Uncontrolled Draining of Rainwater and Health Consequences in Yaoundé – Cameroon

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ABSTRACT

Context: Like many sub Saharan African cities, Yaoundé is experiencing a faster growth of its population and urban perimeter. The urban population has grown from 812 000 inhabitants in 1987 to 2 100 000 inhabitants in 2006. However, this population growth has not been monitored by the city planners and decision makers. Accordingly, the city is lacking basic urban facilities. such as a good sewage system to evacuate urban waste water. Objective: This paper aims at addressing health consequences resulting from inadequate management of rainwater in Yaoundé. Material and methods: From the data gathered by us in the framework of the PERSAN programme focused on urban health, a cross sectional study has been carried out in 2002 and 2006 across the city. Based on socio-environmental and medical surveys, the study covered neighborhoods and 3 034 households in Yaoundé. Results: It comes out that that the present urban draining network is outdated and ineffective. This has led to increasing floods in several sectors of the city, with health hazards. It has been noted that many diarrheal diseases in Yaoundé are related to the poor sanitation resulting from urban waste coupled with standing waters. Conclusion: We are of the opinion that to solve this problem, there is urgent need to set up a new town-planning mechanism which takes into account the city's demographic and space dynamics.

RESUMEN

Contexto: Como muchas ciudades africanas secundarias del Sahara, Yaoundé está experimentando un crecimiento rápido de su población y perímetro urbano. La población urbana ha crecido de 812 000 habitantes en 1987 a 2 100 000 habitantes en 2006. Sin embargo, este crecimiento de la población no ha sido supervisado por los planificadores de la ciudad y los que toman decisión. Por consiguiente, la ciudad está careciendo de instalaciones urbanas básicas tales como un buen sistema de las aguas residuales para evacuar las aguas negras urbanas. Objetivo: Este papel tiene como objetivo exponer las consecuencias de la salud resultando de la gerencia inadecuada del agua de lluvia en Yaoundé. Material y métodos: De los datos recopilados por nosotros en el marco del programa de PERSAN centrado en salud urbana, un estudio representativo se ha realizado en 2002 y 2006 a través de la ciudad. Basado en los exámenes socio-ambientales y médicos, se estudia vecindades cubiertas y 3 034 casas en Yaoundé. Resultados: Se puede concluir que la actual red de drenaje urbana es anticuada e ineficaz. Esto ha conducido a varias inundaciones en varios sectores de la ciudad, con los peligros para la salud. Se ha observado que muchas enfermedades diarreicas en Yaoundé están relacionadas con el saneamiento pobre resultando de la basura urbana juntada con aguas estancadas. Conclusión: Somos de la opinión que para solucionar este problema, hay necesidad urgente de instalar un nuevo mecanismo de la ciudad-planeamiento que considere la ciudad dinámica demográfica y del espacio.

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INTRODUCTION

The rapid urbanization of our planet dates back to the 19th century (Palen, 1981). In 1950, 29% of the world's population lived in the cities. This figure is currently estimated to 50% and it is projected that by 2030, this proportion will reach 61% (UNPF, 2007). More intriguing than these global figures is the rapid and spectacular process within developing countries in general and Africa in particular. Urbanization in Africa has been unusual with

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a rapid shift from 15% in 1950 to about 41% urban currently. It is estimated that by 2030, the continent may attain 54% urban proportion (UNPF, 2007). This phenomenal growth has been qualified variously as “galloping” and “wild“ (Sietchiping, 2003) to express not only the uncontrolled nature of urban growth, but also the ecological consequences and implications that they may have on human health and well-being (Trang *et al.,* 2007; Cifuentes, 1998). Health and well-being concerns of inhabitants of Sub-Saharan Africa are linked to, or associated with the unplanned urban centers (Bashir, 2002). In fact, in sub-Saharan Africa, setting adequate socio-urban facilities at the disposal of all and everyone (such as sanitary infrastructures) is a challenge to policy makers. In Yaoundé for instance, this challenge is far from being attained as the situation of rainwater draining is disappointing. The rapid and uncontrolled development of the city has opened out into the absence of a good sewage system to contain urban waste water. With regards to rainwater, actions adopted by the authorities are hampered by poor facilities which in most cases are inefficient. On the event of a little downpour, the city is frequently flooded. Thus, the current waste water evacuation mode can’t be considered like conveniences, but like harms as health risks they trigger on town’s dwellers are huge. Infectious diseases have been found as a permanent feature of informal settlements in Yaoundé, namely in marshy areas (Nguendo, 2000). Since diarrheas are an inter-human communicable disease for which inadequate sanitation facilities are of great importance in its diffusion process, we posited that lack or poor rainwater disposal might be a risk factor associated to the development of diarrheas in Yaoundé. In the first section of this paper, will be given a brief presentation of the spatial and methodological framework of the research. In the second one, the urban draining network will be tackled. Finally, health risks incurred by city dwellers will be examined.

