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Integrated Assessment of the Sanitary Environment in Attiéké Production Areas in Bingerville (Côte d'Ivoire): An Interdisciplinary Approach Combining Sanitation, Entomology, and Social Perceptions

Eliachie Larissa Eméline Angoua[1, 2*]

[1]*Training and Research Unit for Earth Sciences and Mineral Resources, Félix Houphouët-Boigny University, Abidjan, Côte d'Ivoire.*
[2]*Research and Development Department, Swiss Center for Scientific Research in Côte d'Ivoire, Abidjan, Côte d'Ivoire.*

**Corresponding author*

Abstract

This study analyzes the impact of residues from "attiéké" production on the quality of the sanitary environment in four neighborhoods in the municipality of Bingerville, Côte d'Ivoire. An integrated methodological approach combining a geographical survey, an entomological survey, a household survey, and microbiological analyses was used to characterize local sanitation practices and assess the associated environmental and health risks. A total of 42 "attiéké" production sites were identified and 171 households surveyed. The results reveal inadequate management of cassava effluents and solid waste, most of which is discharged into the immediate environment, generating stagnant water, garbage deposits, and numerous larval breeding sites. Of the 1,266 breeding sites identified, 41% were located in used tires and 38% in bricks. The genera *Aedes* (825 breeding sites) and *Culex* (1,203 breeding sites) largely dominated all the sites studied. Microbiological analyses revealed significant contamination of wastewater and effluents, marked by high concentrations of *Escherichia coli* and *Bacillus cereus*, while *Salmonella spp*. was absent. Diseases perceived by households, particularly malaria and typhoid fever, were more prevalent in neighborhoods with the highest concentration of risk factors. These results show that unregulated "attiéké" production contributes to the deterioration of the sanitary environment and increases the population's exposure to water-borne and vector-borne risks. The study highlights the urgent need to promote community sanitation solutions, strengthen the supervision of production sites, and develop multisectoral actions to sustainably reduce health risks.

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Introduction

The sanitary environment is a key determinant of public health and well-being, particularly in densely populated urban areas. It encompasses all the physical, biological, and social conditions that influence quality of life, including solid waste management, wastewater management, and access to basic infrastructure (Dongo, 2006; WHO, 2023). According to the World Health Organization, nearly 12.6 million deaths worldwide each year are attributed to unhealthy or polluted environments, with more than 90% occurring in low- and middle-income countries (WHO, 2023). In sub-Saharan Africa, cities are undergoing rapid and often unplanned

urbanization, leading to uncontrolled accumulation of domestic waste and liquid effluents (Kaza *et al.,* 2018). In Côte d'Ivoire, the city of Abidjan illustrates this problem. Urban expansion there far exceeds the capacity of urban management services: illegal dumping, stagnant water, lack of drainage, and inequalities in waste collection characterize several municipalities (Brisoux and Elgorriaga, 2018). The municipality of Bingerville, formerly a semi-rural area, is now part of the District of Abidjan and faces increasing anthropogenic pressure. Its local economy relies heavily on the artisanal production of "attiéké", a fermented semolina made from cassava (Manihot esculenta), produced mainly by women from the "Ebrié" communities (UVICOCI, 2014; Krabi *et al.,* 2015).

This activity, which is highly valued in socio-economic terms, nevertheless causes significant environmental damage. The production of "attiéké" generates large volumes of solid waste (fibers, peelings, pulp waste) and liquid effluents rich in organic matter and cyanide compounds (Asiedu, 1991; Colin *et al.,* 2007). These effluents, which are discharged untreated into the environment, contaminate soil and surface water, causing ecological imbalances and microbiological risks (Ubalua, 2007; Kpata-Konan *et al.,* 2011; Dongo *et al.,* 2013). Furthermore, the accumulation of waste in makeshift containers such as tires, bricks, or basins promotes the proliferation of mosquitoes that carry diseases such as malaria, dengue fever, and yellow fever (*Anopheles, Aedes, Culex*) (Azrag and Mohammed, 2018; WHO, 2021).

Beyond its environmental and entomological dimensions, this issue also has social and behavioral dimensions. Waste management methods, risk perception, education levels, and hygiene practices directly influence the health vulnerability of populations (Adingra, 2018; UN-Habitat, 2022).

