Evaluation of the Biosolid Biotransformation Process Procedures of the Tunja Residual Water Treatment Plant - Boyacá, Through Compostation with Addition of Beetle Larvae

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Abstract: The treatment of wastewater, allows to reduce the contaminants that the water acquires when being used in different domestic and industrial processes. Within some of its processes, sludges are obtained, which represent a risk to the human and biotic health of the environment, as they contain a large number of pathogenic microorganisms. The constant increase in the world population in turn generates an increase in the production of Biosólidos, which implies finding suitable alternatives for its final disposal, if this by-product is disposed directly in the soil without prior treatment, it can transport pathogens due to the effects of runoff causing high levels of risk. Composting is an alternative in the treatment of Biosólidos since, it allows the stabilization of physicochemical and microbiological parameters. The addition of beetle larvae contributes to the reduction of microorganisms present in the by-product. The monitoring of the behavior of the parameters in the composting and biotransformation stages, allows to determine the optimal conditions for the process, obtaining a material that can be classified according to the minimum ranges established by the Environmental Protection Agency of the United States of America and the Ministry of Housing, City and Territory of Colombia.

Keywords: Biosolids, beetle larvae, composting, biotransformation, sludge.

I. INTRODUCTION

The world population demands the improvement of techniques of remediation and prevention of pollution of natural resources and the environment, through the use and proper disposal of materials susceptible to the presence of unfavorable components for health (Robles Martínez et al.,2016). Biosolids, also called sewage sludge are insoluble biological solid waste or organic waste that results from different wastewater treatment techniques (Bhavisha et al, 2017). According to María Julia Mazzarino, in her document "Sewage Sludge in Bariloche: from Hazardous Waste to Agronomic Resource", Biosolids, due to their characteristics and origin, have a high risk for the environment since they contain heavy metals, pathogens and tendency to vector attraction (Mazzarino & Satti, 2012).

The amount of Biosolids that is generated in Colombia is closely related to the number of wastewater treatment systems in operation as sources of production of this type of materials, in addition to the number of subscribers assigned to the sewer service. Historical records show that for the year 2014 about 8.35 million subscribers were registered, which increased in 2017 to 9.40 million under normal conditions of collection, transport and final disposal of wastewater through networks or pipelines; Likewise, 622 wastewater treatment plants were registered in 2014 and 682 in 2017. The increase in the volumes of purified water in this treatment infrastructure has been denoted with figures of 25.8, 26.7 and 27, 7 cubic meters per second (m3 / s) for the years 2015, 2016 and 2017 respectively (Superintendence of Domiciliary Public Services, 2018). This may mean not very high figures, but with a tendency to increase, since over time the increase is noticeable, in the coverage and quantity of wastewater treatment systems that trigger a proportional increase in the generation of Biosolids (Donoso et al, 2016).

There are few cases in the national situation in which biosolids are treated for proper application in the soil, which is why they are considered as solid waste that requires disposal in safety cells or sanitary landfills; The latter is currently not the best option since its useful life is limited and in most cases it is not the most suitable place for receiving such materials (Donoso et al, 2016). This creates difficulties related to the availability of adequate sites and with capacity for final disposal, associated with the increase in the disposal of solid waste in the country, according to figures set forth by the Superintendence of Public Home Services, in which by 2010 it it had 26,537 Ton / day of solid waste disposed in the national territory, while for 2017 this figure increased to 30,081 Ton / day (Superintendence of Domiciliary Public Services, 2018).

In the interest of providing safe and appropriate alternatives for the disposal of this type of materials, some background studies are studied that indicate that biosolids are basically organic matter resulting from wastewater treatment and, depending on their characteristics, may have different uses; One of them is the application to the soil since it contains nutrients that renew the organic matter in the soil (United States Environmental Protection Agency (EPA), 2000). By having a great fertilizer value, they can be immersed in the improvement of some soil properties, because they contain a high degree of nutrients such as nitrogen and phosphorus. The result of its application is the considerable increase in soil productivity linked to the effect of organic matter (Donoso et al, 2016).

