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RESEARCH ARTICLE

PERFORMANCE AND CHALLENGES OF CURRENT HOUSEHOLD SOLID WASTE MANAGEMENT SYSTEM IN ABOMEY-CALAVI DISTRICT IN BENIN

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Abstract

Since 2020, the Beninese government has been experimenting with a new household solid waste management system in five municipalities in southern Benin. The present study aims to assess the performance of this current management system in the central district of Abomey-Calavi. A survey with 236 households and stakeholders, a characterization of solid waste according to household standing and seasons, and SWOT analysis were carried out. The results show that the novelty of the current management system lies in the structuring of the intervention and responsibilities of the various actors. The coordination of the system is the entire responsibility of a new actor, the SGDS (Waste and Sanitation Management Company). At total, 23505 tons of waste are pre-collectedin 2022, representing 80% of pre-collection rate. However, the recovery rate is very low. It was concluded that the current solid waste management system is neither optimal nor sustainable again. Public–private–government partnership and collaboration with households deserves to be reinforced. A formalized policy of optimal waste recovery for each component also deserves to be developed. This results can serve as an efficient decision-making tool.

Introduction: -

Management of household solid waste (HSW) has been growing in complexity and in costs within the last decades. The increase in environmental awareness, stricter legislation, urban concentration, population growth and development of new products has resulted in a challenge that strikes different countries in various ways, depending on the stages of development regarding environmental and solid waste management. Nonetheless, it can be stated that, even with different approaches and realities, the solid waste management challenges broadly present across the world and are quite similar [1].

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HSW management incorporates several inter-related aspects of waste generation, waste composition, collection, recycling (if any), pretreatment and treatment, and finally disposal. Thus, a strategic approach for sustainable management of solid waste covering all aspects of its management in an integrated manner is necessary for maximizing the efficiency of the system [2]. It must be considered as a central axis of the development policies of African countries that aspire to emergence [3].

These management aspects thus require input from legal, economic, governmental, political, administrative, and environmental players. The failure of one component is sufficient to cause the whole management to collapse. The management structure and function is site-specific and depends on socio-economic, behavioral, cultural, institutional and political frameworks. The stakeholders need to interact and cooperate for the management system to achieve its target [4][5].

In Benin, rapid population growth coupled with the widespread adoption of modern production and consumption models in the major cities has led to a sharp increase in the production of all kinds of waste. The average per capita generation HSW is 0.45kg/day. In 2012, the average HSW generation estimated is about 1381525 tons [6]. Although per capita waste production levels are low, rapid population growth combined with ongoing urbanization will triple waste production. The African Clean Cities Platform (ACCP), has indicated that waste production will rise from 2900 tons/day in 2020 to 3500 tons in 2025 with per capita generation waste of 0.5 kg/day [7].

Faced with the increase in waste production combined with the economic crisis, the capabilities of the government and local actors, particularly town councils, to provide proper facilitation of the solid waste management services have been limited [8]. Most of this service is provided by informal youth groups and formal structures, including NGOs, with low collection costs that vary according to pre-collection structure and household type [9]. As a result, the gap between waste production and collection has widened. In the major towns of southern Benin (Porto-Novo, Cotonou, Abomey-Calavi, Ouidah and Sèmè-Podji), grouped together in the communes of Grand Nokoué, only 15% of the 375.828 tons of waste produced annually was collected and transported to the collection points [6]. Waste is either disposed in uncontrolled landfills or simply burned. This has led the proliferation of illegal dumps. In the municipality of Abomey-Calavi, 34 uncontrolled dumps located between 0 and 30 m from the first dwellings have been counted [10]. This way of managing waste entails enormous risks to the environment and the economy and consequently the health of the populations [11], [12], [2].

Since the year 2018, the government had reviewing the legal and institutional framework for managing solid waste in the towns of Grand Nokoué. This management, which transfers and distributes responsibilities from the State to local authorities according the law 97-029 of 15 January 1999 on decentralization, has become a function of central government through the project of modernization of solid waste management in Grand Nokoué. This project proposes a new management policy that aims to collect 90% of the waste produced in the area, and to recover 60% of them by 2025. This new strategy has been in the trial phase since October 2020.

Thus, the objective of this study is to assess the current system of HSW management in the central district of Abomey-Calavi and to highlight the challenges still remaining.

Material and Methods

Study area:-

The study was carried out in the central district of Abomey-Calavi in the department of the Atlantic in the south of Benin. The municipality of Abomey-Calavi is located between 6°22' and 6°30' north latitude and 2°15 and 2°22' east longitude. It covers an area of 539 km² and is subdivided into nine (9) districts including Abomey- Calavi. It comprises seventy-one (71) villages [13]. The climate is characterized by the alternation of two rainy seasons and two dry seasons. of unequal duration. Average annual rainfall is 1,346 ± 307 mm. Average monthly minimum temperatures (1990-2019) range from 24.06 to 26.77°C. In the census of 2013, its population was of 656400 inhabitants [14]. Projections indicate a population of 985538 in 2022. The district of Abomey-Calavi is home to 27262 households, with an average of 4.7 inhabitants/household. Socio-economic activities include agriculture, fishing, livestock breeding, oyster farming, tourism, trade, river-lagoon transport and quarrying.