In peri-urban areas such as Bingerville, the lack of collective sanitation and weak community governance mechanisms exacerbate environmental problems, compromising the achievement of Sustainable Development Goal 6 (SDG 6): "Ensure access to water and sanitation for all and ensure sustainable water resource management" (UN-Habitat, 2022).

This study therefore takes an interdisciplinary approach combining sanitation, entomology, and sociology to analyze the interactions between residues from cassava processing, the quality of the sanitary environment, and public health risks. This integrated approach contributes to a better understanding of the health impacts of urban agri-food activities and offers avenues for action for the sustainable management of artisanal sanitation in West African contexts.

Materials and Methods

Study area

The study was conducted in the municipality of Bingerville, located 18 km east of Abidjan (Côte d'Ivoire), between latitudes 5°35' and 5°37' N and longitudes 3°87' and 3°90' W. This municipality, covering an area of approximately 10,200 hectares, belongs to the Autonomous District of Abidjan. It is bordered to the east by the department of Alépé, to the west by the municipality of Cocody, to the north by Anyama, and to the south by Grand-Bassam (Monssou *et al.,* 2016). The climate is humid sub-equatorial, marked by two rainy seasons and two dry seasons, which promotes water stagnation and the proliferation of insect vectors.

The study focused on four areas representative of artisanal "attiéké" production: Akouai-Santai, Adjamé-Bingerville, Adjin, and Harris.

These localities, populated mainly by Ebrié communities, are home to the main cassava processing workshops and are characterized by:

- Rapid and unplanned urbanization;
- Lack of a collective drainage network;
- Illegal dumping of waste and uncontrolled effluent discharge.

Field equipment

The geographical survey was carried out using a Garmin 64S GPS device, a digital camera, gloves, and a tape measure to identify and characterize environmental factors (standing water, garbage deposits, cassava effluent).

Water sampling equipment

Wastewater and effluent samples were collected using ladles, clean containers, sterile bottles, and a flambéro for sterilization between each sample.

Household questionnaire

A questionnaire structured into five sections (basic information, wastewater management, excreta management, cassava residue management, health profile) was administered to 171 households, including 58 “attiéké” producers.

This sample size was chosen based on the application of Cochran's formula (1977) for a population of over 10,000 inhabitants, with a confidence level of 95% and a margin of error of 7.5%, which is widely used in urban health surveys (Sphere, 2018).

Entomological data

The entomological survey consisted of locating, identifying, and counting larval breeding sites in the four neighborhoods, distinguishing between *Aedes*, Culex, and *Anopheles* larvae. No larval index was calculated, as the study was based on direct counting of breeding sites.

Microbiological analyses

The analysis focused on wastewater and cassava effluent samples. They were carried out in accordance with ISO 9308-1:2014 for *Escherichia coli* (*E. coli*), ISO 6579-1:2017 for *Salmonella spp*., ISO 7932:2004 for *Bacillus cereus*. The results were expressed in CFU/mL and compared to the WHO guideline values for non-potable water (≤ 100 CFU/mL; WHO, 2012). The analysis targeted the presence of bacteria indicative of fecal and food contamination: *E. coli*, *Salmonella spp*., and *Bacillus cereus*.

Geographic survey

This involved systematically surveying the study areas to identify environmental factors related to “attiéké” production and domestic waste.

Entomological survey

Manual counting of larval breeding sites was carried out at the same sites as the geographical survey. Each breeding site was described according to its type, location, and the presence or absence of larvae. Larval breeding sites were identified in stagnant water found in tires, open containers, bricks, or depressions in the ground.

Household survey

The questionnaire, administered in French and the local language, was structured in five sections: (i) general household characteristics; (ii) wastewater management; (iii) excreta management; and household waste; (iv) cassava residue management (solid waste and effluents); (v) household health profile. The interview was conducted face-to-face with the head of the household or an adult over the age of 18, in accordance with Statistics Canada (2010) recommendations for obtaining reliable data. Households were selected at random from those located within a 100-meter radius of the production sites.

Microbiological analyses

Microbiological analyses were performed in accordance with internationally recognized standard protocols. The detection and enumeration of Escherichia coli followed ISO 9308-1:2014, which is based on the inoculation of samples on TBX medium and incubation at 44°C to select characteristic thermo tolerant bacteria. The identification of *Salmonella spp*. was conducted in accordance with ISO 6579-1:2017, involving a series of steps including pre-enrichment, selective enrichment, isolation on specific media, and then identification and biochemical confirmation of typical colonies. The enumeration of *Bacillus cereus* was carried out in accordance with ISO 7932:2004, based on surface seeding on MOSSEL medium and incubation in aerobic conditions at 30°C to allow the expression of characteristic colonies.