On the other hand, it favors agricultural production because organic matter exerts a greater influence on the soil and its physical properties, in proportion to the distribution of the particle size (Peñarete Murcia, 2012). Among the properties that are benefited by the use of biosolids as fertilizer, the soil texture and water retention ability are discussed, which offers favorable conditions for strengthening roots and increasing tolerance of plants to drought (Peñarete Murcia, 2012). In order to carry out a purpose such as this, its classification is essential considering that, as a result of wastewater treatment, biosolids have characteristics that can cause damage to humans and ecosystems. (Clarke et al, 2017).

The use of beetle larvae as a waste biotransformer agent is a recent issue, so there is currently little research, which mainly focuses on the use of this type of larvae in organic waste to obtain fertilizers, whose effects have shown acceptable results in most cases. Although the use of beetle larvae has had admissible results in the generation of organic fertilizer from organic waste, this project contributes to scientific knowledge regarding the efficiency of beetle larvae in the variation of physicochemical, microbiological and heavy metal parameters, determining its viability in the management of biosolids applicable to the soil that are produced in wastewater treatment plants.

For the above, biosolids from the Wastewater Treatment Plant of the Municipality of Tunja in Boyacá are taken as a case study, carrying out a composting process with the addition of beetle larvae in their ripening phase, classifying the final product according to the Code of federal regulations for the use or disposal of sewage sludge 40 CFR 503 developed by the United States Environmental Protection Agency (USEPA), which can be classified in Class A or Class B according to the contaminant concentration limit.

II. METHODOLOGY

Recognition of the study área

The PTAR wastewater treatment plant in the municipality of Tunja - Boyacá is located in the village of Pirgua in the north-east of the municipality of Tunja, on the border with the municipality of Oicata, between the Jordan River and the Las Cebollas stream. The PTAR is It consists of three independent modules designed each with the capacity to treat a flow of 120 lts / s; Currently, two of the modules are operational with an average flow of 130 l / s. The process carried out by the plant is biological and includes a mixed anaerobic-aerobic train. The components of the treatment in the WWTP are based on a preliminary treatment with a self-cleaning grid and a sand trap, subsequently it has a secondary treatment in which an anaerobic process is carried out with a UASB and aerobic reactor with an aeration tank in addition to involving secondary settler, finally performs a by-product treatment using a sludge thickener, a centrifugal dehydrator, a methane burner and an H_2S washH2S (Pineda Buitrago, 2017). With the modules in operation, between 25 and 30 tons / month of sludge are generated with a collection frequency of between 8 to 10 times a month and its final disposal during 2018 is being carried out in safety cells in the environmental technological park of La Sabana.

Experimental design

The size defined for the piles is directly related to oxygenation and temperature throughout the composting process, since small piles retain a higher oxygen concentration, while large piles guarantee high temperatures (District Department of Habitad Mayor's Office of Bogota, 2014). Therefore, it is inferred that the higher the volume, the greater the probability of increasing the temperature in the piles (Acosta Castellanos et al, 2019). For this study, static pyramid-shaped piles with a height of 1.2m, a base width of 2.2m and a crown width of 0.5m were used to complete an approximate volume of 3.1 m3 as seen in Figure 1. Similarly, it was taken into account that at greater heights the greater the probability of compaction of the material, making it difficult to perform periodic flips necessary to maintain aeration and uniformity during composting (Barrena Gómez, 2006).

