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Sustainable Recovery of Urban Organic Waste: A Case Study of Composting Waste from the Mfidi Market in Kinshasa, Democratic Republic of the Congo

Benjamin K. Katumbi [a*], Gurvitch O. Nsiala [a], Hervé B. Ngangu [a], Céline F. Nyembo [a] and Emmanuel M. Biey [a]

[a] *Department of Environmental Sciences, Faculty of Sciences, Laboratory of Ecotoxicology, Ecosystem Health, Environmental Biotechnology and Microbiology, University of Kinshasa, B.P 190, Kin XI, Kinshasa, RD Congo.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study aimed to evaluate the methods of solid waste management in the Mfidi market in order to detect the various problems and propose strategies to fight against insalubrity.
Study Design: This research consists of four parts, an introduction with literature review, a description of the study environment, the methods used and finally the results obtained.

**Corresponding author: E-mail: katumbikyassa@gmail.com;*

Location and Duration of the Study: This study took place in the Mfidi market in Kinshasa from January 20 to May 15, 2023.
Methodology: The methodological approach was based on observation and experimentation. The quantification consisted in characterizing the waste, recovering the biodegradable organic fraction by the technique of composting. Then test the effectiveness of this compost in its application in the field.
Results: This study showed that the quantity of waste at the Mfidi market varies daily between 1,580 and 4,827 kg, with an average of 3,543.8 kg. With regard to the characteristics of the waste, we note that plants and others are the most important with an average proportion of 59.5%, followed respectively by cardboard and paper (16.6%), plastics (14.6 %), metals (5.4%), textiles (2.1%) and glass (1.9%). The organic fraction was recycled into compost, whose contribution to soil fertility was justified by the growth of the species *Amaranthus hubridus sp*.
Conclusion: The establishment of an integrated solid waste management system within the Mfidi market can guarantee sanitation conditions in this market.

Keywords: Solid waste management; recovery; compost; mfidi market.

1. INTRODUCTION

In most metropolises in developing countries, coverage of waste management is still incomplete and urban decision-makers must position themselves with regard to the production of “sustainable” management [1]. In these countries, waste is sent to landfills in most cases. However, this practice is not accompanied by selective sorting of waste at the place of production, in order to reduce the quantities buried and to develop recovery channels for certain types of waste.

In the Democratic Republic of Congo, waste management is not organized in an integrated and sustainable way [2]. This problem is encountered in the Mfidi market installed in the town of Makala in Kinshasa where waste is not managed rationally. The waste generated in this market is dumped in the approaches to the streets, in certain ravines in the city, the others are sometimes dumped in open areas, in swamps or along the banks of waterways by the sanitation workers of public administration of the market and/or by users. This situation results in nuisances and a state of unsanitary conditions, the consequences of which are floods, the appearance of various deadly diseases raging among the population and the proliferation of disease vectors [3].

While in an integrated vision of sustainable development, the problem of waste implies that it cannot be considered as an isolated object, nor even be limited to the only aspects of recovery and disposal. They must be understood from a holistic perspective of risk and resource management, which covers the entire life cycle of the waste, from its generation to its ultimate treatment [4]. While the informal recycling of certain types of waste (e.g. glass, paper/cardboard, cans, scrap metal, plastics, etc.), recovered by individuals from landfills and places of production (households, shops, markets, garages, etc.) are a source of income, the same cannot be said for organic waste. Also, in the circular economy approach, organic waste can be recycled into compost, organic fertilizer [5]. The latter can replace synthetic fertilizers and be used as a soil amendment (fertilizer) in agriculture with the advantages of improving agricultural production, stabilizing soils, etc.

1.1 Objective

This study aimed to evaluate the methods of solid waste management in the Mfidi market in order to detect the various problems and propose strategies to fight against insalubrity.

2. MATERIALS AND METHODS

2.1 Mfidi Market

This study was carried out in the Mfidi market in Kinshasa city. It is located at 04°23'21.2'' East longitude and 015°18'43.7'' South latitude.This market, with an area of 4500 m^2, is made up of open spaces between houses and serves as places of sale [6].

