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# Characterization of the Environmental Risk of Cysticercosis Induced Epilepsy in the City of Abidjan

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**Abstract**

The objective of this study was to identify areas at risk of infestation by Taenia solium larva in the Abidjan agglomeration. For this purpose, environmental data were collected within the residence areas of patients enrolled during a study on cysticercosis conducted among patients attending hospitals for epilepsy.

The methodological approach was based on the construction of a composite index based on both environmental and anthropogenic data collected in the living environment of these epileptic patients. Based on a spatial grid of 1,164 tiles of 500 m side, presence or absence of an environmental element at risk (wild discharge of garbage, stagnant water, clogged gutters, wastewater spillways in the streets) or anthropogenic one (pigsty, pigmeat salep) was respectively noted as one (1) zero (0). Therefore, for each tile the sum of the items accounted in the tile was used as composite index. Then, the values of these indices were spatialized in order to determine the environmental risk of each area of residence.

The results show that only 20% of the area of the the study's territory is subject to an environmental and anthropogenic risk of infestation by the larva of Tænia solium. Indeed, areas of low and medium levels of risk were found as the most extensively contaminated. However, areas covered by high or very high risk represent only 2.28% and 0.59% of the living space of epileptic patients respectively.

In conclusion, one fifth of the total area of residence is impacted by a relatively moderate level of environmental risk.

**Keywords:** Environmental Risk; Cysticercosis; Tænia Solium; Epilepsy; Cartography; Abidjan

## Abbreviations

CSNTU: Centre for Studies on Networks, Transport, Urban Planning and Public Buildings; CIGN: Geographic and Digital Information Center; CG: Clogged Gutters; WGD: Wild Garbage Dump; PRSP: Poverty Reduction Strategy Paper; SW: Stagnant Water; GPS: Global Positioning System; NISES: National Institute of Statistics and Economic Studies; SOPIM: Société de Promotion Immobilière; UTM: Universal Transverse Mercator; SPM: Sale of Pork Meat; WGS: World Geodetic System

## Introduction

Cysticercosis is a parasitosis due to infestation by the larva of Tænia solium. In endemic area, it accounts for 25 to 28% of neurological diseases [1]. Transmission occurs through the consumption of water or food soiled by the eggs of the parasite. Cysticercosis is endemic in geographical areas where pig farming and consumption of pork is intense associated with poor access to sanitation facilities. Uncivil practices of the populations such as the discharge of garbage and wastewater in public places, the wandering of pigs and especially open-air defecation will lead to eggs dispersion and human contamination. From this point of view, the geographical location of a person in a healthy or unhealthy environment is decisive in the occurrence of this disease [2].

Therefore, it is highly likely that this disease may have a favorable breeding ground in the degraded and unhealthy urban environment of developing countries. Indeed, in these countries, decades of rapid and uncontrolled urbanization have had as a corollary a deficit in waste management and sanitation that leads to the existence of areas of spread of many pathologies [3-5].

Abidjan, the main urban hub of Côte d'Ivoire, is not spared by this situation. Once the "Pearl of the Lagoons", the Ivorian economic capital experienced a rapid and steady deterioration of its living environment under the combined effects of the economic recession of 1980, a demographic explosion, an anarchic urbanization and politico-military crisis occurring in recent decades [6]. During this study, most of the programs implemented have not been able to slow down this degradation of urban environment. This situation explains persistence in various insane places in the city where pigs are free wandering dispersing their pathogens. This supports our research theme about existence of pockets of insalubrity in some places of Abidjan, as source of risks for populations to contract cysticercosis.

The main objective of this study is therefore to determine, on the basis of environmental data collected in the areas of residence of epileptic patients (positive or negative for cysticercosis), a risk index for transmission of cysticercosis in the Abidjan. This study is part of a seroprevalence survey of cysticercosis among epileptic patients




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attending the neurology services of Abidjan [7,8].

## Methods

The general methodological approach adopted for this study revolves around 1) the geolocation of environmental and anthropogenic parameters of the patients' residence space, 2) the construction of a composite index to measure the risk related to infestation by the Larva of Taenia solium and the 3) spatialization of areas at risk of this disease.

