GSC Biological and Pharmaceutical Sciences
eISSN: 2581-3250 CODEN (USA): GBPSC2
Cross Ref DOI: 10.30574/gscbps
Journal homepage: https://gscbps.gsconlinepress.com/

(RESEARCH ARTICLE)

Check for updates

SUSTAINABLE WASTEWATER MANAGEMENT AND WATERBORNE DISEASE VULNERABILITY AMONG CHILDREN UNDER FIVE IN TAHOUA, NIGER

KANE Rabé [1,*], ADAMOU ARIA Cheick Issouf [2], Mahaman Sani LAOUALI [3], IDI SAIDOU Sani [4], ABDOURAHAMANE ILLIASSOU Salamatou [5] and HABOU Rabiou [6]

[1] Higher Institute of Environment and Ecology, Department of Water and Fisheries, Hummay Salamna University of Diffa, P.O. Box 78, Diffa, Niger.
[2] Department of Water Engineering and Sanitation, National Water Institute, University of Abomey-Calavi, Benin Republic.
[3] Key Laboratory of Water Chemistry, Faculty of Science and Technology, Abdou Moumouni University of Niamey, P.O. Box 10662, Niamey, Niger.
[4] Department of Plant Production and Biodiversity, Faculty of Agronomic and Ecological Sciences, Hummay Salamna University of Diffa, P.O. Box 78, Diffa, Niger
[5] Faculty of Agronomic and Ecological Sciences, Hummay Salamna University of Diffa, P.O. Box 78, Diffa, Niger
[6] Faculty of Agronomic and Ecological Sciences, Hummay Salamna University of Diffa, P.O. Box 78, Diffa, Niger
* Corresponding Author; Email: kanerabe@gmail.com

ORCID Details
KANE Rabé: https://orcid.org/0000-0002-7900-9387
IDI SAIDOU Sani: https://orcid.org/0009-0004-2722-3092
ABDOURAHAMANE ILLIASSOU Salamatou: https://orcid.org/0000-0003-4414-4703
HABOU Rabiou: https://orcid.org/0000-0003-2490-6686

GSC Biological and Pharmaceutical Sciences, 2026, 37(01), 187–200

Publication history: Received on 09 September 2026; revised on 15 October 2026; accepted on 17 October 2026

Article DOI: https://doi.org/10.30574/gscbps.2026.37.1.0366

Copyright © 2026 Author(s) retain the copyright of this article. This article is published under the terms of the Creative Commons Attribution License 4.0

ABSTRACT

In Tahoua, access to safe water, adequate sanitation, and effective wastewater management remains a major concern. These conditions may increase exposure to contaminated water and environments, particularly among children under five years of age, who are more susceptible to waterborne diseases. This study aimed to analyze waterborne disease morbidity among children under five years of age monitored at five Integrated Health Centers (IHCs) in Tahoua. We collected data through a survey of 360 households and a review of health records from January to August 2024. The results show that 78.33% of households dump wastewater on the street, exposing the population to serious sanitary risks. The most frequently reported diseases were malaria (41.94%) and diarrhea (36.11%), with children under five years of age accounting for 75% of reported cases. The spatiotemporal analysis revealed a concentration of malaria cases in the northern and western areas and of diarrhea cases in the southern and southwestern areas, with a morbidity peak during the rainy season (July–August). Statistical analysis confirmed a significant variation in malaria cases among months ($p = 0.025$), while Pearson correlations showed strong relationships between wastewater dumping on the street and diarrhea ($r = 0.829$) and dysentery ($r = 0.967$). Principal component analysis highlighted an association between

informal wastewater disposal practices and waterborne diseases, whereas the use of sumps appeared to be a protective factor. These findings underline the need to strengthen sanitation infrastructure, community awareness, and epidemiological monitoring, particularly in the most exposed areas.

Keywords: Domestic wastewater management; Waterborne diseases; Sanitation; Under-five children; Public health; Tahoua, Niger.

1 INTRODUCTION

Waterborne diseases remain one of the main threats to children's survival and development in low-income Sahelian countries. Worldwide, despite a substantial decline in morbidity and diarrhea since 1990, diarrheal diseases remain among the leading causes of death in children under five years of age, accounting for more than one million deaths in 2021. This reflects an unequally distributed burden in sub-Saharan Africa (Bill & Foundation, 2024). These diseases include illnesses directly linked to contaminated water consumption, inadequate sanitation, and insufficient hygiene. According to a joint report by WHO and UNICEF (2021), inadequate WASH services are responsible for about 842,000 deaths annually worldwide, representing approximately 3.6% of the global disease burden measured in disability-adjusted life years. The same report indicates that 525,000 child deaths could be prevented every year through interventions that improve access to WASH services (WHO & UNICEF, 2021). In sub-Saharan Africa, these challenges are exacerbated by rapid demographic growth, urbanization, and limited financial resources (BAD, 2021).

In the Nigerien context, only 13% of inhabitants have access to improved sanitation, while 71% regularly practice open defecation (WHO, 2023). Although malaria is a vector-borne disease, it is directly linked to poor water conditions that favor mosquito proliferation. The study on malaria indicators in Niger reported that 29% of children aged 6–59 months tested positive for malaria (INS, 2022). This disease accounts for 28% of medical consultations and 50% of registered deaths in health centers, with children under five years of age being the most affected group (WHO, 2023). The city of Tahoua faces similar sanitary challenges, including rapid urbanization, insufficient WASH infrastructure, and a high prevalence of waterborne diseases. In this context, where access to WASH services remains limited, children under five years of age remain particularly vulnerable to waterborne diseases, which represent a major cause of morbidity and mortality. This study aimed to analyze morbidity associated with waterborne diseases among children under five years of age in the Integrated Health Centers (IHCs) of Tahoua in order to describe their frequency and spatiotemporal distribution and to identify contextual factors that may influence their occurrence.