The results were expressed in colony-forming units per milliliter (CFU/mL). Their interpretation was based on the indicative thresholds proposed by the World Health Organization (WHO) for water not intended for human consumption, which consider a concentration of less than or equal to 100 CFU/mL to be an acceptable level for non-potable exposure (WHO, 2012).

This comparison made it possible to assess the level of microbiological contamination associated with local effluent discharge practices.

Data processing and analysis

The data were entered into EpiData, processed in Excel, and analyzed using descriptive statistics. The interpretation sought to establish links between domestic practices, environmental factors, the presence of larval breeding sites, and health risks.

Results and Discussion

Spatial distribution of "attiéké" production sites

The analysis identified a high concentration of "attiéké" production sites in four main areas of the municipality of Bingerville: Adjin, Akouai-Santai, Adjamé-Bingerville, and Harris. Production is organized either in producer groups or family units. A total of 39 production sites were identified, 11 of which belong to groups and 28 to individual producers. The Akouai-Santai and Adjamé-Bingerville neighborhoods account for the majority of these activities, representing 43% and 34% of the sites listed, respectively. The Adjin and Harris neighborhoods have fewer sites, but are still involved in the activity.

These results show a polarization of "attiéké" production in the most densely populated areas, where the activity is a structuring element of the local socio-economic fabric. Table I presents a detailed breakdown of the different types of sites by location.

Sociodemographic profile and environmental characteristics of households

Sociodemographic profile of respondents

The household survey included 171 households, 58 of which were involved in "attiéké" production (34%). The majority of respondents were women (79.87%), highlighting their central role in this activity. Approximately 51% of respondents were from Bingerville.

There was considerable diversity in terms of educational attainment: 58% of respondents had attended school, with 43% having completed higher education, 29.31% secondary education, and 25.86% primary education. The majority of households lived in family compounds (48%), followed by low-cost housing (31%) and communal compounds (18%).

Environmental and health characteristics of "attiéké" production areas

Household waste management

The majority of households store their waste in trash cans (82%). Others use bags (10%) or various containers (4%). A minority (2.51%) have no storage equipment. Waste is stored either in the yard (61.63%) or outside (36.47%).

Management of cassava residues

Households producing "attiéké" generate solid residues such as cassava peelings and fibers. The 37 deposits observed show that 44.82% of households store residues in trash cans, 18.96% in bags, 10.34% without any equipment, and 25.87% dump them directly in illegal dumps.

Wastewater management

A total of 57 stagnant water points were identified in the neighborhoods studied. Wastewater from "attiéké" production is mainly discharged into ravines (44%) or the street (36%).

Other options include gutters (13%), septic tanks (3%), courtyards (3%), and cesspools (1%). Six drainage pipes were observed, three of which were faulty.

Excreta management

Most households have a latrine (95.6%). Approximately 61.40% dispose of their excreta in a septic tank, 24.56% in a cesspool, and a minority continue to dispose of excreta in inappropriate places (streets, nature). Approximately 50.94% of households have had their septic tanks emptied.

Health profile, entomological risks, and distribution of environmental factors

Household health characteristics

The most commonly reported diseases are malaria (77.98%) and typhoid fever (10.06%). Nearly 69% of respondents attribute these diseases to unsanitary conditions: garbage dumps, poor sewage disposal, and "attiéké" effluent. According to households, 15.72% of diseases are linked to inadequate management of cassava effluent and 30.18% to solid waste from production. Public hospitals are the primary source of treatment (47.79%).

Entomological risks associated with larval breeding sites

The entomological study identified 1,266 larval breeding sites in the four neighborhoods. The Akouai-Santai neighborhood has the highest concentration of breeding sites (808), followed by Adjamé-Bingerville (281), Adjin (150), and Harris (27).

Overall and neighborhood counts

Table II shows the distribution of the 1,266 larval breeding sites identified in four neighborhoods in the municipality of Bingerville, distinguishing between the three main genera of mosquitoes identified: *Aedes*, *Anopheles*, and *Culex*. The analysis highlights significant variations between neighborhoods, revealing different vector risks.