Fieldsurveys

For the household survey, a sample size at the district level was determined using the method of Dagnelie [15]:

$$N = U^2_{1-\frac{\alpha}{2}} * \frac{p(1-p)}{d^2}$$

Where N is the sample size ; $U_{1-\frac{\alpha}{2}}$ = 1.96 is the value corresponding to a confidence level of 95 %; p is the proportion of households assumed to have knowledge of waste management (81%) and d is the desired accuracy set at 5%.

The number of households to be surveyed is equal to 236, proportionally distributed by quota sampling methodamong the standing type designated in the district. Quotas were determined by counting “high standing” and “lowstanding” household using the transept method (Figure 1). The high standing household is composed that haveelectricity, luxurious apartment, more than two meals per day, household income greater than 100000 FCFA (152.45 €). A household is classified as "low standing" if it has fewer or none of the above elements.

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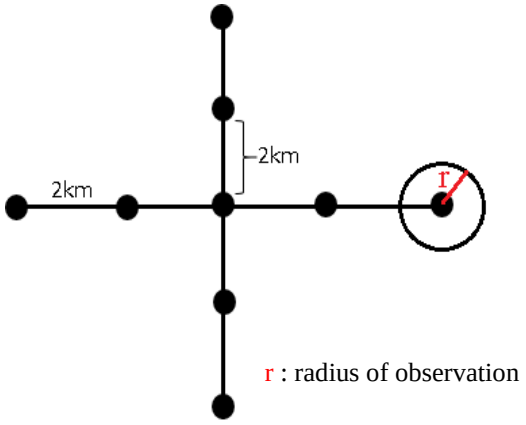


Figure1:- Transept for observation and counting of high and low standing households.

Quotas are calculated by dividing the total number of households of a given standing by the total number of households within the radius of observation. Thus, 79 high standing and 157 low standing households surveyed. Structured interviews were carried out using a questionnaire and enabled us to understand the behavior, practices and attitudes of populations in terms of waste management and their perception of the level of sanitation in their living environment.

We also, have had discussions with the leaders of structures pre-collection and waste collection and the responsible for the management of waste of SGDS based on semi-structured interviews. The aspects included the organization of the sector; perceptions of the new waste management system before and after the advent of the Grand Nokoué project; and the strengths and weaknesses of the system set up in Grand Nokoué.

Waste composition study

Field work for waste composition study was carried out at household residence. Solids waste were characterized during the rainy and dry seasons. Data were collected once a week for three weeks in each household. The MODECOM (2017) method was adapted. This method is a repository for characterizing waste into thirteen (13) categories: putrescible elements, non-classified incombustibles, plastics, paper, cardboard, glass, textiles, sanitary textiles, fine elements, non-classified combustibles, metals, composites and hazardous waste. The segregation of waste was done manually and the weight of individual component was taken with a scale (CAMRY EMPERRORS, 44ibs X 2oz) to determine the percentage of each component in total waste.

Data processing and analysis

After the data was collected, they were entered in the Excel 2016 spreadsheet. The data was processed under Excel for the calculation of averages, frequencies and the production of some graphs. The QGIS 2.14 software was used to

project the geographic coordinates on a base map. Qualitative data was subject to content analysis and synthesis. The SWOT (Strengths - Weaknesses - Opportunities - Threats) tool has been used to analyze the performance of the management system and identify the challenges still to be met.

Results and Discussion:-

Composition of household solid waste

Figures 2 and 3 show the composition of HSW by standing and season in the Abomey-Calavi district. They show that the variation of the different categories of waste was similar during both seasons but differs from one standing to another. This variation of the categories between standing is low. Putrescible elements are the dominant fractionof waste with percentages ranging between 40 and 46 % during the dry season, and 46 and 57 % in rainy season followed by fine elements with percentages situated between 24 and 28.5%; plastics, paper-cardboard, glass and metals (2 and 13%). Textiles and hazardous waste are in low proportions (0.5 and 5%).

