Introduction

Dengue fever is a viral disease caused by an arbovirus belonging to the Flavivirus genus of the Flaviviridae family. There are four viral serotypes of this virus, designated DENV-1, DENV-2, DENV-3 and DENV-4. It is transmitted by Stegomyia species mosquitoes, and in particular by Stegomyia aegypti (formerly Aedes aegypti). Dengue is the predominant arthropod borne viral disease affecting humans. Dengue virus causes a wide range of symptoms from asymptomatic or mild disease (dengue fever) to severe forms such as dengue haemorrhagic fever (DHF) and dengue shock syndrome (DSS). There is no vaccine and no curative treatment available. Globally, 2.5 billion people in more than 100 countries are exposed to this virus annually. There are 50–100 million cases per year, with 500,000 hospitalizations and 25,000 deaths worldwide. The World Health Organization has estimated that there has been a 30-fold increase in dengue cases since the end of the 20th century.

Dengue fever occurs in French Guiana with the same patterns as those described for most parts Latin America: the emergence of haemorrhagic dengue fever and endemicity of disease. The first cases of dengue-like syndromes were described in 1940. The vector was eradicated between 1950 and 1960, its new introduction has been responsible of new outbreaks in 1960. The first serological confirmation of the circulation of the virus was in 1965. The first outbreak with haemorrhagic cases occurred in 1991. Since that time, the four dengue virus serotypes have circulated in coastal French Guiana, where the main part of the population is concentrated. The outbreaks have occurred without periodicity or seasonality. Until 2005, no dengue fever outbreak has been described in the interior of French Guiana.

At the end of December 2005, the first alert from the High Maroni location was given by the ‘centre national de référence (CNR) des arbovirus et virus influenzae de l’Institut Pasteur de la Guyane (IPG)’ which had observed an abnormal increase in the number of dengue cases since the end of November. From the town of Maripasoula only (figure 1), the biggest settlement on the High Maroni (3800 inhabitants), six sera (IgM) or RT–PCR were positive for dengue between November and the beginning of January 2006, whereas only 15 probable or confirmed cases normally occur in this locality each year. That signal was confirmed by the medical teams from Maripasoula, Grand Santi and Papaïchton health centres.

With this new situation, the ‘cellule de veille sanitaire (CVS)’ of the local health authorities decided to conduct an epidemiological and entomological investigation. The objectives were to confirm the occurrence of a dengue fever outbreak in the interior of French Guiana; to describe this emergence of dengue fever, and to set up specific measures to limit the spread of dengue fever within the local population.

Methods

A multidisciplinary team was constituted, composed of people from the ‘Cellule Inter Régionale d’Épidémiologie Antilles-Guyane (Cire AG)’; the local health authorities; the CVS; the departmental vector control team from the ‘Service Départemental de Désinfection’ (SDD), and the IPG.

The study area was the town of Maripasoula, which was preferred to the towns of Grand Santi and Papaïchton because of its bigger size and some logistical advantages during the rainy season (from December to June).
Epidemiology

The chosen epidemiological method was the one validated by the Cire AG for the investigations previously performed in Martinique (French West Indies). Essentially, the survey started at the notified dengue fever cases and, using a standardized approach, investigated around them to look for other suspected dengue fever cases, as follows.

A suspected case of dengue fever was defined by the occurrence of fever (equal to, or more than $38\,\text{C}$); no evidence of other infection (particularly malaria, excluded by using rapid diagnostic tests and/or thick blood smears), and associated with one or more non-specific symptoms including headache, myalgia, arthralgia and/or retro-orbital pains. A probable case was defined by the association of above criteria and a positive dengue fever serological test based on immunoglobulin M (IgM). A confirmed case was associated with a biological confirmation: virus isolation or viral RNA detection by reverse transcription–PCR (RT–PCR). The identification of the first cases was confirmed by the local health services. The survey started at the home and the working place of the suspected or probable or confirmed cases, and an active search was done from one place to another. All the surrounding houses and buildings were investigated, within a radius of 100 m. All the people living or working in the visited places were questioned about their health in the three previous months and their knowledge of sick persons in their family or professional circle. If any water barrels were found in their garden, the reason for their presence was asked.

