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Management and energy recovery of plastic waste in the urban municipality of Mamou (Republic of Guinea)

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ABSTRACT: *This research makes a general inventory of the management and identification of ways to recover energy from solid household waste in the city and in particular plastic waste. The main results obtained relate to: the average monthly production of household solid waste varied from 134.75 kg to 170.5 kg, recorded respectively in January and July 2020; the quantities of household solid waste production in the town of Mamou varied from 3710.876 kg (Télico) to 1055.250 kg (Loppe 1), with a total annual production of 60.089 tonnes and an average daily production per inhabitant of 0.643 kg /hbt/j; the quantities of annual production of plastic waste in the different districts of Mamou varied from 75.85 kg (Sabou) to 447.50 kg (Télico), with an annual quantity of 5153.39 kg. The neighborhoods (Télico, Poudrière 2, Almamya Dumez, Poudrière 1 and Kimbely 1) remain the highest producers of plastic waste, with the respective values (447.50 kg; 405.52 kg; 370.79 kg; 307.85 kg and 260.54 kg). The annual ratios of plastic waste in Mamou's household solid waste vary from 4% (Séré-centre) to 18% (Poudrière 1), with an annual average value of 9%. The following districts (Poudrière 1, Almamya Dumez, Almamya Mosquée, Almamya Résidence and Télico), have the highest plastic waste production rates, with the respective values (18%; 15%; 14%; 13% and 12%). Knowing that, plastics can take up to billions of years to degrade naturally due to its stability, thus it is a growing social problem due to environmental pollution and depletion of sites burial.*
Keywords: *Management, recovery, recycling, domestic waste, plastics.*

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I. INTRODUCTION

The issue of urban waste is a problem that arises both locally and globally. Indeed, their ever-increasing production is one of the characteristic features of the evolution of our societies, whether in developed or developing countries [1]. Waste develops, diversifies, amplifies due to population growth, urban concentration, modernization of the way of life linked to industrial development and consumer technology. This waste, which is a risk factor for soil, water, air and health, is also a source of waste of raw materials and energy [2].

The advent of new modes of consumption linked to industrial production has made men consume more products that are not biodegradable. This is the case of plastic materials, the consumption of which leads to the production of new forms of waste that resist the "digestion" of nature [3]. The rapid and uncontrolled urbanization of African countries has caused the deterioration of the environment. One of its most worrying consequences in developing countries, and particularly in Africa, is facing problems in the management of solid, liquid and toxic waste. One need only walk through any African city to see the manifestations of this problem: litter piles, litter along roads, blocked streams, health-threatening landfills in residential areas, and improper disposal of toxic waste [4]. The high rate of urbanization in African countries leads to rapid accumulation of waste. The social and economic changes that most African countries have undergone since the 1960s have also led to an increase in waste generation per person [5].

Guinea, through its cities and particularly the city of Mamou, is not left behind when it comes to waste management. In the town of Mamou, a large quantity of solid waste is produced, and the piles of this garbage give off unpleasant smells, undermining hygienic conditions. And this, because of a real problem of equipment, treatment and evacuation of this waste. Plastic packaging waste, which constitutes a high rate in urban garbage at the household level, pollutes and makes unhealthy.Since their appearance in the 1840s, plastics have revolutionized our daily lives and our environment. The development of these materials is explained by their multiple qualities; formability, hydrophobicity, biological inertness, low density, mechanical strength and low price [6].

According to some authors, plastic waste represents nearly 10% of the total tonnage of waste from most cities in Guinea. There are mainly polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS) and polyethylene terephthalate (PET). This plastic waste creates real environmental problems. Indeed they are difficult to decompose, pose a problem of insalubrity and visual pollution. To fight against the negative effects of waste and particularly plastics [9].

