

Municipal Solid Waste Sorting in Burundi, Inventory and Perspectives: Case of Bujumbura City

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Abstract:- The sorting of municipal solid waste (MSW) by residents is a recommended and inexpensive practice that allows sustainable waste management with the recovery of homogeneous fractions for further valorisation. However, MSW continues to be collected unsorted and is sent to new uncontrolled open-air landfills, despite the recommendations. The purpose of this study is to analyse the MSW management in Bujumbura city and to identify the main problems that hinder the sorting of waste by the inhabitants. Methodologically, on site visit was carried out to establish an inventory of the dispersion of MSW in the city. To assess the profile of their impact, leachate was sampled and characterized (pH, electrical conductivity and heavy metal content by ICP-MS). In addition, to understand better the MSW management in Bujumbura, a survey questionnaire was used on a random sample of 80 citizens of Bujumbura aged 10 years and over. The results showed that MSW was found in an unsorted and uncontrolled open-air landfill. The heavy metals content of the leachates sampled exceeded the limit value for Cu, Cr, Fe and Mn. Moreover, the survey realized in this study shows that the majority of Bujumbura's citizens (76.3%) do not sort MSW. They face various challenges such as the lack of adequate information on MSW management, the lack of separate containers, the collection of waste by categories and the lack of collection services. The chi-square test showed a significant dependence between the involvement of the local administration in raising awareness of sustainable management and the way in which municipal solid waste are managed ($p < 0.05$). However, referring to coefficient of contingency (0.390), this relation is weak and additional factors would be useful to justify the actual management of MSW in Bujumbura. To ensure MSW sorting and sustainable management in Bujumbura, the specific intervention points are highlighted and concern: the wide dissemination of information through the media, local administration, the development of waste collection and recycling services, environmental education through the Burundian education system. Government and other stakeholders should invest in order to provide all the information necessary to promote the successful establishment of the city of Bujumbura.

Keywords:- *Municipal Solid Waste (MSW), sorting, Burundi.*

I. INTRODUCTION

Most developing countries (DCs) use open landfills to dump unsorted municipal solid waste (MSW) [12, 18]. This practice is a problem in constant debate because it develops negative impacts on the environment [17]. Unsorted waste is the source of environmental pollution since it can contain various harmful elements that contaminate the soil, and generate leachate loaded with these hazardous contaminants of air and groundwater [1, 2, 5]. High biodiversity mortality rates may be due to high concentrations of hazardous compounds [2]. The problem of soil contamination in these open dumps requires adequate solutions to be proposed in order to protect the population from epidemiological or chronic diseases [17].

Moreover, in urban areas especially in the Northern part of Bujumbura town (the economic Capital), the former open dumps, which are currently closed, become areas exploited for agricultural or residential purposes. This land use results in adverse effects on the environment and human health in particular [17]. One of the solution to avoid some contamination is the sorting of solid waste by residents, an easy and inexpensive practice that allows sustainable waste management with the recovery of sorted fractions for the benefit of the population [10, 12].

However, the behaviour of households for MSW sorting at source is influenced by various factors such as the "Moral Standard" (moral perception on good or bad action), attitude towards MSW sorting due to lack of simple tools such as sorting garbage cans, space, time and cooperation from individuals [14]. The same situation was highlighted by Ezechi et al. in Nigeria [7]. The authors proposed the participation of everyone in waste management. On the contrary the reference [20] had shown that in China the relationship between intent and behaviour in waste sorting has weakened after the addition of pathways influenced by better accessibility factors and government awareness for waste sorting [20]. This practice is not widely used in developing countries, particularly in Burundi.

Indeed, municipal solid waste continues to be collected unsorted and is sent to new uncontrolled open-air landfills, despite the recommendations. Following this observation, what would be the appropriate prospects? The purpose of this study is to identify the main problems that hinder the sorting of waste by residents in Bujumbura and to examine to what extent they are aware and/or informed of the interest

they have in the sustainable management of their solid waste that can be beneficial to them.