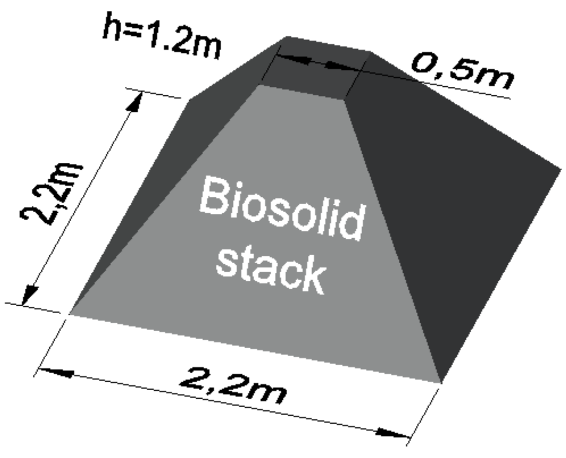

Figure 1: Structure for composting stack

For the stabilization of the substrate it is required the addition of a support material that in addition to the composting process, therefore, sugarcane bagasse is used in a proportion of 40% support material and 60% biosolid per stack. In order to obtain a homogeneous mixture of the material, it was required to assemble each composting stack in 0.20 m layers, guaranteeing the pyramidal structure and the volumetric percentage of its components. In this phase of the investigation, some environmental aspects such as direct infiltrations to the ground or runoff and the propagation of vectors are used as a premise; therefore, preventive measures were taken, such as the installation of 6-gauge plastics at the base of the piles, the installation of a structure that protects the material from precipitation, the development of trenches around the assembly to control the runoff and the location of the assembly experimental far from vector sources.

Variable Tracking

Taking into account that the process of biotransformation of Biosolids must be carried out under controlled scenarios, so that appropriate conditions for the action of microorganisms are guaranteed, in the development of the project the daily monitoring of variables such as temperature, and which is the main performance indicator of the biotransformation process (Barrena Gómez, 2006); because high temperatures guarantee sterilization in the material by inhibiting the action of organisms such as viruses and pathogens. Ideally, find a balance in temperature so that hygienization is guaranteed in its thermophilic phase taking into consideration that the greatest microbial diversity is carried out from 35 to 40 ° C, the maximum biodegradation from 45 to 55 ° C and sanitation when exceeding 55 ° C (Orden, 2018). The pH, since its temporary decrease is mainly related to the release of organic acids at the beginning of the composting process, followed by an elevation thereof, by the production of ammonia thanks to nitrogen compounds in the material (Prono, 2016).

The humidity, since, in the process of degradation of the material the main responsible are the microorganisms and the water is fundamental for its metabolic functions, so it is said that a recommended humidity for optimum efficiency in the degradation process is between 45 and 60%. Aeration, which ensures an adequate development of composting since, due to their aerobic conditions, these conditions provide benefits in terms of greenhouse gas production and bad odors (Rosas Fonseca, 2012). It has been determined through some studies that CH4 and N2O emissions are the main problems in composting, due to the importance of the environmental impacts that these gases are in the atmosphere; however, this problem can be minimized through aeration. (Wu, S. et al, 2017) The flips, as an instrument that guarantees aeration in the mixture, it is advisable to perform the flips once or twice a week, moving the piles from one place to another mixing and decreasing the compaction of its content (District Department of Habitad Mayor's Office of Bogota, 2014).

Figure 2. Variable tracking

Adding beetle larvae

In the biotransformation process of biosolids, beetle larvae were used, since their chewing buccal apparatus and the polyphagous feeding of these organisms, facilitates the transformation of the residue into bioabono (Santos Ortiz, 2017). he beetles from the larva state, perform the work of biotransformation of organic matter, providing organic colloids and providing essential nutrients for plant growth. In Colombia, about 109 genera and 595 species of degrading beetles are known (García Atencia et al, 2015).

The larvae of beetle that are used correspond to native species and are placed in the piles at room temperature during the ripening phase, considering that the condition of the material at the time of application of the larvae is of low toxicity. During this cycle the larvae carry out their feeding process with the ability to perform movements in the treated biosolids, oxygenating and allowing the growth of bacteria in it that can become beneficial in soils.

The assembly at this stage of the process is carried out with 70 beetle larvae distributed in two bioassays with specific granulometric conditions. The bioassay 1 is formed with the material that passes the sieve No. 4, being previously rammed to reduce the amount of material of great proportions (sugarcane bagasse), increasing the possibility that the resulting sample contains particles of the structuring material. The bioassay 2 conforms to the sample of material taken in the field without alteration in its granulometry, allowing a comparison of the evolution of the biotransformation under different grading conditions. The volume of each bioassay corresponds to 0.024 m3 with a weight of 12 kg. See figures 3 and 4.

