Suffering for Water, Suffering from Water: Access to Drinking-water and Associated Health Risks in Cameroon

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ABSTRACT

Although many African countries, along the equator, receive a great amount of rainfall and possess a dense hydrographic network, access to drinking-water remains a great challenge. In many households, water is used for various purposes, including domestic and crafts activities. According to the World Health Organization, an estimated four billion cases of diarrhoea occurs worldwide, of which 88% are ascribed to unsafe drinking-water. This study aimed at evaluating health risks in the usage of contaminated drinking-water and its relationship with the prevalence of diarrhoeal diseases in Yaoundé, Cameroon. In this cross-sectional epidemiological design, 3,034 households with children aged less than five years were investigated. Households were selected from among 20 representative neighbourhoods out of 105 that made up the city. The study revealed a diarrhoea prevalence of 14.4% (437 diarrhoea cases out of 3,034 children tested). Among various risk factors examined, water-supply modes and quality of drinking-water were statistically associated with diarrhoea cases. Moreover, levels of diarrhoea attacks varied considerably from one neighbourhood to the other. The spatial analysis helped determine neighbourhoods of higher and lower prevalence of diarrhoea in the city.

Key words: Cross-sectional studies; Diarrhoea; Disparity; Drinking-water; Risk factors; Water quality; Water pollution; Water supply; Cameroon

INTRODUCTION

The availability of safe drinking-water is an increasing major concern for the interventional community, especially in light of changing climate-depleting biodiversity. Access to safe drinking-water for domestic use has become a major challenge for contemporary societies with its increased demand. Demand for clean and safe water has become more acute in the context of growing global population, particularly in less-developed countries (1). While developed countries invest heavily on the supply of fresh water to their entire population, developing countries are struggling to cater to the water needs of their citizens, especially in the context of rapid population growth and urbanization. Hence, urbanization has been phenomenal and puzzling with a rapid shift from 15% in 1950 to about 41% in 2007. It is estimated that, by 2030, the continent may attain 54% of urban proportion (2). This phenomenal growth has been qualified as sudden and wild to express the uncontrolled nature of urban growth and the implications it may have on the well-being of city-dwellers. Sub-Saharan Africa is ranked among the world’s regions which are mostly at a disadvantage. It is confronted with acute ‘water problems’ (a threat in water shortage in sufficient and satisfactory quantity for human needs), which has negative impacts on a large number of people. It is estimated that close to 300 million people do not have access to drinking-water (3). Results of research showed that water used in most households in developing countries are unsafe for consumption (4-6). It is also evident that, each year, contaminated drinking-water contributes to the death of millions of the poorest people of the world from preventable diseases (7). More importantly, vulnerable groups, such as children, women, and the elderly, are the main victims. Empirical evidence also shows the nexus sanitation, polluted drinking-water, and health. In particular, two types of relationship are often stressed. First, contamination by human or animal faeces is the most regular and pervasive health risk associated with drinking-water.
water; when such defect is recent and when those responsible for it include carriers of communicable enteric diseases, microorganisms that cause these diseases may be present in the water. Second, contaminated drinking-water may result in waterborne diseases, such as cholera, dysentery, and other diseases that may cause diarrhoeas (8).

Globally, it is estimated that 88% of diarrhoeal disease cases are attributable to unsafe water. In fact, the World Health Organization (WHO) estimates that about 1.1 billion people globally drink unsafe water (9,10). According to the WHO/United Nations Children's Fund, diarrhoeal diseases account for 4.3% of the total global burden of disease (62.5 million disability-adjusted life-years) (11). Despite the number of studies carried out, relatively little is known about the key contribution of unsafe drinking (reference is made here to pathogens found in water) in the occurrence of diarrhoeal diseases. Among the regions of the world, sub-Saharan Africa has been poorly covered despite being the fastest-growing urban population and the majority of city-dwellers having the least access to urban infrastructure and services. Within the context of cities in Cameroon which are witnessing constant population growth (12), access to water through taps is a luxury which only a few inhabitants can afford. With the population growth and the urban sprawling, connecting running water throughout the city requires expanding the water supply network, which the city councils and the government cannot afford. Therefore, many urban dwellers resort to various water sources of poor quality. Unsafe water is often contaminated with faecal material, domestic and industrial wastes. Such polluted water results in an increased risk of transmission of disease to individuals (13). Diarrhoeal diseases are often caused by contaminated water, poor sanitation, and poor hygiene. In Cameroon, diarrhoeal diseases are the most prevalent waterborne diseases among children aged less than five years. In Yaoundé, for example, the prevalence of diarrhoea is increasing. Results of studies conducted in the city among children aged less than five years showed that the rate of prevalence increased from 10.8% in 1998 to 13.1% in 2004 (14).