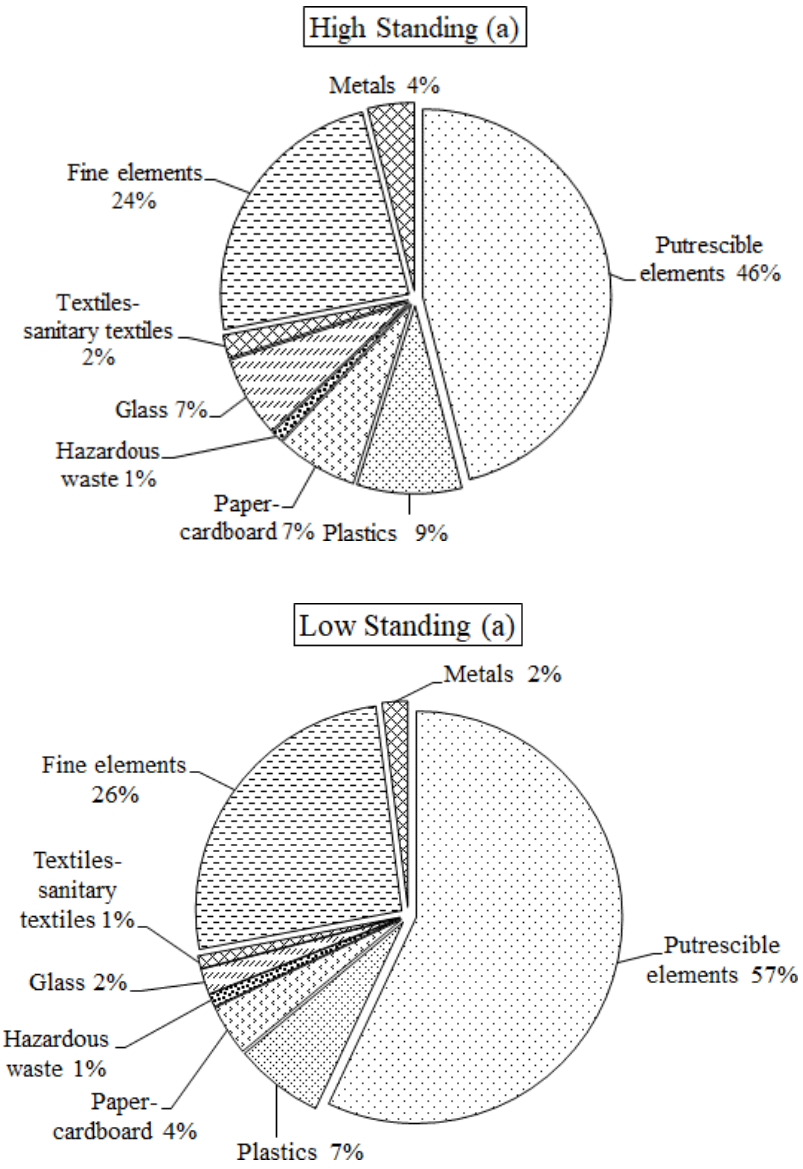


Figure2:- Composition of waste in rainy season by standing (a) high standing ;(b) low standing

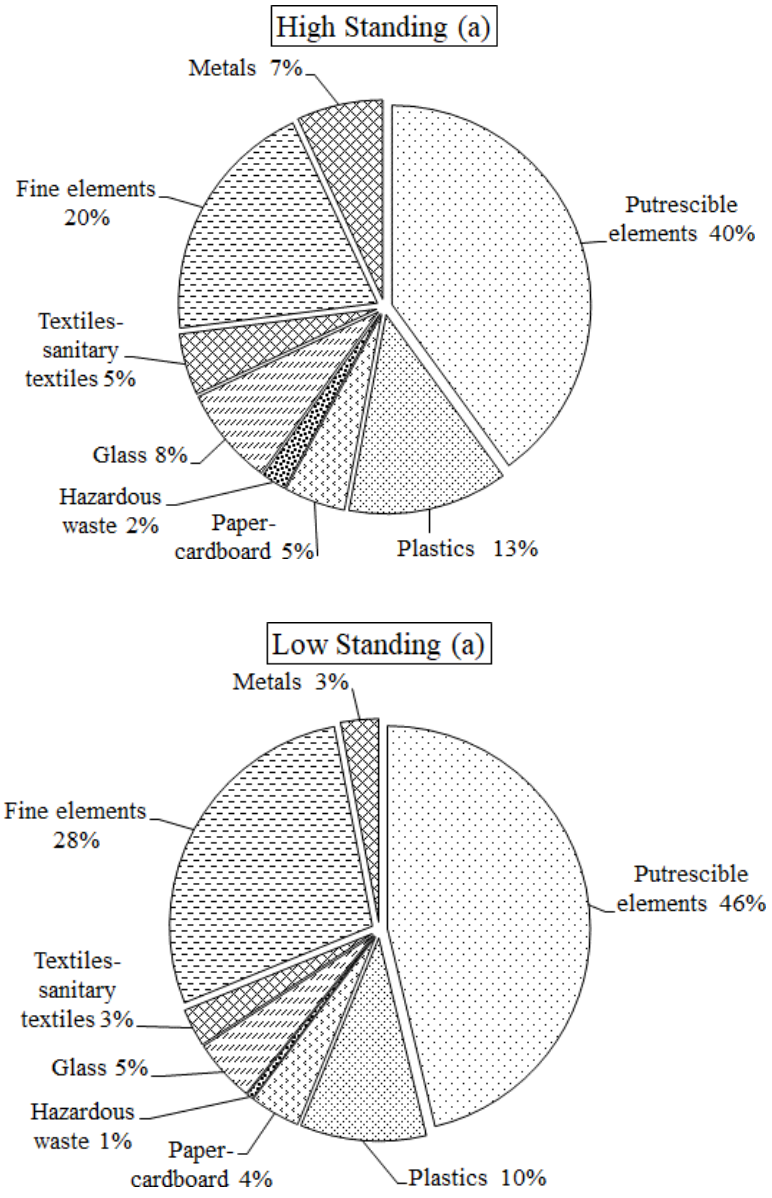
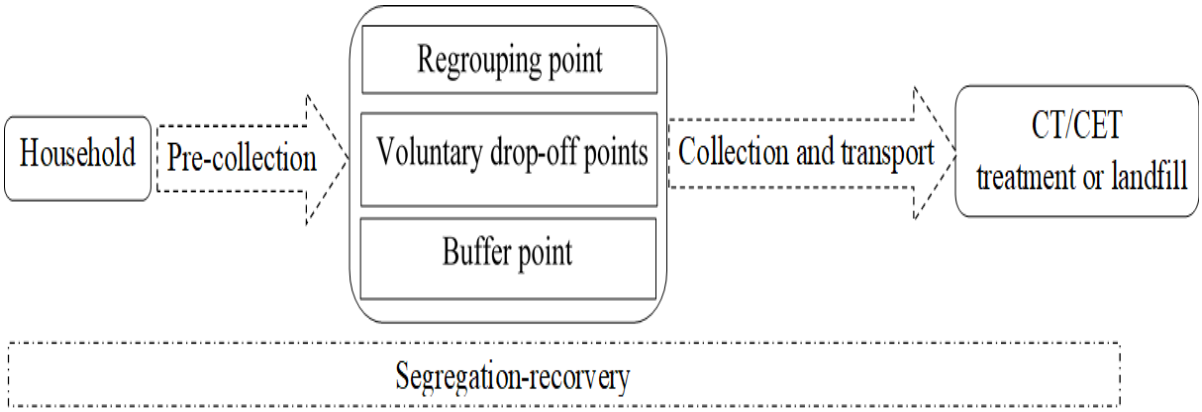