STUDY AREA AND RESEARCH METHODOLOGY

Conceptual Framework

Fast-growing population, extreme poverty of large numbers of urban households, and persistent deterioration of living conditions are some of the challenges facing cities of the developing world (Esrey, 1996; Frumkin, 2006). For at least four decades, a wide–ranging research effort has investigated the cost-benefits of providing safe and convenient living conditions to households in the developing world (Harpham and Tanner, 1995; Huttly, 2002). Most of the work has focused on housing conditions, notably on the relationship between wastewater, sanitation and disease (Bouhoum and Schwartzbrod, 1998; UN-Habitat, 2006). Research notes that all forms of waste water are infectious, pollutant and a risk to human health and the environment (Mara *et al.*, 2007). It is also evident that each year, poor hygiene and lack of sanitation facilities contribute to the death of millions of the world’s poorest people from preventable diseases (Pruss *et al.*, 2002; Cairncross *et al.*, 2003). More importantly, women and children are the main victims. Considering the nexus wastewater, sanitation and health, empirical evidence points to their close linkages. In particular, the relationship could be outlined as follows:

(a) Rain water may host hundreds of disease-causing organisms (Dalsgaard, 2007; Trang.

(b) Food or drinking contaminated by untreated wastewater may result in water-borne diseases including cholera, dysentery and other diseases that responsible for diarrheas (Black and Fawcett, 2008).

Concerning diarrheal diseases, it is estimated that 1.8 million people die worldwide every year. Amongst them, 90 % are children under 5 mostly in developing countries. Diarrheal diseases account for 4,3% of the total global disease burden (62,5 million Disability Adjusted Life Years). An estimated 88% of this burden is attributed to unsafe drinking water supply, inadequate sanitation, and poor hygiene (Tumwine *et al.*, 2002). These risk factors do not evenly threaten urban districts, as slums and informal settlements are more vulnerable to communicable diseases (Kawachi and Berkman, 2003). Despite the quantity of studies carried out, relatively little is known about the key contribution of poor management of rainwater in diarrheal incidence. Among the regions of the world, Sub-Saharan Africa needs to fill the research gaps in the area, especially because the region has the fastest growing urban population and the majority of city dwellers have least access to urban equipments. This paper aims at demonstrating the link between failure in provision an adequate draining system and health outcomes (with reference to diarrheas) in a Sub-Saharan African capital city (Yaoundé).

We adopt the World Health Organization (WHO) definition of health that stipulates that health is a “complete state of physical, mental and social wellbeing, and does not consist only in an absence of disease or disability” (WHO, 2007). Typical health measurement includes indicators like mortality, morbidity and life expectancy. For this study, we have chosen morbidity, and more precisely morbidity attributed to diarrheal diseases. Diarrhea is generally characterized by the frequent occurrence of watery stools. In a technical sense, however, it is more difficult to define because the suggested elements which are asymptomatic of the definition of diarrhea vary according to the objectives of each study (Baqui and *et al.,* 1991). Following clinical signs, we have considered diarrhea as: (i) the sudden and frequent occurrence of abundant and consistently abnormal watery or mucus stools more than three times a day and more than 300 g per stool (Gascon and al., 2000; Molbak and *et al.,* 1994), (ii) the stools should be mixed with a phlegm-like substance or blood, and are associated with dysentery, (ii) and to indicate its acute character, the episode must last for about 14 days. Since diarrheas are an inter-human communicable disease for which unhealthy living conditions are of great importance in its diffusion process, we posited that lack or poor rainwater collection system might be a risk factor associate to the development of diarrheas.

Study area: choice justification

The study area is Yaoundé, the capital city of Cameroon in Central Africa. Yaoundé is located 3°52′ north of the equator. The city is located in the Mfoundi drainage basin and covers over 256 km^2 (Figure 1) and experiences a typical Equatorial climate: regular and abundant rainfall (1 600 mm/year), an annual average temperature of 23°C, two dry seasons (november-march and june-july) and two rainy seasons(april-may and august-october). The area is covered by (i) well drained red ferrallitic and lateritic soils on the upper slopes and summits, (ii) and by colluvial and alluvial deposits in the valleys (Onguene, 1993). Within the current urban perimeter, one observes mixed vegetation having relics of forest on hill summits, and market-gardening plants along river valleys.