2 MATERIALS AND METHODS

2.1 Study area

The city of Tahoua is located between the communes of Kalfou and Tahoua, in the department of Tahoua (Fig. 1). It covers an area of 363 km^2 and is located between 5°02′ and 5°23′ E longitude and 14°45′ and 15°01′ N latitude (PDC Tahoua, 2016).

Located about 550 km east of Niamey, the capital city, Tahoua shares borders with the rural commune of Affala to the north, the rural commune of Bambaye to the south, the rural commune of Kalfou to the east, and the rural commune of Takanamatt to the west (PDC Tahoua, 2016). Administratively, the urban commune of Tahoua is now divided into two districts comprising 22 neighborhoods, 18 of which are official.

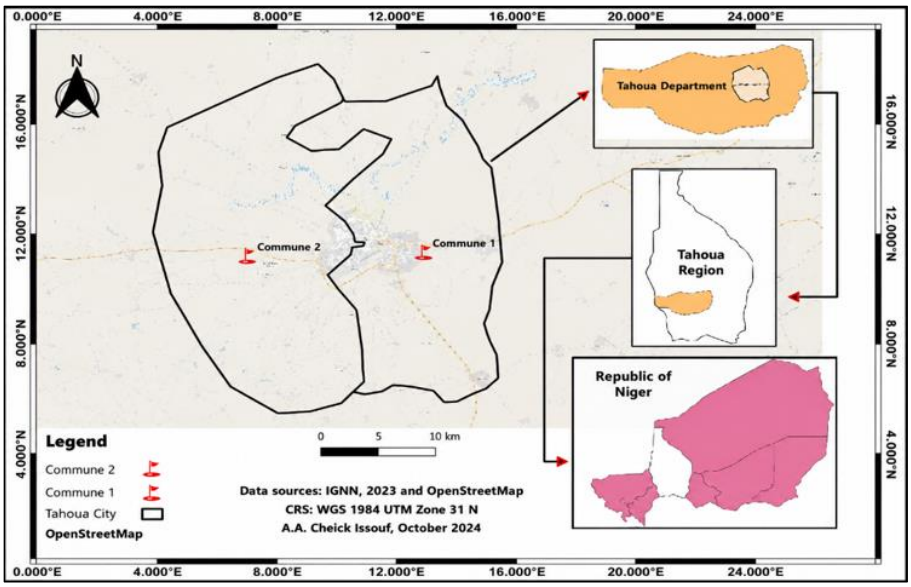


Figure 1: Location of the study area (Aria, 2024)

2.2 Methodological approach

2.2.1 Sampling

The household sampling method was based on the 2024 population projection from the General Population and Housing Census (RGPH, 2024).

The projection considered the reference population in 2012, the population growth rate, and the number of years between the reference and projection years. Thus, the following formula was used to estimate the population of the city of Tahoua:

$$\mathbf{P_n = P_0 \times (1 + \alpha)^n}$$

Where:

- Pn: population in the projection year;
- P0: population in the reference year;
- r: population growth rate;
- n: number of years between Pn and P0.

The reference population of the city of Tahoua according to the 2012 RGPH was 117,826 inhabitants, with a population growth rate of 4.2%.

Therefore:

- $P_{2024} = 117826 \times (1 + 0.042)^{12}$
- P_{2024} = 193043 inhabitants

To obtain the total number of households in the study area, we used the average number of inhabitants per household, which is 7 persons for the Tahoua region according to the National Statistical Institute (INS). The ratio between the estimated population and the average number of persons per household gives the estimated number of households in the city of Tahoua.

Therefore :

$$\text{Number of households} = \frac{\text{Current estimated population}}{\text{Average number of persons per household}}$$

$$\text{Number of households} = \frac{193043}{7}$$

Total estimated number of households in 2024 = 27,578.

A random sampling technique was chosen. In this case, each household had a measurable probability of being selected. Thus, the formula presented by Rea et al. (1997) was used to calculate the sample size. The formula is:

$$n = \frac{t_p{}^2 \times P(1-P) \times N}{t_p{}^2 \times P(1-P) + (N-1) \times y^2}$$

Where:

- n: sample size;
- N: population (number of households), real or estimated;
- P: expected proportion of the population to respond (40%);
- tp: confidence interval;
- y: margin of error (Julien, 2018).

To ensure that the surveyed sample was representative and that reliable responses were obtained, we considered a confidence interval of 95% (1.96) and a margin of error of 5%.

By applying these parameters, we obtained:

$$n = \frac{1{,}96^2 \times 0{,}5(1-0{,}5) \times 27578}{1{,}96^2 \times 0{,}5(1-0{,}5) + (27578-1) \times 0{,}005^2}$$

n = 356 households, adjusted to 360.

2.2.2 Data collection

A descriptive and analytical cross-sectional survey was conducted using questionnaires. The questionnaire was used to collect data on socioeconomic and sociodemographic characteristics, access to water, wastewater management, and excreta management. It was structured into sections with multiple-choice and single-choice questions and administered using KoboCollect.

Existing individual sanitation facilities were identified using QField. In total, the 360 surveyed households were located in the two districts of the city, with two neighborhoods per district (eight neighborhoods in total), as shown in Fig. 2. A balanced distribution of households was adopted, with 45 households per neighborhood, because domestic wastewater and excreta management practices were considered relatively similar among the neighborhoods.