Figure3:- Composition of waste in dry season by standing (a) high standing ; (b) low standing

This result is in line with those of Permana and al. [16] in the city of Makassar in Indonesia, Fénil and Culote [17] in Cape Town, Haiti, Miezah and al. [18] in Ghana. The average proportions obtained for biodegradable materials, glass and plastics are high compared to those obtained in 2012 by Yémadjè [10] in the municipality of Abomey- Calavi and low for fine elements, notably sand. This demonstrates the major changes that have taken place in urbanization and the spread of modern production and consumption models in large cities. The composition of waste, also depends on various factors as food habits, different seasons, living standing of the people and other associated factors [19]. The high fraction of organic waste is an opportunity and potential of converting waste to energy or other products.

General organization of household solid waste management

The HSW management system is subdivided in four (04) links: waste generation (households); pre-collection, collection and transport, and treatment or landfill (Figure 4). However, the mode of intervention varies according to the state of the road.



(CT: tranfer center; CET: technical landfill centers)

Figure 4: - Overview of household solid waste management in Abomey-Calavi District

This organization is similar to that reported by Topanou [20] and Kplé [13] in the municipality of Abomey-Calavi et Effebi et al. [21] in the city of Treicheville in Côte d'Ivoire. This is the classic management principle generally implemented in southern countries.

Different actors involved in the waste management system and their roles

Four main actors are involved directly in the waste management system, each with their own specific roles: households, the Economic Interest Group (GIE)/ Small and Medium Enterprises (SME), the Waste and Sanitation Management Company (SGDS) and the Abomey-Calavi municipality (Figure 5).

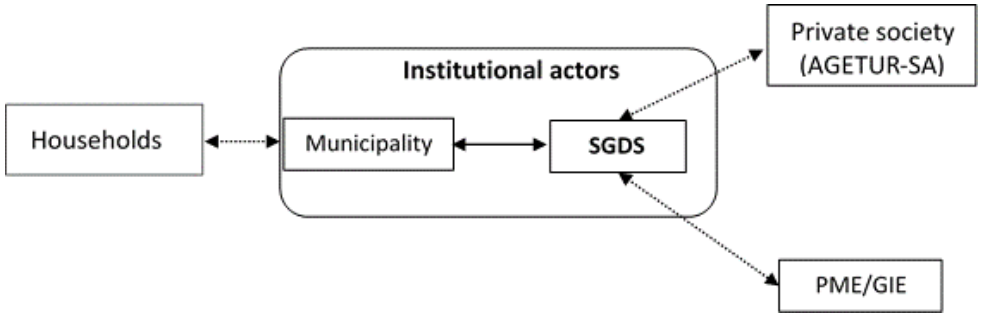


Figure 5: - Actors involved in the waste management system and their relationship.

