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Post-flood waste characterization test in the Municipality of Athiémé

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Abstract

In the municipality of Athiémé, recurrent and cyclical flood are serious generators of waste. These waste referred as post-flood waste, as it is not the subject of any information or study, are not consider neither the authorities responsible for the management of household waste nor the crisis management unit flooding in the municipality of Athiémé. This study was initiated to induce awareness among the various actors whose this responsibility fall. To make success the study, the methodological approach used proposes a characterization of post-flood waste. This characterization is done in two stages consisting of a typological characterization and a mass estimation of post-flood waste. The typological characterization relied mainly on the material goods and dwellings of the inhabitants, located in the geographical influence of the flood. As for the mass estimation of post-flood waste, it has been possible by multiplying the number of issues exposed to flood risk by the quantity of waste produced per unit of stakes, the issues here being the material goods and the buildings of inhabitants. The application of this methodological approach shows that in the Commune of Athiémé, post-flood waste consists mainly of waste resulting from the partial or total destruction of dwellings (48%), furniture waste (33%) and mixed waste (19%). All of this waste, according to the magnitude of the floods, gives an average mass which varies from 714,846 kg (ie 714,846 tons) with the big flood of 2010 to 139,672 kg (or 139,672 tons) in 2016. This colossal mass post-flood waste, although

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reused at 38% for waste resulting from the destruction of the building, must be taken into account by the authorities at various levels in terms of their management. In this perspective, suggestions were made for their upstream estimation, with well-defined parameters, data and tools.

Keywords: Benin, Athieme, post-flood waste, characterization, typology, estimation

Introduction

Many authors addressing the issue of waste regularly focus on household waste (AZONHE, 2009 ; SEBO, 2014). However, there are several types of waste including industrial waste, agricultural waste, etc. (ADEME, 1993 ; AFNOR, 1996). However, human activities, whether lucrative or not, are not the only factors that generate waste. There are also natural disasters such as earthquakes, volcanic eruptions, cyclones and floods. Global warming in recent years further increases the scale of disasters (GIEC, 2007). The Municipality of Athiémé is familiar with these floods since it suffers one every year. Its occurrence generates numerous partial or total destruction of homes and equipment, the submersion of rooms, deleterious microclimates in the rooms, etc. (AFFO, 2018). BONNEMAINS (2009) moreover defines this flood-related waste as « all materials, materials, objects and deposits which, following a natural or technological disaster, are unfit for consumption, unusable as they are, liable to have an impact on the environment, human health, public health or harm biodiversity » (BONNEMAINS, 2009). Despite the acuteness of the problem of post-flood waste and the importance of its political, social, cultural and environmental issue arising from the definition of BONNEMAINS (2009), it is observed in the Municipality of Athiémé, that only the populations develop management strategies for said endogenous waste applied in households or in affected towns. This failure to take post-flood waste into account in contingency plans by the authorities at various levels, waste managers and crisis managers, does not it denote their "ignorance" of the subject and of the multitude of related data that they must process? Indeed, post-flood waste management cannot be anticipated without a minimum of knowledge of the waste deposit. The production of precise knowledge on the quantification and nature of post-flood waste offers the possibility of obtaining the information necessary for the various actors to complete their crisis management system, anticipate and plan the management of waste linked to floods during periods of flooding. crisis, to reduce the vulnerability of their territory to the risk of flooding and thus to meet some of their regulatory obligations (BERAUD, et al., 2012). « However, local actors such as engineering do not yet have the tools to characterize the deposit resulting from submersion » (CEPRI, 2012). This gap constitutes the challenge

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on which the present study is based, which thus tries to produce an estimation of the volume and the nature of the waste linked to the floods in the Municipality of Athiémé.

1. Area of Study

The Municipality of Athiémé is located about 8 km from the city of Lokossa (by the Lokossa-Zounhouè-Athiémé axis) and 104 km from the city of Cotonou. It covers an area of 238 km2. It is bounded to the north by the Municipality of Lokossa, to the south by the Municipality of Grand-Popo, to the east by the Municipality of Houéyogbé and to the west by the Togolese Republic with which it shares a natural border which is the river. Mono (Djènontin, 2006; Sèbo, 2011; Etchiha, 2011). The Municipality of Athiémé is located between the parallels 6 ° 28 "and 6 ° 40" north latitude and the meridians 1 ° 35 "and 1 ° 47" east longitude (Figure 1).