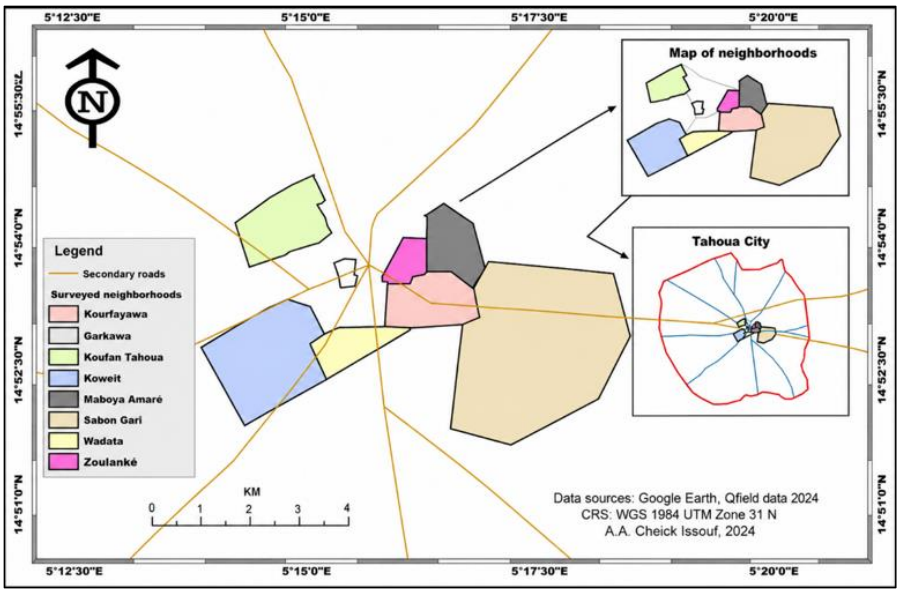


Figure 2: Surveyed neighborhoods (Aria, 2024)

2.2.3 Morbidity data collection

Morbidity data were collected from five IHCs in the city, specifically concerning the number of waterborne disease cases (malaria, diarrhea, and dysentery) registered at the centers from January to August 2024. These health centers were located in different neighborhoods included in the study. Only five of the eight targeted neighborhoods had IHCs (three in District 1 and two in District 2).

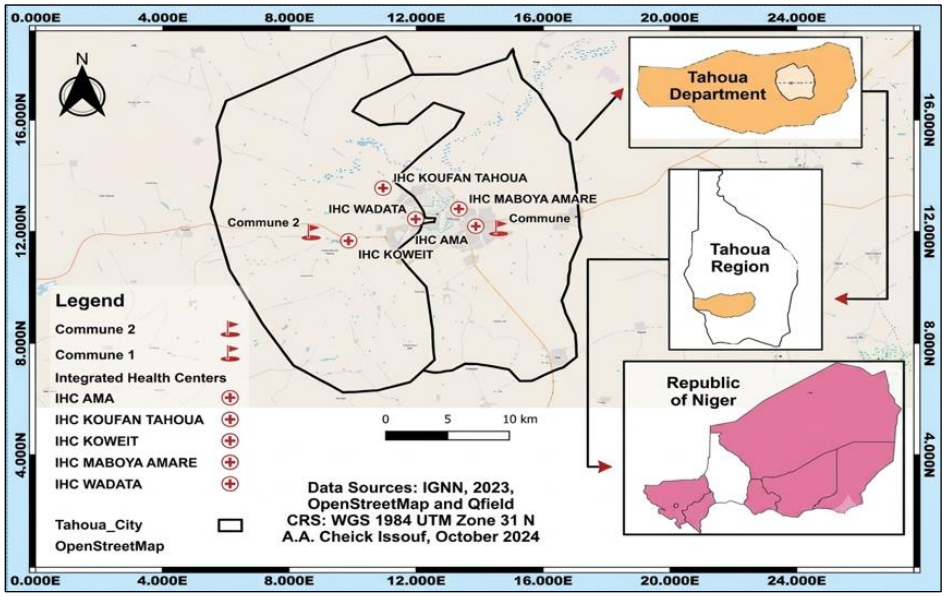


Figure 3: Map of the Integrated Health Centers

2.2.4 Interviews with IHC personnel

Through guided, semi-structured interviews, information on environmental and sanitary issues, partnerships, and wastewater management perspectives was collected from the persons in charge of the health centers.

2.2.5 Data processing and analysis

The following tools were used for data processing and analysis:

- Word: word processing and data analysis;
- Excel: dynamic cross-tabulations, tables, and graphs;
- ArcGIS: mapping of infrastructure, neighborhoods, and other maps;
- QGIS: import and organization of data collected using QField.

3 RESULTS AND DISCUSSION

3.1 Domestic wastewater evacuation modes

The lack of a common sanitation system in the city and poor wastewater management practices in some households result in a large proportion of wastewater being inadequately managed. Analysis of Fig. 4 shows that the majority of households (78.33%) dump their wastewater directly onto the street. This practice causes serious public health and hygiene problems. A further 16.39% of households dump their wastewater in the house yard, while only 5.28% use sumps.

This finding is comparable to that observed in N'djili, Democratic Republic of the Congo, where 64.44% of households dump their wastewater onto streets or into gutters (RISASI ETUTU et al., 2023). Similar trends have been reported in other Sahelian cities: in N'Djamena, Chad, almost 95% of households dump their wastewater without treatment (Mangueina et al., 2024), while in some peri-urban areas of the Sahel, including Ghana and Burkina Faso, more than 80% of wastewater is discharged into the environment (Compaoré et al., 2024). These comparisons confirm that Tahoua shares structural challenges with other African cities characterized by the absence of collective sanitation systems and the predominance of informal practices.

