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Impact of Solid Domestic Waste Management on Drainage Systems in Developing Urban Areas

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Abstract: ***Urbanization and waste production are closely related subjects. Solid waste management remains a serious challenge for developing countries. The reason for this situation includes: misunderstanding, weak rules and regulations, unreliable methods, inappropriate storage. Most of the wastes produced end up in the drainage systems and considerably impact its functionality, giving rise to floods. This research assesses the impact of uncollected solid waste on the drainage system of an urbanized drainage basin. The pilot site chosen for this work was a drainage basin called Abiergué. With its urban and cultural diversity, Abiergué is a microcosm of most drainage basins in its mother town Yaoundé. The quantity of wastes produced and collected was determined by collecting, sorting and weighing solid domestic wastes from 307 Households living in the area. The fraction of uncollected solid wastes circulating in the drainage system was assessed as well as the amount of soil sediments conveyed by storm water. Soil traps designed and installed in drains helped to capture these solid materials in the drainage systems. It was found that about 45 % of wastes generated in the area were not collected. These wastes together with sediments accounted for an increase of 10% of the volume of runoffs in the drainage system.***

Keywords: Abiergué; urban areas, runoff; soil trap; solid domestic waste

1. Introduction

In most cities characterized by a developing economy, there is a great need for suitable drainage systems to help manage surface water runoff. Neighborhoods keep popping up without proper planning, and this implies, designing 'adapted' (i.e. drainage systems incorporating waste management issues) drainage and sewage or waste disposal systems. Residents regularly dump their waste in storm drains, and this clogs them, preventing the normal flow of water and causing these storm drains to overflow. It is common to see flooded streets with litter floating everywhere after a short period of rainfall [1]. Drainage systems are designed to make sure that waste water and sewage are transported neatly to disposal points, thereby keeping the environment well drained and free of waste. They aim to manage the water quantity (flooding), water quality (pollution) and amenity issues in the environment. Solid wastes, when disposed improperly, can be an environmental hazard. Rapid urbanization process of countries is the root cause of all the many problems and challenges in waste management. The rate at which heaps of solid wastes are being grouped on the principal streets of the cities is alarming and devastating [2]; [3]. In addition, drainage systems (especially in developed countries) are engineered usually without taking into consideration the aspect of solid domestic waste and soil sediments. The role played by these wastes in the functioning of the drainage systems is undeniable as such it is very important to consider these elements [4].

2. Methodology

2.1 Presentation of the area of study

The Abiergué drainage basin is situated in Yaoundé which is the administrative and political capital of Cameroon, localized between latitudes 3°53'30'', 3°54'0''North and longitudes 11°26'30'', 11°30'00''East (Fig 1). The hydrography of this basin is characterized by a stream of the third order on Strälher-horton classification with a bifurcation ratio of 3.7 and drainage density of 1.58km/km^2 [5]. The stream flows south – west, on a distance of about 8 km, towards the Mefou River that it joins at the Nkolbisson district [6], [7]. This area was chosen because it is a microcosm of its mother town of Yaoundé as it contains the various settlement patterns found in the city and encloses as well residential, commercial and administrative districts. the topography of the area of study has the main features found in Yaoundé (hilly, low-lying areas with swamps etc.). The population of the drainage basin was estimated to be 201 677 inhabitants, with a growth rate of about 3.1% [8]. Abiergué drainage basin is a highly cosmopolitan area regrouping most of the ethnic groups of Cameroon. The average altitude of the city is estimated at 726 m with a surface area of 136.14 km^2 by 2012.

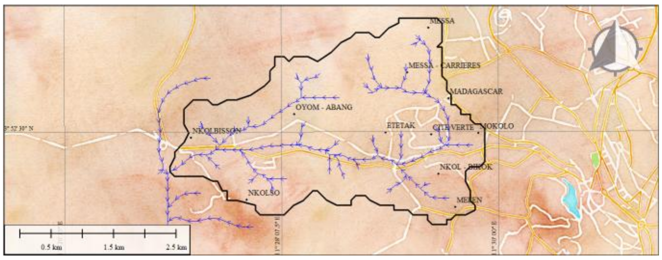

Figure 1: localization of the Abiergué drainage basin

2.2. Assessing waste generation

In order to determine the amount of waste generated by the inhabitants of the Abiergué drainage, a representative sample of the population was determined. Equation 1 (proposed by [9]) was used to assess the sample size.

$$SS = f(1-f)x\left(\frac{\left(U_{1-\frac{\alpha}{2}}\right)}{I}\right)^2 \quad (1)$$

Where
SS = Sample Size
$U_{1-\frac{\alpha}{2}}$ = Confidential Interval
f = frequency observed in a sample of adequate size (According to [9], the recommended Sample Size should be greater than 30)
I = allowable error on the frequency (expressed in %);
α = level of risk

Once the sample sized determined, surveys were next carried out at various households and administrative structures with the help of anonymous and self-administered questionnaires (to increase the return rate) as well as plastic bags (of capacity 50l). The administrators were multi-lingual and as such used English, French, Pidgin English and even local languages for exchange with the responded, whatever they preferred. A Gantt chart was elaborated with the help of Microsoft Office Project Professional 2010 to schedule the activities on the field.