2.2 Experimental Site

The experiments in the recovery of organic waste into compost took place in the experimental site of aerobic composting of solid waste of the Department of Sciences and Environmental

Management at the University of Kinshasa. The experimental site has several compost bins intended to receive organic waste and produce compost.

2.3 Methodology

The methodological approach was based on observation and description. This approach is divided into two stages: a preliminary phase and a field phase.

2.3.1 Observation

The observation consisted of carrying out an inventory of the solid waste management methods at the Mfidi market. That is to say the way in which the waste is stored, transported and/or disposed of there. This observation applied to the entire market.

2.3.2 Collection of waste samples

The raw solid waste taken into account in this study is the waste generated by all the vendors in this market. The waste was collected at the collection point where it is piled up without having been sorted beforehand. This operation lasted four days. Then the solid waste collected was sorted and weighed in order to know their categories and their proportion according to the method described by [7].

2.3.3 Composting process

The sorting made it possible to separate the waste according to their categories. Only organic waste was retained for the composting process. According to the method described by [7], two 60 m^3 windrows were formed using the piled technique from 14 tonnes of organic waste. These piles were watered 3 times a week, turned every two weeks.

All the physicochemical analyzes were carried out within three days in order to fully appreciate the evolution of the composting process. After three months, the two windrows produced mature compost, a sample of which was taken for quality analysis, then tested on flat agricultural strips (composted soil and control soil).

2.3.4 Compost quality monitoring

The measurement of parameters such as pH and temperature were obtained IN SITU from a sample of the compost produced using a HACH Senslol brand multiparameter according to the method described by [8]. The other physico-chemical analyzes carried out on the substrates were carried out jointly in the laboratory of the Department of Chemistry and Industry and in the laboratory of the Department of Environmental Sciences of the Faculty of Sciences, at the University of Kinshasa.

2.3.5 Choice of Amaranth in the trial

Amaranthus hybridus is a fairly tall herbaceous plant species in the Amaranthaceae family. It is an annual plant 20 to 120 cm high, very variable in shape and coloration [9]. The choice of this species is justified by its availability and by the fact that it is among the most popular species in market gardening in the city of Kinshasa.

2.3.6 Compost testing

The seeds used in this study came from the experimental garden of the Faculty of Agronomic Sciences of the University of Kinshasa.

On one side, 100 kg of compost were spread, then mixed with the soil of the experimental bed. On the other hand, the flowerbed with the control soils was not mixed with the compost. 80 feet of amaranth were transplanted in each flower bed (30 feet constituted the border and 50 feet constituted the useful surface). Stem length measurements were taken after a 7-day interval over the 50-foot working area (Fig. 1). The experiment lasted 21 days.

The entire and useful plot: concerns all 80 feet of amaranths planted in composted and non-composted soil. The useful plot: concerns 50 feet of amaranths planted in composted and non-composted soil.

2.4 Data Processing

Verification of the homogeneity between the 2 variances by finding the value of F calculated:

Here, we take the numerator the largest value the variance and the denominator the smallest value.

So : S2=5,23 >S1=3,19 hence :

$$F = \frac{S2^2}{S1^2} = \frac{5{,}23}{3{,}19} = 1{,}64 \text{ (Pvalue)}$$

The dof of control soil (S1) and composted soil (S2) = N-1 = 50-1 =49

At the threshold of:

- 0.05 degree of confidence = 1.63 (value read in the table = F tabular);
- 0.01 degree of confidence = 2.01 (value read in the table = F tabular).

the comparison between the calculated F (P value) and the Ftabular (from dof).

- If P value < 0.05% degree of confidence: the difference is significant;
- If P value < 0.01% degree of confidence: the difference is very significant;
- If P value > 0.05% degree of confidence: the difference is not significant.

So :

- $F_{calculated}$ (P_{value}) = 1,64 > $F_{tabular}$ = 1,63 to 0,05 : so the difference is no Significant at 0.05% ;
- $F_{calculated}$ (P_{value}) = 1,64 < $F_{tabular}$ = 2,01 to 0,01 : so the difference is very significant at 0.01%.