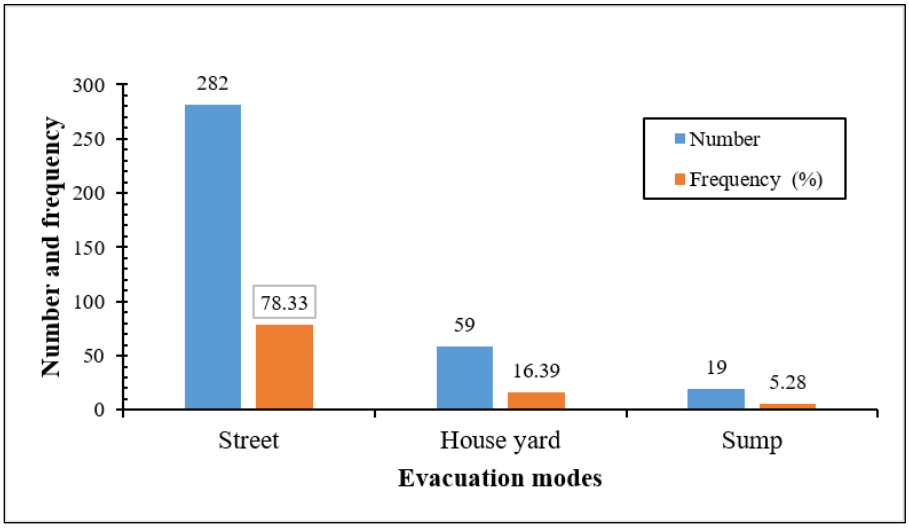


Figure 4: Domestic wastewater evacuation modes

3.2 Households' knowledge of waterborne diseases

Table 1 presents households' knowledge of waterborne diseases. The perceptions of the surveyed households show that the majority recognize malaria (41.94%) as a waterborne illness, associating it with water stagnation in neighborhoods that favors mosquito proliferation. Diarrhea is identified by 36.11% of households and is associated with the consumption of contaminated water, while vomiting is cited by 10.28% of households. Cholera and typhoid are cited by 4.44% and 0.56% of households, respectively.

On the other hand, a study conducted by SOW (2018) showed that helminth-related diseases were the most frequently cited (67%) by households, while diarrheal diseases were less frequently identified (28.70%). According to Bamba and N'Doli (2020), in Abobo, Côte d'Ivoire, populations are exposed to malaria (63.46%), typhoid (14.26%), acute respiratory infections (13.52%), and diarrheal diseases (9.66%).

Table 1: Households' knowledge on waterborne diseases

Diseases	Frequency (%)
Malaria	41.94%
Diarrhea	36.11%
Vomiting	10.28%
Cholera	4.44%
No idea	6.67%
Typhoid	0.56%
Total	100.00%

3.3 Households' perception of the relationship between poor wastewater and sludge management and health

Almost all households (88.61%) recognized that poor domestic wastewater and sludge disposal causes health risks. This finding highlights the importance of improving domestic wastewater and sludge disposal systems in the city to prevent adverse public health consequences. Only 4.17% of households did not perceive this relationship, while 7.22% did not know whether such a relationship exists (Fig. 5).

A study conducted in Ziguinchor, Senegal, revealed that almost all respondents believed that wastewater can cause diseases (95%). This finding indicates that the population is aware of sanitary risks (Aïssatou, 2021). Such awareness may be beneficial if it encourages the population to adopt appropriate wastewater management practices.

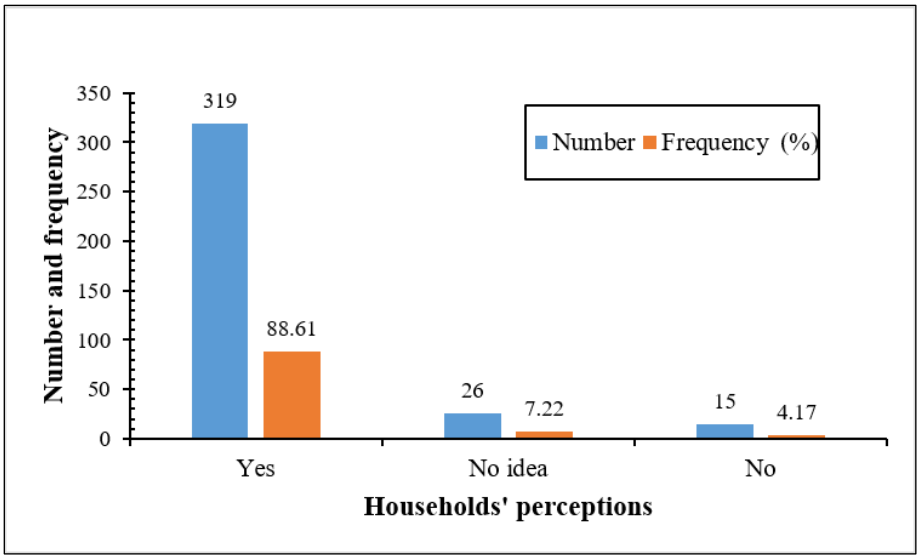


Figure 5: Households' perception of the relationship between poor wastewater and sludge management and health

3.4 Vulnerable population groups to waterborne diseases

Seventy-five percent of respondents reported that children under five years of age are the most affected by waterborne diseases because of their developing immune systems, frequent exposure to unsanitary environments, and difficulty adopting strict hygiene practices. Older people were also considered affected (16.11%), while adults were considered the least affected (1.39%); 1.11% of respondents indicated that some diseases can affect all age groups (Table 2). In the commune of Ziguinchor, Senegal, the most affected population categories were children (65%), pregnant women (11%), and older people (4%) (Aïssatou, 2021).

Table 2: Vulnerable population groups to waterborne diseases

Age groups	Observed number	Frequency (%)
Adults	5	1.39
No answer	23	6.39
All age groups	4	1.11
Older people	58	16.11
Children under five	270	75.00
Total	360	100

3.5 Distribution of total waterborne disease cases by IHC

Analysis of Fig. 6 shows a significant variation in the number of cases among the IHCs. IHC Wadata registered 1,055 cases, representing the highest disease burden during the study period, followed by IHC Koufan Tahoua (928 cases) and IHC Koweit (887 cases), which also had substantial disease burdens. IHC AMA and IHC Maboya Amare had lower disease burdens, with 521 and 486 cases, respectively.