All the skips in the markets found within the area of study were identified via field observations. From this exercise, the capacities of these skips could be determined and the volumes of produced daily by these markets were as such figured.

2.3. Waste collected

All the actors involved in the waste collection (private and public) in the area of study were identified and were followed during their various collection duties. Despite the presence of some people that collect waste from households, the main waste collection company in Yaoundé is a private structure called HYSACAM. All other individuals or groups that collect waste against remuneration dump their waste in skips provided by HYSACAM. The volume and the weight of the waste the collected from the drainage basin was obtained at the weighbridge, within the headquarter of HYSACAM.

2.4. Waste uncollected

In order to determine the potential amount of waste found in nature and/or dumped in an unauthorized way, a two-step method was used:

- Step one: Determining the *total amount of solid domestic waste (SDW)* generated in the drainage basin (*Wt*). This will consist of waste produced by households (W_{HH}), markets (W_m) and administrative buildings (W_a), that constitute the main actors in waste production in the watershed.
  $$W_t = (W_{HH} + W_m + W_a) \quad (2)$$
- Step two: Determining the *amount of SDW carried away by all structures or actors in charge of waste collection in the watershed* (*Ws*);

The potential amount of waste found in nature (*Wi*) was next determine using equation 3.

$$W_i = (W_t - W_s) \quad (3)$$

2.5. Solid domestic waste and sediments conveyed by runoff

Among the numerous existing soil traps types, trenches and check dams were used to capture waste conveyed by runoffs. Both types were used in natural drains (earth drains) because of their malleable nature contrarily in artificial drains which are paved rendering their use (especially trenches) quasi-impossible.

Not all particles are responsible for drain blockages, suspended particles flow easily to main water bodies in the drainage basin meanwhile those of more significant size are sometimes abandoned in these drains and their accumulations finish up blocking the drain in question. The suspended material, in general, can influence in blockage of drain only after the more significant ones or other solid materials such as solid domestic waste have already settled in and/or paralyzed the drain. This is the reason that caused the researchers to focalize on those particles susceptible to block a drain. It is from such judgment that the spacing between the re-enforcement weaved together on the various soil traps were established. As such small spacing were used for the wire gauze but not too small either. Indeed, the objective was not to prevent water from flowing but to retain gross particles and slow the flow of water. The wire gauze had a net spacing of 2 cm.

Another wire gauze material was placed at the base of the earth trench. This material was to be the structure on which the transported sediments in the runoff which crossed the check dam was to be dropped on. It had to give the possibility for water to drain throughout easily leaving behind it the material of interest (sediments). The wire gauze used here had very small net size (0.5 cm). For artificial drains, the wire gauze material placed at the base of a trench in earth drains was placed on a second trap installed some few meters after the first soil traps with larger spacing. Figure 2 illustrate the disposition of soil traps.

The outlets of drains were chosen to place these setups. They were chosen because these points corresponded to the areas where most of the water circulating in the elementary drainage basin in which the soil traps are found are conveyed into the main water body Abiergué. However, the setups were placed some distance from the outlet. This precaution was to prevent the up flow of water (from the nearby watercourses) to invade the storm drains and carry along the experimental outcome (waste) or charging them, hence biasing the end results.

Care was equally taken to install the experimental setups in drains having gentle slopes. Indeed, drains with high slopes offered high energy to water they conveyed and this energy could disrupt carry away all the experimental setups as well as the outputs or result.

For each experimental set-up placed within a channel, the area which could influence the result at each of those setups was determined. The delimitation of these zones was done with the help of a GPS and a GIS software: Global mapper.

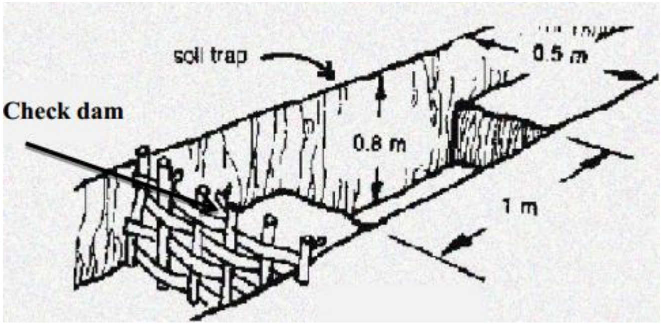

Figure 2: Soil trap (check dam and trench)

After every rainfall event, the wastes were removed with the help of spades from the various drains and were sorted. The measurement of the data was done with the help of a spring balance of 50 kg and a plastic bag in which the waste was placed. The data were recorded after every rain event. 10 l buckets were used to determine the volumes of the waste trapped in the different drains types.

3. Results

With a return rate of 93%, significant information on waste management was obtained via questionnaires from 307 households. Table 1 summarizes the outcome of monitoring an experiment conducted in the watershed to collect, weigh and analyze solid domestic waste from household samples among different sociocultural and economic strata of the city.

