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Humus physical-chemical features obtained from biosolids from wastewater treatment processes

Características físico-químicas de humus obtenido de biosólidos provenientes de procesos de tratamiento de aguas residuales

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Abstract

Global practices of handling, storage, transportation, and disposal of organic waste constitute one of the challenges of complexity and relevance; Since these are considered as a potential focus of pollution of natural resources. One of the factors, increased incidence, relates to the treatment of domestic wastewater, which has as a by-product the biosolids; These defined as elements, solid, semi-solid or liquid possessing high content of organic matter (MO) and nutrients like nitrogen (N), phosphorus (P) and potassium (K); and is considered the possibility of process and take advantage of them, using different alternatives to reuse. One of them, the technique of vermicomposting, is based on OM stabilize it by the action of worms of different species, which are able to feed on these substrates, generating humus, which can be used as soil or manure. This research shows the case where developed a system of reactors, with worms of the Californian red species, *Eisenia foetida*; using as raw material from biosolids from the treatment of wastewater of the New Granada Campus, UMNG, Cajicá, Cundinamarca. Is it aimed at generating and measuring a biological process of stabilization that the conditions of the biosolids, where retrieved humus can be used as amendment to the recovery of soils; establishing the physicochemical characteristics of the final product, under the framework of the NTC 5167. And can conclude that it is within the limits established by the regulation, to be used as a soil conditioner, degraded or Decompensated by anthropogenic or natural processes.

Keywords: humus; vermicomposting; biosolids; commercial fertilizer.

Introduction

The manipulation, storage, transport and final disposition of the organic residues needs prompt attention for its impact on the environment since they are considered to be a potential source of affectation of the natural usable resources.

Between them, there are the residues generated in the treatment of domestic wastewater which takes the biosolids as by-products

These are defined as solid, semisolid or liquid elements that possess a high content of Organic Matter (MO) and macronutrients as nitrogen (N), I phosphorous (P) and potassium (K). It is considered to be the alternative of processing them and to take advantage of them, using different options orientated to the reuse.

One of them is the practice of vermicompost, which MO is based on the stabilization of, for the operation of worms of different species, which are capable of being nourished of this residual substrate producing humus, which could be in use as a conditioner of soils or organic credit.

The case of raised study developed in the University Campus of the Military University New Granada, UMNG located in Cajicá's municipality, Cundinamarca's department; where a system developed of vermicomposting, with the species *Eisenia foetida.*

It was used as raw material the biosolids from the Plant of Wastewater Treatment - (PTAR) of the UMNG; a plant that produces a maximum flow of 2,5 L/s of residual water and generates on average 40 kg/weekly of biosolid (Aguacol, 2008).

It was intended, establish variations in the initial biosolid and the resultant humus (in the process of vermicomposting raised), the improvements evaluated in the conditions of the substratum, in its characteristics physicist - chemistries of MO'S concentrations, macro and mike elements, according to the established for the norm NTC 5167 (Colombian Institute of Technical Procedure and Certification - ICONTEC, 2004).

Organic residues of wastewater treatment plants

The integral management of organic residues, represents one of the challenges of major relevancy worldwide, due to the fact that they are considered to be a potential area of pollution of the natural usable resources for the human being; which has led to raising biotechnological alternatives that allow its stabilization and utilization, for benefit of the planet (Martínez, 2015).

One of the factors of a major incident in pollutant processes relates to the processing of served and affluent industrial waters in the Plants of Wastewater Treatment - (PTAR). In the by-products from these methodologies, the residual muds are outlined or biosolids, which are generated in high levels (Hernández-Rodríguez, Ojeda-Barrios, López-Díaz & Arras-Vota, 2010).

Between the principal characteristics physicist-chemistry, of this substratum, you can find:

pH in values near to the neutral one; as the brought for Peñarete, Silva, Daza, Torres & Urrutia (2013), showing a value of 7,6 for biosolids of PTAR Cañaveralejo de Cali (V).

Density valued for 1,24 g/cm3 in a cycle of the culture of four months (Peñarete Murcia *et al.*, 2013).

The high content of Organic Matter (MO), between 60 and 70 %; as well as of values raised in content of such macronutrients as, nitrogen (N), phosphorus (P) and potassium (K), cataloged like essential for the vegetable development (Castro, Henríquez y Bertsch, 2008).

