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ARTICLE

Waste degradation and leachate quality on composting platform: A case study in Lome, Togo

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Edem K. Koledzi, Martin P. Aina, Kwamivi N. Segbeaya, Maglwa Tcha-Thom, Gnon Baba and James T. Agbebavi

Full Length Research Paper

Waste degradation and leachate quality on composting platform: A case study in Lome, Togo

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Chemical or organic compounds released during the waste composting could be harmful to the environment. The purpose of this work is to investigate the stability indices of organic matter after the lixiviation runs on composting platforms. The results showed that the organic matter became resistant to biodegradation after 2 months of wastes composting, that the nitrates content decreased, while the phosphorus one increased. The organic load predominantly hydrophilic substances (HPI*) decreased significantly ($p < 0.05$) during composting polymerizing into humic acids (AH characteristics of the leachate, such as a pH < 8 , a (BOD₅/COD) ratio > 0.1 and a (AH*+HPO*) content $< 50\%$ pointed to the class of an intermediate leachate. However, the values of COD* and hydrophobic substances (HPO*). The increase in (AH*+HPO*) fractions is correlated with Specific UV Absorbance (SUVA) value which rose from 4 to 25 L.gC⁻¹.cm⁻¹. Some < 4000 mgO₂.L⁻¹, of SUVA > 20 L.gC⁻¹.cm⁻¹ and an HPI* concentration $< 30\%$ suggested a stabilized leachate. Thus, during the 4 months, the resultant compost although mature was not stable. The leachate characterization has permitted to understand both its quality and the state of the waste where it originates from, making it possible to prevent any chemicals leakage into the environment.

Key words: Waste, composting, organic matter, hydrophobic fractionation.

INTRODUCTION

Composting is one of the oldest waste management processes for an agricultural application. Formerly, this process was made naturally from dead leaves. Nowadays with the increasing production of household or urban and industrial wastes especially urban waste,

simulated natural-methods have been designed to reduce significantly the waste volume by more than 50% and to transform most of it, thru through the mineralization of the organic compounds, the water loss and the porosity change, into more stable products, which are less harmful

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to the environment (Magdi et al., 2004). Indeed, composting technologies are differentiated mainly by the configuration and aeration which may be done by air injection or reversals heaps at selected frequencies according to the decomposition and humidity rate, material porosity and composting duration. The Decomposition is fast initially in the process and then turning frequency is reduced during the degradation phase leading to the compost maturation. Periodic control of moisture during processing followed by sprinkling of water to maintain an optimal moisture is indispensable. Another method is the leachate characterization by an elution test on the waste.

The leachate quality and the estimation of the windrow settling remain the most explored research fields in assessing the waste stabilization. Many authors apply batch tests for the assessment of the waste behaviour and release (Lagier, 2000; Kylefors et al., 2003). The parameters used for the leachate quality correlated with the source waste are pH, conductivity, COD, BOD₅, and TKN. The increase in the conductivity and a pH 8 allows to conclude that the waste is in the humification, maturation or stabilization phase. Ramade (1998) attempted to classify leachates of different ages (young leachate, middle leachate, stabilized leachate) according to their biodegradability represented by the BOD₅/COD ratio.

In addition, during the degradation the disappearance of the volatile fatty acids, and the formation of very stable high molecular weight organic compounds called humic substances, which are predominantly humic acid (HA) and hydrophobic fraction (HPO). The measure of the dissolved organic carbon (DOC) is the best indicator of the compost stabilization degree, (Castaldi et al., 2005). Its interpretation is sometimes coupled with the Specific UV Absorbance (SUVA) index. It increases with the aromaticity and the molecular weight of the molecules (François et al., 2006; Labanowski, 2004) thus with the evolution of a windrow towards the waste stabilization.

In Republic of Togo, projects such as the construction of a central landfill in Lomé is totally disconnected from the ground reality and from the already very advanced actions taken by the NGOs. In 2010, the NGO « Ecosystème Naturel Propre » (ENPRO), together with GTVD (Gestion, Traitement et Valorisation des Déchets) Laboratory have implemented a waste composting platform processes more than 20 tons of waste per day instead of the initially planned 5 tons per day. But given the high demand of compost, the number of lots to cover became very high, therefore the uncovered windrows experience heavy rains which results in high production of leachate seeping into the soil and forming puddles inside and outside the platform. Thus, the objective of this study is to evaluate the quality of the leachate discharged from the platforms into ground and the stability and quality of the organic matter in the compost which will be available to the farmers for agriculture.

