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Assessment of Papers and Cardboard Wastes and Their potential use for the Production of Combustible Briquettes

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Abstract: The problem of waste management in some poor countries is usually linked to their non-preliminary quantification. This study aims at quantifying the flow of paper and cardboard waste in Maroua town and to evaluate its recycling capacity for combustible briquettes production. Paper and cardboard wastes produced by households, public sector, private organizations and shopping centers were collected and quantify. The production of combustible briquettes with this type of material was evaluated. Some physicochemical parameters as moisture content, volatile matter content, fixed carbon content and ash content of the briquettes were evaluated. The environmental impacts of the use of the briquettes were determined. Globally, annual flow of total rejected papers waste was found to be around 81,713.00 kg in Maroua town. Moisture content of combustible briquettes produced and dried at room temperature during 7 days is 4.02±0.47%. Higher fixed carbon content has been observed with combustibles briquettes made with waste pretreated with alkali solution (39.99±9.0 %). With total amount of 81.7 tons of paper waste rejected each year by targeted sectors of this study, it is estimated the production of 102.141 tons of combustible briquettes. This was found to be equal to about 153.2 tons of firewood use as combustible. It appears that the recycling for the cooking energy production of paper and cardboard wastes could significantly reduce the firewood consumption and thus deforestation.

Keywords:- *Paper, cardboard, wastes, briquettes, cooking energy, Cameroon*

I. INTRODUCTION

The safeguarding of environment can be considered as one of pillars for sustainable development. In many countries of subtropical Africa, this is timidly integrated in the development plans (Ngahane, 2015). The treatment of waste represents a significant cost for all municipalities (El Maguiri *et al.*, 2015). In Sahelian countries such as in far north region of Cameroon, the recycling of paper and cardboard waste are less interesting to people because of low knowledge about it's potential use represents a significant cost for all municipalities (El Maguiri *et al.*, 2015). In Sahelian countries such as in far north region of Cameroon, the recycling of paper and cardboard waste are less interesting to people because of low knowledge about it's potential use. In addition, it is perceived as presenting minor or no risk to the environment. However, the quantities produced are significant and vary from one city to another. For example, paper and carton waste was evaluated as 3.5% of waste in Yaoundé while it is 3.7% in Douala, 1.3% in Bafoussam, to 1.7% in Garoua (Sotamenou, 2010). Specifically, papers represent 2.3% and carton 1.2% of waste produced in Garoua town (Ngnikam *et al.*, 2017). According to the document of National Strategy of Waste Management in Cameroon (2015), from 2007 to 2015 period, four branches of activities jointly generate 80% of all waste papers. These sectors include education (125 tons per month), trading and business (69 tons per month), administration (47 tons per month), banks assurances services (36 tons per month). It is known now that waste papers and cardboard present environmental risk if their management is poorly carried out.

Papers, carton and plastic are combustibles (Prévot, 2000). In the context of energy optimization for sustainable economy and sustainable management of climate change, together with the energy crisis problem and health diseases, the problem of waste paper management seems to be a serious issue for environmental management in northern Cameroon. We investigate by average of quadratic fallacy, and completion by observations during the management process and propose improvement as described by Lyberg, (2012). The objective of this work is to evaluate papers and cardboard wastes produced in Maroua town and use these wastes as material to produce combustible briquettes.

II. MATERIALS

1-Tools for assessment, pretreatment and characterization of papers and cardboard wastes

Paper and cardboard waste quantities are evaluated using a scale of 10^{-3} gram of precision. According to standard NF ISO 14021 and Olek *et al.*, (2002), various categories of those types of wastes were distinguished. Sand and plastics are added to papers and cardboards during the production of briquettes to improve its calorific value. Clay and arabic gum are used as binders.

Pretreatment of paper, cardboard and plastic wastes is done by washing them with acidic (H_2SO_4 and CH_3COOH) and alkali (NaOH and NaClO) solutions diluted in water to wash away inks on those papers and cardboard. Samples are processed as presented in table1.

Table 1: samples

Briquette (%)	Paper/ Cardboard	Sand	Plastic	Clay	Arabic gum
A*	87	5	2	5	1
B*	89.75	4	1.75	4	0.8
C*	91.9	3	1.5	3	0.6
D*	94.6	2	1	2	0.4
E*	97.3	1	0.5	1	0.2
F*	99.75	0	0.25	0	0

Compaction is realized by using manual press.