Systems of treatment for organic residues

Since alternatives to the treatment of the organic substrate, there appears the compost and the production of credits. And his option, the vermicomposting, as an applied technology that presents a biotechnological process of degradation and MO'S stabilization, by means of the action of worms, which feed of the residues, accelerating its decomposition (Fernández, 2011; Hernández-Rodríguez, *et al.*, 2010).

To this level, the credit presents a series of properties and characteristics that help to increase the fertility of the soil. Inside the physical properties, the improvement is outlined in the structure, texture, and permeability of the soil, increasing the level of water retention (Fund for the protection of the water - FONAG, 2010).

It is necessary to annotate, also, that the use and incorporation of chemical fertilizers and credits, appears as a practice associated with replacing the needs relating to

the growth of the different vegetable species in a culture, as well as the recovery of the soils, bearing in mind that its application allows to increasing MO'S levels (Acosta and Peralta,2015).

Studies realized in preliminary investigations, show that the organic credits can be implemented in lands in which intense cultures are realized; providing as a benefit the improvement in the structure of the soil, by means of the increase of the capacity of water retention (Fernández , 2011).

On the market it is easy to find credits and chemical commercial fertilizers of solid character described like simple, compound and of blending, as well as liquids and fertilizers organ - mineral; that differ from the organic ones due to the fact that they generate harmful effects with a use extended in the time (Motta & Pinzón, 2011).

According to the NTC 5167 (ICONTEC, 2004), the classification of organic credits solid minerals is defined as a mixture or combination of mineral and organic credits of animal, vegetable origin, pedogenetic (geological) or from muds of treatment of wastewater (biosolids), that contain minimal percentages of MO (expressed as organic carbon total oxidable); determining its use in processes of recovery of soils (ICONTEC, 2004).

The methodology applied in the biological reactors

This work was realized in the facilities of the University Campus, UMNG, Cajicá, Cundinamarca located to a length of 74°00.552 ' Or, latitude of 4°56.543 ' N and height of 2580 msnm; with an average temperature of 13 °C and with relative average dampness of 82 % (as physical characteristics of the area).

Samples took of biosolids, from the PTAR UMNG (Figure 1A and 1B), due preserved, labeled, and packed in iceboxes with temperature brought near to 4 °C. Registered for the analysis, following the methodologies of "*Standart Methods for the Examination of Water and Wastewater*".

Figure 1. Facilities of PTAR UMNG, Cajicá, Cundinamarca
Source: the authors

The project was carried out by the implementation of a biological reactor (system of vermicomposting); allowing to evaluate the behavior of individuals of the species Eisenia foetida (Figure 2A), obtained of a previous culture of the supplier - "Lombricultura de Tenjo" adapted to the consumption of biosolids.

The substratum used as raw material for the supply of the worms was the biosolid, which appears in Figure 2B.

Figure 2. Species of culture Eisenia foetida in Biosolid PTAR-UMNG
Source: the authors

El design of the reactor, in modular beds (Figure 3) allowed the control of the necessary conditions for the development of the process, using a container for it of 2,00 m of length, 1,00 m of width and 0,30 m of height, covered with plastic in its interior, with divisors, according to the showed figure.

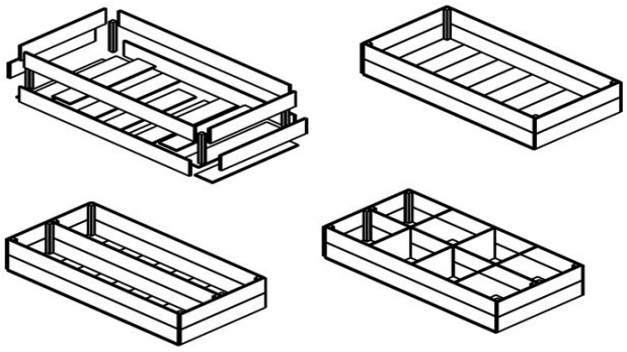

Figure 3. Modular beds of vermicomposting
Source: the authors

The interior of the reactor was adapted by a gravel cap of 0,15 m of height; followed by a substratum cap (biosolid) of 0,05 m of thickness, correspondent to approximately 60 kg; adding the individuals (worms) in the top part, according to a population study and of consumption, before realized. Covered with poly-shade, in order to mitigate the environmental effects of dampness loss, climatic variations, proliferation of vectors and for the condition of photophobia of the worms; everything inside a greenhouse.

Evaluations techniques

The reactor worked for 90 days; where monthly there was applied, additional, a cap of 0,075 m of biosolids, corresponding to a total of 95 kg, finishing the month 1 and finishing the month 2. Spent three months, there was realized the final analysis (characterization) of the resultant humus.

