Characteristics and epidemiological profile of Buruli ulcer in the district of Tiassalé, south Côte d’Ivoire

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A B S T R A C T

Buruli ulcer (BU) is a cutaneous infectious disease caused by Mycobacterium ulcerans. It is the third most common mycobacterial disease in the world in the immunocompetent patient and second in Côte d’Ivoire after tuberculosis. This study aimed to assess the characteristics and epidemiological profile of BU in the district of Tiassalé, an important focus of the disease in south Côte d’Ivoire, in order to better direct actions for prevention and control. Retrospective clinical data of BU cases in the period 2005–2010 from all 19 district health centres were collected and linked with geographical and environmental survey data. A total of 1145 cases of BU were recorded between 2005 and 2010 in the district of Tiassalé. Children under the age of 15 years were the most affected (53.0%) with a higher prevalence among males compared to females (54.7% versus 45.3%). Among individuals aged 15–49 years, females had a higher prevalence than males (54.2% versus 45.8%). The villages of Ahondo, Léléblé and Taabo, located in close proximity to the man-made Lake Taabo that was constructed in the late 1970s by damming the Bandama River, and the village of Sokrobo located downstream of the dam, showed the highest BU rates in the sub-prefecture of Taabo. In the sub-prefecture of Tiassalé, the villages of Affikro, Morokro and N’Zianouan, located near N’Zi River, a tributary of the Bandama River, were the most affected. The distribution of BU is associated with environmental patterns (i.e. distance between village and Lake Taabo or Bandama River and its tributary N’Zi River). Awareness campaigns, coupled with early diagnosis and improved clinical management of BU, have been implemented in the district of Tiassalé and the incidence of BU has declined.

1. Introduction

Buruli ulcer (BU) is an infectious disease of the skin caused by Mycobacterium ulcerans (Junghanss et al., 2014). BU is the third most common mycobacterial disease in the world in the immunocompetent patient, after tuberculosis and leprosy (Darie, 2003; WHO, 2008a; Huang and Johnson, 2014). In Côte d’Ivoire, BU is the second most important mycobacterial disease after tuberculosis (Kanga and Kacou, 2001; Kanga et al., 2006; N’krumah et al., 2016). Although BU occurs at any age, the highest rates are observed among children aged below 15 years (Auoulat et al., 1996; Kanga and Kacou, 2001; Portaels et al., 2015), mainly in tropical and subtropical regions, in rural marshy areas (Marston et al., 1995; Amofah et al., 2002; Ahoua et al., 2009). According to the World Health Organization (WHO), the countries most affected by BU in the past 10 years are Benin, Côte d’Ivoire and Ghana in Africa, French Guyana in Latin America, and Australia and Papua New Guinea in Oceania (Raghanathan et al., 2005; WHO, 2015).

Despite a number of detailed epidemiological investigations, the exact mode of transmission of BU remains elusive (WHO, 2008a; Merritt et al., 2010). However, regular contact of individuals in endemic areas with stagnant or slow flowing freshwater bodies during agricultural activities (rice and vegetable farming, fishing, etc.) and activities such as laundry, dishwashing and bathing were identified as risk factors for the onset of BU (Raghanathan et al., 2005; Quek et al., 2007; Wagner et al., 2008; Ahoua et al., 2009; Kenu et al., 2014a; N’krumah et al., 2016). Additionally, the poten-
tial role of insect bites in the transmission of *M. ulcerans* has been investigated (Marsollier et al., 2003; Johnson et al., 2007; Doanño et al., 2011; Benbow et al., 2014; Zogo et al., 2015). Wearing protective equipment (e.g. boots, gloves, sleeve pants and shirts) for agricultural activities and prior to contact open freshwater sources was associated with a lower odds of BU, showing a preventive fraction of over 70% (N’krumah et al., 2016). In Côte d’Ivoire, unlike the Savannah regions where the prevalence of BU is very low or even zero, a high prevalence is noted in the south, particularly in the pre-forest area (Kanga and Kacou, 2001; Brou et al., 2006). The district of Tiassalé is located in the ‘V-Baoulé’, a characteristic eco-zone where the tropical savanna meets the tropical rainforest in the south of Côte d’Ivoire (N’Goran et al., 1997; Koné et al., 2015). The Bandama River crosses the district from north to south and the area is endemic for BU (Doanño et al., 2011; N’krumah et al., 2016).