### Study data

Patients enrolled in this study were selected during a clinical study conducted in the three main hospitals of the town. This cohort was described elsewhere [7].

The three main types of data used in the study are map data, field data and socio-economic data related to the patients and their household.

The cartographic data concern the geographical file of the administrative division of Abidjan city. It regroups the limits of the Abidjan agglomeration, the division into communes and districts. These data were collected in digital format from the Geographic and Digital Information Center (CIGN) and are free to use.

The field data were related to the geographical location of epileptic patients who consulted the various neurology departments of Abidjan city (Table 1). Environmental and anthropogenic parameters characteristic of the living environment the patients were attached to the location of the patient itself. Location data of the patients was acquired using a GPS during a field mission that took place between April and July 2018. Environmental and anthropogenic parameters were acquired during the same field study.

Garming eTrex 20 GPS receptors have a spatial accuracy of more or less three meters. In addition, they were configured according to the WGS projection system, UTM 1984 Zone 30 North.

### Geolocation of environmental and anthropogenic parameters of the patient's residence space

The database of epileptic patients, who attended the neurology units of Abidjan during the study period [7], provided us with information on the municipalities and neighborhoods of the residence of the latter. The list of residence quarters and of administrative division was adapted from the common or popular names of the sub-neighborhoods declared by the patients

This list was used to organized field study to collect environmental and anthropogenic data. Points of wild dumps of garbage, stagnant water, clogged gutters, sewage spillways in the streets dispatched in the environment of the households were spotted using Garmin eTrex 20 GPS and located on the map. All event extending in lenth were identified by several points on the map, which allowed to grasp the spatial magnitude of this phenomenon. The same technique was used for the recording of anthropogenic elements (pigsty, pork outlet etc). Full description of these environmental event was also recorded.

### Construction of a composite index to measure the risk of cysticercosis

Environmental and anthropogenic factors in the immediate living environment of the patients, considered as sources of exposure to Taenia solium eggs infestation were listed and geo-localized. They were used to build an index classifying the exposure risk. Index was built as the sum of presence (1)/absence (0) of all the environmental or anthropogenic events recorded.

### Spatialization of the cysticercosis risk in the city of Abidjan

In order to overcome the administrative boundaries of municipalities and neighborhoods likely to extend the attribution of environmental and anthropogenic parameters far from their collection sites, the study area was divided into tiles of 500 × 500 meters. This splitting generates a regular mesh all over the area suitable to analyze risks. For each tile of 500 × 500 meters, a coefficient was assigned equal to the sum of the coefficient assigned to each (environmental or anthropogenic) element present in this area. Risk mapping consisted than, in categorizing the composite index into classes following a graded line method (or natural thresholds) as used in conventional thematic mapping beach system [3,9]. The value of the coefficient observed in each 500-square-meter spatial unit was considered as the composite index to be related to the number of cases of cysticercosis.

After this step, the different composite indices were categorized into classes following the graduated line method (or natural thresholds). This is a technique used in conventional thematic mapping [3,9]. It is based on natural groupings of data. In effect, features are divided into classes whose boundaries are defined where there are large differences between data values. It consists in drawing a graduated line with our minimum and maximum value (0 and 41 in the case of the present study). Then the points corresponding to the different values are marked and then grouped together according to the discontinuities that appear. The 0 values, which correspond to an absence of risk, have not been counted.

For a composite index value between 1 and 3, the risk of cysticercosis was considered low. When the value of the composite index is between 4 and 10, the level of risk was considered medium. Conversely, a high risk was induced by a composite index value between 11 and 24, while the risk was considered very high when the composite index was greater than 25. The 0 values, which correspond to an absence of risk, were not counted. Therefore, in the present study, four classes representing the levels of risk induced by the values of the composite index have been identified.