Then we can hypothesize that (i) MSW is not well sorted at source, (ii) the population of Bujumbura may have deficits that prevent them from managing MSW in a sustainable manner. This study should provide useful information to the various stakeholders, decision-makers and bottom-up actors who should act dynamically to promote sustainable municipal solid waste management in the city of Bujumbura. Tools to help the promotion of source separation is the main objective to avoid the nuisances caused by the uncontrolled MSW landfilling and to allow for recycling and use of sorted materials.

II. MATERIAL AND METHOD

This study was conducted in the city of Bujumbura from March 2019 to June 2019, the economic capital of Burundi, which includes three municipalities: Ntawangwa in the North, Mukaza in the centre and Muha in the South. On the methodological level, we carried out on site visit to establish an inventory of the dispersion of municipal solid waste in the city and the problems caused by this situation. To do this, a Garmin GPS, a smartphone, a camera, an on-site monitoring device, a laptop and a pen were used to collect the useful information. Four leachate samples were collected at the Buterere landfill. Measures of pH and conductivity were performed. These four leachates were mixed into one sample which was kept in a polyethylene bottle and brought in Belgium the 4MAT laboratory at ULB. Heavy metals were analyzed there by an ICP-MS instrument Agilent Technologies 7700 series.

In addition, for a better understanding of the reason for this situation, a survey questionnaire to collect data on the subject was distributed in the area of this study to a random sample of 80 citizens aged 10 years old and over. The answers to these questions were intended to understand people's perception of the concept of municipal solid waste, to understand current management methods, to identify the difficulties that prevent MSW sorting at source of urban solid waste and to propose a better management.

The results of this survey were analyzed qualitatively and quantitatively in graphical form for greater clarity, and then treated by using SPSS 22 as software for descriptive and analytical statistics. The discussion of the results leads to the formulation of recommendations for the sustainable management of municipal solid waste in the city of Bujumbura, the Capital of one of the developing countries.

III. RESULTS

A. MSW management in Bujumbura: challenges

Looking around different municipalities of the city of Bujumbura shows that all solid municipal waste produced by households is collected unsorted and is sent to an uncontrolled open-air landfill. An ongoing study shows that the soil of the Buterere site (Fig. 1), a former unsorted waste landfill, contains high level of contaminants, 10 years after its closure [11]. Indeed, the fermentable fraction of the stored waste is transformed into compost while the non-biodegradable fraction persists.

Currently, the Mubone landfill is operating (Fig. 2) and receives all unsorted municipal solid waste. On this site, intense odorous emanations are to be deplored. On the other hand, contaminated leachate, linked to rainwater percolation, damages the groundwater and reaches the streams and crop fields surrounding the site.



Fig 1:- Persistent unsorted solid waste at the old landfill of Buterere -Bujumbura city



Fig 2:- Unsorted solid waste at current landfill of Mubone - Bujumbura city

Metals	Buterere	El-Jadida (Maroc)	Burundi's standards
Cr	2.02±0.05	0.1563	1
Co	0.042±0.001	-	0.5
Cu	1.784±0.015	0.1578	0.5
Fe	56.14±0.27	24	3
Mn	3.03±0.47	1.257	<1
Ni	0.133±0.001	0.1338	0.5
Pb	0.373±0.001	-	0.05
Zn	2.260±0.037	0.7472	3

Table 1:- Heavy metal contents (mg/l) in landfill's leachates

The local population suffers from these nuisances and often advocates the closure of the landfill through the media. In view of this situation, an improvement can be suggested by proposing the sorting and recovery of the different categories of solid waste. In this way, this better waste management in the city of Bujumbura would allow the inhabitants to benefit from the recovery of certain secondary materials and to reduce the current nuisance of soil, air and water with an environmental degradation at open air landfill sites. All these proposals are also based on the results of the survey carried out in this study among the inhabitants.

Measures of the pH on leachates from the Buterere site give a value of 7.43 ± 0.06 which is in the range of values frequently observed for the other landfill sites (4.5 to 9) and do not exceed the value allowed in Burundi [8,16]. The measure of electric conductivity (EC) for these leachates is $6,616 \pm 5 \mu\text{S}/\text{cm}$. It is in the range values of other landfills, from 2.5 to 35mS/cm (for example the site of El-Jadija), but higher than the admissible value of 1mS/cm for Burundi [4, 16]. This is showing that these leachates, very loaded with soluble salts, do pollute the environment in addition to groundwater.