Like many sub Saharan African cities, Yaoundé is currently experiencing very rapid urbanization. In 1926, date of the first population census, Yaoundé had 100 000 inhabitants. With an estimated annual growth rate of 4,5 per cent since 1980, urban population has grown from 812 000 inhabitants in 1987 to 1 500 000 inhabitants in 2000, and to about 2 100 000 inhabitants in 2006 (NIS, 2006). However, this population growth has not been monitored by the city planners and decision makers. Consequently local authorities have failed to provide neighborhoods with adequate utilities, services and infrastructure. Therefore, city dwellers are facing difficulties such as draining their waste water. Under this backdrop, this paper examines health outcomes in the sole context of poor draining system collection.

DATA AND METHODS

The data used in this work were obtained from an interdisciplinary survey carried out in Yaoundé under the auspices of the ‘‘Populations et Espaces à Risques Sanitaires’’ (PERSAN) research programme. The survey covered neighborhoods and households in Yaoundé, and used a stratified sampling procedure based on two stages to select targeted neighborhoods and households. First, using GIS techniques, areas risky to water runoff and to floods were identified. These areas prone to floods are made up of flat and marshy zones where slopes are less than 5 degrees (Figure 2). In the second stage, 3 034 households were selected from these areas with risk of floods. Households were selected on the basis of having a child of less than 5 years of age as they appear to be more vulnerable to infectious diseases. Within this interdisciplinary research programme targeting health in a tropical urban environment, two surveys were conducted:

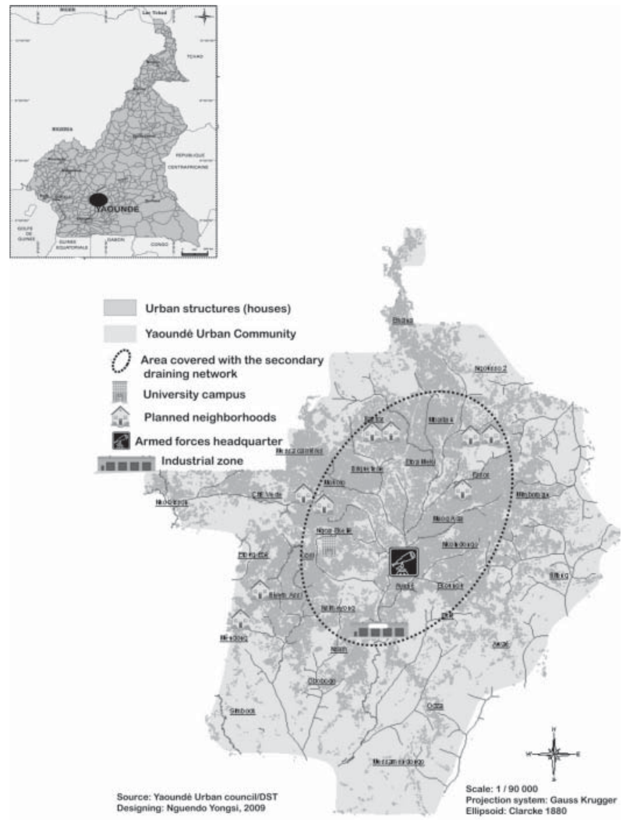

Figure 1. Yaoundé City.

- A socio-environmental survey whose objective was to appraise the urban draining system. With regards to rainwater, data-collection was conducted in different parts of the city to identify the types of facilities set down to drain rainwater, and to evaluate the condition and efficiency of these facilities. A semi-guideline discussion was held with some authorities and a review of existing relevant documents on the topic were undertaken to complement the field work.

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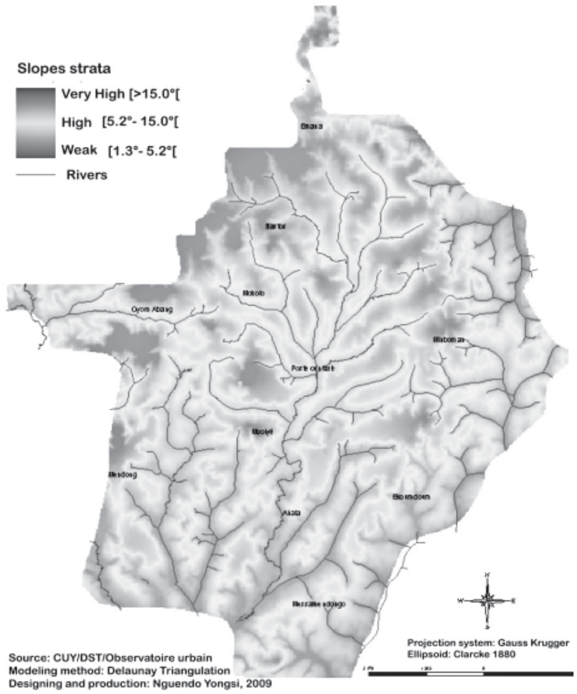


Figure 2. Slopes' map of Yaoundé: a modeling.