Households are the first players in the chain. They are the waste producers and have the role to adhere to the project; to condition best the garbage; assist in the identification, removal and monitoring anarchic dumps and apply the decisions of change. From an operational way, SGDS, coordinate all pre-collection, collection, transport and landfill activities. He's supervised by the Ministry of the Living Environment and Sustainable Development (MCVDD). He maintains direct relations with Small and Medium-sized Enterprises (SMEs) or Economic Interest Groups (GIEs) and the Agence d'Exécution des Travaux Urbains (AGETUR-SA.). SME/GIE are service providers, particularly for the pre-collection of waste, and AGETUR SA is actively involved in the landfilling of waste. For better monitoring of all activities, the SGDS has field agents at regrouping points (APR), transfer centers (CT), technical landfill centers (CET) and zone supervisors. Abomey-Calavi town council has an overview of the whole of its territory and

sets up an interface capable of relaying all information useful for the proper execution of services and for the maintenance of cleanliness in the municipality.

These actors are different from those mentioned by Yémadjè [10] in their studies in the Abomey-Calavi municipality, which mention the "Collectif des Structures non gouvernementales de la Gestion des ordures et d'assainissement de la Commune d'Abomey-Calavi (COSGAC)" and the pre-collection NGOs in place of the SME/GIEs and the SGDS. This reflects the change in management policy. The coordination of the process previously entrusted to DST (Technical Services Directorate) of the municipality is now the entire responsibility of the SGDS. It should be emphasized that it was the numerous previous pre-collection NGOs that were grouped into Small and Medium-sized Enterprises and then into Economic Interest Groups (GIE) in order to professionalize the organization.

Management of waste in the households

Waste is stored in bins without any segregation. These bins are of various types (Figure 6). Jute bags are used in majority in both standing by 39.4% and 35.5% of households surveyed respectively, followed by plastic buckets (27%) and woven bags by 24.7% and 22.6% of households in both standing respectively. Rubbish bags and approved bin are used by a low number of household,8.1 and 4.1% respectively, in high standing households.

(a) Plastic buckets (b)Woven bags (c) Jute bag (d) Approved bin

Figure 6:- Various solid waste collection bins used by households.

For the disposal method, collection by pre-collection structures is dominant in both standing, accounting for 80% of households surveyed. The remaining households burnt or dispose of their waste in the natural environment, particularly in the low standing. The latter say they are not yet aware of the operating principles of the new solid waste management system in Grand Nokoué. The high rate is justified by the fact that for the moment, households in the district are no longer subject to subscription fees for the removal of their household solid waste. The Government of Benin has declared pre-collection operations free until the fee will be set and the payment via the electricity bill comes into effect in Grand-Nokoué to which the municipality of Abomey-Calavi belongs. These results corroborate those of Adandé et al. [22] who showed that in the city of Cotonou the household subscription rate to pre-collection structures rose from 15.12% in 2017 to 78% in 2020 with the advent of the SGDS.

Pre-collectionboperation of household solid waste

Figure 7 presents the total quantity of waste pre-collected during the year 2022.

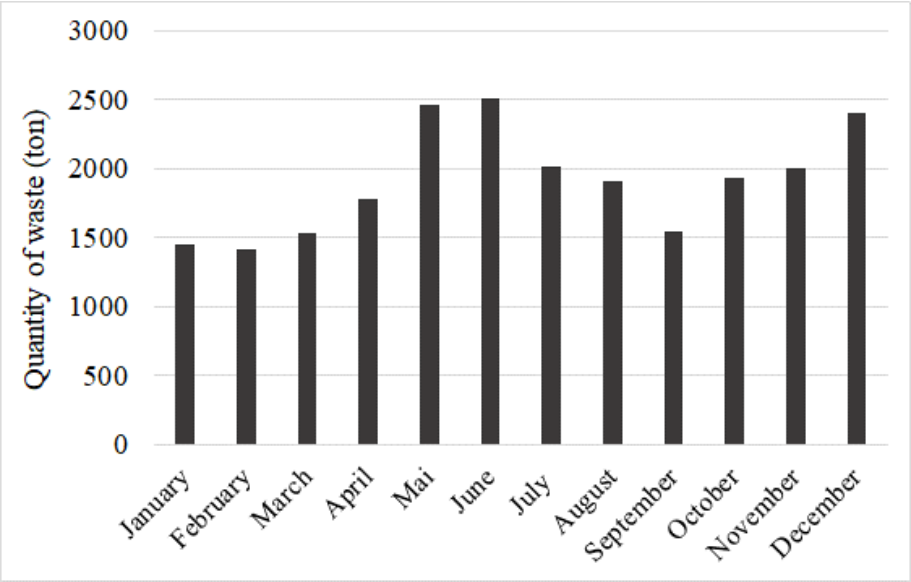


Figure 7:- Quantity of solid waste pre-collected in Abomey-Calavi district in 2022.