Figure 3: Bioassay 1

Figure 4: Bioassay 2

Material characterization

The characterization of the material is crucial for the evaluation of the process that is carried out during composting and biotransformation. In this way, a sampling is carried out for laboratory analysis of the biosolids before assembly, another at the end of the composting process and another at the end of the biotransformation process.

The parameters evaluated correspond to those present in the code of federal regulations for the use or disposal of sewage sludge 40 CFR 503 developed by the US EPA. In this way the characterization involves: heavy metals such as arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium and zinc; In addition to microorganisms such as total coliforms, salmonella sp and helminth eggs. Additionally, total organic carbon (C), total nitrogen (N), total phosphorus (F) and organic matter were analyzed, calculating the C / N, C / P and N / P ratios.

III. RESULTS

Composting in the experimental phase is carried out for 19 weeks while biotransformation takes place in 8 weeks; time in which the following results are obtained:

Variable Tracking

During composting, the fluctuation of the pH data is due to changes in temperature in the material, due to the turning activities in the material that homogenize the exterior conditions with the interior of the stack. In this way, a fairly appropriate behavior is evident within the mesophilic, thermophilic, cooling and maturation phases. Throughout the 19 weeks in which the composting takes place, a tendency in the pH located between 7.0 and 7.2 pH units is observed. The temperature, like the pH, shows small fluctuations with a general behavior quite appropriate throughout its evolution, giving rise to a mesophilic phase in which the increase in temperatures that subsequently triggers a thermophilic phase located in the highest ranges begins. of the variable at 33.6 ° C, ending in a cooling and maturation at the end of the period. The trend of this variable in the process is between 21 ° C and 32 ° C.

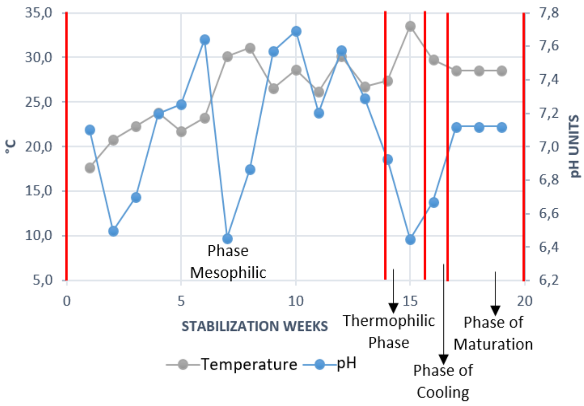

Figure 5: pH and temperature behavior in the composting phase

When grouping the variables in Figure 5, a clear response of the pH with respect to the temperature is observed, since at each temperature increase the pH tends to acidity, while, at each temperature decline, the pH tends to neutrality and The basicity. The same graph shows the evolution of composting with an initial temperature of 17.7 ° C and a pH of 7.1 pH units, which begin a mesophilic phase, characterized by the gradual increase in temperature whose response in The pH is manifested in reverse and takes place in the experimental setting between weeks 1 to 14, which in turn form the mesophilic microorganisms, which are involved in the degradation of matter.

The highest temperature reached in the cell is 33.6 ° C with a pH of 6.5 pH units respectively that is maintained during week 15 and is associated with the thermophilic phase of composting that gives way to inhibition of action of organisms such as viruses and pathogens in addition to sugars, fats, starches and proteins, which is corroborated by the respective laboratory tests.

In weeks 16 to 17 a decrease in temperature is observed until reaching 28.6 ° C and an increase in pH up to 7.1 pH units, characterized by a cooling phase in which the degradation of polymers with the appearance of fungi, in addition to some mesophilic microorganisms. In this way the last phase corresponding to maturation, is observed between weeks 17 to 19 where the temperature and pH are stabilized resulting in the proliferation of humic and fulvic acids, completely reducing microbial activity (District Department of Habitad Mayor's Office of Bogota, 2014).