- A medical survey on 3 034 households. Each household was to comprise a child aged less than five years. This health survey was carried out by teams of doctors at the end of their training programme in the Faculty of Medicine and Biomedical Sciences of the University of Yaoundé I, under our coordination. This survey aimed to detect cases of diarrhea in children within the selected households. Thus when a case of diarrhea was reported, a stool sample was taken and dispatched to the bacteriological, virological and parasitological laboratories of the Cameroon Pasteur Institute within the accepted requirements, for confirmation and for identification of the causal germs. Each positive sample was correlated with the socio-environmental data pertaining to the household to which the infected child belonged to.

RESULTS AND COMMENTS

A city deprived of a functioning sanitary system

Slightly located north of the equator, Yaoundé is a perfect example of an equatorial city. Type of climate prevailing here is the Guinean type whose main characteristics are regular and abundant rainfall, and existence of four seasons (two dry seasons and two raining seasons). During these seasons, one estimates at 1 600 mm, volume of water which the city receives annually. More remarkable is that these repeatedly torrential rains lead to rapid streaming. Storm water runoff is hampered by: (a) urbanization marked by a high density of dwellings that reduce run-off surface, (b) the pave routes and tarred surfaces which considerably reduce infiltration of water. Consequently, rainwater runs out into dwellings as the city is deprived of a good system of sewage or collective sanitation system to ensure collection and draining of waste and rainwater. Observations drawn from various catchments areas show the dysfunctioning level of the draining systems (Table 1) that are shared out the various hydrographic basins (Figure 3).

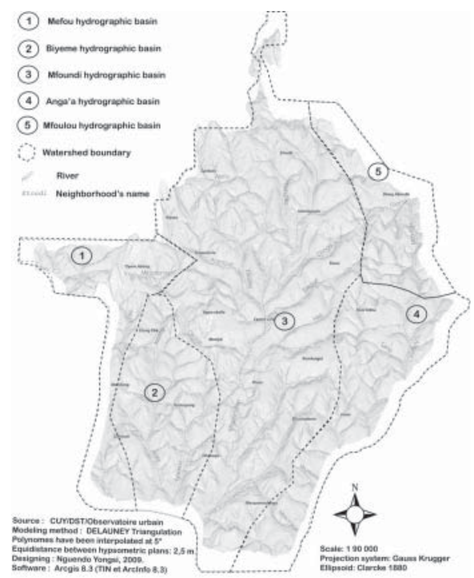


Figure 3. 3D rendering of a digital terrain model of Yaoundé and of hydrographic basins

An ineffective draining system

At the background of rainwater draining problems in Yaoundé, one finds two natural elements having contradictory effects: (a) hydrography, whose division portray an easy draining but which quickly appear as a constraint since each river needs to be canalized; (b) topographic and pedological conditions because though the city displays steep slopes which make easier fast flows, natural draining suffers from the flat feature of the lower areas. As for the grounds, their high content of clay (12-37% vs 0,6-1,8% for organic matters) considerably slows down the in-depth infiltration and generates mud or dust development (Mainam *et al.*, 2002). The situation is aggravated by the fast urbanization for which local authorities endeavored to control with a weak and unequal effectiveness (Table 2).

Table 1.
Situation of Sewage disposal stations in Yaoundé.

Stations	Localization	Opening date	Sewage treatment type	Purification capability	Current state of functioning
Grand Messa	Mingoa hydrographic basin	1967	stimulated mud with an average load	450 m3/day, for 4 500 inhabitants	Out of order since 1985: The waste water is directly drained into the Municipal lake and into the Mingoa basin.
Université Yaoundé	Mfoundi hydrographic basin	1967	stimulated mud with a weak load	500 m3/ day,for 195 000 inhabitants	Out of order since 1982: The waste water is directly drained into the Melen/Obili and Atemengue lakes.
Centre Hospita lier Universitaire	Oledzoa hydrographic basin	1976	stimulated mud with a weak load	425 m3/day	Out of order since 1982: The waste water is directly drained into the Ngoa Ékellé Pool or bog.
Cité Verte	Abiergue hydrographic basin	1982	stimulated mud with a weak load, but with filters	1 020 m3/day , for 12 000 inhabitants,	Out of order since the opening date (1982) as there was nobody to manage. Presently, all the mechanical and electronical equipments are stolen. Consequently, the waste water is directly drained into the Abiergue river.
Biyem Assi	Biyeme hydrographic basin	1984	Macrophytes lagoonage	No data	Slightly in good state: The pipes are broken and the filters obstructed with sand and gravel
Nsam	Bassin du Mfoundi	Unfinished	stimulated mud with a weak load, bud with drying mud bed	5 943 m3/day, for 29 014 inhabitants	Never used : Works have been stopped since 1987
Palais de l'Unité	Mfoundi hydrographic basin	1985	stimulated mud with a weak load	190 m3/day for 1 150 inhabitants	Stop by order: the waste water is directly drained into the Mfoundi and Tongolo rivers.
Hôpital Général	Ntem hydrographic basin	1988	stimulated mud with a weak load, bud with drying mud bed	355 m3/ day for 855 habitants	Good functioning state : Constantly kept alive
Lycée de Nkolbisson	Mefou hydrographic basin	1989	stimulated mud with a weak load	144 m3/day	Out of order
Hôpital de la Caisse	Ebogo hydrographic basin	1990	stimulated mud with a weak load	120 m3/day	Good functioning state: Constantly kept alive