## Results

### Air of the study

Overall, nine out of the ten municipalities in the Abidjan agglomeration were concerned by this study. These were the communes of: Abobo, Adjamé, Attécoubé, Cocody, Koumassi, Marcory, Treichville, Port-Bouët and Yopougon. In all these municipalities, 93 residence districts for epileptic patients have been identified out of the 149 in the city. (Table 2 and Figure 1).

### Spatial distribution of environmental and anthropogenic elements

The distribution of environmental elements and those related to anthropogenic activities collected in the areas of residence of patients is uneven both according to the municipalities and according to the

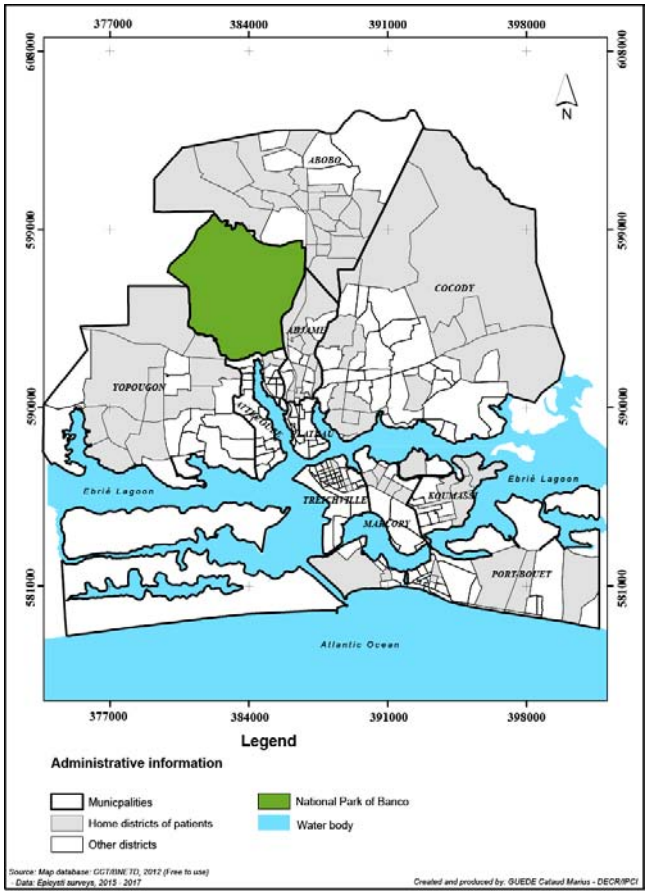


**Figure 1:** Geographical distribution of residence areas for epileptic patients in Abidjan.

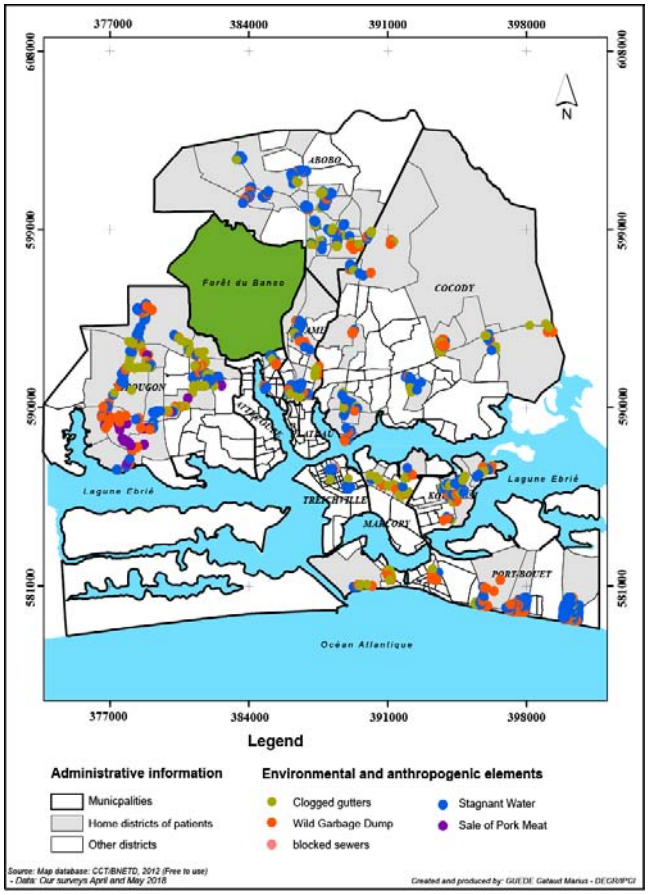


**Figure 2:** Spatial distribution of points of environmental and anthropogenic elements collected in the residence quarters of epileptic patients.

types of elements.

