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Validation of Models used for Simulating Solid Domestic Wastes and Soil Sediments Flow in Urban Drainage Systems

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ABSTRACT: In developing countries drainage systems are most often designed without taking into consideration the reality of solid domestic wastes and soil sediments that regular fill the limited number of drains in a drainage system. Soil sediments from erosion are usually conveyed by runoff into the drains however the poor land use practices accelerate the process of erosion. On the other hand, because of the poor waste management most of the waste produced by households are left uncollected and end up in the drainage system. The Abiergué drainage basin was used to assess the impact of solid domestic wastes and soil sediments on the design of drainage system in developing countries. Models were designed to take into consideration this aspect. However, the initial model used computed values of runoff obtained from precipitation and runoff coefficient. As such a new experiment was to be carried out to determine the real values of runoff on the field using a rangefinder. These values together with the collected waste (soil sediment and solid domestic waste) were to be used to determine the real values of the coefficient of the models. Once obtained the models were to be used to generate the simulated amount of waste and compare with the field data.If any significant difference was observed, then a calibration of the model was to be envisage. The Pearson correlation was used to assess the significance of the results. The experiment revealed a significant correlation and hence no calibration of the models were necessary. The study equally revealed that solid domestic waste and soil sediments accounted for an increase in the volume of total runoff ranging from 2% -10%.

KEYWORDS: Drainage system, Models, Runoff, Solid Domestic Wastes, Soil Sediments,

I- INTRODUCTION

Despite the important diversity observed in most urban areas of countries characterized by a developing economy, they are however characterized by a poor organization reflected by poor house implantation, poor drainage network (inexistent most often), poor waste management with a significant fraction dumped in the environment, little or no effective legislative control, uncontrolled land use… ([1];[2]; [3];[4];[5]).Domestic waste generation is of particular importance as they constitute a nuisance. They have been found to be one of the main causes of urban flooding. [6], realized that most of African towns south of sub-Sahara have a significant demographic growth which further complicate the problem of waste management.

In most African towns the efficiency of waste collection structures barely reaches 50% ([7];[5];[8];[9];[10]; [2]; [3]; [4]). A substantial amount still remain uncollected in nature. During rain events runoff convey these uncollected waste into the drainage system considerably reducing their efficiency. As such under normal circumstances, a certain precipitation that could be conveyed by the drainage system without giving rise to any flood situation will not be evacuated easily by the drainage system filled with solid domestic waste ([11];[12]. Many inhabitants of urban areas due to one reason or another literally dump their wastes in drains during rain event to be carried by runoff. In addition to all this, the poor land use also accelerate soil erosion which also significantly contribute to the obstruction of drains. According to [13], it will be important to develop appropriate drainage systems, which will take into consideration solid domestic wastes, sediments as additional components of the runoff.

A model had been developed in order to simulate the flow of these ***wastes*** (soil sediments and solid domestic wastes) in nature. This model (developed by [12]) was to help generate the volume of ***wastes*** which were to be considered during the design of the drainage system so as to take consider those ***wastes*** that can end up affecting the drainage system.

Two models were developed: a model that simulates the volume of solid domestic waste produced with respect to precipitation and a second model that simulated the volume of soil sediments produced with respect to precipitation. In the first case precipitation was used (together with a runoff coefficient) to convey the***wastes***. But practically, runoff is the main element responsible for the transport of these ***wastes***in the drainage system.

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This study was carried out to test, recalibrate (if necessary) and validate the model using runoff determined on the field. The experience was to be reproduced under identical conditions i.e. in both natural and artificial drains (two main types of drain found in developed countries), in structured and spontaneous neighborhoods.

II- METHODOLOGY

A. Physiography

Situated within Yaoundé, the Abiergué drainage basin is located between latitudes 3°53'30'', 3°54'0'' North and longitudes 11°26'30'', 11°30'00'' East. Regarding to the administrative zoning (carried out in 2008), this watershed is found within the sub divisions of Yaoundé II and VII, division of Mfoundi, Center Region, Cameroon. The localization of this watershed is illustrated in Figure 1.