The support of the survey was a questionnaire in two parts: the first was used for all the places and all the people living or working inside and the second was just used for the people having presented suspected dengue fever criteria during the three previous months. The survey was explained with an information tool and it was systematically asked if the people agreed to answer to the questions before starting the questionnaire. No blood samples were taken, because the clinical symptoms existed 3 months before for some people. If an inhabitant or a worker was away, three visits were always made to try to meet him/her.

Entomology

The local vector control team was responsible for the evaluation of the importance of breeding places all over the town, quarter-by-quarter. This evaluation had to be done for all the houses, inhabited or not, and some information had to be collected on a specific questionnaire: Breteau index (number of positive breeding places for S. aegypti compared with the total number of the visited houses), total number of positive and negative breeding places for S. aegypti, number of barrels (and positive barrels for S. aegypti breeding places) and finally the number of positive and negative tyres for S. aegypti.

The IPG entomology team was responsible for the adult mosquito population study. Some captures were done in a randomized sample of 30 houses, and by light trapping in the forest close to the town, near the main roads coming downtown. This sample was constituted by using an aerial picture of Maripasoula (French ‘Institut Géographique National’, 2001), numerating all the houses and using a randomized number table generated by Epi Info version 6.04 dfr (Centers for Disease Control and Prevention, Atlanta). A search for the dengue virus by PCR on the captured mosquitoes determined whether any were infected. This research was performed by the CNR of IPG.

Data statistical analysis

Data were analysed with SAS® version 8.12 (SAS Institute Inc., Cary, NC) in the epidemiology unit of IPG. Standard statistical tests were used (Student’s $t$-test and Fisher exact test). All the data were integrated within a geographical information system, using ArcGIS® 9.0 (ESRI, Redlands, CA).

Results

The survey was performed in Maripasoula between the 20 and 23 February 2006.
Epidemiology

Seventy-five houses were investigated (25.0% of the 300 houses of Maripasoula). There were 6.2 inhabitants living per house (from 1 to 17, median equal to 6.0 inhabitants). Eight working places were investigated. There were 5.2 workers per place (from 1 to 13, median = 5.5 workers). Some rain water garden barrels were found around 31 houses (41.3% of the investigated houses), the average number of barrels were 3.0 per house (from 1 to 15, median = 2.0 barrels) and they had been there for an average of 131.0 months (from 1 to 840, median = 18.0 months). In only two houses (6.5% of the 31 houses with barrels) were the barrels covered. Those barrels existed for several reasons: in addition with the public water for 15 houses (48.4%), to replace an inexistant water public network for five houses (16.1%), to prepare the manioc for one house (3.2%), to prepare the cement for one house (3.2%) and without any specific use for one house (3.2%).

A total of 528 people were surveyed (13.9% of the total population) (table 1): 486 in their houses and 42 in their working places. No one refused to take part in the survey. For the people interviewed in their house, the average age was 17.2 years (from 1 to 996 months, median = 156 months). The sex ratio was 0.93 (234 men and 252 women). At least one trip outside the district during the three previous months was declared by 146 people (30.0%). For the people interviewed at their working place, the average age was 33.7-years old (from 252 to 624 months, median 426 months). The sex ratio was 1.0 (21 men and 21 women). At least one trip outside the district during the three previous months was admitted by 37 people (88.1%). For all the surveyed people, there was no statistical association between the occurrence of a fever episode during the last 3 months and sex (P = 0.51), age (P = 0.16), time spent in the district (P = 0.38), number of trips outside the district during the three previous months (P = 0.61) and existence of barrels around the house (P = 0.4).