During the 19 weeks of composting, the control of humidity continues in the field with the fist test, guaranteeing the suitable conditions of humidity in the material; observing that there is no significant loss of moisture in each turn, which does not generate the need for the addition of water at any time during the process. The turns in the material are carried out during the 19 weeks on a weekly basis, which allows the process to be homogenized in the stack, setting the temperature, pH and humidity.

Throughout the biotransformation favorable conditions are observed in the bioassay containing the sample with sugarcane bagasse (bioassay 2), finding an unfavorable scenario in the behavior of the bioassay with the screened sample (bioassay 1) as evidenced in Figures 6 and 7; where the pH in the biogasay conformed with bagasse manifests a constant behavior with a tendency to neutrality, throughout the biotransformation, starting from 5.53 pH units and ending at 7.0 pH units. At the same time, the pH in the bioassay conformed with the screened sample shows fluctuations ranging between 5.18 pH units and 6.6 pH units, registering a value of 6.0 pH units at the end of biotransformation.

The temperature on the other hand demonstrates a constant behavior in the sugarcane bagasse bioassay being maintained between 17.85 ° C at 17.9 ° C, with respect to the bioassay with the screened sample, which, as in the pH, it demonstrates quite marked and, in addition, high fluctuations that reach 19.2 ° C in week 5, agreeing with a pH decline corresponding to 5.4 pH units. The above is possible to associate that the material being screened, contains a minimum vacuum ratio that prevents aeration, generating the increase in temperatures in the bioassay, which in turn leads to conditions suitable for the acidification of the material, which triggers in conditions inappropriate for the survival of the larvae contained in the bioassay.

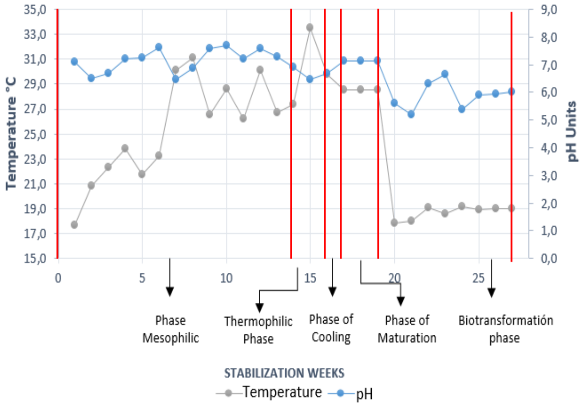

Figure 6: Composting and biotransformation behavior with bioassay 1

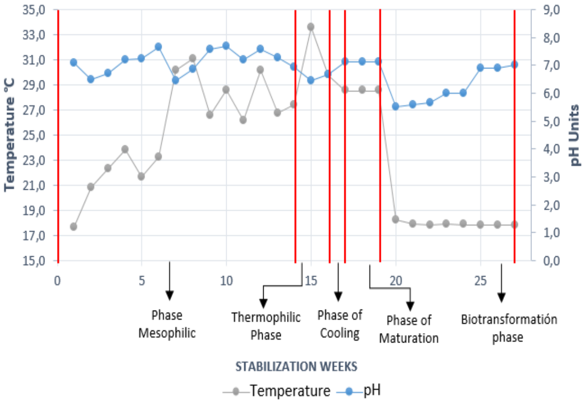

Figure 7: Composting behavior and biotransformation with bioassay 2

In Figure 8 the humidity is observed during the biotransformation demonstrates a loss of moisture with greater proportion in the bioassay with the sample containing bagasse of sugarcane, so the screened sample, although, loses moisture during the first 3 weeks, throughout the subsequent weeks it remains. This is attributed to the fact that the structuring material, containing a greater proportion of voids, allows the circulation of air in the bioassay, causing a loss of moisture.