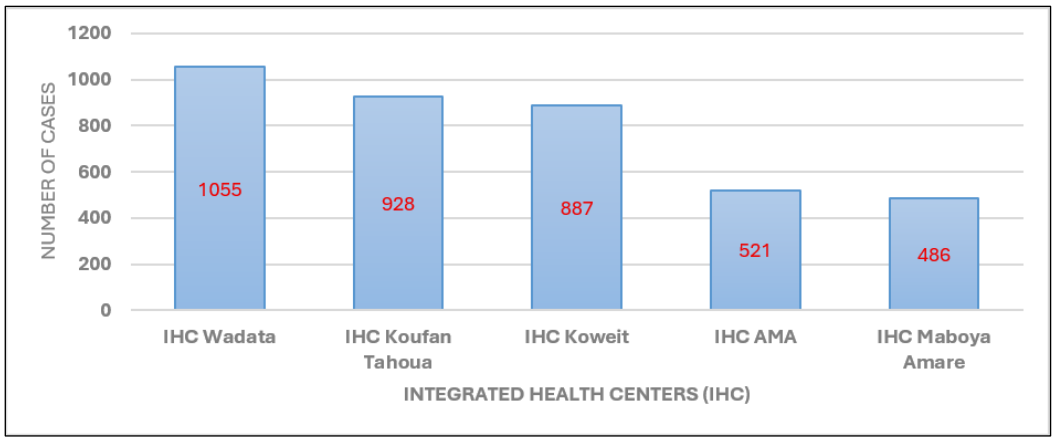


Figure 6: Total waterborne disease cases by IHC

3.6 Number of disease cases (malaria, diarrhea, and dysentery) by IHC

Analysis of the distribution of waterborne disease cases in the five IHCs (Fig. 7) reveals a predominance of malaria, particularly in IHC Koufan Tahoua (506 cases), Koweit (473 cases), AMA (411 cases), and Maboya Amare (302 cases). This trend indicates high exposure of populations to mosquito bites. However, the situation differs at IHC Wadata, where diarrhea predominates with 642 cases, exceeding malaria (235 cases) and dysentery (178 cases).

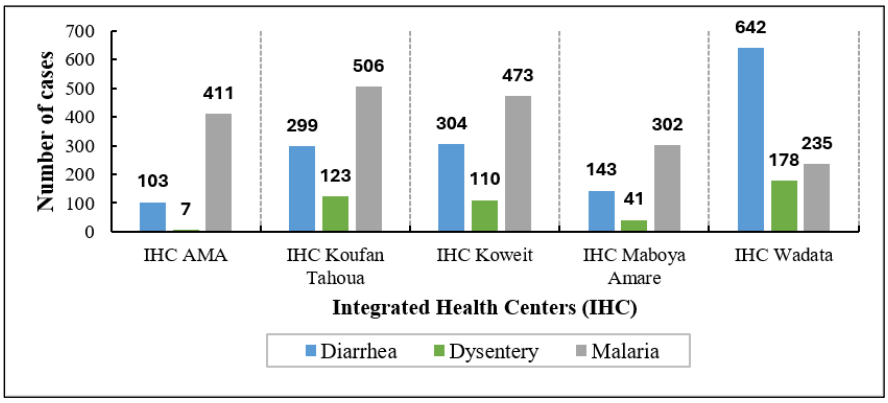


Figure 7: Number of disease cases by IHC

3.7 Monthly evolution of waterborne diseases in the IHCs

The monthly evolution of malaria, diarrhea, and dysentery cases (Fig. 8) shows a clear influence of seasonality on the morbidity associated with waterborne diseases. Diarrhea remained relatively stable between January and June (140–200 cases), followed by a notable increase in July and August (nearly 300 cases). Dysentery, although less frequent, showed occasional increases in March and August. Malaria remained the most concerning disease, rising from a moderate level at the beginning of the year (230 cases in January) to a peak in August (almost 800 cases), indicating increased mosquito proliferation during the rainy season. Overall, the results show that the rainy season (June–August) constitutes an important factor in the spread of waterborne diseases by simultaneously favoring water contamination and vector proliferation.

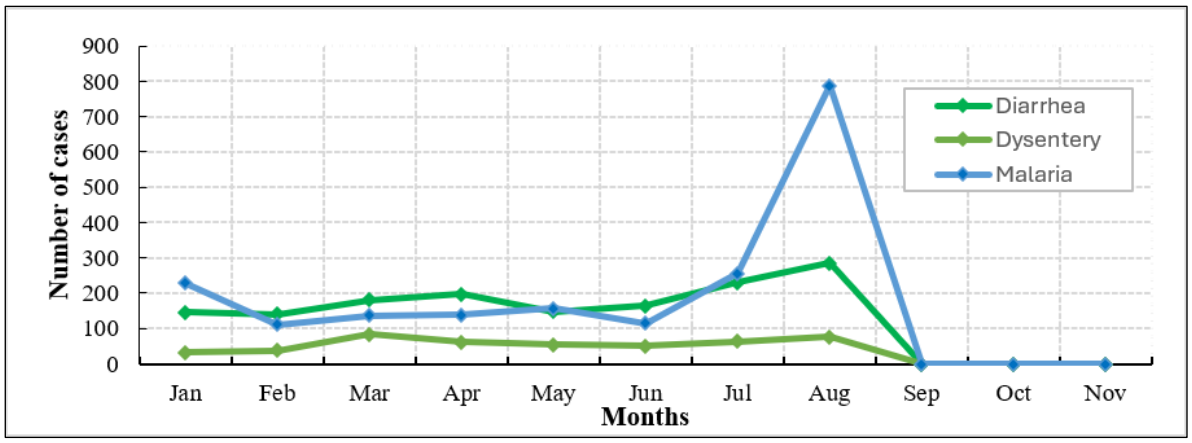


Figure 8: Monthly evolution of waterborne diseases

3.8 Spatial distribution of malaria among IHCs

Figure 9 illustrates the spatial distribution of malaria cases registered from June to August 2024 in the five IHCs. The analysis of the map shows marked spatial heterogeneity in the distribution of cases. The IHCs of Koufan Tahoua in the west and Koweit in the north recorded a large number of cases, ranging from 436 to 506, indicating a high malaria burden. IHC AMA in the east presents an intermediate situation, with the number of cases ranging from 367 to 436. In contrast, IHC Maboya Amare in the northeast and Wadata in the central part of the city recorded the lowest numbers of cases, ranging from 235 to 289. Overall, this distribution shows that malaria cases were more concentrated in the northwestern part of the city, while the central and northeastern areas were relatively less affected.