3. RESULTS AND DISCUSSION

The results obtained after these various field manipulations and experiments are presented and discussed below.

3.1 Results

3.1.1 Quantification of the waste produced per day at the Mfidi market

The table 1 shows that waste produced in the Mfidi market varies daily between 1,580 and 4,827 kg, with an average of 3,543.8 kg. Looking at the waste components, we note that plants and others are the most important with an average proportion of 59.5%, followed respectively by cardboard and papers (16.6%), plastics (14.6%), metals (5.4%), textiles (2.1%) and glass (1.9%).

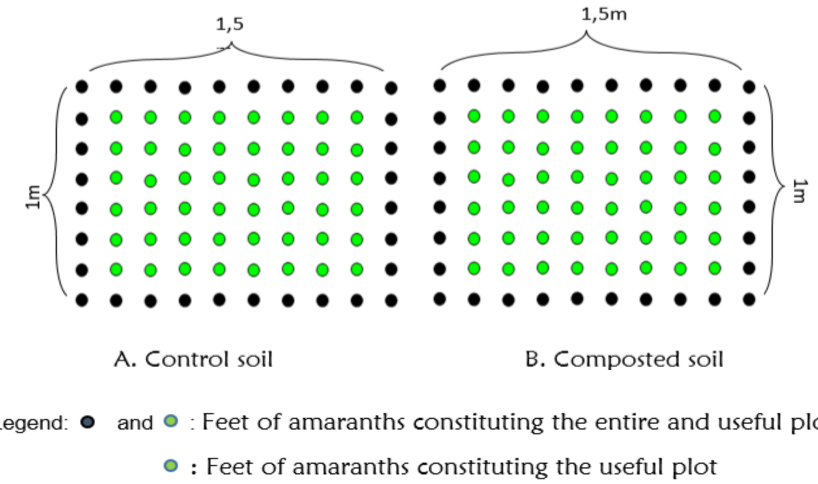

Fig. 1. (A and B). Experimental device of the 80 feet of Amarantes in a plot

Table 1. Proportion of waste quantification per day and per vendor

Solid Waste Components	W_1	W_2	W_3	W_4	Average	
	kg	kg	kg	kg	kg	%
	by Mass on Wet Basis					
Textiles	27	52	140	75	74	2.1
Cardboard and paper	750	695	430	472	587	16.6
Plants and others	3250	3305	350	1528	2108	59.5
Plastics	499	525	393	657	519	14.6
Metals	205	146	198	215	191	5.4
Glass	96	51	69	47	66	1.9
Total	4827	4774	1580	2994	3543.8	100

3.1.2 Mfidi market solid waste directions

- Plastic waste (bags and bottles) was directed towards the production of plastic pavers;
- The scrap metals were sold at a price of 250 CDF (USD 0.1$)/kg to small itinerant buyers of metals, who in turn sell them to the company Harimex which recycles metals at 17th Street, in the Municipality of Limete in Kinshasa.
- The glass waste was sold at a price of 150 CDF (USD 0.06$)/Kg to mobile buying mothers of glasses.
- The collected textile waste was simply burned. Indeed, there are no recovery alternatives for these types of waste in Kinshasa, except to dispose of them by burning them.

3.1.3 Recovery of biodegradable waste by composting

In total, 14 tons of biodegradable waste (including cardboard and paper) were subjected to aerobic composting in windrows (2 heaps).

The compost obtained, i.e. a production of 8250 kg representing 59% of the initial waste, was packaged in 50 kg bags). This compost obtained had a brown color and a fresh smell.

The mature compost packaged in bags after 3 months is presented in Fig. 2 (a, b and c) below:

3.1.4 Evolution of compost quality parameters

Evolution of compost quality parameters shown in Table 2.