A total of 23505 tons of waste are pre-collected, representing an average of 0.40 kg of waste per inhabitant per day. Quantities are highest in May (2457.652 tons), June (2508.41 tons) and December (2400.31 tons), and lowest in January (1450.3 tons) and February (1408.4 tons). Considering the projected population of the Abomey-Calavi district in 2022 and the specific daily waste production, the annual waste generated is estimated at 29028.88 tons. The pre-collection rate is therefore estimated at 80%.

Abomey-Calavi district is subdivided into 5 pre-collection lots to be covered by the 5 pre-collection structures including 3 SMEs and 2 GIEs. Pre-collection is carried out door-to-door by waste collectors, or by voluntary household collection at designated points (Figure 8). More than half of households (58 %) in the both standing confirmed that the frequency of emptying of bins in households is 2 times at least a week as defined. For the rest of households, the frequency is not respected, once a week and sometimes more than a week. There are 5 voluntary drop-off points (PAV) for solid waste, equipped with 660-liter bins.

The waste pre-collected is then transported to 5 regrouping points (PR) (Figure 9) designed to receive the waste from a given lot. Three of these PR are fixed (Tokpa-Zoungo, Tchinangbégbo, Ahossougbéta) and 2 are mobile (Togoudo, Zoca). They serve as transit points and are equipped with 15 to 20m^3 containers. In addition to these consolidation points, there is a buffer point (undeveloped area) which also serves as a transit point for household solid waste to the technical landfill centers (CET). The distribution of these fixed PR and PAV is shown in Figure 10.

Figure8:- Voluntary drop-off points.

Figure9:- Regrouping point

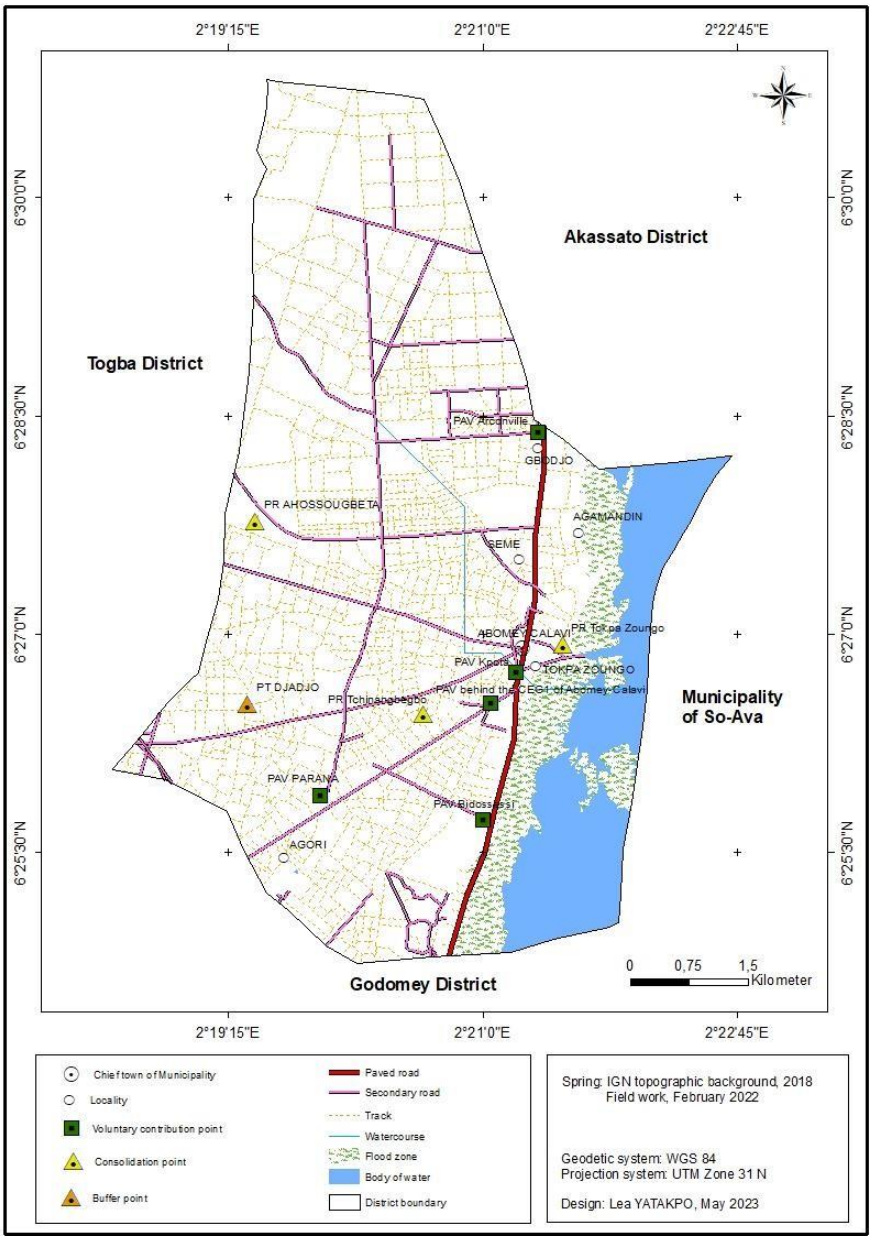


Figure10:- Distribution of regrouping and drop-off points in Abomey-Calavi district