The Akouai-Santai neighborhood accounts for almost all of the breeding sites identified (63.8% of the total). The following were observed there:

• 648 breeding sites positive for *Aedes*: the highest number in the study.

• 793 *Culex*-positive breeding sites: a particularly high concentration.

• 15 *Anopheles*-positive breeding sites: a significant presence.

This exceptional accumulation indicates that local environmental conditions (high presence of stagnant water, used tires, damp bricks, effluents) greatly favor the reproduction of mosquitoes, particularly *Aedes* (dengue, yellow fever, chikungunya) and *Culex* (viral fevers and nocturnal nuisances).

Akouai-Santai clearly stands out as the entomological hotspot of the municipality.

The Harris neighborhood has the highest presence of *Anopheles*. The Harris neighborhood has a lower number of breeding sites (2.1%), but one notable feature: 18 breeding sites tested positive for *Anopheles*, representing 44% of all *Anopheles* breeding sites identified in the study.

This suggests that local water conditions (standing water on the ground, temporary swampy areas, undrained alleys) provide favorable habitats for *Anopheles* larvae, the vector of malaria.

Despite a lower total number of breeding sites, the risk of malaria is proportionally higher.

The Adjamé-Bingerville neighborhood is overwhelmingly dominated by Culex. In Adjamé-Bingerville, 281 breeding sites were identified, including:

• 250 breeding sites for *Culex*: 89% of the neighborhood's breeding sites.

• 8 breeding sites for *Anopheles*, but no positive breeding sites for *Aedes*.

The strong predominance of *Culex* reflects environments rich in decomposing organic matter and polluted water, characteristic of areas where cassava effluent and wastewater stagnate along the alleys.

This neighborhood therefore presents a significant risk in terms of nocturnal nuisances and possible vector-borne diseases linked to Culex, even though the risk of dengue fever (*Aedes*) is much lower there.

The Adjin neighborhood has a high presence of *Aedes* and a total absence of *Anopheles*. A total of 150 breeding sites were identified in this neighborhood, including 146 breeding sites for *Aedes* (nearly 97%), 142 breeding sites for *Culex*, and no breeding sites for *Anopheles*.

This neighborhood has a specific epidemiological profile:

• Conditions that are highly favorable to the development of *Aedes* mosquitoes, likely due to the presence of containers (bricks, tires) and small pools of water.

• An absence of *Anopheles* mosquitoes, suggesting that local water characteristics do not correspond to the habitats preferred by this genus (clear, unpolluted water).

The strong presence of the *Aedes* and *Culex* genera indicates a significant risk of the emergence or persistence of vector-borne diseases (dengue fever, malaria, viral fevers), amplified by the environmental conditions observed around “attiéké” production sites.

The *Culex* genus is the most prevalent, with 1,203 breeding sites (approximately 95% of sites); *Aedes* is also widely present, with 825 breeding sites; *Anopheles*, although less prevalent (41 breeding sites), remains a concern due to its involvement in the transmission of malaria.

Types of larval breeding sites

Analysis of containers showed that 41% of breeding sites (520/1266) were located in used tires, 38% (468/1266) in bricks or brick fragments, and 21% in open containers, pits, wet vegetation, and various types of stagnant water.

Distribution of environmental risk factors

The assessment of the four neighborhoods studied revealed a significant concentration of environmental factors likely to promote the transmission of waterborne or vector-borne diseases. Three main categories of risk were identified: stagnant water, illegal garbage dumps, and cassava effluent outlets. Their distribution is not uniform and reflects land use dynamics, household density, and local sanitation practices.

Standing water

A total of 57 standing water sites were identified. The highest values were observed in Akouai-Santai (22 sites) and Harris (20 sites), where the presence of used tires and open containers promotes the long-term accumulation of water. In Adjamé-Bingerville (9 points) and Adjin (6 points), stagnant water mainly comes from domestic waste and runoff accumulated in bricks, gutters, or makeshift pits. These conditions create an environment conducive to the development of larval habitats, particularly for mosquitoes of the *Culex* and *Aedes* genera.