MATERIALS AND METHODS

Location of composting platform wastes sampling

The study site is located in north-western district of Lomé, the capital of Togo. It covers a fenced area of 2500 m². The composting method used is the rollover swath method at a frequency of two weeks.

Samples C1 (day, 0), C2 (day, 37) and C3 (day, 72) of waste and composts were collected during the fermentation stage while C4 (day, 103) and C5 (day, 124) were collected during the maturation stage. The study was conducted from April to July. The quartering was done in order to mitigate any variability's at the same stage of degradation. The amount of waste collected after the on-site quartering is 50 kg.

Humidity and volatile matter contents in composts

The water content test was performed in triplicate. The humidity rate was measured by weighing the samples before and after drying at 35°C. The volatile matter was determined by loss on ignition, for 2 h at 550°C, using a muffle furnace (Nabertherm B170).

Elution test

The elution was realized in glass bottles using distilled water and dried wastes in a ratio L / S = 10 and placed on an orbital shaker (Labotech HS 500) for 48 h at 150 rpm. The mixture was then sieved using a 1 mm mesh sieve. The solid fraction remaining on the sieve was oven dried at 105°C to constant weight and weighed to determine the moisture content of the waste after leaching. Then the samples are stored at 4-5°C and kept away from light for further analysis, except for the fractionation on column (Bone et al., 2003).

pH, conductivity and Eh of the leachate

After lixiviation the pH, conductivity and the redox potential were measured from the centrifuged and filtered leachate (Cayuela et al., 2006). The pH was measured according to NFT 90-008 protocol, using a pHmeter Crison BASIC 20+. The conductivity was determined using a conductivity meter (Merterlab CDM 210) using measuring cell from Radiometer Analytical CD 6745-9. The redox potential of the solution was carried out using a WTW multimeter coupled with a Mettler Toledo Pt 4805-S7 / 120.

COD, BOD₅, alkalinity and volatile fatty acids contents

Chemical oxygen demand (COD) was determined on the unfiltered and filtered leachate through the COD tubes Lange LCK 614, 50-300 mg/l O₂ range using the spectrophotometer DR Lange Cadas 50S. The BOD₅ was measured on the raw leachate with OxiTop WTW according to NFT 90-103 protocol. The ratio BOD₅/COD of different leachate was calculated and followed over time to determine the biodegradability character and evolution of the molecules (Christ et al., 1996; Munnich et al., 2006). The Complete Alkalinity Titration (CAT) and Volatile Fatty Acids (VFA) were performed on the filtered and centrifuged leachate. For all three subsamples, 20 mL of leachate were titrated by the addition of 0.1 N sulfuric acid until pH = 4. VFA were also measured by titration. The pH of the solution was adjusted to 3.5 then the sample was boiled for 3 minutes, allowing the de-carbonation of the solution. After cooling, it was titrated with a solution of sodium hydroxide (0.05 N) to pH 4 with a volume V2 mL of NaOH. Then, the pH was

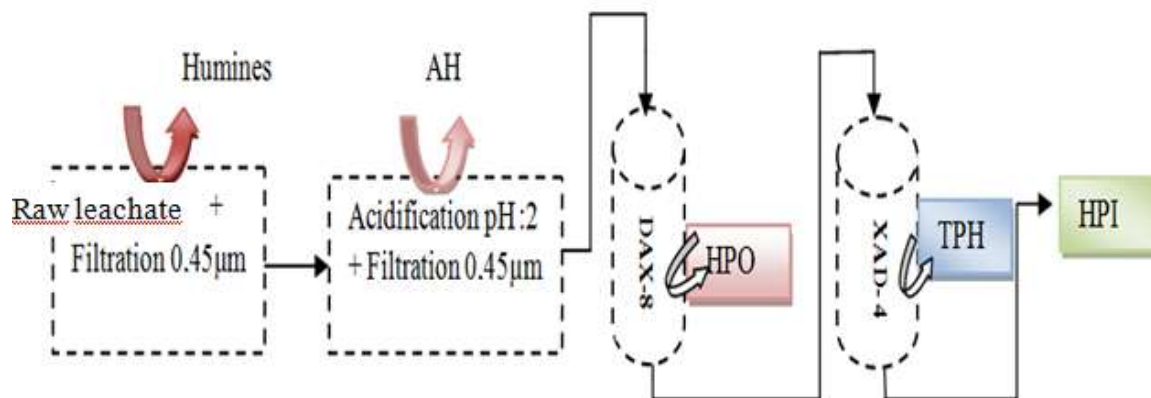


Figure 1. Splitting protocol of the MO column following the hydrophobicity.

raised to a value of 7 with a total volume V3 mL of NaOH. These two volumes expressed in mL were related to the VFA concentration in (gL^{-1} of acetic acid).