It is characterized by a subequatorial climate with two rainy seasons alternated by two dry seasons (DJENONTIN, 2006). Its flat relief and eroded in places, is marked by numerous depressions and banks (cords) of sand and sandstone, which constitute watersheds or valleys of rivers and are sheltered by ponds, swamps and bas- funds (DJENONTIN, 2006).

In addition, the soils in the study area are clayey, black hydromorphic clayey, sandy-clayey or sandy-clay, very suitable for pluriculture. They congeal with seasonal water and are mostly inundated by flood waters from the Mono River.

According to the overseas scientific and technical research office, the Mono river is the main watercourse of the municipality. The MONO is a 400 km long river. It flows from North to South. It has its source in the Bafilo mountains, some 20 km from Alédjo, at an altitude of around 800 km. It is an undeniable factor in the flooding phenomenon because of its overflow which has become annual.

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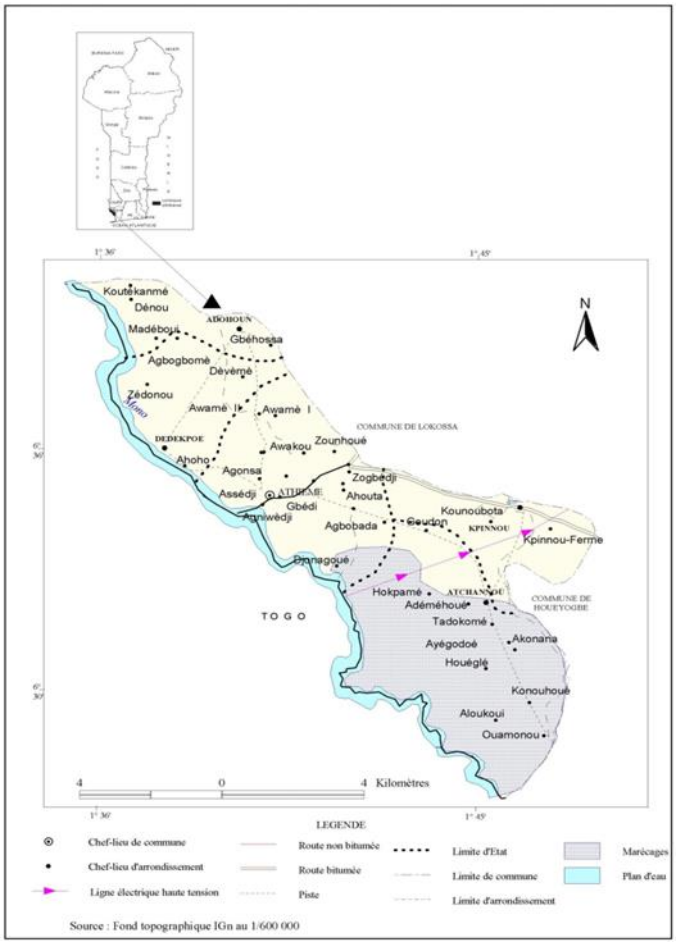

Figure 1: geographical and administrative situation of the Municipality of Athiémé

2. Methodology

Since the floods in the Municipality of Athiémé usually come from the flooding of the Mono River, the speed of the flood current is such that it cannot move large materials such as pebbles and boulders. The post-flood waste observed is therefore only visible at the level of submerged or destroyed buildings since there is no other disposal area for said waste after the water has been withdrawn. In addition, this low speed of the submergence current combined with the rural and agricultural characteristics of the Municipality of Athiémé, allows the population to shelter electrical and electronic goods (refrigerators, freezers, appliances, TV, hi-fi, etc.) as well as vehicles. In addition, no post-flood waste management strategy has been designed and implemented by the crisis management unit in the Municipality of Athiémé. This information, resulting from preliminary investigations in a real environment, through direct observation, a summary documentary analysis,

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and discussions with municipal authorities, guided the methodological approach adopted in the context of this study.