III. METHODS

1- Quantification of paper and cardboard wastes

Eurostat (2001) methodology proposes to separate all flows in five categories: local's extractions, importations, rejection into nature, exportations and non-used local's extractions (Morris, 2016).

To quantify paper and cardboard waste productions in the town, a survey was done during 3 months in various offices and households in order to determine their productions. Volume assessed was obtained by following equation (Mizero, 2015):

$$Q = V \times \rho$$

where: Q quantity (kg) and V volume (m^3) of paper and carboard wastes per year; and ρ is the volumic mass (kg/m^3) of paper and cardboard wastes

$$Rr = \frac{Evacuated\ solids\ wastes}{Produced\ solids\ wastes}$$

2- Characteristics of combustible briquettes

Density Test

Kers *et al.* (2010) show that, density of briquettes made by bio-waste depend on the density of bio-waste, applied pression during manufacturing, temperature and exposition time of drying. It is calculated as following.

$$\rho_N = m_N / V_N$$

Moisture content of briquettes

Moisture content of dried briquettes (H_{brute} and H_{dry}) were measured. Three samples of each type of briquette were formed. The mass of 10 grams of each was taken (M_0) and dried in an oven at 105°C for 24 hours, following standard protocol BS EN 14,774-1. Samples are thereafter weighted to obtain dry mass (M_f). The moisture content was then calculated using the below equation.

$$H_{dry} = \frac{M0 - Mf}{M0} \times 100$$

Where M_0 is initial mass and M_f dry mass

Volatile matter content

Volatile matter content is an important index of coal quality characteristics. In order to measure it, one gram of each type of briquettes has been taken and put in oven at 105°C for drying. Dried matter is introduced in the muffle furnace for 7 minutes and calcined at 550°C. Volatile matter content of combustible is expressed through the following equation:

$$MOV = [(M_{105°C} - M_{550°C}) \times 100] / M_{dry}$$

MOV: volatile matter content, $M_{105°C}$: Mass obtained after heating at 105°C, $M_{550°C}$: mass obtained after heating at 550°C.

Ash content

One gram of each dried briquettes was introduced in stove for roasting at 850° C during 5 hours before weighed. Ash content is measured using the following equation:

$$A_{sh\ (\%)} = \frac{Mash}{Mv} \times 100\%$$

M_{ash}: mass of powder obtained after incineration at 850°C, M_v: mass of d at 550°C.

Fixed carbon content

Fixed carbon content of each samples of combustible briquette has been determined as follows:

$$C_f\ (\%) = 100 - (M_v + H_{dry} + A_{sh})$$

C_f (%) is fixed carbon content obtained of each combustible briquette, M_v is volatile matter content, H_{dry} is moisture content in each combustible briquette and A_{sh} is ash content in each combustible briquette.

IV. RESULTS

1-Flows of paper waste during 2019-2020

Globally, flow of Total Rejected papers waste is 81,713 kg in Maroua. Table 2 gives more details related to various sectors targeted by the survey. It is noticed that from households, flows are higher than those of the rest of investigated sectors. Exportations in household represent 97.56% of the Total Exportation. Local Extractions in household represent 75.12% from Total of locals Extractions. Rejected waste papers toward nature (water and soil) in household represent 88.3% from Total of Rejected waste papers.

Table 2: Average flows of rejected second generation paper waste in Maroua town (kg)

	Household	*Office Sectors*	*Shopping and business offices*	*Private Organizations*	*TOTAL*
Exportation (EXP)	37 082	115	41	771	38 009
Importation (IMP)	1 658	5 478	565	3 062	10 763
Locals Extractions	27 761	5 585	448	3 119	36 917
Non-used locals Extractions	9 321	5 474	407	2 348	17 550
Rejected waste papers toward nature	72 506	5 700	331	3 176	81 713

2- Characteristics of combustibles briquettes

In table 3, the major characteristics of produced briquettes are summarized.