Of all the neighborhoods covered by the study, 1,375 points were identified, including 28 anthropogenic elements (Table 3). Among them, surface water was the main element in the vicinity of residence of epileptic patients. Indeed, the 646 spots of Stagnant Water (SW) were spotted accounting for 47% of the overall 1,375 elements. Spots of Clogged Gutters (CO) estimated at 361 (26.3% of ground elements) and of Wild Garbage Dump (WGD) (340 i.e. 24.8%) constitute the second and third most important environmental parameters identified respectively. Spots of sale of Pork (SP) estimated at 28 (2.0% of all elements) were found mainly in Yopougon municipality (Table 3).

Spatial distribution of environmental and anthropogenic elements was not uniform over the neighborhoods and communes of the city of Abidjan. Municipalities of Port-Bouët (387), Yopougon (367), Abobo (211) and Cocody (126) concentrate the largest numbers of spots. In Marcory, Attécoubé and Treichville they accounted for 36 to 24, and in Koumassi and Adjamé 92 and 78 spots were identified respectively. However, this spatial distribution varied greatly with the type of spot. In all the different districts except of Marcory, the SW were the most frequent elements identified and therefore, the most present in the living environment of the populations. They were mostly frequent in Port-Bouët (236), Yopougon (139) and Abobo (117). For the environmental type of elements WDG points were the most frequent, with 96 spots in Port-Bouët, 74 in Yopougon and 47 in Abobo, but only 2 and 5 in Treichville and Marcory respectively. Interestingly, with regard to CO, data reveals that Yopougon concentrates alone one third of the total spots (Table 4 and Figure 2).

## Mapping of the environmental and anthropogenic risk related to cysticercosis in the city of Abidjan

According to the risk definition we adopted, only 20% of the space was impacted by a low to high risk, among which 9.1% (19,439,628 $m^2$) was at low risk and 7.8% and 2.3% was at medium and high level respectively (Figure 3).

Regarding the spatialization of this phenomenon, the estimated level of risk is average for 11.2% and low for 6.5% of the neighborhoods circumscribed by the study in the municipality of Abobo. However, less than 1% of the total coverage of the residence quarters of the epileptic patients was in high-risk areas.

In the municipality of Attécoubé, the analysis of spatial data revealed that 45.4% of the area of residence of epileptic patients is in a situation of medium risk while a sector covering 15% of this space is facing a low level of risk. It should be noted that in this municipality, no perimeter with high and very high levels of risk has been identified. In addition, 39.6% of the overall extent of the living environment of