2.1. Unit of deposit considered

Post-flood waste consists of waste from flooding of housing, waste from flooding of activities, and waste from flooding of the territory and the natural environment (BERAUD, 2013). In the present study, the unit of deposit considered constitutes waste from the housing.

2.2. Method of post-flood waste categorization

The identification of post-flood waste is carried out through sampling and manual sorting of waste, according to predefined categories (BEN AMMAR, 2006). It is categorized by waste component. For that, 02 housing totally destroyed, 02 housing partially destroyed and 02 housing flooded but not destroyed were chosen since they are subject to flooding every year. The whole deposit of each selected housing is considered a sample of waste. It is this waste that was sorted by hand and classified into the various predefined categories as follows:

- furniture waste (furniture of residential accommodation);
- household and assimilated waste;
- demolition waste from the residential building..

2.3. Method of post-flood waste quantification

In order to get the amount of post-flood waste (Q_d), the number of houses affected (L_i) by the flood is multiplied by the amount of waste produced per house ($Q_{d/l}$).

$$Qd = Li \times Qd/l$$

For this, the impacted dwellings were classified into "completely destroyed dwellings", "partially destroyed dwellings" and "flooded dwellings without destruction of the building". The different categories of waste were weighed by series of housing in order to determine the average weight of each category of waste potentially produced by a series of housing. It should be remembered that a category of waste consists of a set of goods present in a household or in a dwelling. The sum of the quantities of waste produced per unit or by type of goods present in a household or in a dwelling gives the quantity of waste produced per dwelling unit. The different categories of post-flood waste predefined in this study are as follows:

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furniture waste

This category of post-flood waste consists of:

- beds,
- mattresses (made of foam or cotton residues or braided in straw)
- office furniture,
- kitchen furniture,
- garden furniture,
- interior furniture,
- carpet,
- textiles (curtains, interior blinds, valances, and bed bumpers).

household and assimilated waste

This denomination refer to non-hazardous household waste with the exception of waste electrical and electronic equipment (WEEE) and furniture waste. These are food, clothing, books, dishes, etc.

waste resulting from the partial or total destruction of the residential building

Waste from the destruction of the residential building can be of different types:

- inert: this is waste that does not decompose, does not burn and does not produce any other physical, chemical or biological reaction liable to harm the environment or health (concrete, concrete blocks, tiles and ceramics, glazing, cuttings, stones, etc.),
- dangerous: this is waste containing substances dangerous for the environment or health (asbestos, wood treated with dangerous substances, products containing tar, paints, varnishes, glues, solvents containing dangerous substances, polluted absorbent products hydrocarbons, etc.),
- non-hazardous: this is waste that is neither inert nor dangerous for the environment and health (metals and their alloys, raw or slightly added wood, paper, cardboard, plaster, plastics, mineral wools, etc.). They are also called Ordinary industrial waste.

In the present study, only inert waste and ordinary industrial waste are quantified.

In addition, it was necessary to determine exhaustively the number of houses affected by the floods. This was made possible by counting the houses affected by the flooding through a field survey.

Finally, Regarding the importance of the deposits, eight teams of five sorters/weighers were involved over an expert appraisal period of 30 days during the months of September and October from 2010 to 2016, ie over seven flood cycles.

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3. Results

3.1. A number of housing affected by flooding in the Municipality of Athiémé

Table I shows the number of houses destroyed by flooding in the Municipality of Athiémé during the research period.

Tableau I : Number of housing destroyed by flooding in the Municipality of Athiémé

Year	2010	2011	2012	2013	2014	2015	2016	Average
Housing completely destroyed	82	75	63	47	51	27	22	52,43
Housing partially destroyed	200	101	85	35	40	34	30	75,00
Submersion of housing without destruction of the building	402	264	192	143	133	71	78	183