Waste management in general, especially plastic packaging in particular in the city of Mamou is today characterized by a crucial lack of the technical and financial means that the municipality needs to deal with an effective management of this waste. However, the sector could be used as one of the solutions to the unemployment problem which is hitting our populations hard, especially young people. Waste management could create thousands of jobs in collection, transport, sorting and recovery [7].

In recent years, there has been an increasingly strong mobilization against the use of plastic bags. Various actions are carried out by public authorities and associations to reduce the impact of these bags on our environment [8].Dumping household waste (plastic and others) in the gutters has unfortunately become the daily life of some citizens of the urban commune of Mamou. And this despite the presence in Mamou for a little over a year, of Molthanas environment, the solid waste management company in the 28 districts of the urban municipality of Mamou which is working hard for the collection of household waste. The latter has installed garbage cans in front of households, shops and stores. The workers of the company also collect the garbage which is in the gutters and which is dumped during heavy rains by citizens.

This work focuses on the management and identification of ways to recover energy from plastic waste (bags and sachets of mineral water). To achieve the expected results, we have set the following objectives: a quantification of plastic waste and identification of recovery techniques.

II. MATERIALS AND METHODS

II.1 Presentation of the study area

The prefecture of Mamou is located on the southern and south-eastern foothills of the Foutah massif. It covers an area of 8000 km² with a population of 236290 inhabitants including 121326 women and 114964 men and an average density of 30 inhabitants/km². It remains limited: to the south by Sierra Leone, to the north by the prefecture of Tougué and Dalaba, to the east by the prefecture of Faranah and Dabola, to the west by that of Kindia.

Its area is divided between an urban commune and 13 rural communities (RC), namely: Bouliwel, Dounet, Gongoré, Kegneko, konkouré, Gnagara, Ourekaba, Porédakar, Saramoussaya, Soya, Teguereya, Timbo, Tolo. These cities are made up of 28 districts. The population is predominantly rural, 79% of Mamou's population is found in rural areas. Its density is 30 inhabitants/km² and its climate is tropical [9]. The map of the urban commune is shown in Figure 1.

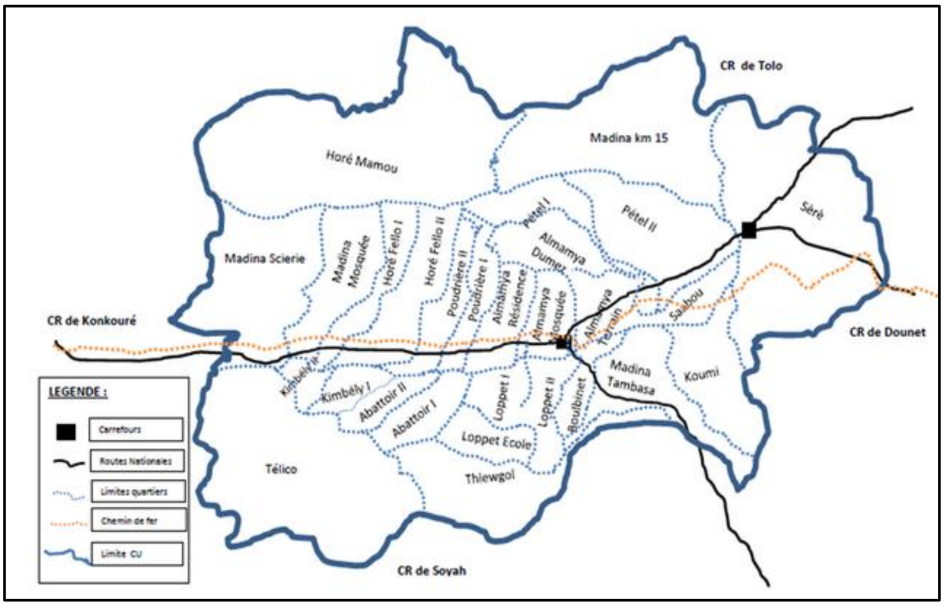


Fig. 1 Map of the Urban Commune of Mamou

II.2 Materials

The management of plastic waste in Mamou required the following materials: polyethylene bags, markers, survey sheets, forks, rakes, shovels, tarpaulin, buckets, boots, gloves, nose guards, wheelbarrows, hook scales.