Illegal dumping of waste

Illegal dumping is a second major factor contributing to unsanitary conditions, with 37 sites identified in the study area. The Akouai-Santai neighborhood has the highest number of dumps (15), located directly near residential areas. The dumps in Adjamé-Bingerville (12) and Adjin (6) are located on the outskirts of residential areas, often in low-lying areas and near the lagoon. In Harris, four dumps have been identified, containing a wide variety of waste: household garbage, cassava residues, used appliances, and sometimes human waste. The lack of structured waste management contributes to odor nuisances, attracts insects and rodents, and degrades the living environment.

Cassava effluent spillways

Effluents from washing and pressing cassava are a specific health risk factor in “attiéké” production areas. A total of 22 effluent spillways were identified in the neighborhoods studied. The highest concentrations are found in Akouai-Santai (9 drains) and Adjamé-Bingerville (7), followed by Adjin (4) and Harris (2). Most of these drains are located directly in front of homes or in the immediate vicinity of production areas. Effluents often accumulate in tires, gutters, or makeshift pools, causing nuisances, local organic pollution, and an increase in larval breeding sites.

Summary of the spatial distribution of risks

The analysis shows that different risk factors frequently overlap in the same areas, particularly in Akouai-Santai and Harris, where the density of domestic activities and “attiéké” production sites encourages their accumulation. This co-presence of solid waste, stagnant water, and cassava effluent can contribute to an increase in mosquito populations and accentuate households' exposure to the pseudo-malarial, diarrheal, and skin diseases reported in the survey.

Thus, the distribution of environmental risks reflects the health vulnerability of the neighborhoods studied, which is directly linked to local waste management practices and the lack of adequate sanitation infrastructure.

Microbiological quality of wastewater and cassava effluent

Microbiological analysis of wastewater and cassava effluent samples collected in the three neighborhoods studied (Harris, Adjamé-Bingerville, and Akouai-Santai) quantified the presence of pollution indicator bacteria, particularly Escherichia coli and *Bacillus cereus*. The results, presented in Table III, showed extremely high concentrations of E. coli (>8×10^4 CFU/mL) in all wastewater samples, exceeding the WHO guideline threshold (≤ 100 CFU/mL for non-potable water). Cassava effluents also showed high values, ranging from 1.3×10^3 CFU/mL to 2.2×10^4 CFU/mL depending on the neighborhood.

Bacillus cereus concentrations were low (<100 CFU/mL) for all matrices analyzed. No samples revealed the presence of *Salmonella spp*.

These results indicate high microbiological contamination, reflecting the influence of effluents and stagnant water on the immediate environment.

Level of exposure of populations to health risks

The exposure of populations to pseudo-malarial and diarrheal diseases varies depending on the neighborhood.

The Akouai-Santai and Harris neighborhoods have the highest levels of exposure, with proportions of pseudo-malarial cases reaching 88% and 62%, respectively.

Figure.1 Overview of the study area (Loba, 2010)