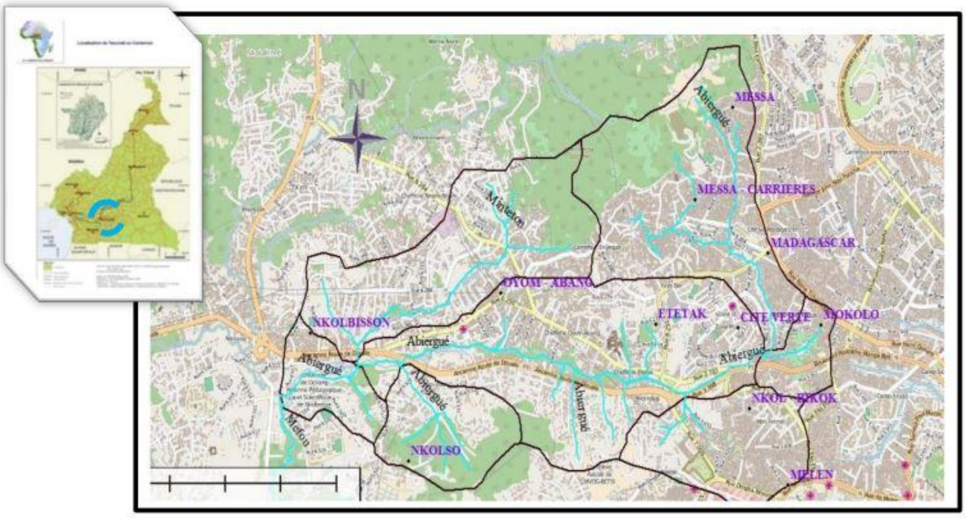

Figure 1: Map of the Abiergué drainage basin

B. Description of the model

Two models were elaborated for simulating the potential volumes of ***wastes*** conveyed in a drainage system. These models describe the mathematical expression of the relation between ***wastes*** and precipitation [13].

- **Model1 (Solid Domestic Wastes and Precipitation):**

This model describes the relationship that exist between volumes of solid domestic waste and precipitation via a linear pattern as expressed by the equation (1):

$$V_{solid\ domestic\ wastes} = a \times \mathrm{R} + b \quad (1)$$

- **Model 2 (Soil sediments and Precipitation)**:

This model describes the relationship that exist between volumes of soil sediments and precipitation via a quadratic pattern as expressed by the equation (2):

$$V_{soil\ sediments} = a \times \mathrm{R}^2 + b \times \mathrm{R} + c \quad (2)$$

Where

$V_{solid\ domestic\ wastes}$= Volume of Solid Domestic Wastes (SDW)

$V_{soil\ sediments}$= Volume of soil

a, b and c = coefficients

R = Rainfall (Precipitation)

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C. Assessing the parameters of the models

In order to test the models, the experiment was repeated under the same environment as the initial experiment i.e. in both natural and artificial drains (two major types of drainsstructure found in developed countries), in structured and spontaneous neighborhoods.

The coefficients of the various equation (a, b, c) were determined for the new experiment using runoff values determine insitu using a rangefinder (figure 2)developed in the laboratories of the University of Dschang in Cameroon [14].