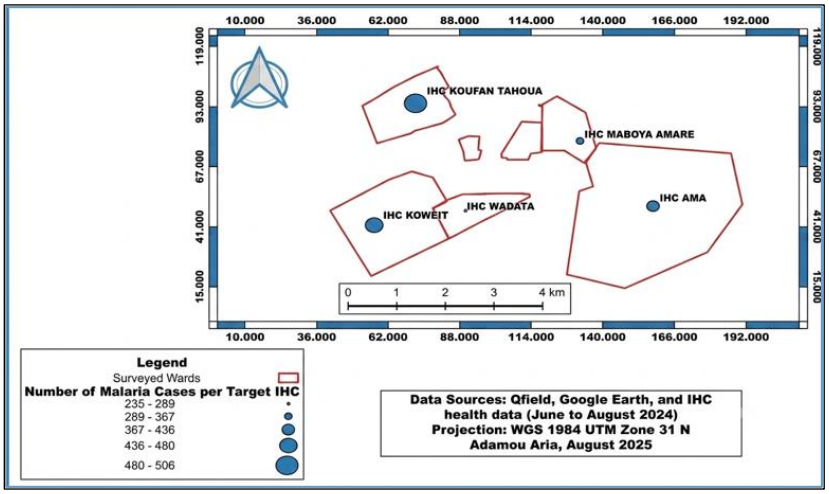


Figure 9: Spatial distribution of malaria among IHCs

3.9 Spatial distribution of diarrhea among IHCs

As shown in Fig. 10, a clear variation in diarrhea cases is observed among the different IHCs. The highest concentrations of cases are located in the western and southwestern areas of the city (IHC Koweit and Wadata), which recorded between 372 and 642 cases. These two IHCs represent the areas with the highest diarrhea burden. IHC Koufan Tahoua in the northwest and Maboya Amare in the northeast show moderate numbers of cases (237–372). IHC AMA, located in the extreme east, registers 103–135 diarrheal cases. In contrast, the spatial distribution of diarrheal diseases between 2015 and 2018 in the Bagoué region of Côte d'Ivoire revealed that the prevalence of diarrheal diseases was low throughout the region, except in Zaguinasso and Kassere in the central area and Kebi and Ouanzomon in the south. The prevalence of diarrhea was moderate in these localities (10–20% of cases) (Kpaka et al., 2020).

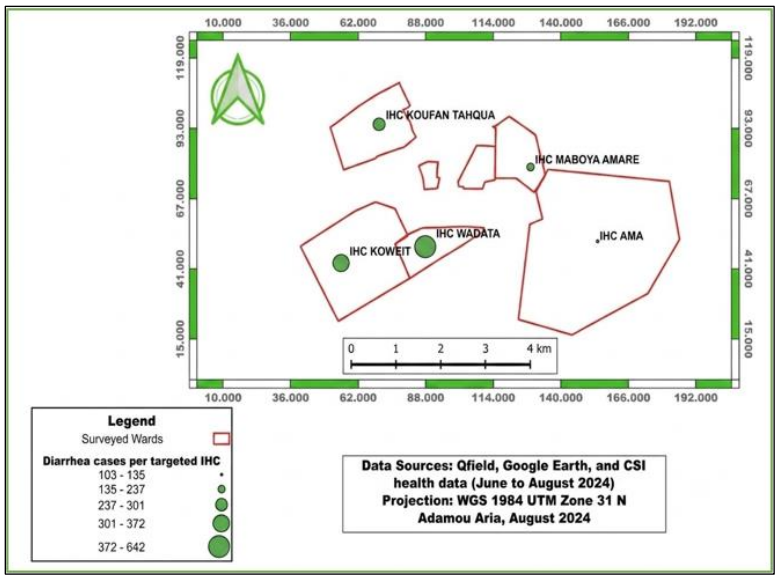


Figure 10: Spatial distribution of diarrhea among IHCs

3.10 Spatial distribution of dysentery among IHCs

Figure 11 presents the spatial distribution of dysentery cases among the IHCs from June to August 2024. The highest concentration was observed in the western area, particularly at IHC Wadata (134–178 cases) and IHC Koweit (82–115 cases). IHC Koufan Tahoua (northwest) and Maboya Amare (northeast) had intermediate dysentery burdens (34–82 cases), while IHC AMA in the southeast was the least affected area (7–34 cases).

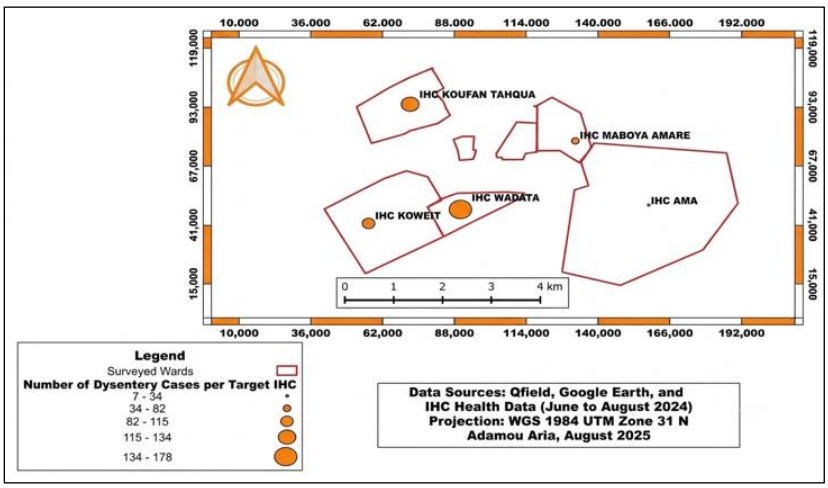


Figure 11: Spatial distribution of dysentery among IHCs

3.11 Statistical analysis

3.11.1 Kruskal–Wallis test

Given that the data on the number of waterborne disease cases (malaria, diarrhea, and dysentery) were not normally distributed, the Kruskal–Wallis test was used to compare the medians of the dependent variables (numbers of malaria, diarrhea, and dysentery cases) across the independent variable (month) to determine whether statistically significant differences existed among months. The hypotheses were tested at a significance level of 5% and a confidence level of 95%.