Nitrogen and phosphorous content

The four forms of nitrogen for pollution study (Nitrites, Nitrates, ammoniacal Nitrogen) and Organic Nitrogen were performed on the filtered leachate by colorimetric methods (François et al., 2006). Nitrites and nitrates are obtained by the Hach kit Nitraver5 and Nitraver3 method respectively using the Hach DR 2010 spectrophotometer. Total nitrogen was determined using tubes tests produced by Laton Gesamt-Stickstoff, TNb- NT LCK 338, 20-100mg/L TNb and Dr Lange spectrophotometer CADAS 50 S. Phosphate pollution was determined by the Hach kit PhosVer3 method using Hach DR 2010 spectrophotometer.

Dissolved organic carbon fractionation and SUVA index

Humic substances was determined after acidification at pH 2. The dissolved organic matter fractionation was carried out to determine the content of each fractions of organic matter. It is based on the sequential use of the DAX-8 and XAD-4 resins. The volume of sample percolating depends on the size of the column (Kylefors et al., 2003) and the volume of resin used. For 5 mL of resin, the volume of leachate percolated is 156 mL for a column ($\varnothing = 1.4$ cm; $H = 4.5$ cm). To rinse the resins after leachate percolation, 20 mL of distilled water is used. The sample at pH 2 was injected using a Masterflex L / S pump into the columns filled with resins at about 50 ml / h. Its passage through the DAX-8 resin and then through the XAD-4 resin separates the hydrophobic compounds that are adsorbed on the DAX-8 resin. Transphilic compounds are adsorbed on XAD-4 resin and the hydrophilic compounds came out unadsorbed (Figure 1). The proportions of different species were determined by measuring the DOC at the input and the output of the column (Marhaba et al., 2003).

The SUVA index is the ratio between absorbance 254 nm and DOC. It is used to estimate the aromaticity and the hydrophobicity of the organic molecules present in the leachate (Xu et al., 2006).

Statistical analysis

Statistical procedures were performed with the GraphPad Prism software package. Data were expressed as the means with

standard deviation (SD), and the letters indicate significant differences between the results of the different samples. Mean separation was assessed by Tukey's multiple range test. Differences at $p < 0.05$ were considered statistically significant.

RESULTS AND DISCUSSION

Except humidity and volatile matter contents carried out on compost, the other parameters were determined on the leachate released by wastes during composting.

Humidity rate

Throughout the treatment, the humidity of raw waste was almost constant but showed a significant decrease after 72 days. Similar results were reflected by the study of the material balances (Koledzi et al., 2011) but since during the treatment the leachate produced has been recirculated to water the waste, one should expect a stronger moisture content at least from 72 days and over (C2). However, addition of water was stopped in May and throughout the rainy period and reduced thereafter until it was stopped in July. Therefore the proposed improvement by recycling the leachate had a real impact in April and May (C1 and C2). In Table 1, it is depicted that during the campaign C1, C2, C3, the humidity rate was high; therefore at this stage the activity of microorganisms should be optimal and then slowly decreases with a decrease in moisture content throughout maturation.

Volatile matter

Sharp decrease in the waste volatile matter was observed (Table 1) till C3; the average value of volatile matter in the initial raw waste was of 157 g/kg, whereas before screening the compost, it fell to 58 g/kg, a reduction of 62%. This decrease can be explained by the consumption of the biodegradable fractions of organic matter during

Table 1. Variations of physico-chemical parameters of leachate and physico-organic load of compost.

| Duration | pH | Eh | Conductivity | Humidity | Volatile matter |
|---------------|------------------------|-----------------------|------------------------|-----------------------|----------------------|
| C1 (0 days) | 6.47±0.02 ^a | 55.5±0.7 ^a | 4.86±0.05 ^a | 51.4±0.5 ^a | 157±59 ^a |
| C2 (37 days) | 6.76±0.04 ^b | 15.5±0.7 ^b | 4.4±0.1 ^b | 49±2 ^a | 112±12 ^{ab} |
| C3 (72 days) | 6.75±0.01 ^b | 16.5±0.7 ^b | 3.2±0.1 ^c | 50±3 ^a | 67±1 ^b |
| C4 (103 days) | 7.23±0.02 ^c | -6±0 ^c | 3.8±0.1 ^d | 41±3 ^b | 77±10 ^b |
| C5 (124 days) | 7.32±0.01 ^c | 2.9±0.2 ^d | 3.9±0.2 ^d | 42±2 ^b | 57±3 ^b |

Means ± standard deviation followed by different letters in the same column differ statistically by the Tukey's test ($p < 0.05$).