The number of operators at pre-collection structures varies between 10 and 43. Waste collectors are equipped with motorized tricycles, tamping skips or BOM (Figures 11 and 12) and some protection equipment (gloves, nose covers, boots). With the current status, it's easier for the SMEs to acquire more efficient equipment for pre- collection operations. SGDS has allocated motorized tricycles to all SMEs under service contract against progressive reimbursement.

The use of these vehicles depends on road conditions. The use of motorized tricycles allows to promote the speed of garbage removal operations and unloading transactions at collection points. This allows some tricycles to make several laps in the same day to dump the waste collected from households in the household waste bins at the collection point. From our investigations with the managers of SMEs, current tricycles make an average of three to four trips per day depending on the collection areas. It should be noted that for areas with a nearby PR, some SMEs go up to six tricycle trips per day. Furthermore, the maximum volume of waste to be collected by an SME per day is $500m^3$.

Before SGDS, these NGOs did not have the adequate legal status to contact financial loans in order to cope with the increasing demands of material resources for pre-collection operations. This state of affairs makes the pre- collection work painful for carters and garbage collectors. The pre-collection of waste required the mobilization ofan abundant workforce. The waste was immediately dumped in the shallows and empty spaces close to the pre- collection sites. The transport of waste to the collection points is done using human-powered carts, using motorized tricycles, or using vans. This make it more difficult the work of the carters who have to travel great distances before reaching the regrouping points created for this purpose [22]. However, more than 50% of those responsible for SMEs surveyed complained about the quality of the tricycles allocated to them by the SGDS, which frequently break down.

Figure11: Motorized tricycles for waste pre-collection

Figure12:- Tamping skips for waste pre-collection.

SMEs are paid per ton of waste pre-collected and emptied at the collection points by the SGDS. However, some SMEs are not satisfied with the method of payment by tonnage instituted by the SGDS. The managers of SMEs surveyed complain about the imbalance in terms of the allocation of zones and the inadequacy of the financial index in terms of tonnage.

Collection and transport of household solid waste

The collection of solid waste consists of the removal (loading and transport) of solid waste from the collection points to the final landfill.

Containers are systematically removed are removed by amplirolls to the Technical Landfill Centre of Ouèssè (Figure 13). Tamping skips evacuate the waste to the Transfer Centre (TC) in 30 to 40 m^3 containers or to the Technical Landfill Center (CET), depending on whether or not the landfill is accessible. This collection can take place up to three times a day, depending on the frequency of pre-collection of solid waste.

Figure13: Ampliroll loading and departure to CET of Ouèssè

Treatment/valorization of household solid waste

There are two main treatments or recovery methods: sorting-recovery and landfill.

1. Sorting-recovery: this is done manually at the regrouping point by the women's cooperatives. The materials recovered are plastics, glass, metals, paper and cardboard. However, informal sorting and recovery is carried out by waste collectors during the pre-collection phase, before the waste is transported to the collection points. This quest for recoverable materials on the part of waste collectors engender the non-compliance with zoning by certain SMEs which encroach on the territory of other SMEs. Assuming that all of materials are recovered from waste, the current maximum recovery rate is around 25%.

2. Landfill: at the CET, waste is stored in cells and covered with bar soil in successive layers. However, the access road to the site, after 35 km of motorable road, is an impracticable and closed to traffic after the heavy rains. This closure can last several days, thus preventing carriers from emptying the containers and carters from lifting the bins. The pre-collection transfer chain is broken and creates a great inconvenience to the population.

Sorting-recovery for the waste valorization inevitably leads to a reduction in the quantities of waste sent to final landfill. For example, the implementation of a compulsory waste separation program in Kuala Lumpar by Malaysian government allowed to reduce 5.5% average daily generation rate of waste [23]. However, this single method is not optimal, given the high proportion of organic matter in waste, which can present significant organic or energy recovery potential. These results are confirmed by Soudi et Chrifi [24] et Rojas [25] who assert that the waste sector in Africa has considerable social and economic potential, but is insufficiently exploited. Yemadjè et al. [26] estimated

the calorific value of municipal solid waste in the Abomey-Calavi commune at around 1000 Kcal/kg. The rational exploitation of this deposit can have positive impacts on the entire household solid waste management chain through the generation of financial resources that will enable the sector to become self-financing [27]. Anaerobic digestion, gazification, combustion et and recovery of landfill gas recovery are possible alternatives of energetic valorisation of waste [28]. For example, the potential energy savings from recycling materials and producing electricity from municipal solid waste by anaerobic digestion in Ahvaz, India, have been estimated at around 176 and 53 GWh/year, respectively [29].