Sources: [Agendia L.P. et al,,2001][Megno,2000][SDAU de Yaoundé,1982].

Table 2.
Facilities used to evacuate rainwater in Yaoundé

	Neighborhoods								
Population and types of infrastructures	Bastos	Etoa Meki	Briqueterie	Efoulan	Ngoa Ekelle1	Essos N & S	Nkolmesseng	Biyem Assi	Elig Effa
Population (in thousands inhabitants)	17 038	32 418	66 398	17 170	61 362	60 891	9 250	27 679	39 680
Big draining channels rainwater oriented (in meter)	0	0	3	0	0	0	0	,,,	0
Rainwater pipes (in meter)	6	1	0	0	2000	2 200	0	5 300	1 700
Waste water pipes (in meter)	0	0	6	0	0	0	0	0	0

Source: [Ministère de la Ville / CUY, 2002]

A glance on infrastructures set up to control run-off generated by rainwater in Yaoundé reveals three types of networks: primary, secondary, and tertiary draining.

Primary draining network, a neglected network

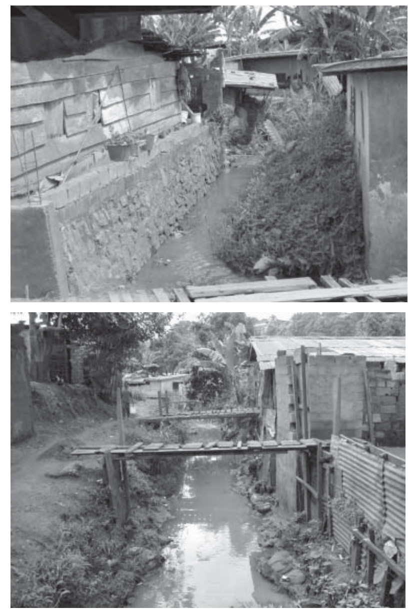
Yaoundé's hydrographic network is dense. The territory is drained by a water body (Mfoundi) and nearly thirty four streams. With eight basins, the network includes both surface and underground waters. Surface water comprises the complex systems of streams, lakes, swamps, and other flowing or lentic water bodies. All flows on the non-carbonaceous micaschists and gneisses of the Yaoundé Pan-African nappe (Vicat *et al*., 2002).

Collection of surface water is till present days ensured in a natural way (Santoir and Bopda, 2004). In fact, each urban district is crossed by a river which theoretically collects and drains streams. Table 3 shows the tangling and influence of that network.

Table 3.
The primary draining network in Yaoundé

Rivers	surface area of the hydrographic basin (ha)	Neighborhoods crossed by the river
Olézoa	357	Ngoa Ekelle 1 et 2, Atemengué
Mingoa	360	Quartier du Lac, Messa, Melen , Elig Effa
Abiergué	341	Mokolo, Nkomkana,Madagascar,Tsinga,Briqueterie,
Ekozoa	292	Bastos, Nlongkak, Tsinga1
Mfoundi, Tongolo, Ntem, Ebogo	2 154	Bastos, Mballa1&2&3,Mfandena,Elig Edzoa,Essos Nord
Djoungolo	139	Elig Essono, Nlongkak
Ewé	352	Essos Sud
Aké	492	Mvog Mbi, Mvan, Ekounou, Kondengui
Total	4 487	

However, the relief layout considerably reduces capacity of the channels of the rivers to contain the discharge. Indeed rivers longitudinal gradients are weak (less than 5%) whereas their transversal gradients are steep (10% on average). It is the case of river Abiergue which over a distance of 1,3 km, her gradient is reduced by 760 m from its source to only 716 m at the point known as «Marché de Charbon» (Nguemou, 1994). This slope imbalance leads to a faster flow on the plateaus and to water stagnation in the valleys whereas a simple readjustment of the waterway would have balanced up the situation (Niang and Gaye, 2002). This steep effect is aggravated by lack of maintenance of those natural networks. The Yaoundé urban Council is the organ responsible for their maintenance. But for some reasons (lack of finance, human, material resources, and of vision in the prioritization of actions to be undertaken), it neither carries out their cleaning up nor their calibration. Consequently these natural networks have been invaded by vegetation making water circulation very difficult. However, city dwellers carelessness is also to be pitied: Spontaneous structures built by these populations have narrowed rivers' bed, further hampering circulation of water, of all sorts of sewage and waste (Figure 4) and consequently have lowered the speed and stream discharge (Hardoy and SatterthERwaite, 1989).