Analyses were done to the biosolid without any type of treatment (initial substratum), to the resultant humus (vermicomposting) and to a sample of control.

The techniques used for the determination of the evaluated parameters were: nitrogen according to Kjeldahl; phosphorous for colorimetry; lead, chrome, cadmium, and potassium for atomic absorption (metals weighed by acid digestion); content of organic carbon for calcination; pH in saturation extract; and density for method of pycnometer

Achieved results

In Table 1 appears the physicochemical characterization obtained of the biosolid, humus, and substratum control, in the parameters previously described; with its respective value maximum limit of NTC 5167 (ICONTEC, 2004).

Table 1. Characterization of the initial biosolid, humus final, experience control and its respective value in the NTC 5167 (ICONTEC, 2004)

Parameter	Initial Biosolid	Final Humus	Control	NTC 5167
pH	6.30	6.80	6.30	Reportar
Moisture content (%)	75.27	69.30	56.40	Max 15%
Density (g/cm3)	0.89	1.20	1.10	Reportar
Carbon ratio: nitrogen (C/N%)	13.26	18.40	9.11	Reportar
Ash content (%)	48.20	68.85	62.43	Reportar
Oxidized organic carbon content (%)	23.87	14.35	17.31	5-15%
Total Nitrogen (%)	4.50	4.90	8.30	Min 2 %
Total Phosphorus (%)	1.10	2.70	2.00	Min 2%
Total Potassium (%)	0.30	1.40	1.10	Min 2%
Cadmium (mg/kg)	0.90	0.60	0.9	Max 39
Chrome (mg /kg)	20.50	11.80	20.50	Max 1200
Lead (mg/kg)	19.00	7.70	19.00	Max 300

Source: the authors

Discussion and analysis

Of the obtained results, in the physical properties, the pH didn´ have a significant variation (C.V=0,04), though an increase is observed in the final humus

This can originate in the process of mineralization of the nitrogenous compounds in nitrates, compounds NOx and other acid organic compounds. Considering that in values of pH nearby for 7 waits for favorable growth of the worms in the mud (Ndegwa & Thompson, 2000).

For their part, the dampness, which is a factor of great importance in the process of compost, for being the way by which the substances and nutrients are transported, allows the assimilation for the great variety of present organisms. This one must go diminishing as the time happens of composting since values lower than 35 % show a system of compost unstably (Román, Martínez & Pantoja, 2013).

Though the final value obtained of the proposed process didn´t expire with the requirements of the Colombian norm, there is demonstrated that the analyzed sample was taken after the eradication; and generally, the obtained humus is extracted, ground and dried by unitary processes that can modify the dampness of the final product.

In the transformation from the thick to thin material, typical of the humus, the increase is explained of density in the system; bearing in mind that densities over 1,4 g/cm3 consider being discharges for soils of thin textures Peñarete *et al.*, 2013).

The content of organic carbon is an indicator of MO'S concentration and an index of the humus quality; according to the NTC 5167 (ICONTEC, 2004) this percentage must be between 5 - 15 %. Figure 4 presents the variation of this parameter in the system of vermicomposting proposed.

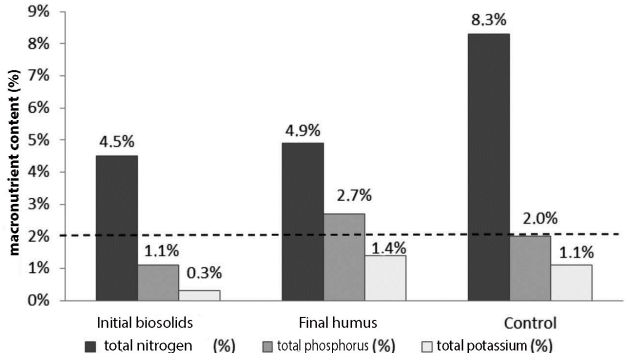

Figure 4. The behavior of the macronutrients in the treatment
Source: the authors

Is observed a decrease of the percentage (C.V=0,25), due to the fact that during 90 days of treatment, MO was the food of the present organisms in the system (It Figures 5). What influences favorably the reduction of the relation C/N, since a major bioavailability of the nitrogen will exist for the plants when it is used as a credit (Sinha, Herat, Bharambe, & Brahambhatt, 2010).