Table 2. Variations of organic parameters of the leachate during composting.

| Duration | CAT | VFA | DOC | AH | HPO | TPH | HPI | SUVA |
|--------------|--------------------------|-------------------------|----------------------|------------------------|------------------------|-------------------------|-------------------------|-----------------------|
| C1 (0 days) | 0.1±0.02 ^a | 0.5±0.1 ^a | 2490±10 ^a | 0±0 ^a | 2.2±0.1 ^a | 25.7±0.2 ^a | 71.7±0.2 ^a | 4.4±0.1 ^a |
| C2 (37 days) | 0.06±0.01 ^{bc} | 0.180±0.05 ^b | 2440±10 ^b | 0.49±0.01 ^b | 13.7±0.3 ^b | 21.2±0.2 ^b | 64.7±0.2 ^{bd} | 9.8±0.3 ^b |
| C3 (72 days) | 0.07±0.01 ^{ac} | 0.6±0.2 ^a | 1133±6 ^c | 0.72±0.02 ^c | 2.5±0.1 ^a | 30.2±0.2 ^c | 66.4±0.5 ^{cd} | 7.3±0.3 ^c |
| C4(103days) | 0.033±0.002 ^d | 0.05±0.02 ^b | 1142±3 ^c | 1.15±0.05 ^d | 6.27±0.02 ^c | 26.77±0.06 ^d | 65±1 ^d | 25.5±0.5 ^d |
| C5(124days) | 0.042±0.001 ^e | 0.07±0.05 ^b | 787±15 ^d | 9.9±0.2 ^e | 37.2±0.2 ^d | 22.7±0.2 ^e | 29.83±0.06 ^e | 23.8±0.8 ^d |

Means ± standard deviation followed by different letters in the same column differ statistically by the Tukey's test ($p < 0.05$).

the treatment. The compost after C3 seemed mature but not stable.

pH, redox potential (Eh), conductivity

The pH is a good indicator of the degree of the organic matter (OM) degradation during different phases of the composting. When the waste was spread without composting or stored in landfills (anaerobic conditions), their pH reached 7 only after 5 to 10 years whereas in composting (aerobic conditions), the degradation process is accelerated and pH becomes 7 in less than 3 months as observed in C3 and C4 in the maturation phase of this study (Table 1). During the first phase or between C1 and C2, the OM that easily degrades was hydrolyzed into organic acids, augmenting the acidity of this period. It is followed by stabilization between C2 and C3, a sign of weak or slow degradation. From C3 the then generated organic acids were degraded and assimilated by a bio-oxidation, which may explain the significant increase of the pH after C3. After 100 days of composting the concentrations of these acids became lower causing a slowdown in the acidity till the end. Similar observations were seen during the anaerobic storage of landfills waste, where the waste degradation leads to the production of a leachate pH less than 6, and then evolves to 7.5 after 5 years before reaching 8 after 10 years, the latter value meaning that the leachate is stable (Renou et al., 2008; Berthe et al., 2008). Thus, it was concluded that the acidity of the leachate depends on the degradation of windrow from which it originates. As the pH value at the end was around 7.3 in the present case study after 124 days (C5), it can be concluded that the compost leachate

was not yet stable and belongs to the class of intermediate leachate.

The redox potential is related to the pH and its evolution here is inversely proportional to that of the pH. It should be between 100 and 160 mV for a stabilized waste. This was not the case as seen from Table 1 (around 3 mV) and hence the waste was not considered to be stable

The conductivity measurement gives a general idea of the mineral load of the leachate and the mineralization degree of the waste. During the first two months, the conductivity decreases and then became stable at the end of treatment (Table 1) due to the mineralization process at the beginning of the maturation stage.

CAT, VFA

The evolution of CAT (Table 2) is related to the pH evolution and decreases with increase in pH as depicted in Table 1. As expected from the theory, the evolution of the VFA must follow the same profile as that of the CAT. The value of the VFA decreases from 0.5 g CH₃COOH/L to 0.05 g CH₃COOH/L after showing an increase in amount of mineral carbon with time. A significant difference ($p < 0.05$) is noticed between the beginning and the end of composting process.