®Nguendo Yongsi, 2006

Figure 4. Natural drains having narrows bed due to constructions works and vegetation invasion, prevent rainwater and various objects from easily running.

Secondary draining network, an unequal and ineffective network

To ensure rain water discharge, a secondary draining network was created. This creation was accompanied with the tarring of roadways and with a lesser extent to untarred paths. The 224 km network stretch consists of concrete reinforced gutters (*buried circular collectors or drains drilled along the streets on both sides of tarred road; their bottom consist of cement layer attached on the ground; they are partly covered with slabs, but in most cases they are dilated*) and of earth gutters (*kinds of ditches out of ground dug on both sides over-*

land routes, sometimes in ''U'' shape, and sometimes in ''V'' shape). However, this network is unevenly distributed in the urban space. The only areas covered are: the city center, the Armed forced headquarter, the Yaoundé I university campus, the planned quarters and the industrial zones. By 2006, above mentioned areas covered about 2000 ha out of the 13 500 ha numbered in the city, representing approximately 15% of urbanized area (Figure 3). Thus, 85 % of the city do not have secondary draining network: a remarkable under-equipment. Not only is this secondary draining network unevenly distributed, but also it is inefficient. A glance on them portrays that their construction is more traffic oriented than meeting sanitation needs. Many roads segments are not connected and are poorly dimensioned to dispose running water in areas they serve. In others segments, sanitation situation is paradoxical: gulley water is channeled towards the interior of houses and neighborhoods. It is the picture along the Mokolo crest line stretching to Madagascar and Tsinga neighborhoods. This not withstanding, there is little or no maintenance work on this network. Obsolete and degraded, gutters covered with flagstones and buried garbage are filled up and have large potholes. Figure 5 gives an idea about how much these materials represent with regard to public health. The open gutters have been blocked by solid materials and household refuse. The cumulated load along the water ways makes rain water flow difficult. Despite, some households collect water for house use.

®Nguendo Yongsi, 2006; Wouafo, 2007

Figure 5. Open gutters blocked by household refuse and covered with vegetation in Yaoundé

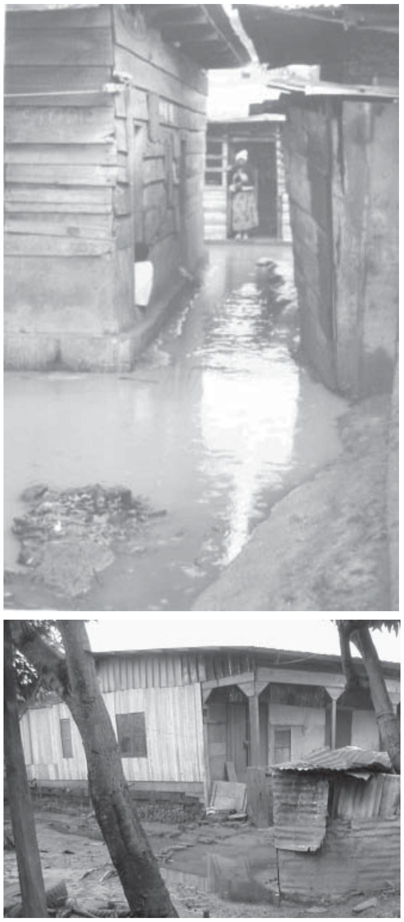
Tertiary draining network, a disarticulated network

This draining network is focused on spontaneous settlements. It is mostly found inside blocks and parcel lands. In densely populated neighborhoods, this tertiary draining network has been either set up by local populations or dug by water during their flow (Figure 6). On the other hand, in less populated areas not well served by earth roads, this network is in the form of lateral earth ditches. It is a poorly maintained network. Management reflects the views of households concern: ditches and draining network are inconsistency in layout, in dimension, and in way of maintenance [Djeuda *et al.*, 2001]. Entire segments are silted up, muddy and covered by grasses.

Their effectiveness is quite relative. In areas where slope is less steep (between 5.2° and 15°), normal flow occurs. But in those where slope

Side ground ditches dug by water during their flow, and of… ground drains worked out by the inhabitants.
®Nguendo Yongsi, 2006

Figure 6. Tertiary draining network aspects in Yaoundé.