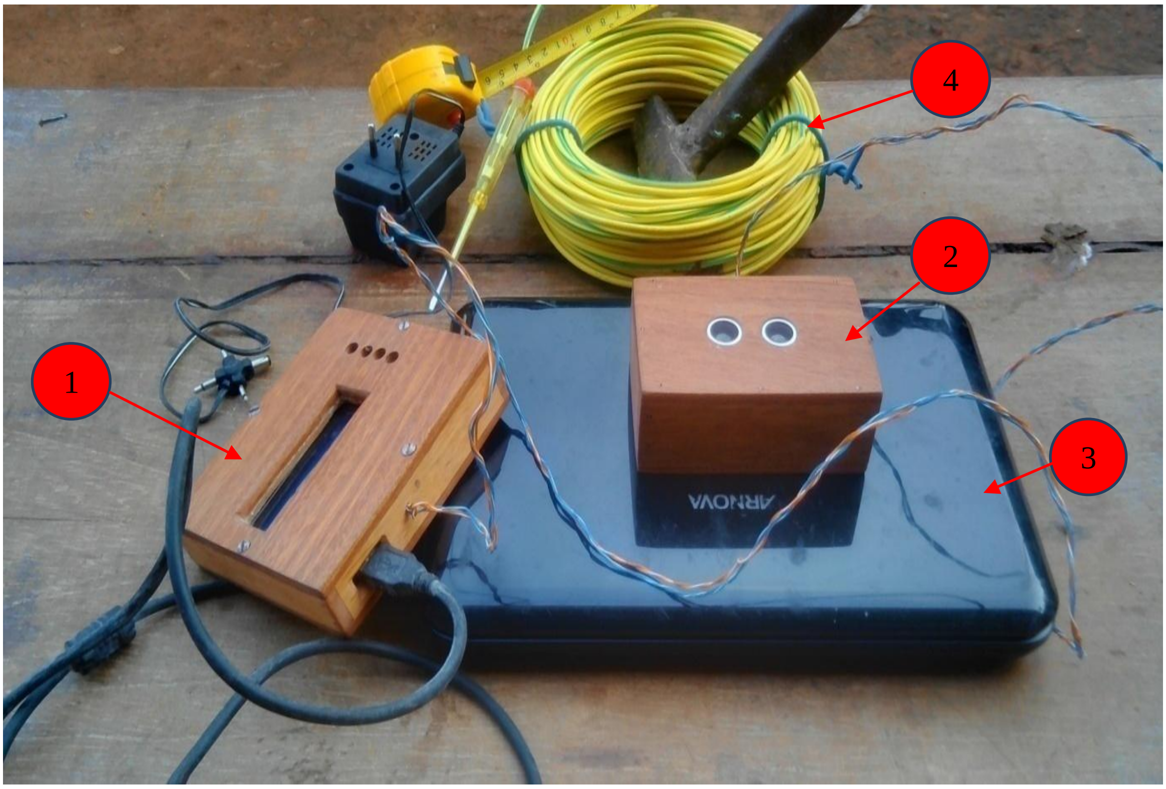

Figure 2: Rangefinder used to assess the height of runoff in drains

1 = The emitter unit of the rangefinder.
2 = The receiver unit of the rangefinder.
3 = The PC unit within which the collected data were stored.
4 = The cable used for supplying the rangefinder with energy

This instrument functions just likethe echo-localization system of some mammals like bats or dolphins. It involves emitting waves (from emitter of the rangefinder) that travels a certain distance (with regard to the capacity of theinstrument) to the targeted element (runoff or drain) and once itmeets the obstacle, it bounces on its surface and is sent back to the instrument (receiver of the rangefinder) that records data.

This experiment is carried out in two main phases:the first phase involved placing the instrument at a fixed position and at a distance above the drain. This first trial consisted in assessing the height of the drain when itwas empty(carried noliquid nor solid material).

The second trial was carried out during different rain events. The height determined in this case was the height at the surface of the water(runoff). The rangefinder computes the difference (height when drain has water – height of when drain is empty).

Figure 3 illustrates how the rangefinder was installed in the drain before the start of the experiment. Key points were studied and chosen for the installation of this devices. The outlet of main drainage areas were targeted as they constituted the points where most of the runoff that falls in the drainage basin conveys to.

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Figure 3: Installation of rangefinder in an artificial drainage system

The volumes of solid domestic wastes and soil sediments were next assessed for the different rainfall periods throughout the whole experiment.Once the data were collected (runoff, solid domestic wastes, soil sediments), their cumulative values were plotted following theircorresponding models i.e. linear for SDM + precipitation and quadratic for soil sediments + precipitation.

D. Correlation analysis

The volume of solid domestic wastes and soil sediments were simulated for the same period during which these elements were determined on the field. A correlation analysis was carried between the volumes simulated and volumes collected on the field. If there existed a significant correlation then the model was to be validated, on the other hand if no correlation existed, then the model was to be rejected and consequently calibrated before use. This will involve modifying the coefficients re-verifying at each time till a significant positive correlation could be observed. The Pearson correlation analysis was carried out within SPSS.
Pearson's correlation coefficient is a statistical measure of the strength of a relationship between paired data. In a sample it is denoted by r and is by design constrained as follows [15]:
$-1 \leq r \leq 1$…………………………………………………………………………………………………. (3)
Correlation is an effect size and so can verbally describe the strength of the correlation using the guide that [15] suggested for the absolute value of r (correlation coefficient):

- .00-.19 "very weak"
- .20-.39 "weak"
- .40-.59 "moderate"
- .60-.79 "strong"
- .80-1.0 "very strong"

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The models were further used to compute the total runoff in the drainage system. Total runoff in the case study can be defined as the sum of materials that are flow within a drain which are: water, soil sediments, and solid domestic wastes. Once computed, the volume occupied by the ***wastes*** was also determine.

III- RESULTS

Table 1 presents the values of the various coefficient obtained after analysis of the data using runoff as the conveying agent obtained from field measurements.