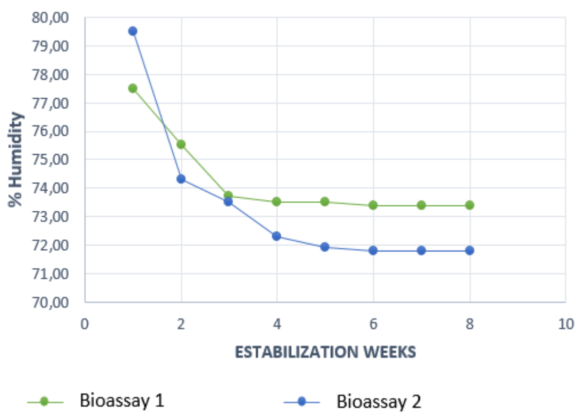

Figure 8: Moisture behavior in bioassays 1 and 2

Microbiological Characterization

Microbiological analyzes in the material allow observing the behavior of pathogens throughout composting and biotransformation. In Table 1, it can be seen that the 4 parameters analyzed, have a favorable behavior in the composted material compared to the crude Biosolid (Prieto et al, 2012). In this sense, total coliforms show a reduction of 47.3%, while algae are reduced by 48.6%, likewise salmonella and helminth eggs are eliminated by 100%. This is attributed to the thermophilic phase that takes place inside the composting, where thanks to the high temperatures sterilization of the material is carried out, eliminating pathogenic microorganisms in addition to easily degradable substances (Barrena Gómez, 2006).

Table 1. Microbiological characterization in the process

Parameter	Unit	Result			
		Biosolid Raw	Composted biosolid	Biotransformed Biosolid Sifted	Biotransformed biosolid with bagasse
Coliformes Totales	(UFC/G)	4,08+06	2,15+06	1,08+06	1,01+06
Huevos de Helmintos	-- (HHV/4g)	Presente	Ausente	Ausente	Ausente
Salmonella Sp	+ (UFC/25g)	Presente	Ausente	Ausente	Ausente
Algas	UFP/4 g peso seco	75	38,5	Ausente	Ausente

Following the analysis of the results, it can be seen that the removal is more efficient for total coliforms in the biotransformation of the material with respect to the raw sludge, obtaining a 73.5% decrease in the bioassay containing the screened material and 75, 2% in the bioassay with the sample containing bagasse of sugarcane, estimating a greater removal in the latter; in the same way it is appreciated that the algae are completely eliminated during the biotransformation in the two bioassays.

Heavy metals or trace elements

The monitoring of heavy metals in the material allows to determine the efficiency of the composting and biotransformation process in 6 of the 10 metals evaluated corresponding to arsenic, copper, mercury, molybdenum, selenium and zinc. Heavy metals are very common contaminants in the soil. Long-term deposition of metals in soil can lead to accumulation, transport, and toxicity caused by the mobility and bioavailability of these metals. The effects of adding organic matter depend not only on the particular type of metal and soil involved, but in general, depending on the characteristics of the organic matter, characteristics such as the degree of humification, the content of heavy metals, the capacity can be modified cation exchange and pH contribution. (A. Chami. Et al, 2013) In Table 2, it is observed that the arsenic and selenium present in the material at the beginning of the process are maintained after composting, however, during the biotransformation of the material a reduction is observed, in quite similar proportions in each bioassay.

On the other hand, copper, molybdenum and zinc respond to a decrease in the composting stage, which is maintained in the biotransformation of the material inside the two bioassays. Mercury, on the other hand, shows a decrease during the composting stage, which continues throughout the biotransformation, noticing better removal results in the bioassay containing the sample with sugarcane bagasse.