®Nguendo Yongsi, 2006

Figure 7. Floods scenes in two spontaneous neighborhoods of Yaoundé.

gradient is lower than 5º, surface plainness supports concentration of streams flowing from slopes and plateaus. High density of buildings increases proportion of water that flow from streams, leading to the development of puddle pools that are difficult to evacuate. This phenomenon is very common in the valleys where structures are covered with corrugated iron sheet roofs sloping in two directions without gutters. Water flow is therefore brutal and spontaneous. However, these urban areas find it difficult to absorb large volume of water due to the nature of soils.

Streams in flow process do provoke floods, leading to (a) destructions caused on buildings due to gulling, (b) domestic problems (sleep disturbance, soaking of house furniture), and (c) inaccessibility of neighborhoods affected by flooding (Figure 7).

Faced with floods frequency (27 per year in Messa-Mokolo and Mfandena neighborhoods; Akongwié, 1999), Yaoundé dwellers have adopted some strategies. In areas constantly flooded by rainwater, two types of coping strategies were observed:

- Some city dwellers moved out of their houses during the floods and return only when they have subsided,

- The others fill up their houses with ground and gravel to the window level, and cover the muddy ground with thin card boards or plywood on which they place their valuable domestic equipments and basic necessities (kerosene heaters, kitchen utensils). Other equipments like beds, mattresses, radio, clothes, are suspended on the walls and ceiling.

Health consequences of poor sanitation resulting rain water

As described above, infrastructures set up to control run-off generated by rainwater in Yaoundé are of relative efficiency. Consequently, water run-off from streets, slopes and plateaus is gathered in shallows hereby represented by ''U'' shape marshy valleys (Figure 8).

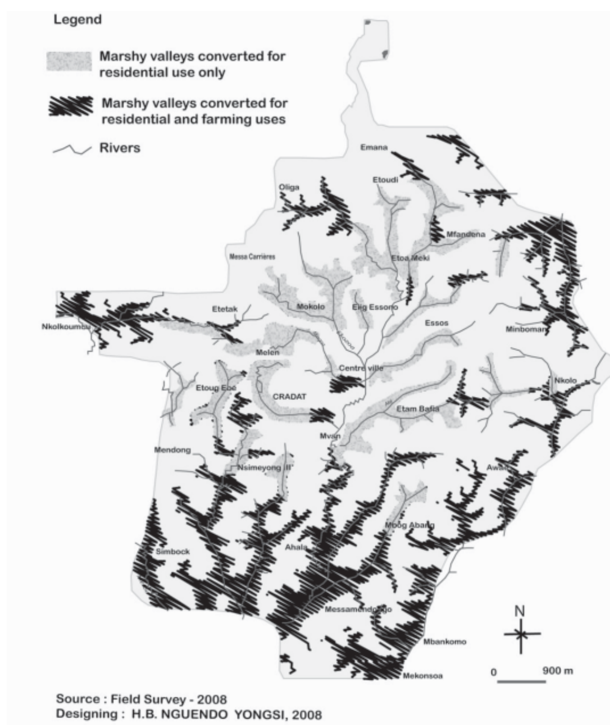


Figure 8. Marshy valleys in Yaoundé.

In these low areas, flooding and dampness are permanent. Environment shaped by floods is unpleasing judging from the hygienic and health perspective. In flooded areas, ground is permanently wet. Rubbish ejected from toilets and drains and domestic refuse concentrate on the ground surface and conspire to generate very disgusting water that sends out bad odors. In meanders unraveling residential buildings, black-colored water loaded with old clothes, with discarded food, with assorted nitrates and with decayed objects runs out. It is in this dirty water that ducks, hens and chickens nourish themselves. As far as stray dogs, goats and pigs, hens and ducks consider these houses refuse like great banquets. It is also in these wet and loaded areas that the winged fly and other insects harmful to man live. Thus, these rain waters, turned to standing water are dangerous since notwithstanding they contain chemicals substances (9%) and heavy metals (4,1%) (Bemmo *et al.*, 1998) known to cause a variety of environmental and health concerns, fecal matters and urine both from humans and animals carry many disease-causing organisms (Ward *et al.*, 1989; Ait Meloul and Hassani, 1999).