Table 3: Some characteristics of the pretreated combustible briquettes

	Density	Moisture content	Volatile matter	Ash	Fixed carbon
Combustibles briquettes pretreated with acidic solution	1.12±0.04 [a]	3.87±0.41% [b]	33.21±3.12% [b]	5.43±0.32% [a]	37.00±6.0 %
Combustibles briquettes pretreated with alkali solution	1.12±0.03[b]	4.18±0.53% [d]	36.79±2.14% [c]	4.59±0.73% [b]	39.99±9.0 %

The average density of the combustible briquettes we produced is 1.12±0.04. Okia *et al.* (2016), shew that combustible briquette densities depend on squeeze force and played pressure during compaction. Moisture content of combustible briquettes dried at room temperature during 7 days is 4.02±0.02%. Briquettes made from pretreated waste with alkali solution take longer time to be dried (maximum of 10 days). Similar briquettes produced by Tizé *et al.*, (2020) associating papers (80%) and clay (20%) had greater moisture content value (7.05 ± 0.38%).

Average value of volatile matter of briquettes produced is 35±2.51%. This result is greater than those varying from 16.0% to 22.9% obtained by Abia *et al.*, (2014). As the ash content is concerned, we have obtained an average of 5.01±0.49 %. This result is not far from the ash content ranged from 6.25% to 3.50% obtained by Sotannde O.A. et al. (2009)

As the fixed carbon is concerned, it has been observed that combustible briquettes pretreated with alkali solution has higher value (39.99±09 %) whereas small fixed carbon content has been observed on combustibles briquettes pretreated with acidic solution (32.22±15 %).

3-Characteristic of smokes emitted by briquettes

During briquettes combustion, CO and CO_2 emitted have been analyzed (table 4)

Table 4: Smoke test

Parameters	Combustibles briquettes pretreated with acidic solution	Combustibles briquettes pretreated with alkali solution
O_2 (%)	19.4±2.3	22.9±0.9
CO (ppm)	1242±12	1051±15
CO_2 (%)	0.98±0.0	1.46±0.0

The results of the tests show that briquettes pretreated with acidic solution produce during combustion more CO (1242±12 ppm) than those ones obtained from pretreated paper waste with alkali solution. On the other hand, it has been noticed that paper waste pretreated with alkali solution has emitted more CO_2 (1.46±0.0%). These results indicate that the pretreatment has significant influence on the amount of CO_2 and CO emission.

4-Environmental impacts of the production unit of combustible briquettes from paper and cardboard wastes

With total amount of 81.7 tons of paper waste rejected each year by targeted sectors of this study, it can be produced 102.141 tons of combustible briquettes according to Tize *et al.* (2020). This previous research has established the relation between combustible produced from the paper waste and firewood. In fact, 1 ton of briquettes is equivalent to 1.5 ton of firewood in term of cooking energy production. Consequently, the above potential quantity of combustible corresponds to 153.2 tons of firewood. It appears that the recycling for the cooking energy production of paper and carboard wastes could significantly reduce the firewood consumption and deforestation.

In addition, paper wastes can serve as substrate to produce biogas. According to Rodriguez *et al.*, (2017), it is possible to produce 253 ml/g of biogas by using pretreated papers. Therefore, the rejected potential paper waste in the town of Maroua can yield a potential of 20,670 m^3 of biogas. Biogas is known as a clean source of energy. It can be used as cooking energy. It is mostly used for the electricity production and thus, contributes to reduce the fossil fuel consumption.

There is a great social impact of recycling paper and carboard wastes into a source of cooking energy mainly in cities such as Maroua. In fact, poor people in cities are facing huge difficulties to have access to cooking energy.

They do not have financial means to buy firewood or cooking gas. Most often, they collect cow dung and any pieces of woody matter in the town. The use of paper and cardboard wastes to produce a cooking energy will help this group of population in order to meet their needs of energy.

V. CONCLUSION

This study has two main objectives. The first was to assess paper and cardboard wastes produced in Maroua town, and the second was to produce and characterize the combustible briquettes made from those wastes. Globally, flow of Total Rejected waste papers and cardboards 81.713 tons in Maroua town.

Briquettes made from pretreated waste with alkali solution take longer time to be dried. In addition, briquettes made with paper waste pretreated with acidic solution emit more CO while those produced after an alkali pretreatment reject more CO_2. The environmental impact of the recycling of those waste materials shows that a potential quantity of 102.141 tons of combustible briquettes could be produced using the assed quantity of wastes. Those briquettes correspond to 153.2 tons of firewood. It appears clearly that the recycling of paper waste can contribute to reduce the firewood consumption and consequently slowing down de deforestation speed in the sahelian zone.

On the social point of view, this type of technology will easy the life to poor people living in town who very often facing a great difficulty to get a cooking source of energy.

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