- H_0: all medians are equal;
- H_1: at least one median is different.

Table 3 presents the descriptive statistics from the Kruskal–Wallis test.

Table 3: Descriptive statistics from the Kruskal–Wallis test

descriptive Statistics							
		Malaria		Diarrhea		Dysentery	
Months	N	Median	Rank of mean	Median	Rank of mean	Median	Rank of mean
August	5	137	36.6	51.00	27.3	23	23.9
April	5	35	16.6	33.00	20.7	14	21.1
February	5	31	13.9	25.00	15.2	10	17.2
January	5	48	23.8	26.00	17.3	6	15.2
July	5	59	25.9	43.00	25.1	13	23.4
June	5	22	13.3	25	19.6	7	18.2
May	5	32	17.6	28	20	9	20.7
March	5	23	16.3	21	18.8	18	24.3
Global	40		20.5		20.5		20.5

Table 4 shows the results of the Kruskal–Wallis test conducted to compare the medians of waterborne disease cases across months. For malaria ($p = 0.026 < 0.05$), the H_1 hypothesis is accepted, indicating a significant difference in the distribution of malaria cases among months. Thus, the prevalence of malaria in the IHCs varies by month. For diarrhea and dysentery, with p-values of 0.778 and 0.895 (> 0.05), respectively, the H_0 hypothesis is accepted, indicating no statistically significant difference in their prevalence among months.

Table 4: Results of the Kruskal–Wallis test

	Waterborne diseases			**Method**
	Malaria	Diarrhea	Dysentery	Adjusted for number of the same value.
H Value	15.96	4.02	2.91	
P Value	0.025	0.777	0.894	
DL	7	7	7	

3.11.2 Relationship between waterborne diseases and domestic wastewater evacuation modes

3.11.2.1 Pearson correlation

The results of the Pearson correlation analysis between wastewater evacuation modes and waterborne diseases are presented in Table 5. The analysis highlights contrasting relationships between wastewater evacuation modes and waterborne diseases.

Table 5: Pearson correlation test

	House yard	**Sump**	**Street**	**Diarrhea**	**Dysentery**
Sump	0.028				
Street	-0.455	-0.903			
Diarrhea	-0.517	-0.681	0.829		
Dysentery	-0.527	-0.832	0.967	0.938	
Malaria	0.624	-0.325	0.021	-0.444	-0.178

The results show a very strong positive correlation between diarrhea and dysentery (r = 0.938), indicating a strong association between them and possible common hygiene-related causes. Similarly, dumping wastewater on the street shows strong positive correlations with diarrhea (r = 0.829) and dysentery (r = 0.967), suggesting that this evacuation

mode is associated with increased health risks. On the other hand, the use of sumps is negatively correlated with waterborne diseases (diarrhea: r = −0.681; dysentery: r = −0.832), indicating a possible protective association. Concerning malaria, the correlations with other variables are generally weak, except for a positive correlation with dumping wastewater in the house yard (r = 0.624), which may create an environment favorable to mosquito proliferation.

3.11.2.2 Principal Component Analysis (PCA)

Table 6 presents the variables' contributions to the first two principal components. The loading-vector analysis shows that on the first principal component (PC1), the variables Street (0.491), Diarrhea (0.482), and Dysentery (0.509) are positively correlated. In contrast, the variables Sump (−0.410) and House yard (−0.292) are negatively correlated with this axis. The second principal component (PC2) essentially opposes Malaria (−0.699) and House yard (−0.517), which are negatively correlated, to Sump (0.446), which makes a positive contribution. Thus, PC1 indicates an opposition between uncontrolled evacuation modes and some waterborne diseases, while PC2 highlights differences between conditions favoring malaria and the use of sumps.

Table 6: Variables' contributions to the first two principal components

Variables	PC1	PC2
House yard	-0.292	-0.517
Sump	-0.410	0.446
Street	0.491	-0.175
Diarrhea	0.482	0.117
Dysentery	0.509	-0.045
Malaria	-0.121	-0.699

To visualize the relative influence of each variable on the principal components, a PCA biplot was performed. The variables' contributions to the components are represented in Fig. 12.

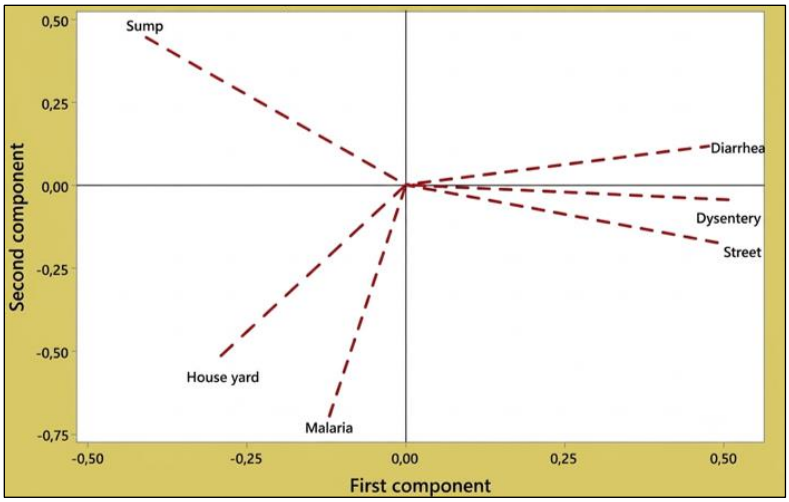


Figure 12: PCA biplot

This figure shows that dumping wastewater on the street is strongly associated with the occurrence of waterborne diseases such as diarrhea and dysentery. Wastewater dumping in the house yard is also correlated with malaria, probably because stagnant water favors mosquito proliferation. The use of sumps appears in opposition to these two profiles; its adoption may reduce exposure to diarrheal diseases and malaria by limiting water stagnation and uncontrolled dumping.