Epidemiological investigations can provide strong evidence linking exposure to the occurrence of diseases in a population and also estimate the magnitude of risk related to a particular exposure. This study, therefore, sought to assess the problem of access to drinking-water in Yaoundé. The objectives were three-fold: (a) to examine patterns of water supply in the Cameroonian capital to illustrate the complexity of the situation; (b) to assess the microbial quality of water used for consumption so as to evaluate its implication on the occurrence of diarrhoeal diseases; and (c) to gain an understanding of the geographic variations or patterns based on the prevalence of diagnosed morbidity.

MATERIALS AND METHODS

Study area and sampling sites

The study was conducted in Yaoundé, the capital city of Cameroon, situated in Central Africa, between latitudes 3°47' and 3°56' North and 11°10' and 11°45' East (Fig. 1). Yaoundé displays the classical equatorial climate, with regular and abundant rainfall of more than 1,600 mm per annum and a fairly high average annual temperature of 23 °C. Divided into four watershed basins, the Yaoundé watershed network is dense. The city is drained by the Mfoundi river and its many tributaries (Fig. 2). Like many sub-Saharan African cities, Yaoundé is currently experiencing very rapid urbanization. The first population census in 1926 estimated that Yaoundé had 100,000 inhabitants. With an estimated annual growth rate of 4.5% since 1980, its population has grown from 812,000 inhabitants in 1987 to 1,500,000 inhabitants in 2000 and to about 2,100,000 inhabitants in 2007. However, this population growth has not been monitored by the city planners and decision-makers. Consequently, local authorities have failed to provide neighbourhoods with adequate utilities, services, and infrastructure.
Therefore, city-dwellers are facing difficulties, such as getting access to water-supply systems.

*Period of study:* This interdisciplinary research programme was initiated in 2002 with sociodemographic and environmental surveys. However, microbiological and medical investigations were conducted in June 2005 and updated in July 2008 during the rainy season in Yaoundé.

**Data-collection methods**

*Target population:* To minimize the risk of confusion between infectious diarrhoea and soft stools normally observed in infants, the study only targeted children aged 6–59 months. Households with no children or whose children did not meet the age criterion were not considered for sampling purposes. In households with several children within this age range, a random age table was used for selecting one single infant.

*Survey frame and type:* The survey covered neighbourhoods and households in Yaoundé and used a stratified random-sampling procedure based on two stages. First, 20 of the 105 neighbourhoods that make up the city were selected. Not only were these neighbourhoods necessary to derive a sample-size sufficient for the scientific validation of the results but they were representative of the seven types that Yaoundé displays (housing estates, communal plots, wealthy residential neighbourhoods, central spontaneous neighbourhoods, urban fringes, and semi-rural neighbourhoods) (Fig. 3). In the second stage of the survey, 3,034 households (Fig. 4) were selected based on having a child aged less than five years as they appear to be more vulnerable to infectious diseases.

A team of the final-year students of the Faculty of Medicine and Biomedical Sciences, and data-col-
lectors from the Cameroonian National Institute of Demography who are specialized in population studies conducted the survey. The team visited selected households to collect data using (a) direct participant-observation technique and (b) structured questionnaire drawn up to respond to the three dimensions of this study, namely:

a. The sociodemographic and environmental dimension which aimed at examining sources and methods of collection of drinking-water and storage practices.