II.3 Methods

The methodology followed was based on documentary research and field surveys. The methodology adapted for carrying out this study consists of: documentary research, contact with the authorities in charge of waste management, identification of collection points for waste samples, collection and transport of waste instead of sorting (within the premises of the Higher Institute of Technology of Mamou), the evaluation of the proportion of each type of waste and the proposal of the axes of recovery of waste of plastic types.

During the period from January 05 to February 25, 2020, we made contact with the municipal authorities in charge of waste management at the town hall, thus the information collected is as follows:

- NGOs, SMEs and other actors involved in waste management in Mamou;
- Public and private trash cans installed in the municipality;
- Waste transport vehicles (containers, garbage bins, carts, trolleys, dumpsters etc.).

The waste was collected in the 28 districts of Mamou from January 05 to December 27, 2020, which are: Abattoir I, Abattoir II, Almamya Terrain, Almamya Résidence, Almamya Dumez, Boulbinet, Horé Fello I, Horé Fello II, Horé Mamou, Kimbely I, Kimbely II, Koumi, Loppet School, Loppet I, Loppet II, Madina km 15, Madina Mosque, Madina Sawmill, Madina Tambasa Sabbou, Sèrè, Telico and Thiewgol.

This collection covered three (03) households of 4 to 10 people in each neighborhood, depending on the standard of living (high standing, medium standing and low standing). The waste collected in 50 kg bags was labeled (date and origin) and then transported on three-wheeled motorcycles within the courtyard of the Mamou Higher Institute of Technology for sorting.

The waste collected was sorted, then quantified by category, these different types of waste are: Fermentable organics, plastics and rubbers, batteries, gravel, bones, glasses, scrap metal, rags or textiles, hides/skins, hair, ashes, wicks, etc. . The ratio of the daily quantity of waste produced per inhabitant is determined by equation 1 [10].

$$R_j = \frac{Q}{P \times t} \quad (1)$$

Or

Rj: Daily ratio of household waste per person in (kg/inhabitant/d);Q: Total mass of waste collected at household level during time t (kg);P: Total number of the population concerned;t: Characterization time in days (d).

The images in Figure 2 show the inventory of household solid waste in the town of Mamou.