There is marked spatial heterogeneity of BU from one village to another. Hence, the use of a geographical information system (GIS) might facilitate a deeper understanding of the spatial distribution and transmission of BU (Blanton et al., 2006; Zhou et al., 2009). The present study intended to (i) investigate the spatial distribution of BU in the district of Tiassalé and (ii) identify hotspots of the disease in the district, which in turn will guide spatial targeting of interventions.

2. Material and methods

2.1. Study area

The district of Tiassalé is located in the south of Côte d’Ivoire, in the Savannah-forest transition zone and is crossed by Bandama River and its tributary, N’Zi River. Located between 5° 32 and 6° 24 N latitude and 4° 29 and 5° 14 W longitude, the district consists of two sub-prefectures, namely Tiassalé and Taabo. In this district, building of a hydroelectric dam in the late 1970s has led to the creation of an artificial lake from the Bandama River with an area of approximately 69 km² (N’Goran et al., 1997, 2003; Sanyu Consultants Inc & JICA, 2001; Koné et al., 2015; N’krumah et al., 2016).

The population of the department of Tiassalé was estimated at 263,495 inhabitants in 2014 according to the general census of population and housing (Institut National Statistique, 2014). The climate is tropical and humid. The average annual precipitation is 1740 mm with an average temperature of 26.6°C (Brou, 2005; Goula et al., 2007). The people of the department of Tiassalé live mostly in rural areas and depend on subsistence agriculture.

2.2. Data collection

2.2.1. Epidemiological data

Collection of retrospective BU case data was performed at the health district directorate of Tiassalé, where all epidemiological records from the health centres of the district are archived. Data from all 19 health facilities (15 rural health centres and four urban health centres) were extracted by nurses in August and September 2012 (N’krumah et al., 2014). Clinical features (reporting year, clinical forms and categories based on WHO (2008a) classification, location of lesions, etc.) and sociodemographic parameters (age, sex, village/city of residence, etc.) of registered BU patients were collected.

BU cases were defined as any BU patient diagnosed according to WHO clinical definition (WHO, 2008b), and confirmed by IS2404 polymerase chain reaction (PCR) analysis (WHO, 2014) conducted at the Institut Pasteur in Abidjan. Of note, our retrospective data collection took place in 2012, and covered the period 2005–2010. We did not collect older data, since the health district of Tiassalé only
compiles data pertaining to BU using a PCR diagnostic approach from 2005 onwards.

2.2.2. Geographical and environmental data

Information regarding villages and main water bodies in the study area were readily obtained from the ‘Centre de Cartographie et de Teledetection of the Bureau National d’Etudes Techniques et de Developpment’ (CCT-BNETD) of Côte d’Ivoire. In the field, we collected geographical coordinates for the human-water contact sites, using a hand-held global positioning system (GPS) receiver (GarminGPSMAP-62sc; Olathe, KS, USA). We georeferenced the main open freshwater points contacted by people (e.g. rivers, dams and water ponds). We calculated the Euclidian distance (shortest point-by-point distance) between the Taabo Dam, the main water bodies contacted by humans and the villages using ArcGIS version 10 (ESRI; Redlands, CA, USA).

2.2.3. Population data

Population data were collected at the office of epidemiological surveillance of the health district of Tiassalé. Village-specific population sizes were estimated on the basis of the general census of population and housing from 1998 (Institut National Statistique, 1998).

2.3. Statistical analysis

Epidemiological data were processed and analysed using EpiInfo version 3.5.3 (Centers for Disease Control and Prevention; Atlanta, GA, USA), while the geographical and environmental data were analysed using ArcGIS version 10.

The annual average incidence of BU during 2005–2010 in the district of Tiassalé per 100,000 persons and the proportions of sociodemographic and clinical characteristics of BU cases were calculated. Epidemiological data were overlaid with environmental data on a map to highlight the spatial distribution of BU cases and environmental risk factors.

The correlation between environmental variables (villages, Euclidian distance between villages and Taabo Dam) and epidemiological data was determined by calculating the correlation coefficient of Bravais Pearson ($r$). The test of significance of the correlation coefficient was performed at the 5% threshold.