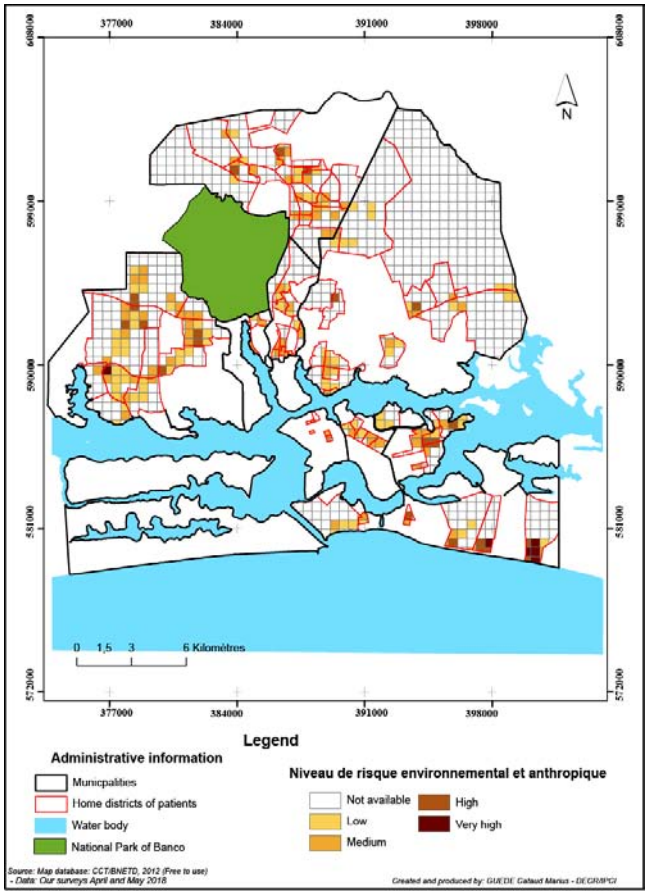


**Figure 3:** Spatialization of the level of environmental and anthropogenic risk in the residence quarters of epileptic patients in Abidjan.

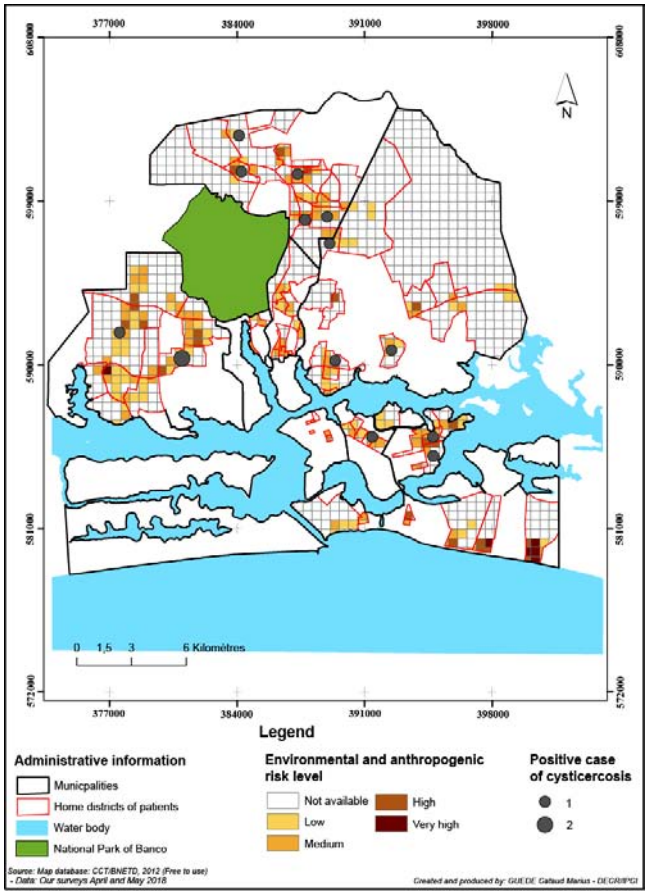


**Figure 4:** Number of positive cases of cysticercosis according to the level of environmental and anthropogenic risk in the residence areas of epileptic patients in Abidjan.

**Table 1:** List of environmental and anthropogenic variables collected.

| | Variables | Factors of exposure to the disease |
|---|---|---|
| **Environmental parameters** | Stagnant water | Existence of stagnant water |
| | Wastewater spillways on neighborhood streets | Proliferation of wastewater spillways |
| | Clogged gutters | Presence of clogged gutters |
| | Littering | Proliferation of littering |
| **Anthropogenic parameters** | Sties | Existence of pig rearing areas |
| | Places of sale of pork meat | Existence of places of marketing of pork |

epileptics in the municipality has a low level of risk.

In the commune of Adjamé, the spatialization of the level of risk has a configuration close to that observed in Attécoubé. Indeed, in this municipality the spaces subject tohigh and very high risks are non-existent. It is observed that approximately 72.4% of the area studied was in a situation of low environmental and anthropic risk. The remaining proportion of the territory has a low risk level at 13.1% and a medium risk level at 14.5%.