The heavy metal contents of the leachate were analyzed by ICP-MS from the brand Agilent Technologies 7700 series. The results prove the presence of heavy metals, with contents exceeding the limit values, as presented in the table 1. High contents of heavy metals were noted for Cu, Cr, Fe and Mn which exceed the limit values in the leachate that is flowing directly into the environment. On the other hand, the contents for other heavy metals such as Zn, Pb, Ni, Co, and Cd are below the limit values in the leachate [14, 16].

Leachates from this site are issued from the physicochemical degradation of unsorted waste being dumped. These untreated leachates constitute a source of pollution of groundwater, knowing that the water table of the locality is shallow (from 0.5 to 2m) and unprotected. These leachates therefore need to be collected in order to undergo an adequate treatment, in order to preserve the environment against pollution.

B. Demographic information of inhabitants surveyed

In the survey conducted among the 80 participants from 3 municipalities in Bujumbura city were dispersed as follows (Fig.3): 43.8% from Ntahangwa, 28.7% from Mukaza and

28.5% from Muha. Of these, 15% were unemployed, 28.7% in the private sector (liberal professions, cleaners and technicians), 52.5% in the public sector (health, education, research, army, police, etc.) and 3.8% in commerce. In their households: 18.8% are composed of 1 to 3 members, 47.5% of 4 to 7 members, 27.5% of 8 to 11 members and 6.2% exceed the number of 11. The age of the respondents varies from 10 to over 50 years.

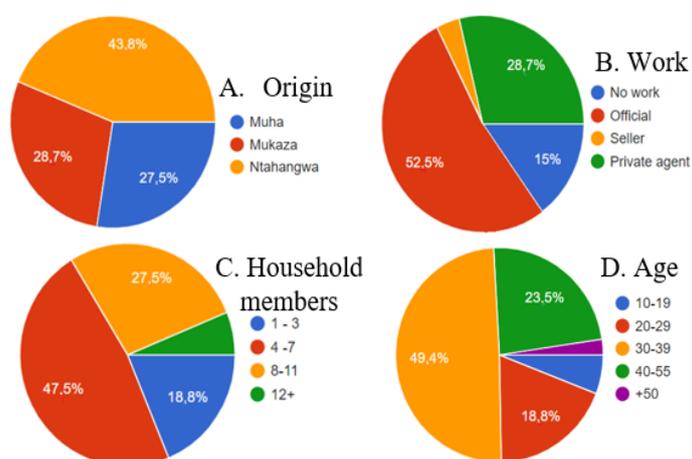


Fig 3:- Origin (A), work (B), household members (C) and age (D) of respondents

C. Basic knowledge of citizens in MSW management

With regard to the characterization of municipal solid waste produced by households, the results show that: 73.8% confirmed that daily household waste is the most abundant in their bins (Fig. 4). This is in line with the results found at Bujumbura in 2015 by Mizero et al. [12]. The survey also shows that bags, plastics, paper and cardboard are produced in large quantities. The survey results also show that participants have very little knowledge of the different categories of waste that can be recyclable, reusable, harmful and hazardous or not.

In terms of the possible danger of certain wastes, the majority of respondents specify that they are hospital and pharmaceutical waste, plastic bags and bottles (Fig. 5). According to them, some wastes are considered non-hazardous and consider that they are therefore not very problematic. This observation highlights the poor knowledge

of the harmful effects of certain wastes and the risks to health [3]. In addition, an important proportion (28.7%) of participants are not informed of the future of their waste and their potential nuisances, compared to 71.3% who are already informed (Table 2). The analysis of this result largely militates for the population of Bujumbura city to be better informed.

D. Behaviour of Bujumbura citizens related to management of MSW

According to our survey on 80 inhabitants of the city of Bujumbura, only 23.8% are sorting their waste at source at home or at work (Table 2). The main reasons that prevent

them from sorting are the lack of adequate information (60.4%) and the lack of tools such as selective containers (Fig. 6). In addition, there is no collection of waste sorted by category, which explains the difficulty of the inhabitants to contribute themselves to a better solution in the city of Bujumbura (Fig. 6).