Photo 1: Solid waste in the Mamou wole stream in the Tambassa district

Photo 2: Solid waste in the gutters in the Almamya Dumez district

Photo 3: Solid waste in the gutters in the Almamya Terrain neighborhood

Photo 4: Solid waste in the gutters in the Loppet Ecole district

Photo 4: Household solid waste for weighing

Photo 5: Weighing of household solid waste

Photo 6: Sorting household solid waste

Photo 7: Plastic waste

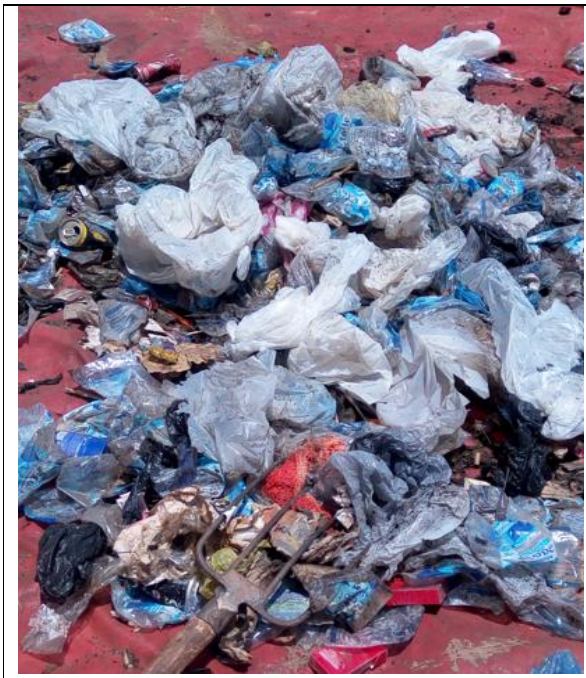


Photo 8: Plastic waste

Photo 9: Weighing of solid plastic waste

Fig. 2 Solid household waste in the city of Mamou

III. RESULTS AND DISCUSSIONS

III.1 Average monthly production of solid waste per household

The average monthly production of household solid waste per household is illustrated by the diagrams in Fig. 3.

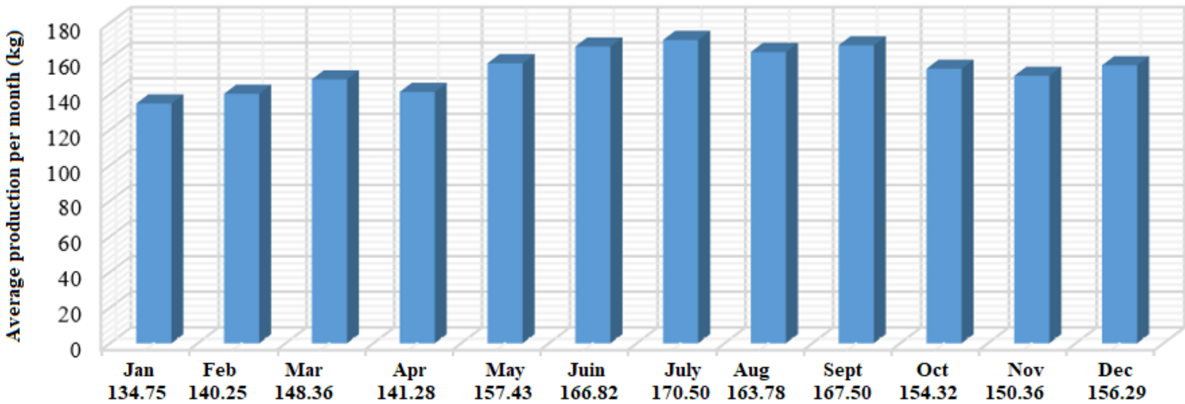


Fig. 3 Average monthly waste production per household

The diagrams in Figure 3 show that during the survey period (year 2020), the average monthly production of household solid waste varies depending on the household and the month of the year. These productions vary from 134.75 kg to 170.5 kg, recorded respectively in January and July. These results show that the quantities of household solid waste are high during the heavy rains or the rainy season (June, July, August and September) with respective values (166.821 kg; 170.5 kg; 163.786 kg and 167.5 kg).

III.2 Annual production of household solid waste by district

The annual production of household solid waste by district is illustrated by the diagrams in Figure 4.