3. Results

3.1. Incidence of BU and socioenvironmental risk factors in the district of Tiassalé

A total of 1145 cases of BU were registered by the 19 district health centres during the period 2005–2010, with an average yearly incidence of 83.3 cases per 100,000 inhabitants. As seen in Table 1, the peak incidence of BU was recorded in 2009 (105.7 cases per 100,000 inhabitants). The annual trend in the incidence of BU over the period 2005–2010 appears to be stable in most of the villages of Taabo and Tiassalé sub-prefectures. However, there is a strong downward trend from 2005 to 2010 in the incidence of BU in the villages of Kotiéssou and Taabo, located in the sub-prefectures of Taabo.

Two thirds (66.1%; 511/773) of the reported BU cases from the Taabo sub-prefectures were concentrated in three villages (i.e. Léléillé, Ahondo and Taabo), located in close proximity to the man-made Lake Taabo. Another 29.9% (231/773) of the patients came from Sokrogbé, a village located downstream of the hydroelectric dam. There was a significant negative correlation ($r = -0.61$, $p = 0.01$) between the incidence of BU in all the villages of the district and the distance between villages and the hydro-electric dam of Taabo. Moreover, of the patients from the sub-prefectures of Tiassalé, more than two thirds (69.4%; 258/372) were concentrated in the villages of Morokro, N’Zianouan and Affikro, which are located in close proximity to N’Zi River, a tributary of Bandama River (Fig. 1).

The spatial occurrence of cumulative cases of BU in the period 2005–2010 in the district of Tiassalé shows that 67.5% (773/1145) of the cases were concentrated in the sub-prefectures of Taabo, while the remaining 32.5% (372/1145) were recorded in the sub-prefectures of Tiassalé. The difference in the proportion of BU cases recorded in the two sub-prefectures was highly statistically significant ($p < 0.001$). In the 6-year study period, the average annual BU incidence in the sub-prefectures of Taabo was 234.2 cases per 100,000 people, while the respective incidence was 39.0 per 100,000 people in Tiassalé. The most highly endemic villages for BU in the sub-prefectures of Taabo were Léléillé, Ahondo, Sokrogbé and Taabo with average annual incidence rates of 811.1, 370.5, 324.7 and 209.1 cases per 100,000 people, respectively. In the sub-prefectures of Tiassalé, the villages of Morokro, Bodo, N’Zianouan and Affikro were the most endemic villages with annual incidence rates of 133.6, 116.5, 91.3 and 62.9 cases per 100,000 people, respectively (Table 2).

3.2. Sociodemographic and clinical characteristics of BU patients

Key characteristics of BU patients, placing emphasis on sociodemographic and clinical issues, are summarised in Table 3. BU cases were almost exclusively recorded in rural areas (98.0%). Considering all age ranges, males and females were equally affected by BU (recorded prevalence 50.9% versus 49.1%). The highest proportion of BU was recorded among children under the age of 15 years (53.0%), followed by adolescents and adults aged 15–49 years (39.3%), while the recorded proportion in people aged 50 years and above was low (7.7%). Among children, males (54.7%) were significantly (p = 0.001) more affected by BU than females (45.3%). In the age group 15–49 years, females (54.2%) were more affected than males (45.8%). This difference in proportion was significant ($p = 0.011$).

Ulcers were the single most encountered clinical form (44.8%) in BU patients. The lower (67.4%) and upper limbs (25.6%) were the body parts most frequently affected by the lesions with a predominance of the clinical form of category II (48%), i.e. a lesion diameter between 5 and 15 cm.

4. Discussion

BU represents a considerable public health problem in Côte d’Ivoire (Kanga et al., 2006; Ahoua et al., 2009), particularly in the district of Tiassalé in the southern part of the country (Doannio et al., 2011; N’krumah et al., 2016). Indeed, for the period 2005–2010, a total of 1145 cases of BU were recorded in the district of Tiassalé. Children below 15 years of age were the most affected group (53.0%) with a higher prevalence among males compared to females (54.7% versus 45.3%). Among individuals aged 15–49 years, females had a higher prevalence than males (54.2% versus 45.8%). Villages located in close proximity to Lake Taabo and downstream of the dam showed the highest incidence of BU in the sub-prefectures of Taabo. In the sub-prefectures of Tiassalé, the villages located near the N’Zi River were the most affected.