The results of the study show (Fig.7) that the MSW of the city of Bujumbura are mainly collected by private companies (38.1%) and independent individuals, paid for their work (35.7%). On the other hand, public companies are not efficient (19%).

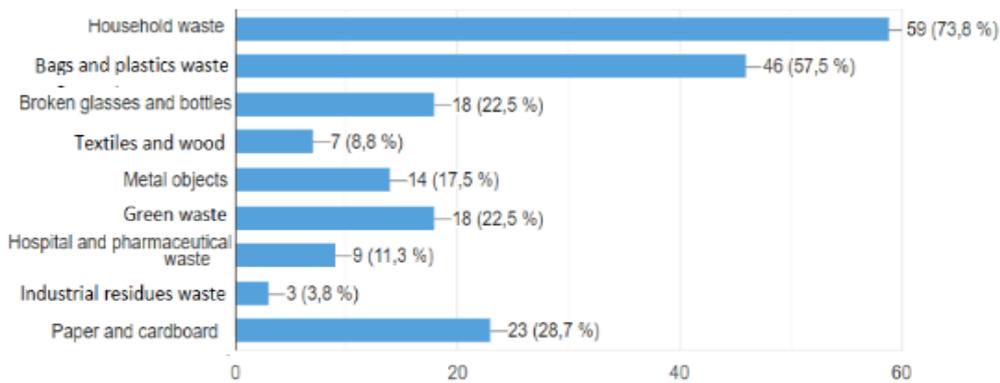


Fig 4:- Proportions of different fractions in MSW

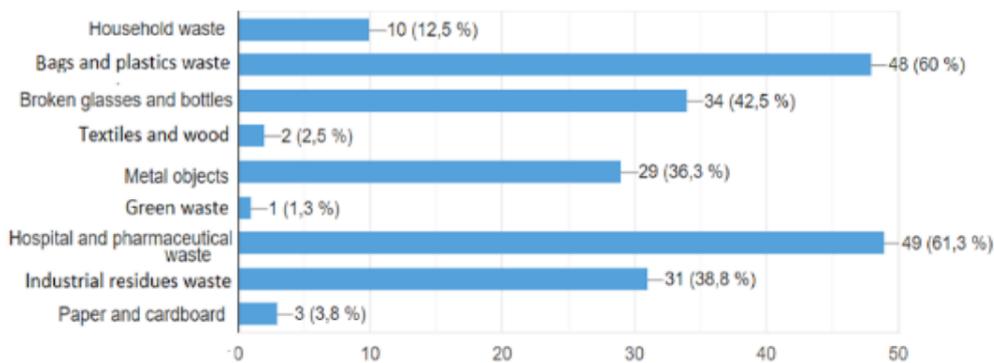


Fig 5:- Citizens' perception of the danger of waste by category (Bujumbura city)

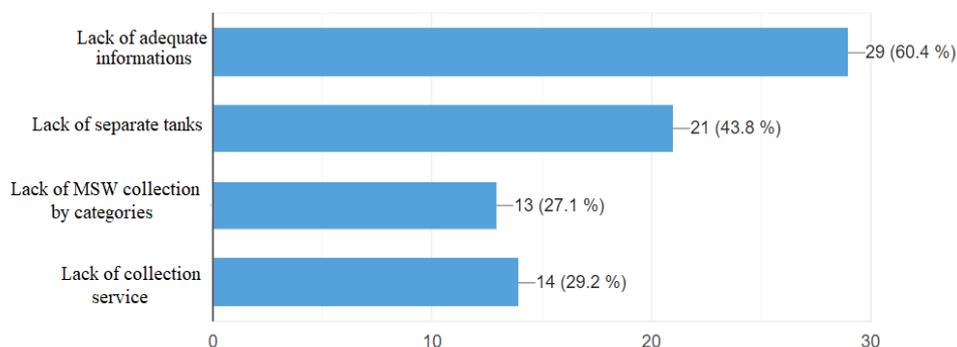


Fig 6:- Main problems in waste sorting (Bujumbura city)