It should be emphasised that the limiting factor to the best recovery of solid waste in this study is the lack of waste segregation at source. When waste arrives in landfills mixed together, its energy potential is reduced [2]. This dynamic does not guarantee that the SGDS objective of recovering 60% of the waste collected by 2025 will be achieved. An optimal recovery policy for each component of waste needs to be developed. This should lead to segregation and collection at source to facilitate subsequent processing [29]. The separation of wet (organic) and dry components will enable waste to be used for various biological and thermochemical processes, where it can be used.

SWOTanalysis of current solid household waste management system

The analysis of the Strengths, Weaknesses, Opportunities and Threats (SWOT) of the current household solid waste management system in Abomey-Calavi district is presented in table 1.

Table1:- SWOT analysis of solid household waste management system

Strengths	Weakness
- Creation and operation of SGDS - Destruction of illegal dumps in the Calavi district; - Fitting out and made available of existing PR - Building of new regrouping points and transfer centers; - Reinforcement of the landfill site; - Involvement of civil society through small and medium-sized enterprises in waste pre-collection services; - Provision of permanent human resources; - Setting up a mechanism to access resources for the acquisition of equipment by SMEs (tricycles, amplirolls, BOMs).	- lack of people's engagement with the project; -Weak collaboration from some households who do not prepare the garbage on the days when the garbage collectors pass; - Methods of remuneration of SGDS unsatisfactory; -Tricycles are unsuited to the relief of the areas servedand the putrescible nature of the waste; -Limited environmental awareness, education and attitudes of population; - Lack of engagement with waste seperation activitiesat source; -improper waste separation facilities; - Poor social security coverage for pre- collection agents; - insufficient of regrouping points; -Lack of integrated approach and proper scientific system; - Non-inclusion of informal sector; - Poor road practicability; - Rapid damage to pre-collection or collection equipment.
Opportunities	**Threats**
- Better engagement of the government to take charge of the solid management system - Existence of active private structures in waste recycling - With high fraction of organic waste (57%) there are opportunities and potential of converting waste to energy or other products.	- High cost of acquisition and maintenance of pre-collection equipment (tricycles); - The government and community have different ideasand ideologies, in general. - Insufficiency of public – private – government partnership.

The challenges and barriers are significant, but so are the opportunities. Most of technical, organizational, financial and socio-cultural barriers addressed in this study are reported by [30].

Many innovations are signs of an improvement in the HSW management system. There are 90% of households surveyed that recognized. The new measures have favored the disappearance of uncontrolled dumps in the study area, contrary to the observations of Yémadjè [8] who reported the presence of multiple uncontrolled dumps in the commune of Abomey-Calavi. This testifies to the effectiveness of the current management system in place in Grand Nokoué. With the destruction of illegal dumps in the district, 68% of respondents rated the level of cleanliness of their living environment as "good".

Despite the fact that the service is free of charge, it has been noted that there is little collaboration from households in the effective implementation of actions. The collection and the efficiency treatment of waste generated by households is therefore still subject to socio-economic realities. These results corroborate those of Béhanzin and al. [31]. It seems appropriate to analyse the effects of socio-economic and ergonomic variables on the efficiency of waste collection. Through a SWOT analysis, Najarneghad et al. [29] have shown in India that the competitive strategy is the most appropriate strategy household waste seperation at the source which is based is based on maximum exploitation of opportunities with simultaneous reduction of weaknesses. Saker et Alkama [32] proposed to involve civil society, which is a key player urban and ecological development. For these authors, the success of household waste management in the city depends greatly on the maturity and awareness of users as managers, at the local level. Information, awareness and behavior change communication (ISCCC) sessions for the population must therefore be stepped up on waste sorting.

Conclusion:-

This study assessed the performance of the current household solid waste management system implemented in the Abomey-Calavi district of Benin. The new management system entirely steered by the Waste and Sanitation Management Company (SGDS) has encouraged a high rate of pre-collection facilities in households. This has led to the disappearance of uncontrolled dumps and an improvement in the health of the population's living environment. The new structure of NGOs as SMEs/GIEs makes it easier for them to acquire more appropriate equipment for pre-collection operations. As a result, waste removal operations and unloading at collection points are becoming easier. Solid waste composes mainly of putrescible materials. However, only paper and cardboard, plastics and metals are recovered. Despite the many organizational, technical, financial and social advantages, the current solid waste management system has a number of problems that affect the efficiency of the pre-collection service and the sustainability of the system. These include the lack of segregation at source, the inappropriate salary treatment of SMEs/GIEs, and recurrent breakdowns of the equipment. To achieve the objectives of the current management system, a formal optimal waste recovery policy needs to be developed for each component of the waste. Information, awareness, raising and behavior change communication (ISCCC) sessions for the population need to be stepped up and entrusted to civil society players, who are key players in urban and ecological development.

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