The retrospective analysis presented here, spanning a 6-year period, revealed that the majority or BU cases in the district of Tiassalé occurred in the sub-prefectures of Taabo (67.5%). A central feature of this setting is the man-made Lake Taabo, constructed in the late 1970s after impounding the Bandama River for hydroelectric power production (N’Goran et al., 1997, 2003; Fürst et al., 2012; Koné et al., 2015; N’krumah et al., 2016). The creation of this man-made lake spurred a wide variety of water contact pat-
terns, including occupational and recreational activities. More than half of BU patients who presented at the formal health system presented with late stages of the disease (ulceration and multiple forms). The most affected villages of the district are either located in close proximity to the hydroelectric dam (Léléblé, Ahondo, and Taabo with respective average annual incidence rates of 811, 371 and 209 BU cases per 100,000 people), or downstream of the dam (Sokrogbo with 325 annual cases per 100,000 inhabitants) in the Taboo sub-prefecture.

Our findings are consistent with the work of Brou et al. (2006), who observed a high prevalence of BU in villages located near irrigation and hydroelectric dams in the southern part of Côte d’Ivoire. According to the same authors, it is especially in the transition zone from tropical rainforest to the Savannah that this relationship is pronounced. In the sub-prefecture of Taabo, unlike other settings, few cases of BU were recorded in the villages of Ahérémou and Pacobo. This might be explained by the fact that these villages are located further away from Lake Taabo and Bandama River compared to the highly endemic villages or villages with improved drinking water supply. The use of tap water by most households in these two villages may limit human-water contact at unprotected open freshwater sources.

Our study also showed that the social-ecological context in the Taabo sub-prefecture (average annual incidence rate of BU was 234 cases per 100,000 people) is strongly influenced by the hydroelectric dam, which might explain a considerably higher risk of developing BU compared to the sub-prefecture of Tiassalé (estimated incidence rate of 39 BU cases per 100,000 people). Damming of the Bandama River for hydroelectric power production has both caused a change in the environment and led to intensification of existing water-associated human agricultural and fishery activities. The impact of this environmental transformation on schistosomiasis has been documented before (N’Goran et al., 1997). Here, the focus is on BU and we speculate that the observed spatial patterns with the highest risk of M. ulcerans infection in close proximity to Lake Taabo is explained by this major water resources development. Previous studies have demonstrated that the transformation of ecosystems caused by the construction of large dams or small
multipurpose dams promotes the creation of new breeding sites of disease vectors (e.g. Anopheles mosquitoes that transmit malaria) or intermediate host snails that are implicated in the transmission of schistosomiasis (Atangana et al., 1980; Birley, 1993; Steinmann et al., 2006). In the sub-prefecture of Tiassalé, the majority of BU patients were reported in the villages of Bodo, N’Zianouan, Affikro and Morokro, where agricultural activities such as rice farming associated with N’Zi River are highly developed. The decrease in the annual incidence of BU in the villages of Kottiéssou and Taabo could be explained by the community awareness activities carried out by the only specialised centre in the district for the management of BU, which has been based in Taabo since 2005. The community outreach activities started in the village of Taabo and the nearest one of Kottiéssou by the specialised centre might have affected BU transmission. In fact, lessons learned from institutional and communities’ capacity building activities in Cameroon (Tabah et al., 2016) and Ghana (Ackumey et al., 2011) have led to a decrease in BU transmission. In all the district of Tiassalé, the peak of BU incidence was recorded in 2009 (105.7 cases per 100,000 people). This could be explained by the fact that the district health authorities have trained health personnel (59 nurses, 27 midwives, 14 doctors and five pharmacists), community leaders (296 community health workers and 121 teachers) and sensitised the urban and rural populations in 2007 and 2008 for early detection of BU. Most BU patients in the district live in rural areas (98%) where access to clean water for family use is difficult, forcing people to obtain water from unprotected surface water sources (N’krumah et al., 2016). The use of mapping can provide valuable information on the distribution and interaction of socioenvironmental risk factors with diseases. It has been used to highlight the distribution of epidemiological profiles of BU and several other diseases, the coverage of health services and

### Table 2
Occurrence of BU cases and incidence in the district of Tiassalé, south Côte d’Ivoire, stratified by sub-prefecture and village in the period 2005–2010.