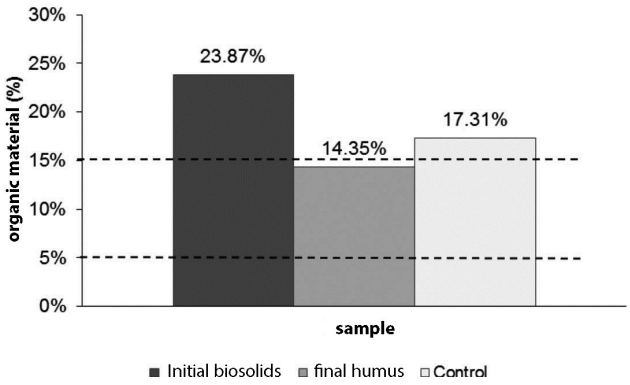

Figure 5. Content of organic matter of the samples initial and end of the vermicomposting
Source: the authors

The content of MO and of nutrients as N and K perform importance for agricultural utilization; nevertheless, it is necessary to have precaution when these appear in substrata of pH high places since they create restrictions for the use in basic soils (Peñarete *et al.*, 2013).

In addition, the direct digestion and the consumption of muds for the worms also might be useful for the stabilization of MO (Jian, Baoyi, Jie, & Meiyan, 2014). The final humus contains a percentage of 14,4 % in MO, which is in the limits established by the norm.

Later it presents the behavior of the macronutrients N-P-K, between the biosolid and the final humus (Figure 4), where an increase of the components is demonstrated, favoring the final product.

The content of total N is directly proportional to the initial materials, of the process of vermicomposting and of the conditions of ripeness (Acosta y Peralta, 2015).

With regard to the analytes N and P, the percentages of content increased significantly (C.V: N=0,04, P=0,42), expiring with the established for the NTC 5167 (ICONTEC, 2004). The N, in the utilization of organic residues it contributes advantages as for providing a regular supply and his potential in the reduction of the nitrogenous pollution (Román *et al.*, 2013).

The increase in the percentage can explain, since it had been mentioned previously, in the mineralization of the nitrogenous compounds in nitrates, NOx and acid organic compounds, which allow increasing the content of the N, so much in the mud without treating (control) as in the final product or humus (Ndegwa & Thompson, 2000).

Consistently, the relation C/N is an indicator of maturity and stability of MO in the compost; and with near values to 25,00, thinks an ideal vermicomposting for the stabilization of the muds and the reduction of solid volatile.

Low values indicate instability in the material (Gaind, 2014), with a high content of N; recommending to mix it with rich materials in C, such as straws and leaves in decomposition (Sinha *et al.,* 2010).

What demonstrates in the relation of the initial biosolid 13,26 in comparison with humus stabilized with value equal C/N to 18,40.

As for the P, in the organic residues, he is fundamentally in nucleic, phospholipids and phytic acids. The significant increase (C.V=0,42) in the final humus, favored the properties of the organic solid final credit, not only increased the levels in the soil directly but also, it managed to improve the capacity of absorption and availability in soil. (Román *et al.,* 2013).

On the other hand, K is a mobile element in the soil, for what (percolation) is easily leached and his available percentage is very limited; as it was observed in the final humus, which didn´t manage to come to the value demanded by the norm, though it was the element that major coefficient of variation; it had: a CV=0,65.

Generally, in different systems of composting there is mentioned that the contents of K found are low (1-1,5 %), bearing in mind that this element can diminish in the final stage of the process when there is not abundant MO (Muñoz, 2005); concluding, that for a compost stabilized completely, the value must be near to 1,5 %; achieving a final humus of the study with values near to 1,4 %.

It is necessary to annotate that, in the sample control, the concentration of the macronutrients increased, simply, for processes of decomposition. Exposing the importance of the paper of the worm, stabilizing the above mentioned components and providing the characteristics wished for the final humus.

As for the behavior of the heavy metals, determined by means of spectrometry of atomic absorption, its variations appear in Figure 6 ; taking into consideration that in figure doesn´t show itself the maximum limit denoted by the NTC 5167 (ICONTEC, 2004), since any analyte approaches the demanded values.