b. Assessment of the microbiological quality of drinking-water to determine to which extent water used was safe for consumption. In each targeted household, 500 mL of water was sampled in the form usually consumed by inhabitants. Drinking-water stored in bottles or other containers was poured into 500-mL sterile bottles. For pipe-borne water, standpipes were allowed to run for at least one minute and thereafter sanitized before water was aseptically collected in sterile wide-mouth glass bottles. Water from wells and springs was collected in pre-sterilized devices and was then poured in sterile polypropylene bottles. All the samples were labelled with different codes for analysis. The samples were sealed and transported (in an ice-cooled box at about 4 °C) to the laboratory and were processed as soon as practicable on the day of collection. Microbiological analyses performed on the samples were total viable count. The total coliforms were enumerated by the membrane filtration (MF) technique described by the American Public Health Association (15). *Salmonella* and *Shigella* species were detected by inoculating water samples into selenite F broth, followed by isolation of the typical organism on selective medium xylose lysine deoxycholate agar (XLD) (16). *Pseudomonas* was detected by placing filtered cellulose nitrate membrane filters onto basic *Pseudomonas* agar. The medium xylose lysine deoxycholate agar was incubated at 42 °C for 40-44 hours. Later, the agar was checked under ultraviolet light to detect pigment thought to be *Pseudomonas aeruginosa* or *Pseudomonas* spp. To detect *Escherichia coli*, all colonies of coliforms, which showed characteristic occurrence on endo agar and mFC agar, were subcultured on eosin methylene blue (EMB) agar, incubated overnight at 37 °C and were subjected to biochemical tests to identify *E. coli* (17). Other enteric bacteria isolated on respective selective or differential media were identified based on their colonial, morphological and biochemical properties, following Bergey’s Manual of Determinative Bacteriology (18).

c. Approved by the National Ethics Committee of Cameroon, the medical dimension aimed at detecting cases of diarrhoea in children within the selected households. Thus, when a case of diarrhoea was reported, a stool sample was collected and dispatched to the bacteriological, virological and parasitological laboratories of the Cameroon Pasteur Institute within the accepted requirements for the confirmation and identification of the causal agents. Each positive sample was linked with the household’s sociodemographic and environmental data.

**Analysis of data**

To have an overview of diarrhoea in the city (spatial analysis), we resorted to modelling. Since the 20 surveyed neighbourhoods were representatives of the 105 neighbourhoods that make up the city, results obtained in the surveyed neighbourhoods were extrapolated to the unsurveyed ones with regard to their respective similarities. This general criterion contained five elements, such as land-occupation modes, geographical situation, quality of housing, level of provision with urban infrastructure, and morphology of the site. The inclusive consideration of those five elements enabled us to elaborate Figure 5, which presents the seven types of settlements. Details on those settlements and examples of both surveyed and unsurveyed neighbourhoods are given in Table 1.

Based on those observed similarities, the prevalence of diarrhoea recorded in neighbourhoods that were surveyed was then credited to those that were not. The choice of weighted average is justified by the fact that the number of investigated households in surveyed neighbourhoods varied from one neighbourhood to another. This weighted average was obtained by the formula:

\[ \sum_{i=1}^{n} \alpha_i = (x_1 \cdot \alpha_1) + (x_2 \cdot \alpha_2) + (x_3 \cdot \alpha_3) + \ldots + (x_n \cdot \alpha_n) \]

\[ \Sigma : \text{Standard mean} \]

\[ x_i : \text{Prevalence of diarrhoea within the first neighbourhood of the considered category} \]

\[ x_2 : \text{Prevalence of diarrhoea within the second neighbourhood of the same category} \]

\[ x_3 : \text{Prevalence of diarrhoea within the third neighbourhood of the considered category, etc.} \]

\[ \alpha : \text{Significance of the surveyed neighbourhood in the category to which it belongs} \]

\[ n : \text{Number of neighbourhoods considered in the } n^{th} \text{category neighbourhood.} \]

This approach permitted to build up Figure 6 and 7. The ArcInfo software (version 8.2) was used for this spatial analysis method whereas the Epi Info soft-
Table 1. Types of settlements in Yaoundé according to their spatial organization