For the municipality of Cocody, more than 92.11% of the total area of residence of the patients determined for the study is not subject to environmental and anthropogenic risk related to cysticercosis. However, the remaining space is subdivided into three risk zones, namely the low-level risk zone (5.3%), the medium-risk area (1.0%) and the high-risk area, which occupies 0.5% of the general area.

In Koumassi, apart from the area not impacted by environmental and anthropogenic risk, which occupies more than 52.5% of the residential areas of epileptics, it is the sector with an average level of risk that covers the largest share of the space with 21.5%. In second place is the one subject to the low risk level. The latter represents 13.3% of the total area of the study area in Koumassi. Finally, the high level of environmental and anthropogenic risk covers an area of 734,867 m² corresponding to an estimated spatial proportion of 12.7%. In this municipality no space with a very high level of risk has been determined.

**Table 2:** Number of residence quarters for epileptic patients

| Commune | Number of places of residence listed by patients | Number of places of residence identified on the map |
|---|---|---|
| Abobo | 21 | 14 |
| Adjamé | 8 | 4 |
| Attécoubé | 5 | 5 |
| Cocody | 26 | 19 |
| Koumassi | 17 | 8 |
| Marcory | 11 | 9 |
| Port-Bouët | 11 | 10 |
| Treichville | 7 | 7 |
| Yopougon | 43 | 17 |
| **Total** | **149** | **93** |

Source: Our Surveys, 2018

**Table 3:** Number of different types of environmental and anthropogenic variables.

| Types of variables | Actual | Proportion (%) |
|---|---|---|
| Clogged gutters | 361 | 26,3 |
| Littering | 340 | 24,7 |
| Stagnant Water | 646 | 47 |
| Sale of Pork Meat | 28 | 2,0 |
| **Total** | **1375** | **100** |

Source: Our Surveys, 2018

**Table 4:** Number of different types of environmental and anthropogenic variables by municipality.

| Commune | CG[1] | WGD[2] | ES[3] | VVP[4] |
|---|---|---|---|---|
| Abobo | 47 | 47 | 117 | 0 |
| Adjamé | 23 | 21 | 34 | 0 |
| Attécoubé | 7 | 9 | 10 | 0 |
| Cocody | 39 | 40 | 47 | 0 |
| Koumassi | 36 | 18 | 38 | 0 |
| Marcory | 26 | 5 | 5 | 0 |
| Port-Bouët | 52 | 96 | 236 | 0 |
| Treichville | 6 | 2 | 16 | 0 |
| Yopougon | 125 | 74 | 140 | 28 |
| Total | **361** | **340** | **646** | **28** |

1: Clogged gutters; 2: Wild Depositof Garbage; 3: Stagnant Water; 4 : Sale of Pork Meat

On the other hand, in the municipalities of Marcory and Treichville no sector with a high and very high level of risk has been identified. In addition, areas not subject to environmental and anthropogenic risk represent respectively 41.2% and 34.3% of the total area of each municipality. However, the area with low environmental and anthropogenic risk is predominant in the municipality of Marcory with a spatial representativeness of 35.5% of the territory while in that of Treichville it is the medium risk zone that is the most important in terms of extent. The latter occupies an area of 190,066 m² or 42.5%.

In the municipality of Port-Bouët 76.2% of the entire perimeter of the residence areas of epileptics is located in a zone of non-existent risk. However, in the remaining sector the area covered by a low level of risk occupies the largest proportion. Indeed, it extended over an area of 1,458,043 m² or 7.6% of the entire sector impacted by the environmental and anthropogenic risk in this municipality. The areas subject to medium, high and very high risk levels cover respectively 977,843 m² (5.1%), 1,124,365 m² (5.9%) and 1,009,850 m² (5.3%) of the observed territory. It should be noted that it is in the municipality of Port-Bouët that the "very high" level of environmental and anthropogenic risk is the most important. It is observed in the southern part of the Gonzaqueville district.