Table 2. Characterization of heavy metals in the process

Parameter	Unit	Result			
		Biosolid Raw	Composted biosolid	Biotransformed Biosolid Sifted	Biotransformed biosolid with bagasse
Arsenic	mg/kg de biosólido	<5	<5	3,63	3,56
Cadmium	mg/kg de biosólido	<0,05	<0,05	<0,05	<0,05
Chromiun	mg/kg de biosólido	<0,05	<0,05	<0,05	<0,05
Copper	mg/kg de biosólido	0,24	<0,1	<0,1	<0,1
Lead	mg/kg de biosólido	3,88	2,16	1,98	1,05
Mercury	mg/kg de biosólido	1,67	0,72	0,66	0,67
Molybdenum	mg/kg de biosólido	<0,1	<0,1	<0,1	<0,1
Níckel	mg/kg de biosólido	<5	<5	2,56	2,62
Selenium	mg/kg de biosólido	<0,3	<0,3	<0,3	<0,3
Zinc	mg/kg de biosólido	2,54	0,68	0,7	0,69

According to this, it is estimated that the reduction of metals generated during the composting stage of the material is related to its migration to the structuring material and its precipitation due to the gravity in the experimental assembly. As for the metals that were diminished in the biotransformation stage, it is important to mention that due to their bioaccumulative property, it is estimated that the action of the beetle larvae causes the content removed in the material to be accumulated in these organisms.

Table 3 shows that the total phosphorus in the crude biosolid corresponds to 5650 mgP / Kg, which then decreases to 3297 mgP / Kg in the composted material and subsequently increases to 6218 and 4828 in the biotransformation process with sieved material and without sifting respectively. Total nitrogen demonstrates a decrease in between the raw and composted biosolids from 5.68 g / 100g to 2.69 g / 100g, whose trend continues in biotransformation with larvae in the sample screened with 1.58 g / 100g of total nitrogen, but it is maintained with a brief inclination to the increase in biotransformation with larvae and sugarcane bagasse with a value of 2.94g /

100g. It is important to keep in mind that possibly, this decrease in the nitrogen level may be related to the reduction of the nutritional value of the compost, in addition to the decrease in its stabilizing effect. (Hua, L. et al, 2009) The total organic carbon on the other hand, although it has a decrease of almost 50% between the raw biosolids and the composting, is recovered during the biotransformation in the two bioassays. Knowing that this parameter works as a source of energy in the heterotrophs present in the soil, its effects on the chemical, physical and biological properties in the soil imply an important factor in their productivity. (Andrade Castañeda et al., 2016) For this reason, the increase in the parameter demonstrates favorable conditions in the final product.

Table 3. Physicochemical characterization in the process

Parameter	Unit	Result			
		Biosolid Raw	Composted biosolid	Biotransformed Biosolid Sifted	Biotransformed biosolid with bagasse
Total Phosphorus (P)	mg P / Kg	5650	3297	6218	4828
Organic material	g/100 g	53,1	34	54,7	66,3
Total organic carbon (C)	g/100 g	30	19,2	30,9	37,5
Total Nitrogen (N)	g/100 g	5,68	2,69	1,58	2,94
C/N	N.A	10,05	7,14	19,56	12,76
C/P	N.A	53,10	58,23	49,69	77,67
N/P	N.A	10,05	8,16	2,54	6,09

The C / N, C / P and N / P relationships are essential to know the benefits of composting, as well as the final product. The C / N ratio in the raw material starts at 5.28 and increases to 7.14 after the composting process, having a value far from the optimum suggested within an organic waste composting, which has been estimated at 25 to 35, taking into account that microorganisms absorb between 15 and 30 carbon fractions for one of nitrogen (Bueno Márquez et al., 2008).

However, during biotransformation with beetle larvae, an increase in the parameter is observed, considering a value close to the optimum for a mature compost estimated at 10, in the bioassay containing the larvae and the sugarcane bagasse with a ratio of 12.76. The C / P ratio for composting of organic waste is recommended between 75 and 150, while the N / P ratio is recommended between 5 and 20. Although the C / P ratio shows an increase between raw material and composted material, This result does not reach the limits mentioned, on the contrary, during the biotransformation of the material it can be seen that in the bioassay containing beetle larvae and sugarcane bagasse, this parameter reaches a value of 77.67 adjusting to the range suggested above. The N / P ratio shows a decrease throughout the experimentation, observing favorable results according to the limits set, with a value of 8.16 in the composted material, and a value of 6.09 in the biotransformation with larvae of sugar beetle and bagasse.