| Type of settlement                  | Main characteristics                                                                 | Neighbourhoods                                                                 |
|------------------------------------|----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Housing estates                    | Legal, recent, planned, less dense, highly provided with water and sanitation infrastructure and with adequate drainage and garbage disposal | Surveyed neighbourhoods: Cité Verte and Biyem Assi                             |
|                                    |                                                                                        | Unsurveyed ones: Messa, Mbella IV, Mvog Ebanda, Mendong, and Olembé             |
| Communal plots                     | Legal, dense, barely provided with water and sanitation infrastructure and with adequate drainage and garbage disposal | Surveyed neighbourhood: Elig Edzoa                                             |
|                                    |                                                                                        | Unsurneyed one: Mimboman                                                       |
| Wealthy residential neighbourhoods | Legal, planned, less dense, highly provided with water and sanitation infrastructure and with adequate drainage and garbage disposal | Surveyed neighbourhoods: Nkolndongo 2, Ekoudou Bastos, and Essos                |
|                                    |                                                                                        | Unsurneyed ones: Ntem Assi, Nkol Ebogo, Lac, Santa Barbara, and Koweit city      |
| Central spontaneous neighbourhoods | Old, legal, dense, barely provided with water and sanitation infrastructure and with adequate drainage and garbage disposal | Surveyed neighbourhoods: Mvog Ada and Obili                                    |
|                                    |                                                                                        | Unsurneyed ones: Briqueterie, Mvog Mbi, Elig Belibi, and Olézoa                 |
| Subcentral spontaneous             | Old, illegal, highly dense, poorly provided with water and sanitation infrastructure and with adequate drainage and garbage disposal | Surveyed neighbourhoods: Mokolo and Elig Effa                                  |
| neighbourhoods                     |                                                                                        | Unsurneyed ones: NgoaEkellé, Oyom Abang, Efoulan, and Ekounou                   |
| Urban fringes areas                | Illegal, recent, relatively dense, poorly provided with water and sanitation infrastructure and with adequate drainage and garbage disposal | Surveyed neighbourhoods: Emana and Nsam                                       |
|                                    |                                                                                        | Unsurneyed ones: Ekombitié, Nkolmesseng, and Odza                              |
| Semi-rural neighbourhoods          | Illegal, recent, less dense, poorly provided with water and sanitation infrastructure and with adequate drainage and garbage disposal | Surveyed neighbourhood: Awaé                                              |
|                                    |                                                                                        | Unsurneyed ones: Simbok, Biteng, and Febe                                    |

ware (version 6.04) and the SPSS package (version 11.1) were used for recording and analysis of data. Statistical approaches, such as frequency distribution and chi-square test, were used for analyzing the data, and the p values of <0.05 were considered significant.

RESULTS

Access to drinking-water in Yaoundé: a differentiated situation

The results of the survey showed that the households in Yaoundé resorted to five different water sources to satisfy their needs (Table 2). In total, 599 (19.7%) households were directly connected to the National Water Company (SNEC), 1,097 (36.1%) shared a common tap located in the courtyard, less than 500 metre away, and 1,042 (35%) fetched water from public taps outside their premises, having to walk a distance of between 500 and 1,000 metre or more.

Microbiological quality of drinking-water in Yaoundé: unsafe water for human consumption

In total, 508 drinking-water samples underwent bacteriological analyses, of which 302 were from households connected to a piped water-supply at home, 154 from wells, 27 from community standpipes, and 25 from springs. From those 508 samples analyzed, 1,242 isolates of enteric bacteria (Enterobactericeae) and 461 isolates of strict aerobic
Health risks associated with drinking-water

Of the 3,034 children who underwent medical investigation, 437 (14.4%) had diarrhoea. Table 4 shows that the source of water used, which is of poor quality as mentioned above, is critical in controlling diarrhoea.

Spatial disparities associated with consumption of water

With regard to the supply sources, we have noticed an uneven distribution of diarrheal diseases throughout the city (fig. 6 and 7). Whereas some neighbourhoods were less exposed to diarrhoeas according the supply source used, those were more vulnerable to the disease.

DISCUSSION

Access to drinking-water in Yaoundé is a worrying situation since 80.2% of the city dwellers did not have access to drinking-water supplied by the national company SNEC. This category of people are those living in the outskirts, such as subcentral spontaneous neighbourhoods and the urban fringes. This is so because, with the galloping population growth, it has been difficult for the SNEC to offer reliable services to everyone. Consequently, many households, not just the poorest, resorted exclusively to groundwaters, such as springs (7.4%) and wells (3%). However, when households that used groundwater as an alternative to avoid high bills or in the case of prolonged shortages/cuts by the SNEC were added, the figure increased to 37.35% for households using water from wells and 63.1% for households using water from springs. Since wells were usually close to houses, households that used water from wells did not suffer much in terms of walking distance (generally less than 50 metre). However, it was quite challenging for those resorting to springs because walking distance varied from 1,000 metre in central spontaneous neighbourhoods to 1,500 metre and even 2,000 metre in the urban fringes and semi-rural neighbourhoods. More intriguing than these figures were water-handling methods, such as collection, transportation, and storage. In fact, many (53.1%) households used uncovered containers, such as buckets, barrels, and PVC basins when collecting drinking-water. The collection procedure consisted of placing containers on the ground and filling them using a plastic pipe held on a leash or in the hands of the user. The plastic pipe which is seldom cleaned is used by