Source: results of field surveys, 2010-2016

The results of the field investigations (Table I) show that the total destruction of homes concerns on average 52 houses in each flood cycle. However, it is important to note that there is a great disparity in the number of houses totally destroyed from year to year. Thus, it has been observed that since the great flood of 2010, this number has decreased each year and has gone from 82 houses totally destroyed in 2010 to 22 houses totally destroyed in 2016. The same is true for partially destroyed houses, the average of which is 75 is very high compared to the number of partially destroyed dwellings recorded in 2016, which is 30. These disparities are no doubt explained by the magnitude of each flood episode, the largest among those considered being that of 2010 while in 2017, the Municipality of Athiémé, after the small-scale flooding of 2016, was hardly flooded. There is also the submersion without destruction of dwellings at which the same trend is observed: an average of 183 submerged dwellings over the seven years of the study with the maximum in 2010 with 402 dwellings concerned and the minimum in 2015 with 71 dwellings concerned. The photos on Plate 1 show the destruction of houses in the Municipality of Athiémé due to flooding.

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Photo 1 : house completely destroyed at Athiémégan
Prise de vue : Caritas Bénin, 2010

Photo 2 : house partialy destroyed (falling) at Ahoho
Prise de vue : AFFO, 2016

Plate 1: houses totally or partially destroyed in the Municipality of Athiémé during the floods

Photo 1 of Plate 1 shows that it is no longer possible for the occupants of the completely destroyed house, who have moved in the meantime, to return to settle there after the water recedes. On the other hand, those whose houses are partially destroyed (photo 2) can, with a few summary modifications, remain in place.

Nature of post-flood waste in the Municipality of Athiémé

Furniture waste

Figure 2 shows the nature of the furniture waste resulting from the floods in the Municipality of Athiémé.

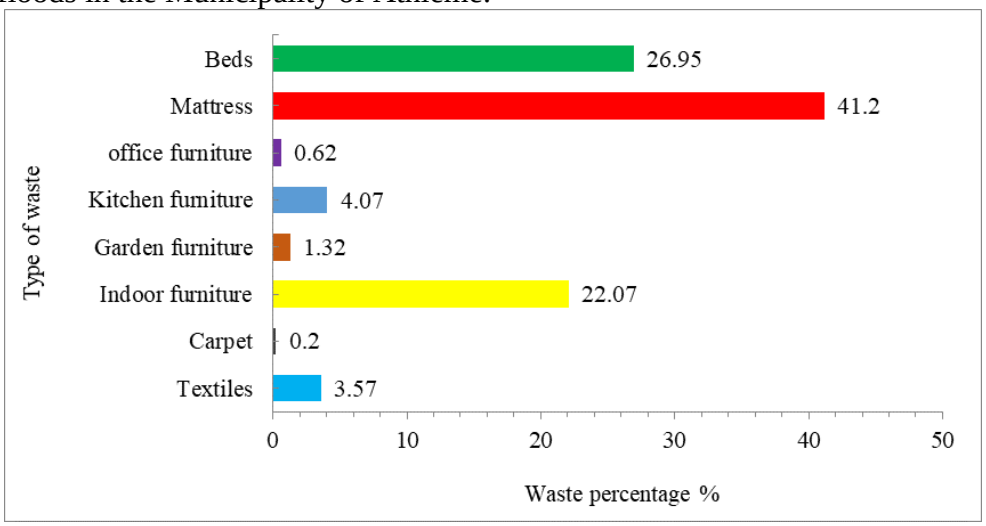

Figure 2 : type of furniture waste
Source: results of fields surbeys, 2010-2016

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The analysis of the results presented in figure 2 shows that the mattresses (in foam or cotton residues or even woven in straw and other beds) constitute the most important elements in total weight of furniture waste (41,20 %). This high proportion is explained by the fact that households still have an element serving as a support for falling asleep, and all these supports are considered to be mattresses. Apart from mattresses, beds and interior furniture follow with 26.95% and 22.07% respectively. Indeed, all households with mattresses (foam or cotton residues or braided in straw) also have beds. This certainly explains the importance of this waste. In living rooms of accommodation, households always try to have at least chairs to sit on and make visitors sit; this also explains the high proportion of interior furniture. It must be said that the bed and interior furniture are mostly made of wood, metals and sometimes even plastic. This is certainly what makes the high weight they present. As for other types of furniture waste, these are often less important goods according to 88% of households. In addition, these are elements whose weight is generally low.