Table 1: Equations of the relationship between *wastes* and precipitation

Neighborhood	Nature of Drains	Relationship between solid domestic waste and precipitation	Relationship between soil sediments and precipitation
Etétack	Artificial	$V_{solid\ domestic\ waste} = 2.7xR + 0.002$	$V_{soil\ sediments} = -1.9 \times R^2 + 3.2 \times R - 0.015$
Oyomabang	Artificial	$V_{solid\ domestic\ waste} = 4.2x\ R + 0.050$	$V_{soil\ sediments} = -0.7 \times R^2 + 2.7 \times R + 0.600$
Nkolso	Artificial	$V_{solid\ domestic\ waste} = 4.1xR + 0.040$	$V_{soil\ sediments} = -1.3x\ R^2 + 4.8 \times R + 0.401$
Cité Verte	Artificial	$V_{solid\ domestic\ waste} = 3.6 \times R + 0.010$	$V_{soil\ sediments} = -0.1 \times R^2 + 7.2 \times R + 0.502$
Etétack	Natural	$V_{solid\ domestic\ waste} = 1.4 \times R + 0.006$	$V_{soil\ sediments} = -2.2 \times R^2 + 9.1 \times R + 0.012$
Oyomabang	Natural	$V_{solid\ domestic\ waste} = 4.0 \times R + 0.740$	$V_{soil\ sediments} = -0.1 \times R^2 + 1.6 \times R + 0.700$
Nkolso	Natural	$V_{solid\ domestic\ waste} = 1.1 \times R + 0.510$	$V_{soil\ sediments} = -0.7x\ R^2 + 8.2 \times R + 0.502$
Cité Verte	Natural	$V_{solid\ domestic\ waste} = 1.7 \times R + 0.500$	$V_{soil\ sediments} = -1.0 \times R^2 + 3.0x\ R + 0.030$

The results of the volume of ***wastes*** produced by these equations were compared with the volumes of waste collected from the field using Pearson correlation in SPSS.
For the spontaneous and structured settlement, the correlation coefficient obtained were as follows (with regard to [16]'s guide):

- **For SDW**

0.666 for Etetack (Spontaneous settlement), = strong
0.551 for Oyomabang (Structure settlement),= moderate
0.554 for Nkolso (Spontaneous settlement), = moderate
0.718 for Cité Verte for (Structure settlement). = strong

- **For Soil Sediment**

0.716 for Etetack (Spontaneous settlement), = strong
0.717 for Oyomabang (Structure settlement), = strong
0.564for Nkolso (Spontaneous settlement), = moderate
0.556 for Cité Verte (Structure settlement). = moderate

The correlation coefficient is found to be varying between moderate and strong with a more or less balance between the structured and spontaneous neighborhood. This result expresses the precision of the model and as such it can be concluded that no adjustment is necessary for the various models.

E. Impact of waste on the volume of runoff

In spontaneous neighborhoods, the increase in volume of runoff accounted for by solid domestic waste and soil sediments are 6 to 7% for Etetack and 2 to 9% for Nkolso. This implies that for spontaneous settlements, the increase ranges from 2-9%.

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In structured settlement, the increase in volume of runoff accounted for by solid domestic waste and soil sediment are 4 to 10% for Cité Verte and 4% for Oyomabang. This implies that for structured settlements, the increase ranges from 4-10%.

IV- CONCLUSION

Floods most often arise as a result of several combining factors. However in countries with a developing economy, poor urbanization and poor waste management are the main causes. Drainage systems are designed in developing nations without usually taking into consideration the reality of poor waste management and poor land use. Drainage systems are usually inexistent in some parts of most urban areas in African cities, yet those present are not productive due to the presence of soil sediments from erosion enhance by human activities as well as poor waste management. Little or no maintenance of the drains is also a key factor that amplifies the development of floods in urban areas.

Models have been developed that take into consideration the solid domestic waste and soil sediments conveyed by runoffs in a drainage system. These models describe the relationship between ***waste*** and runoff. For solid domestic wastes and runoff, a linear patterns was observed and a quadratic pattern for soil sediments and runoff. However before implementation of these models, they had to be tested, calibrated if necessary and validated.Based on the methodology used and the result obtained it can be concluded that:

- A positive correlation exist between the data produced by the models through simulation and those obtained from the field. The correlation ranges from a medium to a strong correlation with regards to the type of the urban area. Consequently the models developed by [13] can be considered valid.
- The solid domestic waste and soil sediments significantly affects the volume of runoffs and consequently the design of the drainage system. The volume accounted for solid domestic waste and soil sediments in runoff ranges from 2% to 10% with respect to the nature of the drain (natural and artificial drain) and the type of neighborhood (structured and spontaneous settlements) as classified by [17].

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