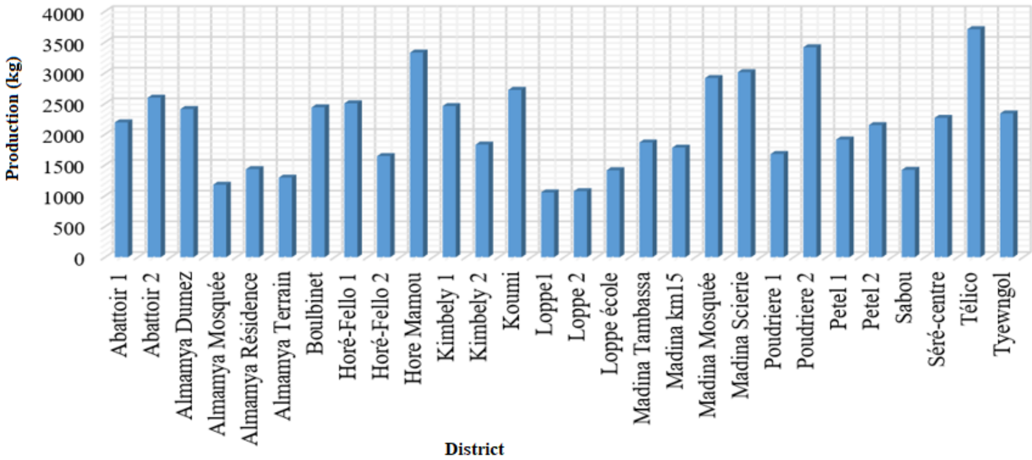


Fig. 4 Annual production of household solid waste by neighborhood

Figure 4 shows that the quantities and composition of annual production of household solid waste are functions of the standard of living of the different households (low standing, medium standing and high standing), which is in line with the results of other authors [11].

These results show that the quantities of household solid waste production for the year 2020 in the town of Mamou vary from 3,710.876 kg (Télico) to 1,055.250 kg (Loppe 1), with a total annual production of 60.089 tons and an average daily production per inhabitant of 0.643 kg/capita/day. This result is consistent with those of other authors, who estimate that the average daily production of household waste per inhabitant is between 0.30 kg/inhab./d to 1.50 kg/inhab./d [12].

The quantities of waste production remain the highest in the following districts: Télico, Poudrière 2, Hore-Mamou and Madina Scierie, i.e. 3710.876 kg respectively; 3416.458kg; 3330.310 kg and 3011.960 kg. This is explained by the density of the population in these neighborhoods, their standard of living and their socio-economic activities.

III.3 Annual production of plastic waste by district

The annual production of plastic waste by district is illustrated by the diagrams in Figure 5.

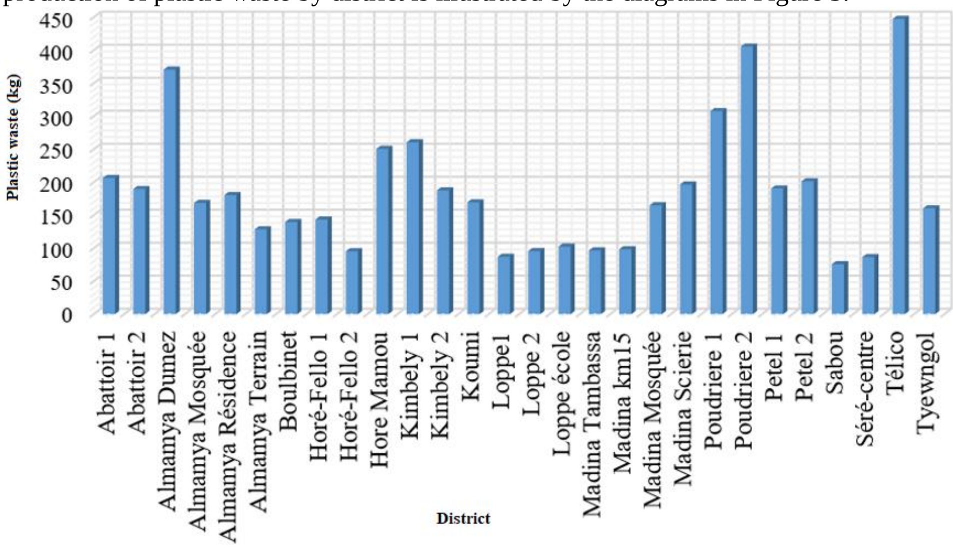
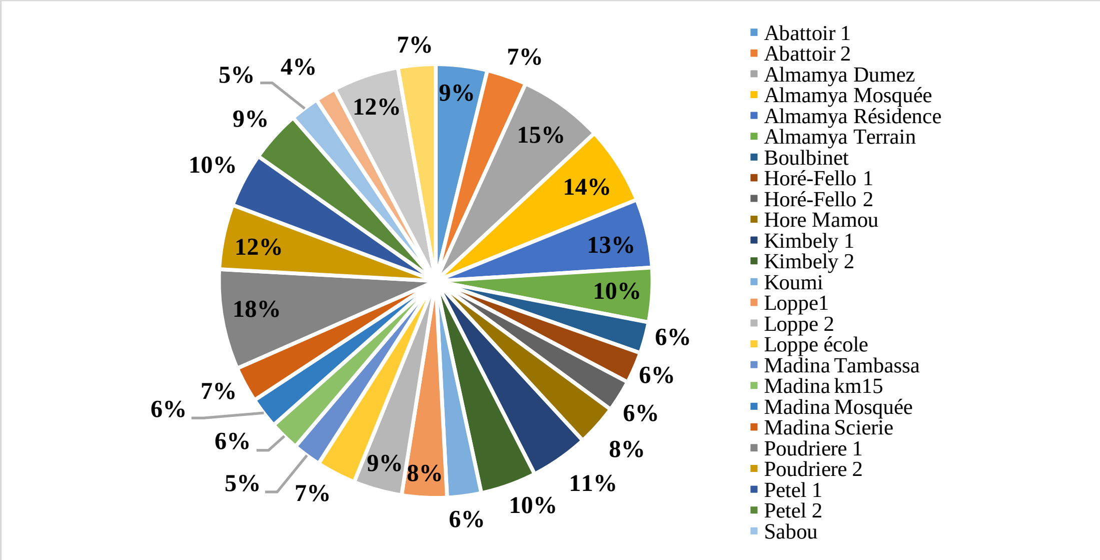