<table>
<thead>
<tr>
<th>Sub-prefecture</th>
<th>Village</th>
<th>Average annual population</th>
<th>Cumulative number of BU cases during the period 2005–2010</th>
<th>Average annual BU cases</th>
<th>Average annual BU incidence (per 100,000 inhabitants)</th>
<th>Average annual BU incidence (per 100,000 inhabitants)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taabo</td>
<td>Ahérémou</td>
<td>2123</td>
<td>3</td>
<td>1</td>
<td>47.1 (0.0–262.2)</td>
<td>234.2 (195.2–277.6)</td>
</tr>
<tr>
<td></td>
<td>Ahondo</td>
<td>6207</td>
<td>140</td>
<td>23</td>
<td>370.5 (235.0–555.5)</td>
<td>86.2 (23.5–220.7)</td>
</tr>
<tr>
<td></td>
<td>Kottiéssou</td>
<td>4638</td>
<td>26</td>
<td>4</td>
<td>21.1 (0.0–39.6)</td>
<td>811.1 (344.9–929.8)</td>
</tr>
<tr>
<td></td>
<td>Lélélé</td>
<td>4685</td>
<td>225</td>
<td>38</td>
<td>324.7 (231.0–443.6)</td>
<td>324.7 (231.0–443.6)</td>
</tr>
<tr>
<td></td>
<td>Pacobo</td>
<td>14,057</td>
<td>2</td>
<td>0.3</td>
<td>209.1 (134.0–331.0)</td>
<td>209.1 (134.0–331.0)</td>
</tr>
<tr>
<td></td>
<td>Sokrogbo</td>
<td>12,011</td>
<td>231</td>
<td>39</td>
<td>210.1 (134.0–331.0)</td>
<td>210.1 (134.0–331.0)</td>
</tr>
<tr>
<td></td>
<td>Taabo</td>
<td>11,477</td>
<td>146</td>
<td>24</td>
<td>324.7 (231.0–443.6)</td>
<td>324.7 (231.0–443.6)</td>
</tr>
<tr>
<td>Tiassalé</td>
<td>Affikro</td>
<td>11,123</td>
<td>39</td>
<td>7</td>
<td>62.9 (25.3–129.6)</td>
<td>39.0 (30.1–49.9)</td>
</tr>
<tr>
<td></td>
<td>Attiguéhi</td>
<td>6888</td>
<td>4</td>
<td>1</td>
<td>14.5 (0.0–80.9)</td>
<td>14.5 (0.0–80.9)</td>
</tr>
<tr>
<td></td>
<td>Binao</td>
<td>12,834</td>
<td>3</td>
<td>1</td>
<td>7.8 (0.0–43.4)</td>
<td>7.8 (0.0–43.4)</td>
</tr>
<tr>
<td></td>
<td>Bodo</td>
<td>5149</td>
<td>38</td>
<td>6</td>
<td>116.5 (42.8–253.5)</td>
<td>116.5 (42.8–253.5)</td>
</tr>
<tr>
<td></td>
<td>Broubrou</td>
<td>10,198</td>
<td>4</td>
<td>1</td>
<td>9.8 (0.0–54.6)</td>
<td>9.8 (0.0–54.6)</td>
</tr>
<tr>
<td></td>
<td>Kondiébouna</td>
<td>12,700</td>
<td>21</td>
<td>4</td>
<td>31.5 (0.0–80.6)</td>
<td>31.5 (0.0–80.6)</td>
</tr>
<tr>
<td></td>
<td>Morokro</td>
<td>14,968</td>
<td>122</td>
<td>20</td>
<td>133.6 (81.6–206.3)</td>
<td>133.6 (81.6–206.3)</td>
</tr>
<tr>
<td></td>
<td>N’Douci</td>
<td>36,357</td>
<td>27</td>
<td>5</td>
<td>13.8 (0.0–32.1)</td>
<td>13.8 (0.0–32.1)</td>
</tr>
<tr>
<td></td>
<td>N’Zianouan</td>
<td>17,519</td>
<td>97</td>
<td>16</td>
<td>91.3 (52.2–148.3)</td>
<td>91.3 (52.2–148.3)</td>
</tr>
<tr>
<td></td>
<td>Tiassalé</td>
<td>36,509</td>
<td>17</td>
<td>3</td>
<td>8.2 (0.0–22.5)</td>
<td>8.2 (0.0–22.5)</td>
</tr>
</tbody>
</table>

### Table 3
Sociodemographic and clinical characteristics of BU cases in the district of Tiassalé, south Côte d’Ivoire in the period 2005–2010.