Questions /Responses	Yes	No
Percentage of citizens informed about the nuisances of MSW	71.3	28.7
Sorting rate by category of waste	23.7	76.3

Table 2:- Level of citizens' information and waste sorting rate in Bujumbura (%)

Moreover, MSW are not collected at all for 7.1% of the citizens. It means that some waste remains in the streets of the city, causing pollution and contagious diseases (Fig. 7). It should be noted that the destination of the waste is not known for 60% of those surveyed in this study, which may justify the presence of waste in areas not designed for dumping and not publicly recognized (wild deposits).

E. Data on sustainable management of MSW

According to this study, 72.5% of respondents reported that they had already been informed of good practices about solid waste management. On the other hand, 27.5% have not yet been informed (Fig. 9). The majority of those informed learned about it through the media (33.8%) and from school (27.5%). It is important to note that the administration slightly intervenes up to 13.7% (Fig. 10), hence the need to show the interest to invest more in this area.

The study shows that informed people are not fully satisfied with it (Fig. 11). Only 30% reported that they are but the rest (70%) want more information for a better understanding of the situation. The level of involvement of local authorities remains low (Fig. 12) with regard to proposals and incentives to the population for waste sorting and assistance in the collection and management of the sorted fractions.

IV. DISCUSSION

The analysis of the results of this study shows that the collection and management of municipal solid waste in the city of Bujumbura is necessary and urgent. Citizens' behaviour towards their daily waste can be improved to enable them to contribute to sustainable management. An intervention at the level of informing citizens must be considered from the top to down: from scientists to decision-makers, from decision-makers to citizens in public places and to children at schools.

Indeed, without this installation, waste is currently unsorted and sent directly from the source of the inhabitants (streets) to the uncontrolled landfill, causing nuisances and environmental pollution. This finding is consistent with the findings of other researchers in developing countries [1,6,9,15].

Sample of inhabitants in this survey containing all age groups from 10 years old and over. Therefore, the lack of basic knowledge detected among the citizens of the city shows a low level especially for those between 20 and 39 years (Fig. 3) belonging to the category of the active population responsible for decision making. The remediation of its shortcomings in the sustainable management of municipal solid waste would be, on one hand, a way of solving the health problem of the city of Bujumbura, and, on the other hand, an economic development to solve the problem of these wastes [13].

MSW in the city of Bujumbura is currently poorly sorted up to 23.7% (Table 2). Indeed, unsorted waste is

collected and directly landfilled generating polluted sites, source of contaminant of air, soil, groundwater and area. It has been proven that the soil, surface water and groundwater from these uncontrolled landfills are contaminated with elements that are harmful and dangerous to health and the environment [1, 11, 17]. The aim of this work is to highlight the urgent need to address an environmental challenge to improve this situation in a short, medium and long term.

The analysis of results of the survey realized on a representative sample of the population of the city of Bujumbura in this study shows that the lack of information, material and financial resources are the main obstacles to realize the sorting. The installation of containers dedicated to specific waste, sorted at source, allows the recycling and reuse of MSW and therefore is beneficial for the population. with a sustainable management [11,12,19]. This observation should therefore make it possible to plan tasks related to the sorting of MSW according to the needs of the city of Bujumbura, the economic capital of Burundi, one of developing countries in the Great Lakes region of Africa.

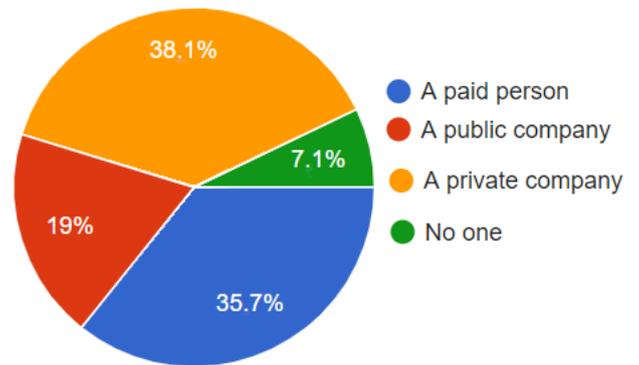


Fig 7:- Collectors of household waste from services (Bujumbura city)