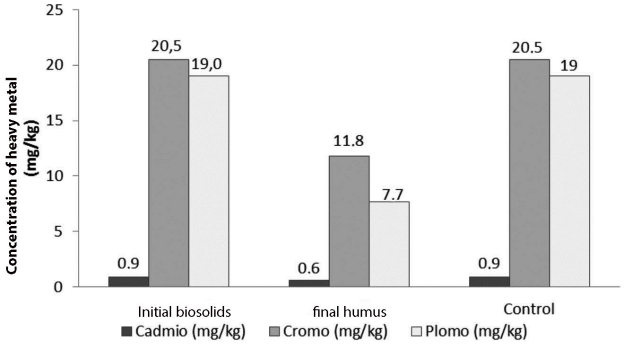

Figure 6. The concentration of metals weighed in the initial biosolid and final humus.
Source: the authors

The results confirm that the worms reduce the level of these metals in the mud vermicomposting; where the concentration diminished significantly (C.V Cd=0,20, Cr = 0,27, Pb = 0,42) with regard to the initial biosolid and final humus.

The toxicity of these parameters is an abounding factor in the agricultural use of the credit, for his harmful long-term effects and the bioaccumulation in the organisms. Though for the microbial natural degradation, the muds manage to become stable slowly, the metals weighed always will remain in the system and with the elapse of the time they will be able to fall to the soil or to join organic molecules of the soil.

The worms activity has an important paper in the reduction of the concentration of these pollutants, if materials were provided to improve the activity of the alive organisms and his reproduction; obtaining a major elimination of the heavy metals (Sinha *et al.,* 2010).

To end there was realized the comparison of the final humus of the experimental case, opposite to an organic credit of commercial character (Table 2). There was selected the credit produced by the Colombian company "Lombricultura de Tenjo", Cundinamarca, bearing in mind that the above mentioned product comes from a process of vermicomposting.

Table 2. Comparison of final humus and Lombritenjo, commercial product

Parameter	Final Humus	Fertilizer Organic Commercial (Lombritenjo)
Moisture content (%)	69.3	25
pH	6.8	7.37
Carbon content organic oxidizable (%)	14.35	19.5
Total Nitrogen (%)	4.9	1.19
Phosphorus (%)	2.7	1.21
Potassium (%)	1.4	1.01
Calcium (%)	6	1.62
Magnesium (%)	1.1	0.67

Source: the authors

In terms of the physical parameters of both materials, there must be born in mind that the sample taken in this study was without the treatment of dried and grinding; therefore this one can be controlled achieving a decrease of the content of dampness. As for the pH both products possess near values to 7, which favors the productive soil.

In the content of organic carbon oxidable, it meets outstanding the final humus due to the fact that its percentage is minor to 15 %, which satisfies the specifications of the norm (5-15 %); on the contrary the commercial product Lombritenjo does not expire with these requirements.

As in its content of macro (N-P-K) and mike (Ca, Mg) nutrients, which are needed in a percentage superior to 2 %.

The previous observations demonstrate the quality of the final obtained humus; which might be used without normative complications; nevertheless, it is necessary to bear in mind the concentration of heavy metals, since for its toxicity and bioaccumulation in the organisms they might affect the soil and the processes that happen in it.

Conclusions

The practices of manipulation, storage, transport and final disposition of the organic residues are a potential area of pollution of the naturally available resources, principally in the related thing to the treatment of waste water, be domestic or manufacturers. These waters generate a by-product, the biosolids, which are elements that possess high content of Organic Matter - MO and macronutrients as N, P, and K; having the possibility of being processed and opportunists, in his reutilization.

In the proposed process, the mineralization and stabilization of the biosolids of the wastewater treatment plant, PTAR UMNG, across the technology of vermicomposting achieved a decrease of the values of organic total carbon of 40 %; what could be due to factors as the biodegradability of the residue, his nature and the size of the particles that compose it. Also, it was possible to establish, comparing the results before and after the treatment, in which appeared an increase of the concentration of nutrients, this a consequence of the mineralization of the MO.

Of the obtained results, the pH didn´t take a significant variation, considering that in near values to 7 waits for favorable growth of animal or vegetable species. With regard to the dampness, as a way of transport of substances and nutrients, it was diminished as the time happened of composting, considering the obtained one to be like modifiable in the unitary realized processes. The relation C/N MO indicated maturity and stability in the resultant compost, revealing the quality of the worm in these processes, stabilizing the above mentioned components and providing the characteristics wished by the final humus.

Comparing the resultant humus with the commercial one demonstrated his quality, which might be used without normative complications; but, there must be born in mind the concentration of heavy metals since for his toxicity and bio accumulation in the organisms it might affect the soil.

For future studies, it is recommended to analyze the physiological effects that the biosolid has on the worms Eisenia foetida, specifically with regard to the heavy metals, in the life cycle of these individuals, in order to give a utilization.

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