A total of 175 people presented with at least one febrile episode during the previous 3 months (33.1% of the studied population). Among those people, 133 presented with the definition criteria of dengue fever cases (suspected, probable or confirmed) (76.0%). The proportion of dengue fever cases was larger in those people who had not travelled (95/345 e.g. 27.5%) than in the population who had travelled (28/183 e.g. 15.3%) in the three previous months (P = 0.01) (table 1). The proportion of dengue fever cases was significantly different among the age classes (P < 10^-3). The age groups with the highest prevalence were the 55-years old and above, and the 11–15 years old. Among the 133 dengue fever cases, it was possible to estimate the beginning of the symptoms for 117 (87.9%) and to construct the epidemic curve (figure 1). This curve showed that the first acute cases occurred during November 2005 and that the outbreak presented its first peak in January 2006. When the survey was performed, the outbreak was still active. Among the 133 suspected cases, 111 had consulted a general practitioner (83.5%), seven were hospitalized in the Maripasoula health center (5.2%), a blood sample was taken from 45 people and 10 (22.2%) were sent to IPG in Cayenne. Of those 10 patients, 4 had a positive IgM serology (40.0%) and were described as probable dengue cases; 2 others had a positive PCR with DEN-2 serotype and were described as confirmed dengue cases. The total number of cases was therefore 127 suspected cases, 4 probable cases and 2 confirmed cases. During the 2 weeks preceding the onset of the clinical symptoms, 25 dengue fever cases had stayed outside the district (14.4%). Suriname was the most frequent destination (40.9%), followed by Cayenne city (18.2%).

### Table 1 Characteristics of the study population, measured during the survey, Maripasoula, February 2006

<table>
<thead>
<tr>
<th>Populations</th>
<th>Size</th>
<th>Sex ratio (Male/Female)</th>
<th>At least one trip during the previous 3 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total population of Maripasoula</td>
<td>3800</td>
<td>NE*</td>
<td>NE*</td>
</tr>
<tr>
<td>Population included in the survey</td>
<td>528</td>
<td>0.9</td>
<td>183</td>
</tr>
<tr>
<td>People having presented a fever episode in the previous 3 month</td>
<td>175</td>
<td>1.1</td>
<td>48</td>
</tr>
<tr>
<td>All dengue fever cases (suspected, probable and confirmed)</td>
<td>133</td>
<td>0.9</td>
<td>28</td>
</tr>
<tr>
<td>Suspected dengue fever cases</td>
<td>127</td>
<td>0.9</td>
<td>26</td>
</tr>
<tr>
<td>Probable dengue fever cases</td>
<td>4</td>
<td>0.75</td>
<td>1</td>
</tr>
<tr>
<td>Confirmed dengue fever cases</td>
<td>2</td>
<td>1.0</td>
<td>1</td>
</tr>
</tbody>
</table>

* a: NE, non evaluated

The integration of epidemiological data within a GIS allowed the occurrence of dengue fever cases to be followed in space and time (figure 2). The geographical distribution of the suspected dengue fever cases suggested a rapid diffusion of the infection in all the area, without geographically restricted clusters.

Entomology

For the evaluation of mosquito breeding places, Breteau index, total number of positive and negative breeding places, number of positive and negative barrels and finally number of positive and negative tyres were estimated for the four main quarters of Maripasoula (figure 3). Those estimations showed that breeding places were found everywhere, no quarter being significantly different from the others. Several types of breeding places existed: tyres, barrels, garbage and other. For the study of adult mosquitoes, the captures made by aspiration were finally performed within 22 buildings: 17 houses, four workshops and one administration building. The other eight buildings could not be investigated. *S. aegypti* were found within 20 buildings (90.9%) and also other species: *S. fulvus*, (two mosquitoes within 4.6% of buildings), two species of *Culex* (159 mosquitoes, 95.5% of buildings) and one species of *Psorophora* (three mosquitoes, 9.0% of buildings). For the light trapping, 12 CDC light traps captured 515 mosquitoes. The total number of caught mosquitoes was 831. A PCR analysis was made on 822 of those mosquitoes, but no dengue fever virus was found.

Public Health control measures

Before, during and after the investigation, some personal and collective vector control measures were set up by the local vector control team and the health authorities. An awareness campaign was started within the local community, especially in the schools.

Discussion

The investigation conducted in Maripasoula in February 2006 described 127 suspected dengue fever cases during a 3-month period, whereas the epidemiological surveillance system usually found 15 cases per year. This investigation showed that all age classes were affected by the dengue virus, but proportionally older people (55-years old and above) and the 11 to 15 years old (P < 10^-3) were more infected.
A significant link was demonstrated between the occurrence of a dengue fever episode and recent trips away from the focus. The proportion of dengue fever cases was higher in the people having not travelled (23.5%) than in the population that had travelled (15.3%) in the three previous months ($P = 0.01$). The epidemic curve showed that the beginning of the outbreak was in November 2005. Breeding places for St. aegypti were found everywhere in the town. Stegomyia aegypti adults were found in 90.9% of the randomly selected buildings of the town (20/22), but PCR tests on those mosquitoes was negative for dengue virus.