3.2.2. Household and assimilated waste

Apart from the destruction of houses, there is also degradation of goods such as clothing, food stocks, books and dishes. These goods are destroyed and transformed into waste respectively for 49.76%; 29.43%; 17.15% and 03.66% for the statistical units surveyed within the framework of this study. The small proportion of books shows that either these are unusual goods or they are goods for which households often do not have the means of purchase: they are therefore few goods. On the other hand, clothing, food stocks and crockery are generally goods available to households in large quantities and which are all exposed to flooding whether in a case of total or partial destruction of the home or in a case of simple submersion of dwellings

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3.2.3. Waste from the destruction of residential buildings

The total or partial destruction of dwellings generates rubble made up of many elements including inert waste and ordinary industrial waste. Figures 3 and 4 show the nature of inert waste and common industrial waste from floods in the Municipality of Athiémé.

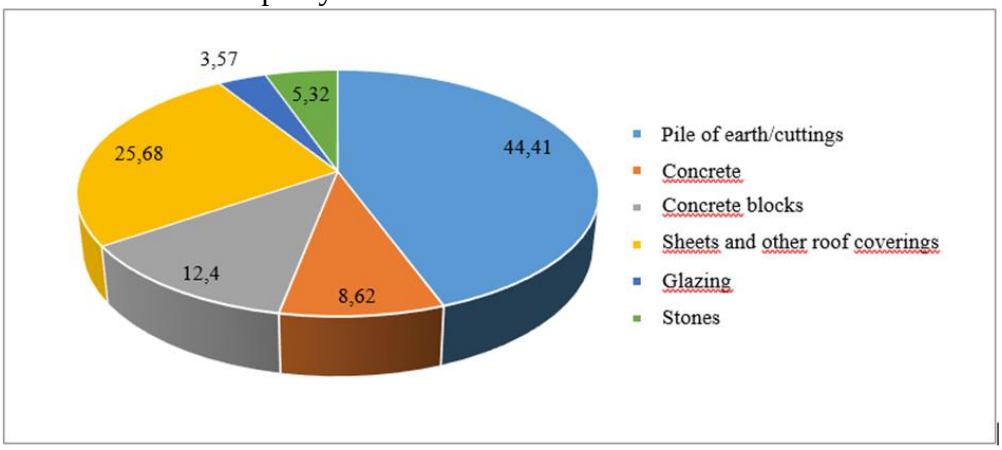

Figure 3 : nature of inert waste
Source: results of fields surveys, 2010-2016

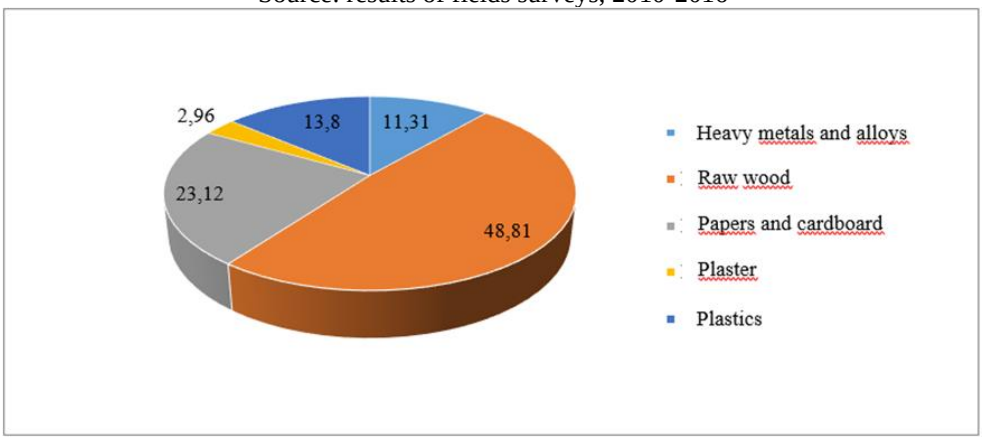

Figure 4 : nature of ordinary industrial waste
Source: results of fields surveys, 2010-2016

Regarding inert waste (figure 3), it is mainly composed of cuttings (earth pile: 44.41%), metal sheets and other roof coverings (25.68%) and concrete blocks (12.40%). %). This waste comes mainly from the walls of destroyed houses. As for glazing (3.57%), it comes mainly from windows and doors. The same is true for part of the metals and alloys, the plaster and part of the woodwork which constitutes ordinary industrial waste. The rest of the metals and alloys come from the bowels of the concrete and the rest of the woodwork comes from the frames of destroyed houses.