Table 2. Evolution of the physico-chemical parameters of the compost

Parameters	Units	Values observed at the end of the composting process	Recommended values
pH	-	6,7	6,5-8,0 (Lokango, 2019 ;Toundou, 2016 ; Biey, 2019)
Electrical conductivity	µS/cm	277	< 1500 (Lokango, 2019 et Biey, 2019)
Temperature	°C	26,9	< 45 or 40 (Charnay, 2005 et Lokango, 2019)
Humidity	%	52,7	40 - 65 (Kangana, 2019 ; Mikono, 2014 et FAO, 2005)
Dry Weight (Ps)	%	47,3	›à 30 (Mikono, 2014 et AFNOR, 2005)
Mg	%	0,74	0,7-3,0 et 0,5-1,4 (Mustin 1987 et castaldi et Al, 2008)
Pb	mg/kg Ps	12,7	< 180 (Mikono K, 2014 et Norme AFNOR, 2005
Zn	mg/kg Ps	43,2	< 600 (Mikono K ,2014 et norme AFNOR ,2005)
Cu	mg/kg Ps	9,0	< 300 (Norme AFNOR, 2005 et Toundou O, 2016
Mn	mg/kgPs	34,9	42,33 and 64 (Luboma M..,2007 et Toundou O, 2016
Fe	mg/kg Ps	11,0	15, 20 (Luboma M..,2007 et Alouiemine S., 2006)
Cd	mg/kg Ps	0,9	< 3 (Mikono, 2014, Biey, 2021 et norme AFNOR, 2005)
Na	mg/kg Ps	0,02	< 2 (Mulomba, 2014 and Ontario standard, 2012)
K	%	0,41	0,4-2,3 and < 3 (Toundou, 2016, AFNOR standard, 2005 and FAO, 2005)
Ca	%	2,96	2,34-3,6 and 3-12 (Mustin, 1987, Toundou 0,2016)
N tot	%	2,02	< à 3 (Compaoré and Nanema, 2016, Castaldi and Al, 2008 and AFNOR standard, 2001)
C tot	%	37,2	≥ 10(Toundou O, 2016, Youcai and Al, 2008 and AFNOR standard, 2005)
P	%	0,98	< 3 (Mulomba, 2014 and AFNOR standard, 2005)
C/N	-	18,4	15-20 and > 8 (Kolwezi, 2011, Mundele, 2016, Toundou, 2016, AFNOR standard, 2005 and FAO, 2005)

(a) (b) (c)

Fig. 2. (a) Pile of biodegradable waste, (b) Compost wall and (c) Packaging compost in bags

3.1.5 Evaluation of compost quality by observing the growth of amaranths (*Amaranthus hubridus* sp)

The observation of the growth of the amaranths made after 21 days, shows that there is a greater improvement in terms of growth, leaf greenness and soil cover (Fig. 3). In the composted soil, these parameters are marked with a very great intensity compared to the control soil where a simple and weak improvement was observed compared to that made on the 21st day.

Fig. 3 highlights the influence of compost on crop growth in an agricultural system (Fig. 4 a & b). The average size of amaranth stems grown on composted soil (17.74 ± 5.23 cm) is significantly greater than that obtained on non-composted soil (4.41 ± 3.19 cm) (Fig. 5 a & b). This difference testifies to the effectiveness of compost in improving the germination power of plants in agriculture (Fig. 6 a & b)

The different heights of amaranth stems in control and composted soils after 21 days of growth are shown in Fig. 4 (a & b) 5 (a & b) and 6 (a & b).