Table 1: Outcome of experiment conducted in the Abiergué drainage basin

Quarter	Number of household	Average household size –person	Population size studied	Biodegradable	Non-biodegradable	Total (kg) for 3 days	Total (kg) day^{-1}	household capita^{-1} day^{-1} (kg)	Total population of the watershed	Total amount of waste produce (kg)
Carrière	43	6.65	286	239	64	303	101.00	0.35	201677	81954
Cite Verte	33	5.88	194	275.2	82.3	357.5	119.17	0.61		
Etetack	38	7.32	278	209.4	77.9	287.3	95.77	0.34		
Madagascar	20	8.20	164	137.9	43.1	181	60.33	0.37		
Melen	35	6.20	217	202.4	55.6	258	86.00	0.40		
Messa	42	5.36	225	187	43.3	230.3	76.77	0.34		
Mokolo	23	6.78	156	133.7	53.7	187.4	62.47	0.40		
Nkolbikok	16	6.19	99	86.8	28.3	115.1	38.37	0.39		
Nkolbisson	5	6.20	31	33.3	10.1	43.4	14.47	0.47		
Nkolso	2	6.00	12	11	2	13	4.33	0.36		
Oyomabang	29	5.59	162	161.5	50.2	211.7	70.57	0.44		
Total				1677.2	510.5			**0.41**		
%				**77%**	**23%**					

The households produce about 82 tons of solid domestic wastes per day (with an average production of 0.56 kg per capita per day) in which the biodegradable wastes accounts for 77 % (≈ 63 tons) and the non-biodegradable wastes accounts for 23% (≈ 19 tons).

Five (5) markets were identified in the drainage basin with the most popular market of Yaoundé (Mokolo). Their daily waste production was determined to be 9125 kg. Administrative structures produce 22 kg of waste per day. This low value can be explained by the fact that administrative wastes are mostly comprising of papers.

According to equation (2), the total amount of solid domestic waste produced per day in the watershed corresponds to: $W_t = 91$ tons.

3.1. Unauthorized dumping and waste collected

Even though it is against legislation to deposit waste in illegal places, most of the respondents were honest in revealing their waste disposal practices. All the quarters within the Abiergué watershed were guilty of waste discarding in valleys, streams or lakesides, in open spaces and nearby bushes, and holes dug around the households. About 60% of the households in the watershed practice unauthorized dumping (most of which precise night dumping as the main way of getting rid of the waste). Sometimes this unauthorized dumping is done in defiance of the council's orders.

In order to minimize the aggressive practice of this unauthorized dumping, the Yaoundé Urban Council via HYSACAM put in place a 'door to door' collection of domestic waste and as they move along from one area to another they equally pick up some of the solid domestic wastes they find on open field or any other site where waste is dumped and easily accessible. It was found out that HYSACAM collects 54 tons of solid domestic waste per day (***Ws***) within the Abiergué drainage basin. According to equation (3), the amount of waste potentially found in nature corresponds to: $Wi \approx 37$ tons of waste (45%).

Biodegradable wastes because of their organic nature decompose naturally faster than non-biodegradable waste and as such, will be expected to have less impact on the persistence of the resurgence of floods, however, practically, that is not the case. Because of the continuous inflow of biodegradable waste, floods keep up and rather intensify.

Out of the 19 tons of non-biodegradable wastes produced, 35% (7 tons) is made up of plastics; 17% (3 tons) for bottles/glass; 14% (3 tons) for paper/cartons; 7% (1 ton) for steel cans/tins and 5% (≈1 ton) for fiber bags.

3.2. Solids conveyed

The soil traps permitted to capture solid domestic waste and soil sediments (originating from quarry activities, urban agriculture) that were conveyed by runoff. Throughout the entire study that was carried out for almost a year, 59 m^3 of solid domestic waste and 77 m^3 of soil sediments were collected with a total runoff of 817m^3 equally assessed during the same periods for the same area. The total solids (solid domestic waste and soil sediments equal to 136 m^3) as such accounted for 10% of the total flow.

Figure 4: Waste captured by soil trap after a rain event

4. Conclusion

Traditional drainage systems are designed to move rainwater as rapidly as possible from the point at which it has fallen to a discharge point via a piped system or open drains system to either a water course or soak away [10]. Whenever these drains don't function as initially planned, they give rise to environmental, health problems: floods situation, stagnant pools that provide breeding grounds for disease vectors such as mosquitoes. In areas where drainage and sanitation are poor, water runs over the ground during rainstorms, picks up feces and contaminates water sources. This contributes significantly to the spread of diseases such as typhoid and cholera, and may increase the likelihood of contracting worm infections from soil contaminated by feces. Flooding itself may displace populations and lead to further health problems. Household wastes when poorly managed, seriously impact on the efficiency of storm drains as they often find their endpoints in them.

Poor waste management is of particular concern to developing countries. These wastes are found to impact seriously on the ability of storm drains to evacuate rainwater and this study has revealed how much (10%) the poor solid domestic waste management and other poor land use practices impact on the drainage system.

Urbanization is a continuous process that will aggravate existing situation if the wastes are not well-managed. With the role played by these wastes in drainage systems, they should be taken into consideration during the design of future adapted drainage systems.

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