EPA classification

The classification of the material is carried out according to the code of federal regulations for the use or disposal of sewage sludge 40 CFR 503 developed by the EPA of the United States, the Biosolid can be classified in Class A or Class B.
As can be seen in Table 4, the material meets the contaminant concentration limit for class A and class B, in the 10 heavy metals suggested by the standard. In this way, compliance with the permissible ranges in the two classes of Biosolids is analyzed, since the material is composted, so compliance is maintained in the material that has been biotransformed in the two bioassays.

Table 3. Classification of the material according to contaminants with EPA 40 CFR 503

Pollutant	Maximum permissible values		Composted biosolid			Biotransformed Biosolid Sifted			Biotransformed biosolid with bagasse		
	Class A	Class B	Result	Meets		Result	Meets		Result	Meets	
				Class A	Class B		Class A	Class B		Class A	Class B
Arsenic	41	75	<5	ok	ok	3,63	ok	ok	3,56	ok	ok
Cadmium	39	85	<0,05	ok	ok	<0,05	ok	ok	<0,05	ok	ok
Chromiun	1200	3000	<0,05	ok	ok	<0,05	ok	ok	<0,05	ok	ok
Copper	1500	4300	<0,1	ok	ok	<0,1	ok	ok	<0,1	ok	ok
Lead	300	840	<0,3	ok	ok	1,98	ok	ok	1,05	ok	ok
Mercury	17	57	2,16	ok	ok	0,66	ok	ok	0,67	ok	ok
Molybdenum	-	75	0,72	ok	ok	<0,1	ok	ok	<0,1	ok	ok
Níckel	420	420	<0,1	ok	ok	2,56	ok	ok	2,62	ok	ok
Selenium	36	100	<5	ok	ok	<0,3	ok	ok	<0,3	ok	ok
Zinc	2800	7500	0,68	ok	ok	0,7	ok	ok	0,69	ok	ok
Limit fecal coliforms / g total solids (dry weight basis)	1,0+03	2,0+06	2,15+06	No	No	1,08+06	No	ok	1,01+06	No	ok
Limit Salmonella sp MNP / 4g total solids (dry weight basis)	3	-	Ausente	ok	ok	Ausente	ok	ok	Ausente	ok	ok
Viable helmint ova / 4g total solids (dry weight basis)	1	-	Ausente	ok	ok	Ausente	ok	ok	Ausente	ok	ok

In the same sense, the material is compared with the permissibility limits for pathogens, as suggested by the standard for class A and class B, so it is possible to interpret that the material after composting does not meet any of the two classes in the fecal coliform parameter; however, the material after the biotransformation has been carried out, if it complies with the B-Class of biosolids in the same parameter.

As for the other parameters related to salmonella and helminth eggs, compliance with the material is denoted from the moment the composting is carried out, assuming that the limits in these parameters are established only for the biosolid class A.

CONCLUSION

The material at the end of the experiment, complies with class B within the pollutant concentration option (PC) and also within the option of cumulative pollutant load rate (CPLR) which can be used in all soil uses except grass and domestic orchards, food crops, soils for grazing animals and soils with high potential for public exposure; on the other hand they must comply with the options for reducing the attraction of vectors embodied in table 4 from option 1 to 10, finally, within this classification the implementation of management plans and some additional site restrictions are required. Although the norm requests the monitoring of enteric viruses for the compliance of the material in class A, this is not carried out for the present investigation, because the breach in the parameter of total coliforms, classifies the material in class B.

The evaluation of the biotransformation process of biosolids extracted from the wastewater treatment plant of the city of Tunja in Boyacá, allows to determine that from a stabilization of the biosolid with a support material within a composting process; The addition of beetle larvae is a viable alternative to improve the microbiological and physicochemical properties of the final product.

According to the above, it can be affirmed that the process of composting in biosolids is appropriate to provide alternatives of disposal to the material following the recommendations that the literature provides about the process, as well as biotransformation contributes to the improvement of the material to comply with the regulations which governs its different types of use.

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