Fig. 5 Annual production of plastic waste by district

Figure 6 shows that the quantities of annual production of plastic waste in the different districts of the city of Mamou vary from 75.85 kg (Sabou) to 447.50 kg (Télico), with an annual quantity of 5153.39 kg. The neighborhoods (Télico, Poudrière 2, Almamya Dumez, Poudrière 1 and Kimbely 1) remain the highest producers of plastic waste, with the respective values (447.50 kg; 405.52 kg; 370.79 kg; 307.85 kg and 260.54 kg). This is explained by the standard of living of the different households and their socio-economic activities.

III.4 Annual plastic waste ratios by neighborhood
Annual plastic waste ratios by neighborhood are shown in the diagrams in Figure 6.



Fg. 6 Annual plastic waste ratios by neighborhood

The diagram in Figure 3.4 shows that the annual ratios of plastic waste in Mamou household solid waste vary from 4% (Séré-centre) to 18% (Poudrière 1), with an annual average value of 9%. The following districts (Poudrière 1, Almamya Dumez, Almamya Mosquée, Almamya Résidence and Télico), have the highest plastic waste production rates, with the respective values (18%; 15%; 14%, 13% and 12%). Similarly, this is explained by the standard of living of the different households and the socio-economic activities carried out in the different neighborhoods.

III.5 Ways of recovering plastic waste
Knowing that, plastics can take up to billions of years to degrade naturally because of its stability, they are, therefore, a growing social problem due to environmental pollution and depletion of sites. landfill [30].Since plastics are generally high calorific value products of 18000 to 38000 kcal/kg, their use for energy recovery or for the production of chemicals can be an alternative option [13].

Several authors have proposed a hierarchy of management and recovery of plastic waste to reduce the environmental impact. It consists of: waste minimization, reuse, recycling, energy recovery and landfill [14, 15]. Waste minimization and reuse are options with limited applicability. Therefore, recycling and energy recovery are alternatives to consider. Energy recovery by incineration seems to be an appropriate solution but is currently questioned, due to the emission of toxic compounds. Recycling represents, therefore, a more appropriate environmental solution, as it allows the recovery of plastics (mechanical recycling) or fuels/raw chemicals (feedstock recycling) from waste plastics with minimal waste [16].