bacteria were obtained and identified. Of the 1,242 isolates of enteric bacteria, 0.2% were Shigella, 1.3% Salmonella, 5.1% Escherichia coli, 12.4% Enterobacter, 13.4% Citrobacter, 22% Proteus, and 37.8% Klebsiella. Of the 461 aerobic bacteria, 28.2% were Acinetobacter, and 71.8% were Pseudomonas (Table 3).
Table 2. Distribution of households in Yaoundé according to drinking-water sources and types of settlements

| Type of settlement        | Private/individual taps | Semi-private water supply | Community taps | Wells | Springs |
|--------------------------|-------------------------|----------------------------|----------------|-------|---------|
|                          | Frequency %             | Frequency %                | Frequency %    | Frequency % | Frequency % |
| Housing estates           | 254                     | 21                         | 2.3            | 2.3    | 2.3     |
| Communal plots            | 76                      | 68                         | 8.5            | 1.5    | 1.5     |
| Wealthy residential       | 46                      | 67                         | 1.5            | 1.5    | 1.5     |
| Neighbourhoods            | 47                      | 431                        | 14.5           | 14.5   | 14.5    |
| Central spontaneous       | 128                     | 122                        | 4.1            | 4.1    | 4.1     |
| Neighbourhoods            | 47                      | 431                        | 14.5           | 14.5   | 14.5    |
| Subcentral spontaneous    | 37                      | 60                         | 2.0            | 0.4    | 0.4     |
| Neighbourhoods            | 11                      | 20.15                      | 1.092          | 1.092  | 1.092   |
| Total                     | 599                     | 1,097                      | 1,042          | 900    | 225     |

All the samples showed positive results for *Streptococcus* and *P. aeruginosa*. This indicates that the water was not free from faecal contamination as *Streptococcus* is one of the indicators for faecal contamination in drinking-water (20). Although *Pseudomonas* does not harm a healthy individual, it can cause a problem in individuals with a weak immune system (21), and it is more reliable and safe if the drinking-water does not show their presence. According to the WHO guideline, total and faecal coliform bacteria should not exceed 10/100 mL in water intended for drinking. The results of the present study clearly indicate that most natural water sources were highly contaminated. It might be due either to poor handling-methods mentioned above, or to the failure of disinfections of raw water at the treatment plant, or to infiltration of contaminated water (sewage) through cross-connection, leakage points, and back-siphonage. However, some studies have associated the occurrence of coliform bac-
Fig. 6. Spatial patterns of diarrhoeas with regard to consumption of groundwater (springs and wells)

a. Distribution of diarrhoeas associated with drinking-water from springs

- (0.86-11.1%)
- (11.2-25.7%)
- (25.8-36.0%)
- No data

b. Distribution of diarrhoeas associated with drinking-water from wells

- (0.00-05.1%)
- (05.2-10.4%)
- (10.5-15.0%)
- No data

Data: PERSAN surveys
Classification method: Mean and standard deviation
Designing: H.B. Nguendo Youngsi, 2009
Software: ArcInfo 8.2 and ArcView 8.2

Fig. 7. Spatial patterns of diarrhoeas with regard to consumption of groundwater (springs and wells)

a. Distribution of diarrhoeas associated with drinking-water from community standpipes

- (09.2-15.4%)
- (15.5-20.6%)
- (20.7-24.04%)
- No data

b. Distribution of diarrhoeas associated with drinking-water from private standpipes

- (0.6.4-07.3%)
- (07.4-09.5%)
- (09.6-11.0%)
- No data

Data: PERSAN surveys
Classification method: Mean and standard deviation
Designing: H.B. Nguendo Youngsi, 2009
Software: ArcInfo 8.2 and ArcView 8.2

Scale: 1:90,000
Projection system: Gauss Krugger
Ellipsoid: Clarke 1880
Yongsi HBN

Health risks associated with drinking-water

Table 4. Prevalence of diarrhoeal diseases according to drinking-water source

| Water source          | Frequency | %   |
|-----------------------|-----------|-----|
| Wells                 | 120       | 27.46|
| Springs               | 178       | 40.73|
| Households            | 46        | 10.52|
| Community standpipes  | 93        | 21.29|

Reading key example: Of the 437 diarrhoeal cases, 27.46% were recorded in households using water from wells; p<0.005, χ² test