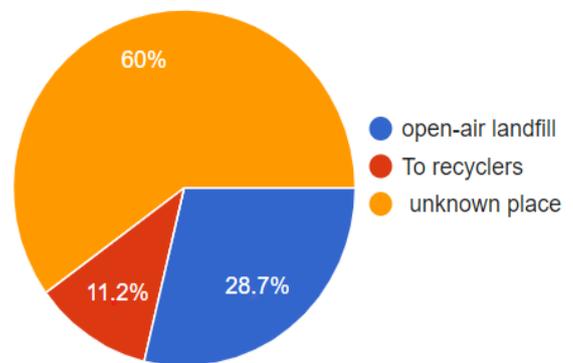


Fig 8:- Destination of waste (Bujumbura city)

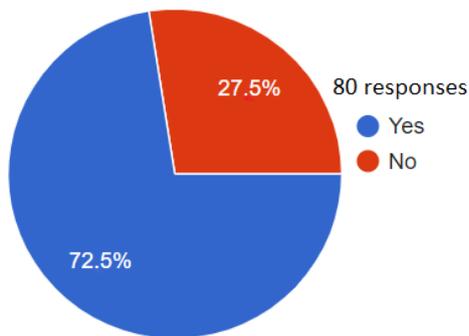


Fig 9:- Citizens informed on good practices on MSW management (Bujumbura city)

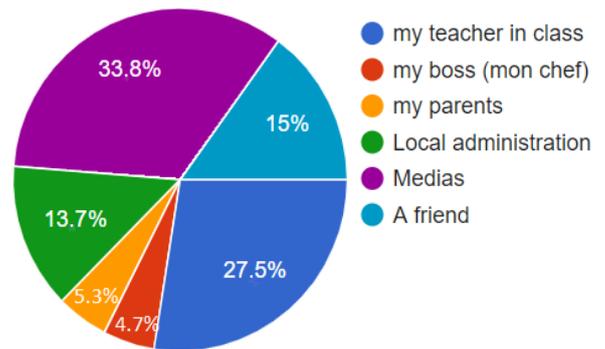


Fig 10:- Source of information in good practices of solid management

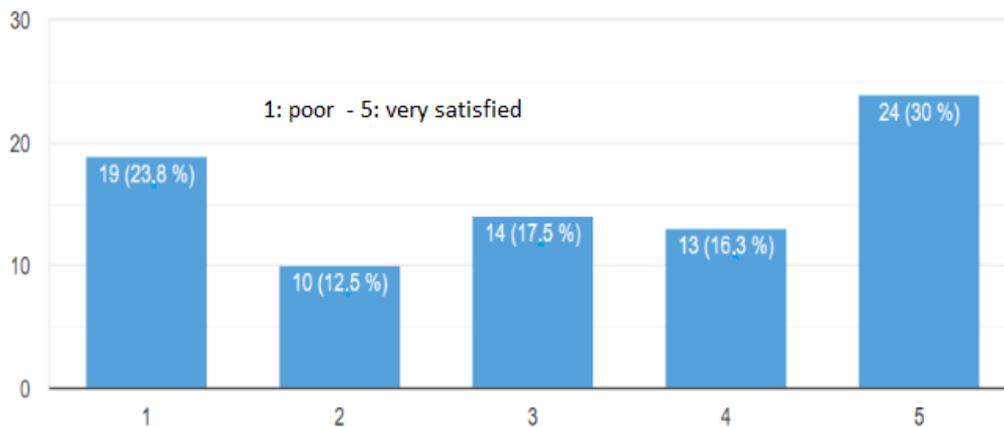


Fig 11:- Level of satisfaction of citizens on information in sustainable management of MSW