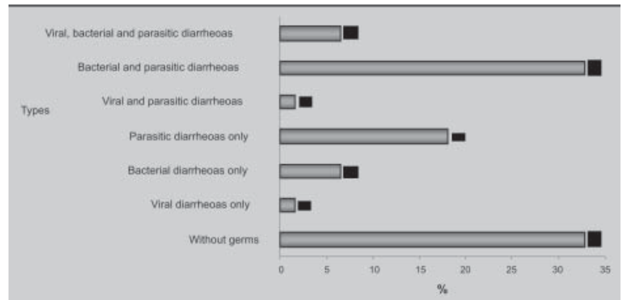
Results of the epidemiological survey we carried out on the 3 034 children showed that out of 437 diagnosed diarrheal cases, 17,3% are found in these marshy hollows prone to floods (Table 4). *Citrobacter freundii, Eschérichia coli, Klebsiella levinea, Shigella, Salmonella, giardia and Pseudomonas sp* were the organisms we isolated on the stool samples [Nguendo Yongsi, 2007]. Then, bacteria, viruses and parasites are the types of pathogens in standing water that are hazardous to humans here as in some Asian and Central America urban settings (Xu *et al.*, 1995; Needham *et al.*, 1998).

Table 4.
Distribution of diarrheas in Yaoundé, according to the morphological units (p <0.05)

Morphological units	Surveyed households		Diarrhoeas recorded	
	frequency	%	frequency	%
Plateaus areas	764	25.2	93	12.2
Slopes areas	1659	54.7	239	14.5
Wet lowlands areas	611	20.1	105	17.3
Coverage	100% (3 034)		437	

Source: Nguendo Yongsi/ PERSAN-IRD survey.

An explanation of such a high diarrheal prevalence lay in the fact that, because of their soils and topography features, these lowlands are urban areas which gather streaming water that contain diluted faeces and above mentioned micro-organisms that are responsible for diarrheal diseases (Figure 9), including bacillary dysentery, gastroenteritis and cholera (Bryan, 1977; Froeze and Kindzierski, 1998).



Source: Nguendo Yongsi/ PERSAN-IRD survey.

Figure 9. Etiologies of diarrheas diagnosed in easily flooded valleys in Yaoundé.

From our direct investigations, we noted that city dwellers catch diarrheal diseases in a variety of ways:

- by direct contact with sewage: for example, direct contact occur as a result of (i) walking in fields irrigated with untreated wastewater, (ii) playing or walking in a yard with failed septic system, (iii) touching raw sewage disposed of in open areas, (iv) swimming or bathing in contaminated rain water,

- through contact with animals or insects carriers, i.e working with or coming into contact with animals or rainwater and not following proper hygiene,

- by eating food or drinking water contaminated with rainwater turned to sewage: in neighborhoods where wastewater (including rainwater) treatment was inadequate or nonexistent, people have become ill by doing the following: (i) eating food exposed to flies or vermin that feed on and that were in contact with sewage, (ii) eating vegetables and fruits contaminated by irrigation with polluted water or sewage sludge, (iii) drinking contaminated water collected from wells and springs (Figure 10).

CONCLUSION

The rapid wave of urbanization in developing countries seems to have taken public authorities unaware as they are confronted with uncontrolled growth of their

Kids collecting water in a well dug in a flooding neighborhood

®Nguendo Yongsi, 2006

This traditional spring might be polluted as it is a resurgence of untreated rainwater.

Figure 10. Drinking water supply modes in Yaoundé

cities. This is typical of Yaoundé which till present does not have a clear and formal development plan. This assertion is justified by the absence of sewage system in the town for the disposal of running water. Indeed, some infrastructures have been initiated to that effect, but with mixed results. The reality is that, Yaoundé has expanded and continues to expand without provision of facilities to ensure adequate circulation of running water. General recourse by urban dwellers to natural draining systems (rivers) and drains dug by them illustrates local authorities' inability to meet population needs. Reliance on these natural and artificial networks makes that, enormous volume of water discharged by heavy rainfall very often result to floods with adverse health consequences on city dwellers. Pathogens we've identified and which responsibility in diarrheal occurrence has been pointed out show that spontaneous flow of rain water is a phenomenon that must not be underestimated.

From the above analyses, several lessons can be drawn. From a conceptual point of view on the urbanization process, we can state that if the current African urbanization is due to many failures in ongoing policies, it is time to articulate urban policies that strike a balance between urban growth and provision of basic urban infrastructure. Moreover, these policies must also extend services in order to reduce disease risks in less equipped neighborhoods. In combination with healthy settlements, the adequate distribution of services can reduce the occurrence and diffusion of diseases. From a public health point of view, wastewater originating either from rain or from households must be treated to prevent diseases. This wastewater treatment might consist of a combination of processes used in steps to remove, kill or 'inactivate' a large proportion of the pollutants and disease-causing organisms in wastewater. Most treatment methods include a preliminary step in which the solid materials are filtered out and separate from the rest of the wastewater. The wastewater further receives treatment through a combination of filtration and biological/chemical processes.

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