Table 3. Distribution of bacterial isolates according to source of drinking-water

| Bacteria                    | Sources of drinking-water |
|-----------------------------|---------------------------|
|                            | Springs      | Wells       | Community standpipes | Households   |
|                            | Frequency  | %           | Frequency  | %           | Frequency  | %           |
| Enteric bacteria            |             |             |             |             |             |             |
| Citrobacter freundii        | 6          | 24.0        | 93         | 60.4        | –          | –           | 68         | 22.52       |
| Escherichia coli            | 7          | 28.0        | 29         | 18.8        | –          | –           | 28         | 9.3         |
| Klebsiella levhina          | 7          | 28.0        | 17         | 11.1        | –          | –           | 32         | 10.6        |
| Shigella                    | 1          | 4.0         | 1          | 0.6         | –          | –           | 1          | 0.7         |
| Enterobacter cloacae        | 7          | 28.0        | 36         | 23.4        | 4          | 14.8        | 145        | 48.0        |
| Klebsiella pneumoniae       | 24         | 96.0        | 137        | 88.9        | 2          | 7.4         | 239        | 79.1        |
| Klebsiella oxytoca          | –          | –           | –          | –           | 1          | 3.7         | –          | –           |
| Serratia                    | 2          | 8.0         | 4          | 2.6         | –          | –           | 8          | 2.6         |
| Morganella morgani          | 3          | 12.0        | 12         | 7.8         | –          | –           | 24         | 7.9         |
| Proteus mirabilis           | 5          | 20.0        | 37         | 24.0        | –          | –           | 73         | 24.1        |
| Proteus vulgaris            | 3          | 12.0        | 53         | 34.4        | –          | –           | 103        | 34.1        |
| Providencia                 | –          | –           | 4          | 2.6         | –          | –           | 8          | 2.6         |
| Salmonellla spp.            | 1          | 4.0         | 5          | 3.2         | –          | –           | 10         | 3.3         |
| Enterobacter aerogenes      | –          | –           | –          | –           | –          | –           | 1          | 0.3         |
| Enterobacter asburiae       | –          | –           | –          | –           | –          | –           | 1          | 0.3         |
| Strict aerobic bacteria     | –          | –           | –          | –           | –          | –           | 1          | 0.3         |
| Acinetobacter baumannii     | 3          | 12.0        | 15         | 9.7         | –          | –           | 112        | 37.1        |
| Pseudomonas aeroginosa      | 12         | 48.0        | 57         | 37.0        | 2          | 7.4         | 147        | 48.7        |
| Pseudomonas spp.            | 7          | 28.0        | 75         | 48.7        | 1          | 3.7         | 30         | 9.9         |

teria in drinking-water system with rainfall events (22). According to these authors, rainfall is a complex variable and may have different impacts on the quality of drinking-water, as rainfall can be a mechanism that introduces coliform bacteria into the system through leaks and cross-connections. Based on both bacterial isolates and total bacterial count performed, the distribution of drinking-water sources according to the microbiological quality is presented in Table 6.

This result is not surprising because the microorganisms found in drinking-water are known to be diarrhoea-causing-pathogens (23,24). Thus, they can be alleged to be the source of diarrhoea diagnosed among children since water used for household consumption is normally collected from wells and springs. This study has also shown a significant neighbourhood-specific geographical variation in childhood diarrhoea (Table 7). In fact, it seems that source of drinking-water supply is also closely related to the type of settlement: neighbourhoods with high exposure to diarrhoea are informal settlements, particularly the spontaneous peri-urban areas. In the category of formal and planned settlements, neighbourhoods of housing estates have been found to be the most vulnerable. Additional insight into these disparities is provided when addressing the phenomenon with regard to the supply sources.

Spatial disparities associated with consumption of water from springs: A real disparity was observed in the distribution of diarrhoea according to the consumption of water collected from springs (Fig. 6a). The most vulnerable individuals were those who were living in the subcentral spontaneous neighbourhoods, such as Ekounou, Etoug Ebe, and Emana, with a prevalence rate of 25.1-36%. The semi-rural
neighbourhoods, such as Eba, Ekombitié, Ahala, and Simbok, and the urban fringes, such as Bilono, Nkolzié, and Oliga, displayed a prevalence rate of 11.2-25.1%.