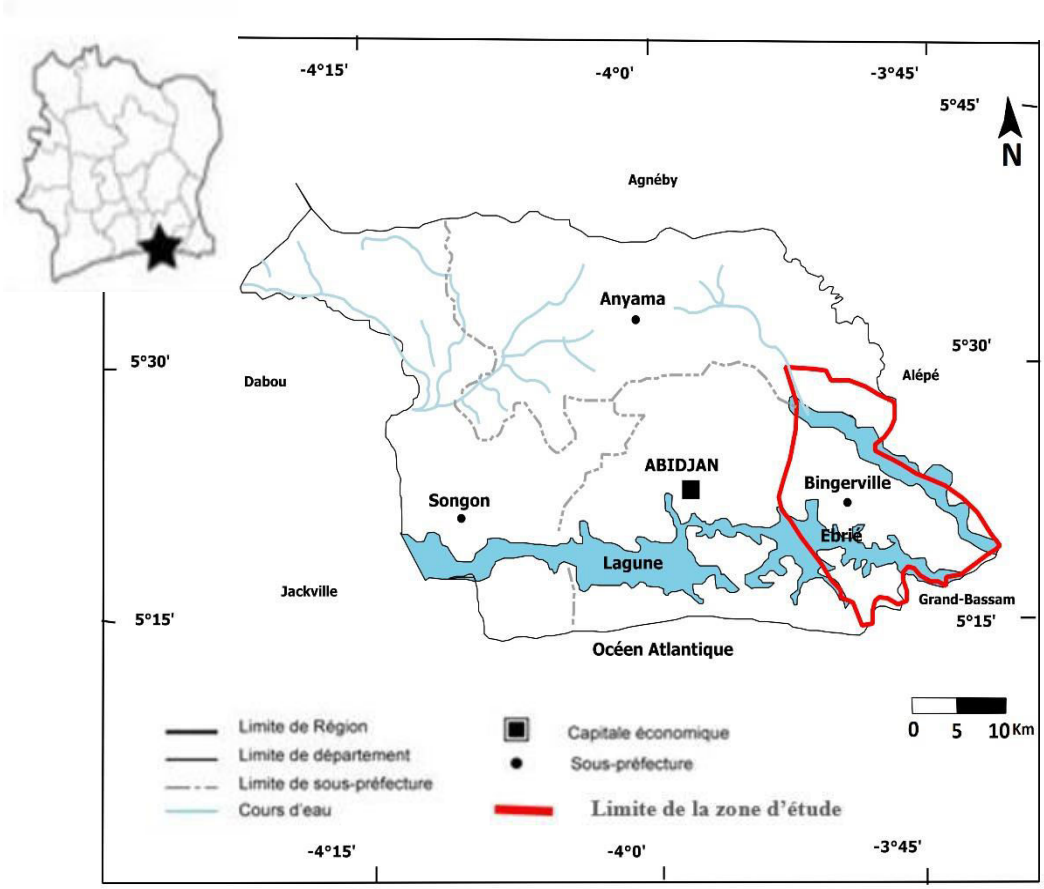

Table.1 Distribution of "attiéké" production sites by neighborhood

Neighborhoods	Group sites	Individual sites	Total
Akouai-Santai	5	14	19
Adjamé-Bingerville	2	10	12
Adjin	1	4	5
Harris	3	0	3
Total	11	28	39

Table.2 Count of larval habitats by type and neighborhood

Neighborhood	*Aedes*	*Anopheles*	*Culex*	Total vacation rentals by neighborhood
Akouai-Santai	648	15	793	808
Harris	27	18	18	27
Adjamé-Bingerville	0	8	250	281
Adjin	150	0	142	150
Total vacation rentals by neighborhood	825	41	1203	1266

Table.3 Average concentration of *E. coli*, *Bacillus cereus* (Bc), and *Salmonella spp.* in Wastewater and cassava effluents

Neighborhood	*E. coli* (UFC/mL) Wastewater	*E. coli* (UFC/mL) Effluents	Bc (UFC/mL) Wastewater	Bc (UFC/mL) Effluents	*Salmonella* Wastewater	*Salmonella* Effluents
Harris	$> 8\times10^4$	$2{,}2\times10^4$	< 100	< 100	Absence	Absence
Adjamé-Bingerville	$> 8\times10^4$	$< 3\times10^2$	< 100	< 100	Absence	Absence
Akouai-Santai	$> 8\times10^4$	$1{,}3\times10^3$	< 100	< 100	Absence	Absence
Threshold OMS	≤ 100 UFC/mL	≤ 100 UFC/mL	≤ 100 UFC/mL	≤ 100 UFC/mL	—	—

In the Adjamé-Bingerville and Adjin neighborhoods, prevalence is more moderate (55.55% and 57.69%). However, cases of typhoid fever and diarrhea have been reported in three neighborhoods (Akouai-Santai, Adjamé-Bingerville, Harris), while no cases have been reported in Adjin. The most exposed neighborhoods have a combination of stagnant water, garbage dumps, and cassava effluent, concentrated in the immediate vicinity of homes and production sites.

Environmental and health dynamics related to "attiéké" production

The results of this study show that "attiéké" production is a major factor in the deterioration of the sanitary environment in the neighborhoods studied in Bingerville.

The various production sites, whether individual or grouped together, simultaneously generate liquid effluents, solid residues, and conditions conducive to the accumulation of stagnant water. This finding is consistent with work carried out in other contexts.

African urban or peri-urban areas, where artisanal food processing activities produce unmanaged waste, accelerating the deterioration of local hygiene conditions (Niyongabo *et al.,* 2021; Kouassi *et al.,* 2020).

Environmental degradation and waste management: a system under pressure

The majority of attiéké-producing households discharge their effluents into the immediate environment (streets, ravines, gutters). These effluents, rich in organic matter and cyanuric compounds from cassava, can cause pollution of soil, surface water, or domestic wastewater (Ubalua, 2007; Da Silva *et al.,* 2019). Microbiological results confirm the presence of significant *E. coli* contamination, indicating a significant risk of fecal pollution. The concentrations observed (>8×10^4 CFU/mL for some wastewater) far exceed the WHO recommended thresholds for non-potable water, indicating a highly contaminated environment.