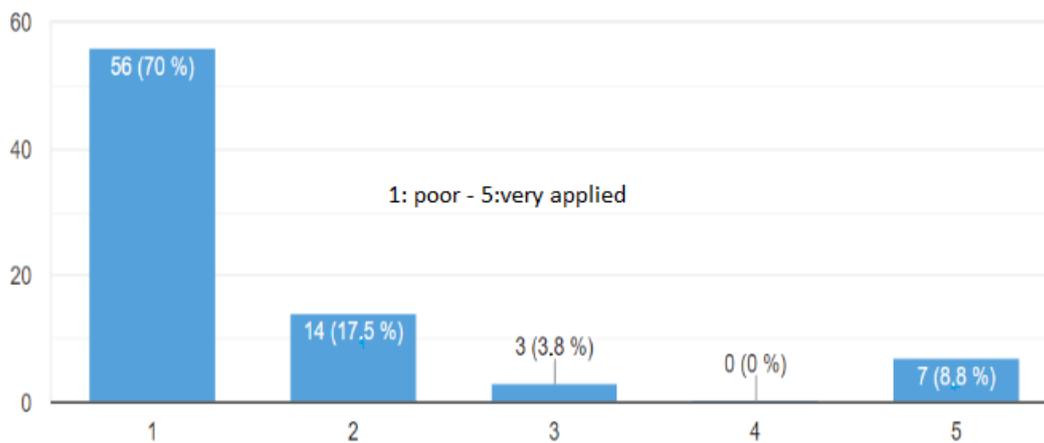


Fig 12:- Level and role of local administration in sustainable sorting and MSW management

The chi-square test carried out by SPSS 22 software via crosstabs, showed that there is a significant relationship between the involvement of the local administration in raising awareness of sustainable management and the way in which municipal solid waste are managed ($p < 0.05$). The value of Chi square is 14.374, with a degree of freedom of 6. The coefficient of contingency being of 0.390, it is important

to mention that this relation between the two observations is weak and of which it would have other factors entering at stake to justify the fact that waste is currently managed in this way in the municipality of Bujumbura. This is probably closely linked to the results obtained (Fig. 12) which show many different sources of information on good practices in the management of municipal solid waste.

Destination of waste in Bujumbura city

Role of local administration in sustainable sorting and management of MSW		To recyclers of MSW	open-air landfill	Another unknown place	Total
Poor	Number	4	16	36	56
	%	44.40%	69.60%	75.00%	70.00%
Rarely applied	Number	4	1	9	14
	%	44.40%	4.30%	18.80%	17,50%
Applied	Number	0	1	2	3
	%	0.00%	4.30%	4.20%	3.80%
More applied	Number	1	5	1	7
	%	11.10%	21.70%	2.10%	8.80%
Total	Number	9	23	48	80
	%	100.00%	100.00%	100.00%	100%

Table 3:- Crosstab between “Destination of waste” vs “Role of local administration” in sustainable sorting and management of MSW”

- Chi-square value of Pearson: 14,374 ($p < 0.05$)
- Coefficient of contingency : 0,390 ($p < 0.05$)

Thus, in order to manage DSM in a sustainable way in developing countries, it is important to point out the essential role played by local decision-makers. In fact, the local administration remains close to the inhabitants, ensuring the implementation of the decisions of the central administration which must set up and initiate sorting and sustainable management of DSM through public and private companies.

V. CONCLUSION

The objective of this paper is to assess the level of basic knowledge, behaviour and management of municipal solid waste in the city of Bujumbura. The results of a survey realized in this study show that the majority of Bujumbura's citizens do not sort waste. They face to different challenges such as the lack of adequate information on municipal solid waste management, the lack of separate containers, waste collection by categories and the lack of collection services. To ensure solid waste management in Bujumbura, the specific points of intervention are highlighted and concern: the wide dissemination of information through the media, local administration, the development of waste collection and recycling services, environmental education through the Burundian education system.

As recommendations, the government and other stakeholders should use the results of this work to invest in order to communicate all the information necessary to promote the proper establishment of the city of Bujumbura. Financial and technical resources must accompany this reform to be successful. Waste recyclers need support to optimize their intervention. Environmental protection laws should also be improved and enforced to ensure the implementation of a sustainable waste management policy in line with sustainable development.

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➤ Conflict of Interest

The authors state there is no conflict of interest.

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