a) Primary recycling
Primary recycling, better known as re-extrusion, is the reintroduction of waste plastics to the extrusion cycle to produce similar products [17].

b) Mechanical recycling (secondary)
Mechanical recycling is the reprocessing of used plastics to form new, similar products. It is a type of secondary plastic recycling where homogeneous waste plastic materials are transformed into products with a level of performance equal to or lower than the original product. Although at first glance the mechanical recycling of plastic waste appears to be a "green" operation, the reprocessing operation is not cost effective as it requires high energy for cleaning, sorting, transportation and treatment [18].

c) Thermal recycling / incineration
It is the recovery of energy by incineration as an effective means of reducing the volume of organic matter. Incineration is a destructive process in which hydrocarbons are converted into their products of combustion. However, in most developed countries, public distrust of incineration currently limits the potential of waste-to-energy technologies, as they produce greenhouse gases and highly toxic pollutants [19].

d) Chemical recycling

Feedstock recycling, also known as tertiary recycling, aims to convert waste polymers into original monomers or other valuable chemicals. These products are useful as raw materials for various downstream industrial processes or as transportation fuels. There are three main approaches: partial oxidation, cracking (thermal, catalytic and hydrocracking) and depolymerization [20].

e) Partial oxidation

The direct combustion of polymer waste can be detrimental to the environment due to the production of harmful substances such as light hydrocarbons, sulfur oxides and dioxins.

However, partial oxidation (using oxygen and/or steam) could generate a mixture of hydrocarbons, syngas ($CO + H2$) and even acetic acid, the quantity and quality depending the type of polymer used [21].

f) Cracking

Cracking processes break down polymer chains into useful lower molecular weight compounds. This can be achieved by reaction with hydrogen, known as hydrocracking, or by reaction in an inert atmosphere, which can be either thermal cracking or catalytic cracking. The products of the plastics cracking process could be used as fuels or chemicals [22].

g) Depolymerization or pyrolysis

Pyrolysis involves the degradation of polymeric materials by heating in the absence of oxygen. The process is usually carried out at temperatures between 350 and 900°C in an inert atmosphere, and results in the formation of a solid residue and a volatile fraction which can be separated into condensable hydrocarbon oil, composed of paraffins, isoparaffins , olefins, naphthenes and aromatics, and a non-condensable gas with a high calorific value [18, 23]. Some examples of tertiary polymer recycling are shown in Table 3.1.

Table (1). Recovery of polymer waste by chemical means [18, 22]

T(°C)	Type of reactor	Process	Material first	Products obtained
420 - 460	Semi-batch reactor	Pyrolyse	PEHD	Diesel
398 - 465	Gray-King	Craquage thermique	PE	Propenylbenzène buténylbenzène
445 - 485	Steel pipe	Craquage thermique	PE	Essence
450	Fixed bed reactor	Craquage catalytique	PEBD	Essence
400 - 550	Semi-batch reactor	Pyrolyse thermique	PEHD	Essence, kérosène et diesel
330 - 490	Batch bed reactor floating	Craquage thermique	PEHD	Diesel
420 - 450	Distiller + column of refining	Craquage catalytique	PE + PP	Diesel
300 - 400	Tubular reactor semi discontinuous	Craquage thermique	PEBD-PEHD	Essence-diesel

IV. CONCLUSION

This present work was carried out in 2020 in the urban municipality of Mamou. The main results obtained concern: the quantification of the average monthly production of household solid waste in the different districts of the urban municipality of Mamou; the determination of the average annual production of household solid waste by district; the determination of the quantity of the average annual production of plastic waste; the description of proposed ways of recovering plastic waste. Several authors have proposed a hierarchy of management and recovery of plastic waste to reduce the environmental impact. It consists of: waste minimization, reuse, recycling, energy recovery and landfill.

This work will be continued with a view to carrying out various experiments in the energy recovery and recycling of this plastic waste.

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