Dissolved organic carbon fractionation and SUVA index

The hydrophilic substances (HPI*) decreased significantly

Table 3. Variations of pollution parameters of the leachate during composting.

| Duration | COD | BOD ₅ | BOD ₅ /COD | P | NT | NH ₄ | NO ₃ | NO ₂ | N _{org} |
|---------------|-----------------------|-----------------------|------------------------|----------------------|--------------------|-----------------------|------------------------|--------------------------|------------------------|
| C1 (0 days) | 4333±404 ^a | 2950±450 ^a | 0.68±0.06 ^a | 4.2±0.5 ^a | 165±3 ^a | 13.5±0.4 ^a | 3.5±0.2 ^a | 0.021±0.001 ^a | 146±2 ^a |
| C2 (37 days) | 1883±284 ^b | 2183±534 ^a | 1.2±0.2 ^b | 4.5±0.5 ^a | 210±2 ^b | 10.1±0.1 ^b | 5.64±0.03 ^b | 0.042±0.002 ^a | 196,4±0.5 ^b |
| C3 (72 days) | 2450±260 ^b | 666±451 ^b | 0.28±0.21 ^c | 4.9±0.5 ^a | 140±1 ^c | 12.9±0.1 ^c | 4.32±0.02 ^c | 0.021±0.001 ^a | 122.6±0.5 ^c |
| C4 (103 days) | 2150±180 ^b | 566±57 ^b | 0.26±0.04 ^c | 4.3±0.4 ^a | 142±1 ^c | 1.8±0.1 ^d | 3.03±0.03 ^d | 0.02±0 ^a | 137±1 ^d |
| C5 (124 days) | 2375±25 ^b | 466±21 ^b | 0.19±0.01 ^c | 6.8±0.4 | 146±1 ^d | 26.1±0.2 ^e | 3.12±0.03 ^d | 0.6±0.4 ^b | 116±1 ^e |

Means± standard deviation followed by different letters in the same column differ statistically by the Tukey's test ($p < 0.05$).

($p < 0.05$) during the pre-treatment (Table 2), from 71.7±0.2% to 29.83±0.06% of the total organic matter content in opposite to HPO* and AH* which increased significantly while TPH* fluctuate. The increase in HPO* and AH* are well correlated with the decrease of HPI*. This may be due to the polymerization of the compounds in biological degradation and chemical oxidation of the waste.

The most stable substances are the AH *, evolved at the 37th day, during the-fermentation phase (0.5%). At the end of degradation period, they accounted for 10% of the organic matter. This value is in accordance with a leachate resulting from a stabilized waste (Berthe, 2008). However, the potentially induced biogas substances (Fricke et al., 2005), like the HPI* and the TPH* represented 52.5% of the organic matter. An improvement has been noted when compared to the material balance where a value of 65% has been obtained but the resulted composts cannot be regarded as stable, taking into consideration the levels of these parameters (Croué et al., 1993). In fact, when (AH*+HPO*) > 50% and HPI* < 30%, the leachate is said to be stabilized (Berthe et al., 2008). In this study, the proportions of (AH * + HPO *) and HPI * are respectively 47.1 ±0.2% and 29.83±0.06% after 124 days. So it may be said that the leachate was almost stabilized. The same conclusion applies to the compost from which the leachate came from.

Dissolved organic carbon (DOC) decreased from 2490±10 mgC/L to 787±15 mgC/L (Table 2) depicting a sound degradation process. SUVA index increased significantly ($p < 0.05$) at each step of composting showing that the molecules polymerized as function of time, confirming the results, of a SUVA index > 20 for a stabilized leachate (François et al., 2006; Berthe et al., 2008). This evolution of the SUVA advocates firmly the transformation of HPI* fractions to more humified molecules like the HPO* and the AH*.

COD and DBO₅

A waste is considered to be stable when its COD reached 30-900 mg O₂/L (Kelly et al., 2006); COD was measured on the filtered and centrifuged leachate after the leaching tests. Due to the fluctuating results of raw leachate, only

COD results of centrifuged and filtered leachate are shown (Table 3). It dropped significantly during the different steps of composting and became stable at the end of the treatment, an indication of a sound degradation of the organic matter by the microbial flora. From C2 (1883±284 mgO₂/L), the COD was stabilized, the residual organic matter less susceptible to degradation and then the COD stabilized until the compost is harvested. The COD value (< 4000 mg O₂/L) of the leachate after 124 days points to a stabilized leachate (Renou et al., 2008; Berthe et al., 2008).

