are being not altered soil properties as REDOX potential and pH that could increase the availability of the metals for crops (Chaney, 1992; Robledo *et al*., 2010).

Conclusions

Results indicate that biosolids are suitable for soil improvement and agricultural applications since they are classified as type A (according to Mexican regulations):

- The Soil used as control presented characteristics of low fertility.
- The physical and chemical characteristics of fertility are improved with the incorporation of biosolids.
- Most important nutrients for growth increased considerably, which can improve the productivity of crops in soils treated with biosolids.
- It is important to continue with the monitoring of the changes that occur in the physical and chemical properties of the soils because of long-term benefits of the use of biosolids on agricultural soils.

- The quantities of metals in soil treated with biosolids slightly increased compared to the soil that had no treatment, these levels of metals are acceptable for agricultural soils.
- The content of heavy metals in corn grains do not exceed the maximum permissible limits by another author (Kabata-Pendias, 2000) and also its concentration increased in corn grains produced in soils applied with biosolids.
- It is necessary to carry out regular evaluations to ensure that the accumulation of metals is no dangerous to soil or crops and thus to make an adequate use of biosolids as a soil amendment.

References

Akrivos, J., D. Mamais, K. Katsara and A. Andreadakis. (2000) Agricultural utilization of lime treated sewage sludge. *Water Science and Technology*. **42** (9), 203-210.

Alleman, J.E., Bryan, E.H., Stumm, T.A., Marlow, W.W., Hocevar, R.C. (1990) Sludge-Amended Brick Production: Applicability for Metal-Laden Residues, *Water Science and Technology*, **22**(12), 309-317.

Chaney, R.L., (1989) Toxic element accumulation in soils and crops: protecting soil fertility and agricultural food-chains. En*: Inorganic Contaminants in the Vadose Zone.* Bar-Yosef, B., Barrow N.J., Goldshmid, J., eds. Springer-Verlag, Berlin, 140-158.

Costa F., Hernández M.T., Moreno J.I. (1987) Factores limitantes de la utilización agrícola de los lodos residuales. En: *Utilización agrícola de los lodos de depuradora*. CSIC. Centro de Edafología y Biología Aplicada del Segura.Murcia, España, 41-60.

Gagnon, B., Ziadi, N., Côté, C., Foisy, M. (2010) Enviromental impact of repeated applicatios of combined paper mill biosolids in silage corn production. *Canadian Journal of Soil Science*, **90**(1), 215-227

Gass W.B., Sweeten J.M. (1992) Benefits of applying sewage sludge on agricultural land. *Texas Agric. Ext. Serv. Publ. B-1637*. College, Station, TX. The Texas A&M Univ. System; 1-13.

INEGI, Instituto Nacional de Estadística y Geografía (1999) *Síntesis Geográfica del Estado de Puebla*. INEGI.

Jurado, G.P., Sierra, T.J.S., Lara, M.C., Saucedo, T.R., Morales N.C., (2013) "Establishment of Native Grasses with Biosolids on Abandoned Croplands in Chihuahua, Mexico, "*Applied and Environmental Soil Science*, **2013**, Article ID 573808, 7 pages http://dx.doi.org/10.1155/2013/573808

Jurado, P., Arredondo, T., Flores, E., Olalde, V., Frías, J. (1991) Efecto de los biosólidos sobre la humedad y los nutrientes del suelo y la producción de forraje en pastizales semiáridos. *Terra Latinoamericana*. **25**(2), 211-218.

Kabata-Pendias, A., Pendias, H. (1992) Trace elements in soils and plants. 3nd ed. CRC. USA 365 p.

Mahady, A.M., Elkhatib, E.A., Fathi, N.O., Lin, Z.Q. (2009) Effects of Co-Application of Biosolids and water treatment residuals on corn grow and bioavailable Phosphorus and Aluminum in Alkaline soils in Egypt. *J Environ Qual.* 2009 May **20**; 38(4).

Miralles, R., Beltrán, M.L., Porcelma, L., Delgado, M., Valero, J., Calvo, R., Walter I. (2007). Emergencia de seis cultivos tratados con lodo, fresco y compostado, de estaciones depuradoras. *Revista Internacional de Calidad Ambienta*l, **18(**003). Universidad Nacional Autónoma de México.

Oumet, R., Pascale, A., Hérbet, M. (2015) Long-term response of forest plantation productivity and soils to a single application of municipal biosolids. *Canadian Journal of Soil Science*, **10**.4141/cjss-2014-048

Postisek, T., Figueroa, U., González, G., Jasso, R. (2010) Aplicación de biosólidos al suelo y su efecto sobre contenido de materia orgánica y nutrimentos. *Terra Latinoamericana*. **28** (4), Soc. Mex. de la Cs. del Suelo.

Reza, I., Hubertus, H., Cox, J. (2009) Production of exceptional quality biosolids (class A) at city of los Angeles´s wastewater plants*. Revista AIDIS,* **2**(1), 84-107.

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Robledo, E., Espinosa, V., Maldonado, R., Rubiños, J. E., Hernández, E., Cortay, L. (2010) Sales Solubles y Metales Pesados en Suelos tratados con biosólidos. *Revista Chapingo. Series Ciencias Forestales y del ambiente*. **16** (2), julio-diciembre, 241-251.

Rojas, M., Dendooven, L., Garza, L., Souza, V., Philippot, L., Cabirol, N. (2010) Effects of biosolids application on Nitrigen dynamics and microbial structure in a saline-sodic soil of the former Lake Texcoco (Mexico). *Bioresour Technol,* 2010 Apr, **101**(7):2491-8.

SEMARNAT, Secretaria de Medio Ambiente y Recursos Naturales (2000) *NOM-021-SEMARNAT-2000. Norma Oficial Mexicana que establece las especificaciones de fertilidad, salinidad y clasificación de suelos, estudio, muestreo y análisis*. DOF, 31 de diciembre de 2002.

SEMARNAT, Secretaría del Medio Ambiente y Recursos Naturales (2002) *NOM-004-SEMARNAT-2002. Norma Oficial Mexicana. Protección ambiental. Lodos y biosólidos. Especificaciones y límites máximos permisibles de contaminantes para su aprovechamiento y disposición final*, México.

Shober, A.L., Stehouwer, R.C., Macneal, K.E. (2003) On-farm assessment of biosolids effects on soil and crop tissue quality. *J. Environ. Qual*. **32**(5),1873-80.

Soil Survey Staff (2010) *Claves para la taxonomía de suelos, Departamento de Agricultura de los Estados Unidos.* Servicio de Conservación de Recursos Naturales.

Corrêa, R.S. (2004) Efficiency of five biosolids to supply nitrogen and phosphorus to ryegrass. *Pesq. agropec. bras*., **39**, 1133-1139.

Torri, S.I., Alberti, C. (2012) Characterization of organic compounds from biosolids of Buenos Aires city *Journal of Soil Science and Plant Nutrition*, 2012, **12** (1), 143-152.

Vaca, R., Lugo, J., Martínez, R., Esteller, M.V., Zavaleta, H. (2011) Effects of Sewage Sludge and Sewage Sludge Compost Amendment on Soil Properties and *Zea mays* L. Plants (Heavy Metals, Quality and Productivity). *Rev. Int. Contam. Ambie*, **27**(4), 303-311, 2011.

Wichelns, D., Qadir, M. (2015) Policy and Institutional Determinants of Wastewater Use in Agriculture. In Drechsel, P., Qadir, M., Wichelns, D. (Eds.), *Wastewater: economic asset in an urbanizing world*, Dordrecht, Springer, Netherlands, 93-112.