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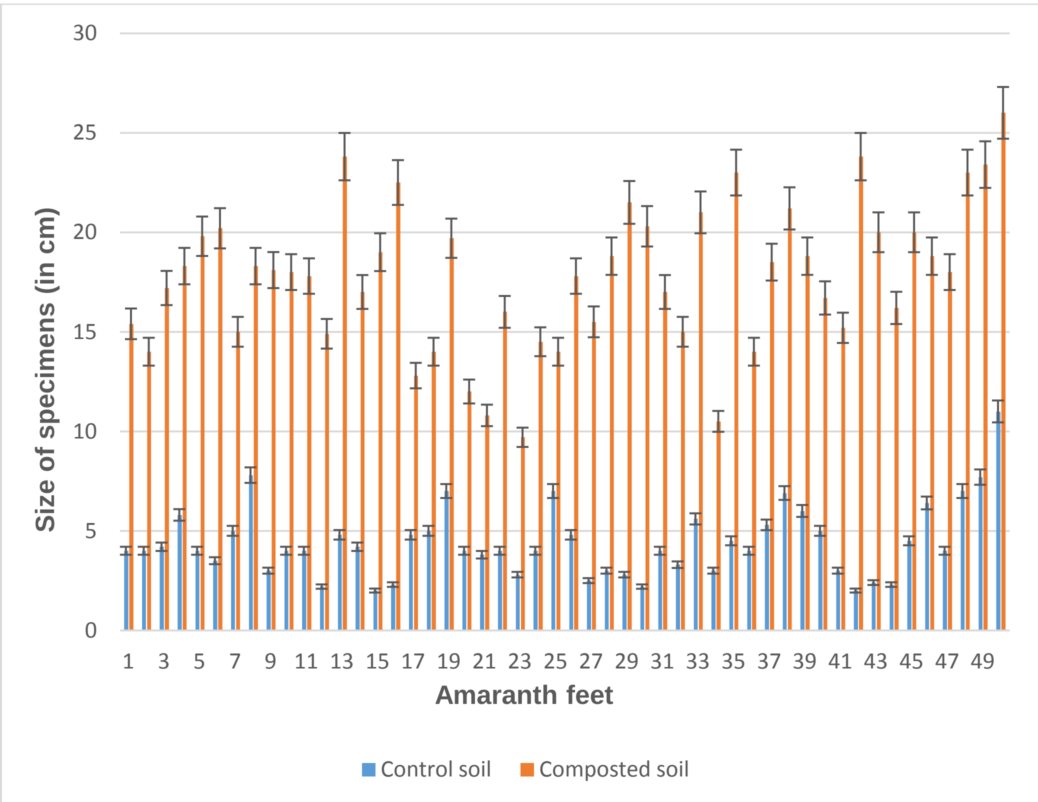
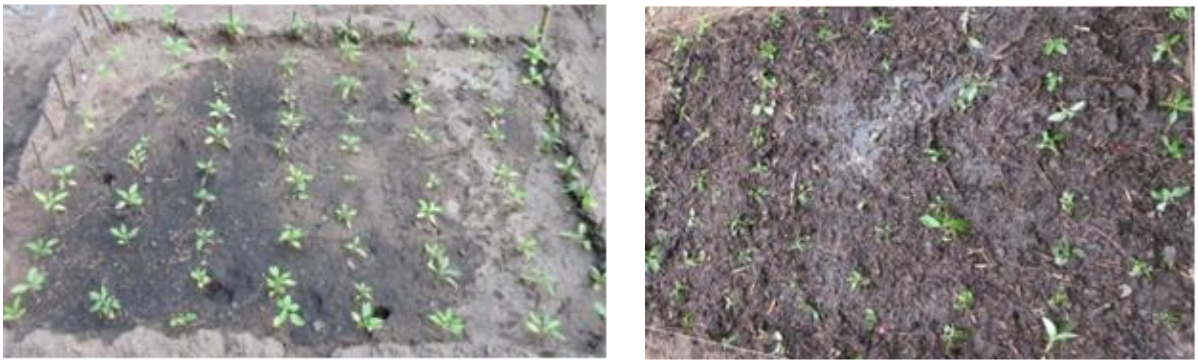


Fig. 3. Height of amaranth stems in control and composted soils after 21 days of growth



(a) (b)

Fig. 4(a) Amaranths on the first day in control soil and (b) compost-amended soil

(a) (b)

Fig. 5(a) Amaranths after 21 days of growth in control soil and (b) composted soil

Fig. 6(a) Measurement of Amaranth stems in control soil and (b) composted soil after 21 days of growth

3.2 Discussion

3.2.1 Quantification of waste per day at the Mfidi market

In view of the results found, it can be seen that the quantity of waste at the Mfidi market varies daily between 1,580 and 4,827 kg, with an average of 3,543.8 kg. With regard to the characteristics of the waste, we note that plants and others are the most important with an average proportion of 59.5%, followed respectively by cardboard and paper (16.6%), plastics (14.6 %), metals (5.4%), textiles (2.1%) and glass (1.9%). These observations show that the waste from the Mfidi market has a composition mainly made up of biodegradable waste.