<table>
<thead>
<tr>
<th>Sociodemographic characteristics</th>
<th>No. (%) of BU cases</th>
<th>p value</th>
<th>Clinical characteristics</th>
<th>No. (%) of BU cases</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total number</strong></td>
<td>1145 (100)</td>
<td></td>
<td>Clinical forms</td>
<td>190 (16.6)</td>
<td></td>
</tr>
<tr>
<td>Area of residence</td>
<td></td>
<td></td>
<td>Nodule</td>
<td>258 (22.5)</td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>1122 (98.0)</td>
<td></td>
<td>Plaque</td>
<td>88 (7.7)</td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>23 (2.0)</td>
<td></td>
<td>Oedema</td>
<td>513 (44.8)</td>
<td></td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td>Ulceration</td>
<td>6 (0.5)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>583 (50.9)</td>
<td>&lt;0.001*</td>
<td>Bone reached</td>
<td>11 (1.0)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>562 (49.1)</td>
<td></td>
<td>Multiple forms with ulcer</td>
<td>79 (6.9)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td><strong>Age (years), stratified by sex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;15</td>
<td>607 (53.0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15–49</td>
<td>450 (39.3)</td>
<td></td>
<td>Lesions classification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥50</td>
<td>88 (7.7)</td>
<td>&lt;0.001*</td>
<td>Category I (D &lt; 5 cm)</td>
<td>332 (29.0)</td>
<td></td>
</tr>
<tr>
<td><strong>Age (years), stratified by sex</strong></td>
<td></td>
<td></td>
<td>Category II (5–15 cm)</td>
<td>550 (48.0)</td>
<td></td>
</tr>
<tr>
<td>&lt;15</td>
<td>332 (54.7)</td>
<td></td>
<td>Category III (D &gt; 15 cm)</td>
<td>263 (23.0)</td>
<td></td>
</tr>
<tr>
<td>15–49</td>
<td>275 (45.3)</td>
<td>0.001*</td>
<td>Localisation of lesions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>206 (45.8)</td>
<td></td>
<td>Lower limbs</td>
<td>772 (67.4)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>244 (54.2)</td>
<td>0.011*</td>
<td>Upper limbs</td>
<td>293 (25.6)</td>
<td></td>
</tr>
<tr>
<td>≥50</td>
<td>45 (51.1)</td>
<td></td>
<td>Other parts</td>
<td>80 (7.0)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Male</td>
<td>43 (48.9)</td>
<td>0.763</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Statistically significant.

Diameter.

Centimeter.
of wastewater disposals or drinking water facilities (Bratschi et al., 2013; Landier et al., 2014; Kenu et al., 2014b). It offers new opportunities for rapid assessment of endemic areas, provides reliable estimates of populations at risk and disease distribution in areas difficult to access and where databases are missing (Randremanna et al., 2001; Bonyah and Owusu-Sekyere, 2012; Lai et al., 2015). In light of the current study, it is fair to say that the risk of BU in the district of Tiassalé is associated with the distance between villages and Lake Taabo or Bandama River and its tributary the N’Zi.

Our results must be interpreted with caution, as the study has some limitations. First, as in any retrospective analysis of BU cases, there is some risk of reporting bias beyond our control. Second, other factors than close proximity to open freshwater bodies might govern risk profiles of BU in the district of Tiassalé. We can only show associations between BU incidence and distance to water bodies without being able to explore causation. Third, we can only make assumptions on year-to-year associations based on reported data from the health centres, while a more active surveillance of early signs and symptoms for BU, confirmed by laboratory diagnosis, might reveal more accurate spatial and temporal risk profiles.

Despite these limitations, we conclude that, in the sub-prefecture of Taabo in the district of Tiassalé, the incidence of BU is well correlated with proximity between villages as well as between villages and open freshwater bodies. The villages closest to the man-made Lake Taabo created by damming of Bandama River and to Bandama River itself and its tributary N’Zi River are the most affected. Local, national and international health authorities have addressed this issue. Indeed, specific awareness and sensitisation campaigns have been launched and public health measures implemented, which have already registered results, as the incidence of BU has declined considerably in the recent past.

Conflict of interest and ethical principle

The authors have no conflicts of interest to declare. The research protocol was approved by the National Ethics Committee (Nº 5383/MSHP 28/10/2009). In addition, the agreement and a letter of support were given by the director of the district of Tiassalé prior to data collection.

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