4 CONCLUSION

The results of the study confirm that waterborne diseases constitute a major public health problem in the city of Tahoua, particularly among children under five years of age, who represent the most vulnerable population. Poor domestic

wastewater management, particularly dumping wastewater on the street, may favor the spread of diseases such as malaria, diarrhea, and dysentery. The spatiotemporal analysis reveals marked geographic heterogeneity, with high morbidity rates in the western and northern neighborhoods, where population density and water stagnation are greater. These observations, supported by the statistical results, highlight the important role of wastewater evacuation modes in the occurrence of waterborne diseases, while the use of sumps appears to be a protective factor.

To sustainably reduce these risks, it is necessary to develop appropriate sanitation infrastructure, promote good hygiene practices, and strengthen epidemiological monitoring by targeting the most exposed areas. Thus, an integrated territorial approach combining sustainable wastewater management, health education, and urban planning appears essential to improve environmental health and reduce waterborne morbidity among children in the city of Tahoua.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Acknowledgments

The authors gratefully acknowledge the local authorities, households, and other stakeholders in Tahoua who contributed to and supported the fieldwork.

Disclosure of conflict of interest

The authors declare that they have no conflict of interest regarding this manuscript.

Statement of ethical approval

Ethical approval was not required for this study because it was a non-interventional field survey focused on household sanitation, wastewater management, and environmental and public health conditions, without clinical intervention or experimental procedures.

Statement of informed consent

Informed consent was obtained from all participants prior to data collection. Participation was voluntary, and participants were informed about the purpose of the study. The information collected was used solely for scientific research purposes.

Data Availability Statement

The data generated and analyzed during the current study are available from the corresponding author upon reasonable request.

REFERENCES

[1] Aïssatou, B. (2021). Assainissement autonome au Sénégal, entre principes et pratiques : l'exemple des quartiers de Goumel, Kenia et Belfort, commune de Ziguinchor.

[2] Akhedjaliah, Florence, N'GUESSAN, Y. (2021). Manuscript Info Abstract ISSN: 2320-5407. Matériels et méthodes: -. International Journal of Advanced Research, 12(10), 507–517. https://doi.org/10.21474/IJAR01/19667

[3] BAD. (2021). Facilité africaine de l'eau. Rapport annuel 2020. In AIMS Allergy and Immunology (Vol. 5, Issue 1).

[4] Bamba, M. D. É., & N'Doli, S. D. E. (2020). Assainissement et risque de maladies chez les populations de Kennedy Clouetcha dans la commune d'Abobo à Abidjan, Côte d'Ivoire. Revues.Acaref.Net, 154–169.

[5] Bill, F., & Foundation, M. G. (2024). Global, regional, and national age-sex-specific burden of diarrhoeal diseases, their risk factors, and aetiologies, 1990–2021, for 204 countries and territories: a systematic analysis for the Global Burden of Disease Study 2021. The Lancet Global Health, 25(May). https://doi.org/10.1016/S1473-3099(24)00691-1

[6] Compaoré, C. O. T., Ouili, A. S., Zongo, S. G., Dabré, D., Maiga, Y., Mogmenga, I., Palé, D., Tindouré, R. G. N., Nikiema, M., Ouattara, C. A. T., & Ouattara, A. S. (2024). Assessing greywater characteristics in the Sahel region and perception of the local population on its reuse in agriculture. Heliyon, 10(14). https://doi.org/10.1016/j.heliyon.2024.e33473

[7] INS. (2022). Enquête sur les Indicateurs du Paludisme au Niger 2021. www.ins.ne

[8] Julien, G. (2018). Fiche technique. In Memento de l'assainissement (GRET/QUAE, pp. 705–826). http://memento-assainissement.gret.org.

[9] Kpaka, D., Doudou, S., Moussa, C., & Fiacre, Y. S. (2020). IMPACT DES PARAMÈTRES ENVIRONNEMENTAUX DANS LA RÉPARTITION SPATIO-TEMPORELLE DES MALADIES DIARRHÉIQUES DANS LA RÉGION DE LA BAGOUÉ. Revue de Géographie de l'Université de Ouagadougou, 2.

[10] Mangueina, D., Awuah, E., Fonteh, M. F., Antwi-Agyei, P., & Nadji, E. T. (2024). Assessment of current water, sanitation, and hygiene (WASH) practices in the third and ninth districts of N'Djamena, Chad. Journal of Water and Health, 22(2), 414–435. https://doi.org/10.2166/wh.2024.324

[11] Ndongo, B., Lako Mbouendeu, S., & Hiregued, J. P. (2015). Impacts socio-sanitaires et environnementaux de la gestion des eaux pluviales en milieu urbain sahélien : cas de Maroua, Cameroun. Afrique SCIENCE, 11(1), 237–251. http://www.afriquescience.info

[12] WHO. (2023). Annual WHO report Niger.

[13] WHO & UNICEF. (2021). Progress on household drinking water, sanitation and hygiene 2000–2020. https://creativecommons.org/licenses/by-nc-sa/3.0/igo/

[14] RISASI ETUTU Junior, R., NSHIMBA LUBILANJI, L., & MASHINI, J.-C. (2023). Mode d'évacuation des eaux usées domestiques des habitants du quartier 2 dans la commune de N'djili. Revue Congo Research Papers, 4(1), 45-56(57). https://doi.org/10.59937/qvbn2830

[15] SOW, M. A. (2018). La problématique de la gestion des eaux usées domestiques dans la commune de Bignona : le cas des quartiers de Bassène et Manguiline. Mémoire de Master 2 en Environnement et Développement. Université Assane Seck de Ziguinchor.

[16] Toussaint, V., Yves, T., & Basile, S. (2013). Dynamique de la population urbaine et problèmes de santé dans l ' Ouest de Cotonou au Bénin Résumé. 200–216.