Spatial disparities associated with consumption of water from wells: Figure 6b shows that the neighbourhoods with the high prevalence of diarrhoea were the semi-rural ones, such as Simbock, Biteng, Awaé, and Bitotol, with a prevalence rate of 10.4-15%. These are all semi-rural settings not yet connected to the National Water Company, and accordingly, individuals rely on groundwater for their needs. The less-exposed neighbourhoods were the subcentral spontaneous and fringes neighbourhoods, such as Oliga, Melen, Ekombitié, and Mballa 4 (5.1-10.3%). However, two types of settings were not exposed to diarrhoea. That was the case of the wealthy residential and the central spontaneous neighbourhoods. The situation in the wealthy residential districts was better because those neighbourhoods are inhabited by rich individuals (ministers, members of parliament, and ambassadors) whose houses are all connected to the water company. During the periods of water cuts or shortage, they resort to bottled mineral water. Yet in the central spontaneous neighbourhoods, the existing wells were so polluted that individuals themselves found water to be undrinkable.

Spatial disparities associated with consumption of wa-

| Sample source                  | Total Wells | Springs | Households (sored waters) | Community standpipes | Total |
|--------------------------------|-------------|---------|---------------------------|----------------------|-------|
| % of samples compared with the WHO guideline value | Guideline value (<10 cfu/mL) | Excess to guideline value (>10 cfu/mL) | Total number of samples |
| Households                     | 3.3         | 96.7    | 302                       |
| Community standpipes           | 55.5        | 44.5    | 27                        |
| Wells                          | 0           | 100     | 154                       |
| Springs                        | 0           | 100     | 25                        |

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Spatial disparities associated with consumption of wa-

| Table 5. Source-wise quality of total bacterial count of water samples |
|---------------------------------------------------------------|
| Sample source | % of samples compared with the WHO guideline value |
|----------------|---------------------------------------------------|
| Households     | Guideline value (<10 cfu/mL) | Excess to guideline value (>10 cfu/mL) |
| Wells          | 3.3 | 96.7 | 302 |
| Springs        | 55.5 | 44.5 | 27 |

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Spatial disparities associated with consumption of wa-

| Table 6. Distribution of drinking-water sources in Yaoundé according to microbiological assessment |
|---------------------------------------------------------------|
| Quality | Wells | Springs | Households (sored waters) | Community standpipes | Total |
|---------|-------|---------|---------------------------|----------------------|-------|
| Frequency | % | Frequency | % | Frequency | % | Frequency | % |
| Safe    | 0    | 0.0    | 0.0   | 0.0 | 10 | 3.3 | 15 | 55.6 | 25 | 4.9 |
| Contaminated | 154 | 100 | 25 | 100 | 292 | 96.7 | 12 | 44.4 | 483 | 95.1 |
| Total   | 154 | 100 | 25 | 100 | 302 | 100 | 27 | 100 | 508 | 100 |

Spatial disparities associated with consumption of water from wells: Figure 6b shows that the neighbourhoods with the high prevalence of diarrhoea were the semi-rural ones, such as Simbock, Biteng, Awaé, and Bitotol, with a prevalence rate of 10.4-15%. These are all semi-rural settings not yet connected to the National Water Company, and accordingly, individuals rely on groundwater for their needs. The less-exposed neighbourhoods were the subcentral spontaneous and fringes neighbourhoods, such as Oliga, Melen, Ekombitié, and Mballa 4 (5.1-10.3%). However, two types of settings were not exposed to diarrhoea. That was the case of the wealthy residential and the central spontaneous neighbourhoods. The situation in the wealthy residential districts was better because those neighbourhoods are inhabited by rich individuals (ministers, members of parliament, and ambassadors) whose houses are all connected to the water company. During the periods of water cuts or shortage, they resort to bottled mineral water. Yet in the central spontaneous neighbourhoods, the existing wells were so polluted that individuals themselves found water to be undrinkable.

Spatial disparities associated with consumption of wa-

| Table 7. Prevalence of diarrhoeal diseases according to type of settlements in Yaoundé |
|---------------------------------------------------------------|
| Type of settlement | Households surveyed | Diarrhoea cases recorded |
|-------------------|----------------------|--------------------------|
|                   | Frequency | % | Frequency | % |
| Planned settlement |          |   |          |   |
| Wealthy residential neighbourhoods | 158 | 5.2 | 12 | 7.6 |
| Housing estates    | 352     | 11.6 | 31 | 8.8 |
| Communal plots     | 304     | 10.2 | 41 | 13.5 |
| Spontaneous settlement |         |    |          |   |
| Semi-rural neighbourhoods | 235 | 7.7 | 26 | 13.7 |
| Peri-urban fringes neighbourhoods | 342 | 11.3 | 57 | 16.3 |
| Subcentral spontaneous neighbourhoods | 1,164 | 38.3 | 176 | 18.4 |
| Central spontaneous neighbourhoods | 479 | 15.7 | 94 | 21.6 |
| Aggregate          | 3,034   | 100 | 437 | 100 |