Solid residues from processing (skins, fibers, pulp) are sometimes stored on the ground or disposed of in illegal dumps, contributing to waste accumulation and promoting unsanitary conditions. These practices reflect the structural inadequacies of waste management in rapidly growing urban areas, which are frequently reported in West Africa (UN-Habitat, 2020). They also reflect the weakness or absence of adequate municipal services in peri-urban neighborhoods.

Stagnant water and proliferation of larval habitats

The presence of 1,266 larval habitats, including more than 41% in tires and 38% in bricks, shows that attiéké production residues and practices contribute significantly to the creation of ecological niches favorable to mosquitoes. These results confirm that abandoned solid waste, when it retains water, is one of the main drivers of mosquito proliferation in urban areas (WHO, 2021; Barrera *et al.,* 2018).

The overwhelming dominance of the *Aedes* and *Culex* genera in all neighborhoods is a worrying sign for public health.

• The genus *Aedes*, mainly found in tires and containers, is the primary vector for dengue, chikungunya, and Zika.

• The genus Culex, which is very abundant in water laden with organic matter, can transmit lymphatic filariasis and is a major nuisance in dense and unsanitary environments.

The absence of larval evidence does not preclude the conclusion that there is a high risk, as the density of the

breeding sites identified far exceeds the thresholds considered favorable for outbreaks according to the WHO (WHO, 2021). The concentration of breeding sites near "attiéké" production areas suggests a direct link between this activity and the increase in entomological nuisance.

Health impacts: perceived diseases and interrelated risks

The diseases most commonly reported by households were pseudo-malarial episodes (56–88% depending on the neighborhood) and typhoid fever.

These trends are consistent with common observations in environments where stagnant water, organic pollution, and fermentable waste coexist (Assoko *et al.,* 2020). The high prevalence of perceived malaria, particularly in Akouai-Santai (88%), may be associated with:

• The very high density of larval breeding sites in this neighborhood,

• The proximity of breeding sites identified around homes,

• Precarious living conditions (open family courtyards, lack of drainage),

• Poor management of wastewater and food waste.

Typhoid fever and diarrhea, although less common, correspond to the microbiological profiles observed in the effluents, particularly the presence of *E. coli* and *Bacillus cereus*. The absence of *Salmonella spp*. in the samples does not rule out a health risk, as the unsanitary conditions identified remain compatible with the fecal-oral transmission of waterborne diseases.

A multidimensional health risk

This study highlights a strong interaction between domestic practices, food processing residues, insect proliferation, socioeconomic conditions, and perceived health risks.

This model reinforces the concept of integrated risk, according to which biological, environmental, and social factors form a system of combined vulnerability, a mechanism widely described in integrated approaches to WASH and urban health (Cumming *et al.,* 2019; Wolf *et al.,* 2023).

Integrated WASH–Entomology–Sociology Approach and Implications for Sanitation Management

Interactions between sanitation practices, entomological risks, and social dynamics

The results of this study reveal that local waste, water, and effluent management practices directly influence vector proliferation and, consequently, households' exposure to health risks. This interdependence is typical of precarious urban environments where infrastructure is limited and behaviors are largely dictated by socioeconomic constraints (Wolf *et al.,* 2023; Cumming and Curtis, 2020).

The high density of breeding sites observed, particularly in Akouai-Santai, shows that uncollected solid waste, cassava effluent, and stagnant water form an environmental continuum that is particularly conducive to mosquito proliferation. This confirms research conducted in urban Africa, which found that discarded tires, abandoned plastics, and domestic water are the main larval reservoirs for *Aedes* and *Culex* (Barrera *et al.,* 2019).

The predominance of the *Culex* genus in waters rich in organic matter is also significant, with cassava effluents, loaded with starch and carbon, creating ideal micro-niches, as already observed in other contexts in West Africa (Oyewole and Awolola, 2021). At the same time, social representations and lifestyles strongly influence how households manage their waste and wastewater. In this study, the majority of respondents attribute perceived diseases, such as malaria, diarrhea, and typhoid fever, to visible factors of unsanitary conditions, reflecting an intuitive but incomplete understanding of health risks.