The BOD₅ was evaluated using the oxygen consumed by microorganisms. In Table 3, a continuous reduction in this parameter is observed, which means that less amount of oxygen is consumed, resulting in less degradation of the organic matter. The degradation slowed down as observed for the COD values from C3. The residual organic matter after 37 days of treatment became resistant to degradation and the microbial flora responsible for digesting of organic matter starts decreasing. As for COD, it was observed that compost obtained in this case are not considered stable. A compost is usable or stable when the BOD₅ ranges between 4 and 120 mg O₂/L. However the BOD₅ value of the leachate (466 ± 21 mg O₂/L) after 124 days depict that it belongs to the class of intermediate leachates (Renou et al., 2008; Berthe et al., 2008).

The BOD₅ / COD ratio indicate the proportion of organic matter and identify the leachate class according to its age. This ratio decreased sharply till C2 of the maturation phase, then stabilized from C3 around 0.2 (Table 3). This result is in agreement with the progression of the organic matter degradation and the waste mineralization. The DBO₅ / DCO ratio > 0.1 after 124 days confirms the former results which stipulated that the leachate was an intermediate leachate in the process of stabilization (Renou et al., 2008; Berthe et al., 2008).

Nitrogen, carbon and phosphorous pollution parameters

During the study period there was no significant amount of nitrites. The content of nitrites were lower than the WHO standards of nitrites contents in potable water

(<0.025 mg/L). A significant released was observed only after three months of composting (Table 3). The same observations is made with nitrates which contents were also lower than WHO standards (<50 mg/L). The organic nitrogen was calculated by subtraction of the concentration of nitrites, nitrates and ammonia nitrogen from the total nitrogen value shown in Table 3. The organic nitrogen amount tends to decrease from 146±2 to 116±1 mgN/L with an increase in the ammonia nitrogen concentration from 13.5±0.4 with 26.1±0.2 mg N/L. The nitrogen was oxidized into its reduced form and Ammonium corresponds to the terminal metabolite of the micro-organisms. To be assumed as stable, a waste or compost must have a nitrates content range of 0.5 to 0.6 mgN/L. In this study we observed a final concentration of nitrates of 2.64 mg N/L and nitrites fell in the same order of concentration.

Phosphorous pollution increased during the degradation process from 4.2 mg to 6.1 mg PO₄³⁻/L (Table 3). Nevertheless, this evolution can be explained by salting out in the medium of pollutants, the phosphorus coming out from the waste in degradation.

The various parameters studied here made it possible to determine the waste degradation and the quality of the leachate produced. This study helped us to understand that composts are not stable even if they are considered mature depending upon different maturity tests (Said-Pulicino et al., 2007).

Additional observations, such as the odours and the colours evolution may also be used to follow the degradation of the leachate. The first obvious observation was the difference in colour of various samples, which turned darker and darker, as the composting proceeds. The waste breaks down gradually thus releases the particles into the water during the elution tests with ease resulting in the intensification of the colour and the thickening of the sample. The second observation was that the leachate extracted from waste C4 and C5 have a muddy aspect. The humic acids content in the leachate is elevated and their degradation is carried out in the presence of dioxygene, so there is also a mineralization process present, which may lead to the muddier aspect. The third remark was the evolution of the odour from the leachate or the waste. The strong odour observed during the campaign C1 was still present during the campaigns C2 and C3 and almost vanished at the last phase of the treatment. The absence of odour indicates the progressive disappearance of organic matter causing the bad odour.

Conclusion

All the stability indicators pointed to conclusion that the leachate belongs to an intermediary leachate class which mean that that although the compost is mature, stability was not achieved during the time frame covered by the study. The initialization of the composting process has

been characterized by strong rates of BOD₅, COD, BOD₅/COD, COD, HPI* fractions and low values of SUVA and pH. The last two evolved inversely as the leachate approaches the indicated characteristic values of a stabilized leachate. The hydrophilic substances like the HPI* fractions were converted to more macro substances like the AH* and the HPO*. Therefore this study proves that the polymerization of some compounds has resulted from the biological degradation and the chemical oxidation of the waste. The analysis of the indicators of pollution (nitrogen and phosphorus) shows that it is possible to have a strong release of these elements into the environment through the leaching of the swaths or windrows exposed to the rain.

Conflict of Interests

The authors have not declared any conflict of interests.


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