Spatial disparities associated with consumption of water from wells: Figure 6b shows that the neighbourhoods with the high prevalence of diarrhoea were the semi-rural ones, such as Simbock, Biteng, Awaé, and Bitotol, with a prevalence rate of 10.4-15%. These are all semi-rural settings not yet connected to the National Water Company, and accordingly, individuals rely on groundwater for their needs. The less-exposed neighbourhoods were the subcentral spontaneous and fringes neighbourhoods, such as Oliga, Melen, Ekombitié, and Mballa 4 (5.1-10.3%). However, two types of settings were not exposed to diarrhoea. That was the case of the wealthy residential and the central spontaneous neighbourhoods. The situation in the wealthy residential districts was better because those neighbourhoods are inhabited by rich individuals (ministers, members of parliament, and ambassadors) whose houses are all connected to the water company. During the periods of water cuts or shortage, they resort to bottled mineral water. Yet in the central spontaneous neighbourhoods, the existing wells were so polluted that individuals themselves found water to be undrinkable.
ter from community standpipes (taps): Several neigh-
bourhoods displayed a high exposure to diarrhoea
as the inhabitants resorted principally to the com-
munity standpipes for their drinking-water (Fig.
7a). The most exposed were the central sponta-
neneous neighbourhoods, such as Mvog Mbi, Mvog
Ada, and NDamvout, with a prevalence rate of 20.7-
24%, and slightly the subcentral spontaneous dis-
tricts, such as Nsam, Nkomkana, Mimboman, and
Elig-Effa, where the prevalence rate ranged from
15.5% to 20.6%. This situation in both the settings
might be due to material and financial difficulties
which prevent the inhabitants to subscribe private
connections from the National Water Company.
Since those inhabitants constitute the labour and
voting class, the Government has granted them
some standpipes.

Spatial disparities associated with consumption of water
from individual/private standpipes (taps): Throughout
the city, only 599 (20.1%) households had access
to this water-supply structure. Although these were
distributed within the six different urban settings,
they were unequally exposed to diarrhoea. Figure
7b shows that the most exposed settings are made
up of central spontaneous and of semi-rural neigh-
bourhoods where a prevalence rate of 9.6-1% was
recorded. These neighbourhoods are mostly inhab-
itied by low-educated individuals. Being conscious
of the frequent and prolonged water rationing or
shortages, they regularly stored water in unsafe
open containers which permit contamination and
from which they drink without any treatment. The
less vulnerable were the urban fringes, such as Oli-
ga, Bilono, and Messa-Carrières where a prevalence
rate of 6.4-7.4% was recorded.

Conclusions
The findings of the study point to some important
policy implications. For instance, access to safe
drinking-water for the majority of urban dwell-
ers requires enabling water regulations that will
increase access to drinking-water supplied by the
National Water Company. It also suggests paying
great attention to water-handling methods by sen-
sitizing households to healthy behaviours in terms
of collection and storage conditions. Second, as
most individuals use water directly from available
sources without any form of treatment, and may,
therefore, be exposed to various water-related dis-
eases, it seems logical to suggest that current regu-
lations be revised to include water-quality testing.
The control of drinking-water quality in the dis-
tribution networks remains a major challenge in
sub-Saharan urban areas. However, comprehensive
planning should be made for continuous monitor-
ing of water sources, especially the contaminated
ones. A further study is needed to determine the
factors responsible for the presence of coliforms in
drinking-water so that effective intervention can be
initiated. As far as possible, water sources must be
protected from contamination by human and ani-
mal wastes. Third, the geographic information sys-
tem techniques are useful in assessing health risks
concerning population-based studies on drink-
ing-water epidemiology. Data on the uneven dis-
tribution of diarrhoea within the city indicate that
promotional messages in health education should
target the vulnerable neighbourhoods. Of high sig-
nificance are the most exposed neighbourhoods
where efficient and coherent policies should be
accomplished. It would also be of value to investigate
other neighbourhood-level determinants, such as
socioeconomic, cultural, environmental and hu-
man behavioural factors, involved in the aetiology
of diarrheal diseases.

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