**Table 5:** List of neighbourhoods with CYSTICERCOSIS SE-positive patients.

| Commune | Districts |
|---|---|
| Abobo | Anokoua-Kouté |
| | Anador |
| | Avocatier |
| | Abobo-Centre |
| | Abobo-Té |
| Cocody | Anono |
| | Cocody-Centre |
| | Plateau-Dokui |
| Koumassi | SOPIM |
| | Embankments |
| Marcory | Hibiscus |
| Yopougon | Gesco-Handling |
| | Old Sicogi District |

Finally, in the municipality of Yopougon, areas with low and medium levels of risk represent in the order of magnitude 16.8% and 13.9% of the total area of residence of epileptic patients. In the same municipality, about 4.1% of the area presents a high environmental and anthropogenic risk while 0.6% faces a very high level of risk. The "very high" risk perimeter is located in the northwestern part of the North Niangon district (Figure 3).

### Distribution of the number of positive cases of cysticercosis according to the risk areas in the city of Abidjan

Out of the 403 epileptic patients enrolled in this study at the neurology departments only 18 had a positive serology for cysticercosis. However, 92 reside outside the city of Abidjan and were not taken into account by the environmental survey. Positive were spread over 14 districts belonging to the five communes: Abobo (5), Cocody (3), Koumassi (2), Marcory (1) and Yopougon (2).

Among them, apart the districts of Anokoua-Kouté (Abobo), Gesco-Manutention Yopougon) and SOPIM (Koumassi), all were described as low level of risk. The SOPIM and Anokoua-Kouté districts were at high risk while the Gesco-Manutention district was at medium risk (Table 5 and Figure 4).

## Discussion

The methodological approach implemented during the present study is based on a process of spatial analysis simplicity to characterize the state of the environment near the place of life of epileptic patients. Indeed, the environmental and anthropogenic data collected have not been hierarchically codified because there is not, to our knowledge,

a predominance of one factor over another in the infestation by the larva of Tænia solium. The various studies devoted to this disease show that it occurs in spaces "where hygienic conditions are defective, sanitary facilities are rare, meat consumption or pork preparations are frequent and where human-animal promiscuity is very important" [10-12] Several studies have revealed that cysticercosis is due to an unhealthy environment and a lack of hygiene, both reservoir of the larva of Tænia solium and vector of diffusion of the latter, without however determining the supremacy of one element of the environment over another [13,14]. It is therefore this idea that motivated the choice of the synthetic indicator used in this study. In addition, the index developed materializes the sufficient presence or not of the environmental parameters identified as close as possible to the area of residence of the patients.

The idea of characterizing the environment but also the risk incurred only in the patient's living space led to the choice of the mapping technique by carroyage. The latter makes it possible to carry out our analysis in a regular and homogeneous spatial mesh over the entire territory studied. This makes it possible to overcome administrative geographical boundaries avoiding any extrapolation of the phenomenon to areas not concerned or influenced. This aspect is also highlighted by CERTU [15] when it states that cartographic representation by carroyage ensures 'independence from the administrative and statistical perimeters to which cartographers and users of Geographic Information Systems (GIS) are accustomed'. In the same spirit Darriau [16] suggests using the assembly of tilesx (carroyage) in urban areas to overcome the imprecision of municipal divisions in the analysis of demographic and socio-economic phenomena. According to Darriau [16], the mapping system by carroyage is very suitable for the study of variables related to the environment. Indeed, for this author the analysis of the spatial distribution of a fact escapes any partition of space therefore cannot be circumscribed within an administrative limit.

The fine-scale spatial analysis of data offered by carroyage maping is already used in various fields of activity. Various applications have been developed especially for plants, i.e. in botany in relation to the census of plant species, or in rural geography in Brazilian cerrados [17]. More recently, this technique has been used by regional urban planning agencies in France to carry out territorial diagnoses. National Institute of Statistics and Economic Studies (INSEE) has also developed this mapping technique to analyze both the distribution of the population and certain other socio-demographic and socio-economic indicators.