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However, it is important to note that the cuttings, cinder blocks and rubble from fallen walls are often fully reused (97.78%) for the construction of new residential buildings. It is the same for a good part (more than 75.36%) of the frame, doors and windows constituting the woodwork. The metal sheets, when they are not completely destroyed, are recovered and reused (67.89%).

3.2.4. The proportion of different categories of post-flood waste

Based on the different categories of post-flood waste, it was determined that waste from the partial or total destruction of homes accounts for 48% while furniture waste is 33%. Finally, the mixed waste is 19%. This is explained by the weight of the various constituent materials of degraded goods which turn into waste.

3.3. Mass composition of post-flood waste in the Municipality of Athiémé

The quantification of post-flood waste was done in kilograms. Table II presents the average results of post-flood waste production during the research period.

Tableau II: average post-flood waste production (in kg)

Types of waste	Années							Average
	2010	2011	2012	2013	2014	2015	2016	
Building destruction waste	1218	729	515	657	604	211	287	≈ 603
Furniture waste	892	745	640	364	152	0	107	≈ 415
Mixed waste	421	375	318	284	276	0	0	≈ 239

Source: results of fields surveys, 2010-2016

These results clearly show that post-flood waste is dominated by rubble from the partial or total destruction of houses (around 603 kg on average) followed by furniture waste (around 415 kg on average) and finally mixed waste. (about 239 kg on average). In total, per flooded residential building, around 1,257 kg of post-flood waste is produced. These averages hide disparities from year to year. These disparities can certainly be explained by the magnitude of the flooding, which differs from year to year. The different consequences of the impact exerted by floods on residential buildings can also induce differentiation in the production of post-flood waste. Depending on the series of housing affected, the results obtained are rather as follows:

- housing totally destroyed: 1792 kg
- housing partially destroyed: 1129 kg
- housing flooded without destruction of the building: 851 kg

Table III presents the results of post-flood waste production by housing series.

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Tableau III: quantification of post-flood waste production (in kg) per housing series

Year	2010	2011	2012	2013	2014	2015	2016	**Average**
Houses totally destructed	146 944	134 400	112 896	84 224	91 392	48 384	39 424	**93 952**
Houses partially destructed	225 800	114 029	95 965	39 515	45 160	38 386	33 870	**84 675**
Submersion of housing without destruction of the building	342 102	224 664	163 392	121 693	113 183	60 421	66 378	**155 976**
Total	**714 846**	**473 093**	**372 253**	**245 432**	**249 735**	**147 191**	**139 672**	**334 603**

Source: results of fields surveys, 2010-2016

The results in Table III show that in terms of total house destruction, around 93,952 kg of post-flood waste is produced on average. However, it is important to note the great disparity in this production of post-flood waste relating to houses totally destroyed from one year to another. Thus, from 2010 to 2016, this production decreases each year and went from 146,944 kg in 2010 to 39,424 kg in 2016. The same is true for partially destroyed housing and flooded housing without destruction of the building. These disparities can certainly be explained by the magnitude of each flooding episode, the largest among those considered being that of 2010.

In addition, the largest deposits of post-flood waste recorded are observed in flooded housing without destruction of the building. In fact, the average post-flood waste production in flooded dwellings without destruction of the building amounts to 155,976 kg while the same average in partially destroyed dwellings is 84,675 kg.

In total, the average post-flood waste production recorded in the Municipality of Athiémé is 334,603 kg (i.e. 334.6 tonnes) within 2010, approximately 714 846 kg (i.e. 714.846 tonnes) and in 2016, approximately 139 672 kg (or 139.672 tonnes).