The serotype 2 dengue fever outbreak that occurred in French Guiana during the first semester 2006 began in the west of the Department, and all the locations on the Maroni River were affected, such as Papaïchton and Grand Santi. It was the first time that a dengue fever outbreak has been described in the country other than in the coastal region, either because the previous epidemiological surveillance system was not effective, or because it was the first time that such an outbreak had occurred in this area of French Guiana. After having completed the investigation, analysed the results, and interviewed a lot of people in the field, we are confident that we have described the emergence of dengue fever in that part of French Guiana. The fact that the occurrence of dengue fever was higher in the people who had not travelled than in the population that had travelled ($P = 0.01$) reinforced our conclusion. The comparison of the results of French Guiana PCR samples with those from Suriname confirmed that DENV-2 virus was present in both populations at the same time, and was phylogenetically related to subtype III (Asian-American subtype).

This survey in Maripasoula evaluated, in a more realistic way, the epidemiological importance of dengue fever within this location of the West French Guiana. It showed that an epidemiological surveillance system based only on biological results, which detected only six probable and confirmed cases for the same period and the same geographical area, was not very sensitive for such a location, which is far from the reference laboratory. Naturally, there were logistical constraints associated with transporting the samples to the laboratory. A strike by the staff of the only airline company to serve Maripasoula between the 31 January and the 9 February 2006 stopped the dispatch of blood samples to the reference laboratory in Cayenne and increased the contrast. However, it was probable that among the 127 suspected dengue fever cases detected by this survey, some of them were not dengue fever. It was not possible, for ethical considerations, to have a blood sample from each of those patients and so it was impossible to evaluate the sensitivity of the chosen definition criteria. Even with this bias, the survey showed that an epidemiological system based only on biological results does not provide an early warning and a good assessment of an epidemiological situation.

This investigation also allowed a better description of the S. aegypti population in Maripasoula. Those populations have been described for a long time and their attendance has already been described by the local vector control team and IPG. But these evaluations showed only very few S. aegypti in Maripasoula and not inside 90.9% of the buildings, which we found. The very high number of inhabitants displacements and the development of urbanization have probably helped the importation and the local implantation of new populations.

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**Figure 2** Geographical distribution of suspected dengue fever (DF) cases (117 patients for whom the date of the beginning of the symptoms was known) and garden barrels within Maripasoula, from week 1 (20–26 November 2005) to week 13 (13–19 February 2006) of the survey.
Our survey did not show that the dengue virus was present in the *Stegomyia* population, but the number of caught mosquitoes (831) was probably too small to demonstrate the level of infected mosquitoes. Some complementary captures could have been useful for this part of the survey and a molecular biological study among a very high number of larvae as well.

Among the potential risks factors, the role of garden barrels was studied. But even though the survey did not demonstrate their association with the outbreak of dengue fever, they remain a risk factor as *Stegomyia* breeding places, and the control of their use has to be improved. They were used mainly to collect the rain water and to use it for several domestic purposes (washing, gardening). An awareness-raising campaign has been organized by the health authorities to explain the dangerous character of their use. Some protective measures, by covering the tops of barrels with nets were set up and the promotion of the use of tuff-tanks as well. An individual and collective management of the garbage was promoted, to enhance the protection of the people against mosquitoes and also to ameliorate the conditions of life.

This survey showed the importance of more detailed epidemiological and entomological investigation favouring the detection of dengue virus emergence in an area previously considered at low risk for this infection.

### Acknowledgements

We thank the local vector team of ‘Service departemental de désinfection (SDD)’, the people from the health center and all the people of Maripasoula who took part in this investigation. We also thank Dr Guy Barnish, Senior Fellow of the Liverpool School of Tropical Medicine (UK), who corrected the manuscript.

**Conflicts of interest:** None declared.

### Key points

- This article described the emergence of dengue fever in the interior of French Guiana.
- The survey underlined the fact that the current epidemiological surveillance system must be improved in order for it to detect another dengue fever outbreak in less time than it took to detect the one we have reported.
- A new public health strategy has been consequently set up. It has to be developed to enhance the sanitary education within a population that has a poor knowledge of dengue fever.

### References

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