The analysis of the data collected during the study both on spatialization of the synthetic index and on cysticercosis cases reveal degradation of the environment. Indeed, 98% of the data collected are marks of insalubrity of the environment. These are stagnant water points, litter dumps, gutters clogged by garbage or enforceable septic tanks. They are supposed to be poqitive environment for contamination by Tænia solium eggs. The concentration of these elements in the vicinity of the living place of epileptics supports their role in the contamination.

Moreover, these environmental parameters are perceived as sources of contamination of populations and disease vectors because their presence increases the exposure of local residents. Authors (Sy I et al, Dongo K et al) in their study on the analysis of the health environment situation of disadvantaged neighborhoods of Yopougon obtained results similar to ours [5]. Indeed, they were able to observe a deficit of the sanitation and garbage management system in these precarious neighborhoods that underpins the use of public spaces and alleys as places of sewage disposal and garbage dump. This situation is also highlighted by Sy et al. [4] when they stated that the growth of the city of Nouakchott has led to many environmental changes linked to the difficulties of sewage disposal, household waste collection and access to drinking water [4]. The state of the sanitary environment of these neighborhoods explodes the populations who live there to different diseases of fecal peril including cysticercosis. Indeed, the presence in the streets of wastewater but also those of sewers that overflow or are open in case of rain on the one hand and defecation in the open air or in wild deposits of garbage on the other hand multiply the chances of individual's tobe in contact with seals containing larvae of Taenia solium. In accordance with the data collection centered only in the residence areas of epileptics and the recommended mapping method by carroyage, the environmental risk related to cysticercosis could be characterized in the living space of the latter. The results obtained show that only 20% of this territory has a sanitary environment conducive to the emergence of cysticercosis. In addition, at the general scale of the city of Abidjan the measurement of the level of environmental risk observed is moderate with some pockets of high or very high risk.

The districts of Gonzagueville and Adjouffou in the municipality of Port-Bouët, which show the highest proportion of very high risk (5.3%) correspond to urban areas of spontaneous habitats. In the latter, the lack of sewerage network favors the use of vacant streets and spaces as garbage dumps and sewage dumps, and even as places of defecation. In addition, the sandy appearance of the soil promotes the retention of rainwater hence the proliferation of stagnant water. Ultimately, both the physical environment and the urban structure of these neighborhoods contribute to the degradation of their health environment, exposing residents to significant health risks.

The spatial distribution of epileptic patients with positive seroprevalence of cysticercosis is not always consistent with the level of degradation of their living environment. Indeed, the majority of neighborhoods with cysticercosis-positive patients have a low or medium risk level. Only the districts of SOPIM and Anokoua-Kouté located respectively in the communes of Koumassi and Abobo have a high environmental and anthropogenic risk.

However, it is initially observed that not all the neighbourhoods surveyed despite the state of environmental degradation they present do not harbour positive cases. Secondly, the district of Adjouffou in the commune of Port-Bouët, which has the highest level of risk in the city of Abidjan with 5.3%, has no positive cases of cysticercosis.

## Conclusion

The mapping of the environmental and anthropogenic risk related to cysticercosis in the Abidjan agglomeration operated from the gridding technique has allowed an efficient spatialization of this phenomenon in the living environment close to the epileptics identified in the neurology departments of the city.

The findings reveal firstly that only 20% of the total area

represented by the patients' neighbourhood of residence is submitted to a moderate environmental risk. Secondly, the sectors where the level of risk is high and/or very high are observed in Gonzagueville and Jean Folly neighbourhoods in the Port-Bouët commune and in Niangon Nord in Yopougon commune.

Methodologically, the development of a composite index to measure the level of exposure of neighbourhoods to environmental and anthropogenic risk appears to be an important decision-making tool. Because it enables the detection of unhealthy areas in urban environments that are potential reservoirs of pathogens, it can guide health authorities in epidemiological surveillance and the implementation of measures to contain diseases.

Following the present study, during which only the immediate environment to epileptic patients was investigated, it would be appropriate to consider the collection of environmental and anthropogenic data in all the neighbourhoods composing the urban space of Abidjan. This would indicate the level of degradation of the urban environment at the scale of Abidjan while also assessing the risk of exposure to faecal peril diseases for the entire city.

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