Discussion

For several decades now, many efforts have been made in Benin in waste management, especially solid household waste. Unfortunately, these efforts are focused on urban areas (ADEGNIKA, 2004; GOMEZ, 2004; GBEDO, 2010; SAIZONOU, et al., 2010; TOPANOU, 2012). Rural areas such as the Municipality of Athiémé are therefore the poor relations of these efforts recorded in terms of waste management (AFFO, 2013; GADO, et al., 2014; SEBO, 2014). This degrading waste management situation is exacerbated in the Municipality by the recurring floods it suffers each year. While the management of flood cycles is planned through the National Civil Protection Agency and its territorial branches, the same is not true for the management of post-flood waste. And this seems normal when no information

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is available on post-flood waste neither in Benin in general, nor in any flood-prone commune (or flood-prone territorial dismemberment) such as Athiémé in particular.

Therefore, this study has practiced showing how enormous post-flood waste can be in terms of mass. Although the reuse of cuttings, concrete blocks and rubble from fallen walls, the framework, doors and windows constituting the woodwork, sheets, for the construction of new residential buildings is common, and would lead to a significant reduction in the volume of post-flood waste, it is important that the management of flooding crisis take this type of waste into account, anticipate and plan its management. The present study, which is therefore a pioneer in the matter in Benin in general and in the Municipality of Athiémé, inevitably has limits which lead to propose that this first experience be re-edited so that the methodological approach proposed here is refined and strengthened. In this perspective, several parameters not included in this study could be introduced, because the estimated extent of the flooding phenomenon, the contiguity or not of the agglomerated space that it could affect, etc. inevitably define the importance of the volume of post-flood waste to be generated. However, if the present study was carried out downstream, the ideal is to have an estimate of post-flood waste whose management is planned by the crisis management unit, so an estimate must be made upstream: the studies to be and the parameters for quantifying post-flood waste must therefore contribute to it. This is why the following parameters, deriving from the limitations of the present study, are suggested:

- water level: the higher the water level in buildings, the more water reaches and damages many elements and goods which turn into waste;
- duration of submersion: the longer a flood, the more moisture it diffuses into property and buildings, thereby facilitating corrosion, etc. making the potential recovery and reuse of goods all the more hypothetical. It is therefore an aggravating factor in the production of post-flood waste;
- geographic influence: the larger the flooded area, the more the quantity of affected goods (potentially reducible to waste) increases;
- predictability of the flood and warning time: it offers the possibility of placing the goods (evacuation of vehicles from an area, securing of stocks of shops, means of production of industries, goods of the population, etc. .) sheltered and thus limit the quantity of waste produced by preventive measures: it depends in particular on the time available between the moment when the alert is given and when the water arrives;
- seasonality: it occurs above all for agricultural waste: if the fields exposed to the risk of flooding are flooded just before harvest, large

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quantities of plant waste will be produced. This variable is less important in urban areas.

The combination of these parameters results in more or less significant and diversified post-flood waste production. It should be specify that these five parameters cited here as proposals in the refinement of a method for quantifying post-flood waste are already part of a French experiment on the quantification of the same waste (CEPRI, 2013) but much more in relation to sudden floods or floods induced by climatic extremes such as storms or cyclones. The French experience uses other parameters that are not suited to the Beninese context.

In addition, the parameters described above derive from the tools or data necessary for formulating the quantification of post-flood waste. The main data are the flooded area, rainfall amounts, topographical data, the results of recently exhaustive residential buildings, commercial or industrial, cultivated areas, etc.

Conclusion

Through the results, this study makes awareness of the importance of post-flood waste deposits in Benin in general and in local authorities such as the Municipality of Athiémé in particular. Around 38% of this waste, consisting mainly of cuttings, concrete blocks and rubble from fallen walls, the framework, doors and windows represent the woodwork, sheets, for the construction of new residential buildings is reused. However, this does not solve the problem. Thus, beyond the awareness that it stipulates, the study suggests anticipation and planning of post-flood waste management. For this, it proposes parameters, data and tools to be used with an appropriate methodology in order to produce a mass characterization each year, and if this is useful a typological characterization, which will be used in decision-making at the level of the crisis management unit as well as at the usual waste management structures.

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