This quantity is close to that produced in certain African countries, nearly 500 grams per person per day, of which nearly 2/3 correspond to a biodegradable fraction, made up of putrescible materials and paper [10].

3.2.2 Mfidi market solid waste directions

Plastic waste (bags and bottles) was directed towards the production of plastic pavers; The scrap was sold at a price of 250 CDF (0.1 USD)/kg to local metal recycling and foundry companies. The glass waste was sold at a price of 150 CDF (0.06 USD)/Kg to glass recycling companies to make new candies and beer. The textile waste collected was simply incinerated. There is currently no alternative for recovering textile waste in Kinshasa. However, research on their ecological valuation is in progress.

Note that in the context of the circular economy, waste is not always a material to be thrown away, but rather to be recycled. Waste is raw material which, through its recycling or recovery, can generate many other resources in terms of goods and services. Considered from a sustainable development perspective, waste can produce resources capable of reviving various activities at the market level, and contribute to reducing the misery and poverty of the population [11].

3.2.3 Recovery of biodegradable waste by composting

In total, 14 tons of biodegradable waste (including cardboard and paper) were subjected to aerobic composting in windrows (2 heaps). The compost obtained, i.e. a production of 8250 kg, represents 59% of the initial waste. Its characteristics indicate a brownish appearance and a fresh smell. Then the compost was packaged in 50 kg bags. These observations are supported by [12] who justifies them by the fact that the waste considered is plant, fruit, garden types unlike solid municipal waste which gives a higher percentage.

3.2.4 Evolution of compost quality parameters

The pH of the compost obtained was 6.7. This value is at the range of neutrality that corresponds to that acceptable in international compost standards ranging from 6.5-8.0 [13,14,12]. The electrical conductivity was 277 µS/cm, respecting the international standard set at a value lower than 1500 µs/cm with a temperature of 26.9°C [15,12].

The dry weight obtained during our experiment is 47.3%, this result is in agreement with those of Mikono, 2019 who found 49%. This result complies with the standards of [16] which sets the minimum value of 30%. The total carbon content obtained is 37.2% C. This result complies with the standards of [16] which sets the value above 10%. The total nitrogen content obtained is 2.02%. It complies with [16] which limits a value < to 3%. The C/N ratio obtained is 18.4; which corresponds to the [17] which limits a value of 15 to 20.

For trace elements (Mn, Fe), Mn has the highest content, i.e. 34.9 mg/kg PS, while iron has a content of 11.0 mg/kg PS. The standard values are respectively 42.33 and 64 [18,14] for Mn and 15.20 [18,19] for Fe. In the light of the values as recorded in Table 2, the values for each element and heavy metals comply with the standards according to [16,17].

3.2.5 Evaluation of compost quality by observing the growth of amaranths (*Amaranthus hubridus* sp)

Observation of the growth of the amaranths made after 21 days shows that there is a greater improvement in terms of growth, leaf greenness and soil cover. In the composted soil, these parameters are marked with a very high intensity compared to the control soil where a simple and weak improvement was observed compared to that made on the 21st day.

The influence of compost on crop growth in an agricultural system is justified. The average size of amaranth stems grown on composted soil (17.74 ± 5.23 cm) is significantly greater than that obtained on non-composted soil (4.41 ± 3.19 cm). This difference testifies to the effectiveness of compost in improving the germination power of plants in agriculture. These results are similar to previous studies conducted [20].

4. CONCLUSION

This study on the management of solid waste produced in the Mfidi market showed that in this market the quantity of waste produced varies daily between 1,580 and 4,827 kg, with an average of 3,543.8 kg. The organic fraction of this waste corresponds on average to 59.5%. The recovery of 14,000 kg of organic waste produced 8,250 kg of compost, the effectiveness of which was assessed on the germination and growth of amaranths. Apart from textiles, all the other fractions have found an outlet.

Thus, the establishment of an integrated solid waste management system within the Mfidi market can guarantee sanitation conditions in this market. In addition, the study suggests continuing research on new techniques for the ecological recycling of textile waste.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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