Social science research on African cities highlights that households adjust their practices according to the available infrastructure, that food waste management often relies on individual or community initiatives rather than municipal services, and that unsanitary conditions become normalized when no alternative is offered (Jaffré and Olivier de Sardan, 2020; Morin *et al.,* 2021). This normalization contributes to the persistence of environmental and health risks and reinforces the structural vulnerability of populations.

Implications for community-based sanitation management

The results of this study highlight the need for a structured community-based approach to achieve sustainable improvements in sanitation in "attiéké" production areas. Appropriate management of organic waste from cassava processing, combined with the installation of simple effluent pretreatment systems and better supervision of food production areas, appears essential to limit pollutant discharges and reduce the proliferation of larval breeding sites. In several comparable contexts, decentralized or community sanitation models (including settling tanks, filtration systems, and artisanal biofilters) have proven effective in reducing the organic load of effluents and mitigating environmental risks (Tendongho *et al.,* 2022; WHO/UNICEF JMP, 2023). This study also confirms that sanitation interventions in urban areas cannot be limited to sectoral approaches; only integrated actions combining sanitation, environmental hygiene, supervised management of food processing activities, and community vector control can reduce larval breeding sites and associated diseases, as has already been demonstrated by several combined programs implemented in similar urban environments (Achee *et al.,* 2019). Such an integrated WASH–health–entomology approach is therefore an essential lever for mitigating health risks in the neighborhoods concerned.

Implications for public policy in West Africa

The findings of this study have major implications for public policy on environmental health in West African countries, where artisanal cassava processing and rapid expansion of peri-urban areas are creating similar challenges. The structuring and supervision of "attiéké" production sites (as well as other cassava derivatives present in the region) appear to be a priority, requiring the development of harmonized regulatory frameworks, the adoption of hygiene standards adapted to local realities, the introduction of regular health checks, and capacity building for producers through targeted training. In addition, improving the management of solid waste and effluents from these activities is a challenge shared by many West African municipalities; they would benefit from developing dedicated collection points, providing appropriate containers, promoting the recovery of cassava residues (particularly through composting or processing for animal feed), and encouraging local pre-treatment solutions such as settling tanks or sand-carbon filters. The fight against associated health risks must also be based on strengthened inter-institutional cooperation, involving national sanitation services, local authorities, ministries of health, entomological surveillance structures, and community organizations. Successful experiences documented in several African cities, where synergies between local actors, public institutions, and NGOs have significantly improved environmental hygiene and reduced vector risks (M'Ba *et al.,* 2023), show that a coordinated, cross-border approach could be a promising way to address the challenges shared by countries in the subregion.

This study highlighted the significant influence of residues from "attiéké" production on the quality of the sanitary environment in several neighborhoods of the municipality of Bingerville, Côte d'Ivoire. The results show that the combination of untreated cassava effluents, abandoned solid residues, stagnant water, and inappropriate domestic practices promotes the degradation of the immediate environment and creates conditions conducive to the proliferation of mosquitoes, particularly of the *Aedes* and *Culex* genera. The microbiological contamination of wastewater and effluents, marked by high concentrations of *E. coli* and *Bacillus cereus*, increases the risk of waterborne diseases, while the diseases perceived by households—mainly malaria and typhoid fever—reflect a particularly worrying health exposure context.

Beyond the specific case of Bingerville, this study highlights dynamics characteristic of urban and peri-urban environments in West Africa, where rapid urbanization, inadequate WASH infrastructure, and unregulated artisanal activities contribute to increasing health vulnerability. The integrated approach used here shows that issues of sanitation, entomological risks, and domestic behaviors cannot be analyzed separately; they interact in complex ways and require multisectoral interventions combining sanitation, environmental hygiene, organic waste management, and vector control.

Ultimately, the results highlight the need to strengthen public policies on the sustainable management of food processing residues, the regulation of "attiéké" production areas, and the implementation of community-based effluent treatment solutions. They also call for increased cooperation between municipalities, sanitation technical services, public health structures, and community actors. Future research should explore in greater detail the links between larval density, clinically confirmed diseases, the environmental toxicity of effluents, and the effectiveness of decentralized WASH

solutions adapted to local contexts. Such an approach would help promote sustainable sanitation that is socially acceptable and compatible with the objectives of healthy cities in West Africa.

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