OPEN ACCESS

Orapuh Journal

ORIGINAL ARTICLE

Journal of Oral & Public Health

Assessment of health risks associated with water-borne diseases due to flooding in the Kwilu River Valley in Kikwit, Democratic Republic of the Congo

Munduku, M. O.[1], Kikozokozo, K. D. [1], Kilensele, M. T.[1], Banganga, G. G.[2], Kalela, I. T.[1], Bondo, B. S.[1], Musibono, E. D.[1], & Mpuru, M. B.[3]

[1]*Department of Environmental Science and Management, Faculty of Science and Technology, University of Kinshasa, Kinshasa XI, Democratic Republic of the Congo*
[2]*Department of Geosciences, Faculty of Science and Technology, University of Kinshasa, Kinshasa XI, Democratic Republic of the Congo*
[3]*Institut Supérieur d'Architecture et d'Urbanisme*

ARTICLE INFO

Received: *11 August 2024*
Accepted: *20 October 2024*
Published: *02 November 2024*

Keywords:
Evaluation, health risk , flood, Kikwit

Peer-Review: *Externally peer-reviewed*

Correspondence to:
Olivier Munduku Midishi
olimunduku@gmail.com

To cite:
Munduku, M. O., Kikozokozo, K. D., Kilensele, M. T., Banganga, G. G., Kalela, I. T., Bondo, B. S., Musibono, E. D., & Mpuru, M. B. (2024). Assessment of health risks associated with water-borne diseases due to flooding in the Kwilu River Valley in Kikwit, Democratic Republic of the Congo. *Orapuh Journal*, *5*(6), e1151
https://dx.doi.org/10.4314/orapj.v5i6.51

ISSN: *2644-3740*

Published by Orapuh, Inc. (info@orapuh.org)

Editor-in-Chief: Prof. V. E. Adamu
Orapuh, Inc., UMTG PMB 405, Serrekunda, The Gambia, editor@orapuh.org.

ABSTRACT

Introduction

Flooding poses a socio-environmental threat by introducing water to areas usually dry, thereby facilitating the spread of various pathogens. Flood-prone areas are vulnerable to numerous health risks, often resulting in fatalities, especially among children under five and pregnant women.

Purpose

This study aims to assess the health risks associated with water-borne diseases caused by flooding in the Kwilu River Valley in Kikwit.

Methods

This research employs a cartographic approach combined with experimentation and descriptive observation to analyze a non-probabilistic sample.

Results

Climatic and geomorphological factors are the primary natural causes of flooding in the Kwilu River Valley. Socio-environmental vulnerabilities among residents in the study area contribute significantly to the health risks associated with flooding. Malaria is the most prevalent water-borne disease in the Kwilu Valley, followed by diarrhoea, pneumonia, and typhoid fever.

Conclusion

The health risks associated with flooding in the Kwilu River Valley in Kikwit are substantial. Pathological surveillance, enhanced drainage systems, and expanded public health campaigns are essential to promote improved living conditions for the community.

INTRODUCTION

Floods are among the most destructive natural disasters worldwide (Ozer, 2022). They result from a combination of natural and anthropogenic factors, primarily related to climate and the environmental characteristics of the affected area (Hec et al., 2019). Floods occur due to various factors, including natural meteorological phenomena,

human activities, and climate change (Vuni et al., 2022). They lead to numerous fatalities, material damage, substantial economic losses, and the spread of water-borne diseases and epidemics globally (World Health Organization [WHO], 2020). These flood-related impacts are felt more acutely in countries with inadequate urban planning and in areas where health facilities are dysfunctional (Kakesa, 2024).

Flooding increases the risk of faeco-oral diseases and facilitates the transmission of pathogens, such as malaria, dengue fever, leptospirosis, yellow fever, and cholera. Additionally, people may be injured by falling trees, power lines, or other debris (Mutungu, 2022). Environmentally, floods damage farmland, reducing crop production and impacting food security. They also spread pollution, negatively affecting both animals and humans.
In epidemiology, risk is defined as the probability that a specific factor will contribute to the onset or development of a pathology. The presence of this factor increases the likelihood of disease development, regardless of other causes (Munduku, 2021).

The World Health Organization (2020) warns of major public health threats facing flood-affected populations, especially the increased risk of water-borne and vector-borne diseases like malaria and dengue fever in flood-prone areas. Although the health risks of water-borne diseases due to flooding in Kikwit have been slightly raised by several authors, there has been little correlation between rainfall data and disease prevalence. Previous studies, such as those by Mutungu (2022) and Kakesa (2024), have not found confirmed cases of water-borne diseases in the Kikwit Nord health zone.

This study identifies natural hazards, such as geomorphological and climatic factors, that heighten flooding risks and maps potential flooding areas. It then correlates rainfall data with recorded water-borne diseases to assess health risks and propose improvements for managing the living environment. The Kwilu River Valley in Kikwit was selected as the study area due to the observed geomorphological and climatic hazards and the high incidence of water-borne diseases following floods. This study is essential for reducing the health risks posed by water-borne diseases linked to flooding, which cause loss of life, disrupt socio-economic activities, and contribute to poverty in Kikwit.

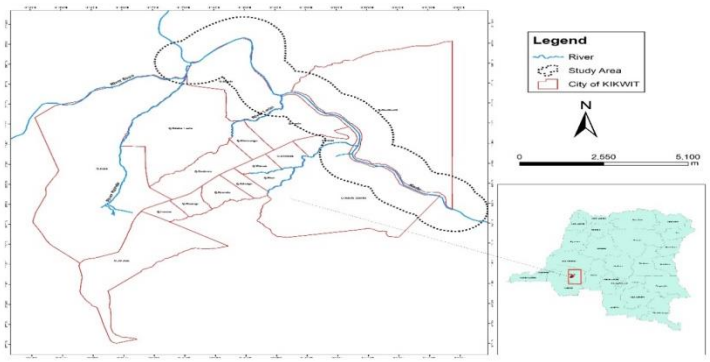
The aim of this study is to assess the health risks of water-borne diseases associated with flooding in the Kwilu River Valley in Kikwit, Democratic Republic of Congo.

METHODS

Study Environment

The town of Kikwit is located in the central-southern part of Bulungu territory in the Kwilu Province of the Democratic Republic of Congo. It lies between 18°51'39.5" and 18°44'14.6" east longitude, and 4°59'53.5" and 05°05'51.5" latitude. Situated 525 km from Kinshasa, Kikwit is accessible by road, air, and the Kwilu River. It covers an area of 92 km² and had an estimated population of 1 million in 2023 (Kitadi et al., 2022).

Figure 1:
Map of the Kwilu River Valley in the Town of Kikwit



The Kwilu is the main river in the province of the same name, located in the southwestern part of the Democratic Republic of Congo. It spans 965 km, with an average flow of 3,299 m³/s, originating in the Republic of Angola and flowing through several Congolese villages and towns before merging with the Kasaï River, a major tributary of the Congo River.

Climate

Kikwit is situated in the humid tropical climate zone AW4 according to the Köppen classification, characterised by an average annual rainfall of 1,000 to 1,400 mm and an average temperature of 25°C (Wilson, 2020).

Relief

The Kikwit region primarily consists of plateau-like terrain, surrounded by hills and valleys, with altitudes ranging from 350 to 450 metres (Selhorst et al., 2020).

https://dx.doi.org/10.4314/orapj.v5i6.51

Study Materials

This cross-sectional study employs a mapping approach to assess the health risks associated with flooding in the Kwilu River Valley. The study focuses on water-borne diseases caused by flooding. To meet this study's objectives, the following tools were used:

- A Garmin GPS (Global Positioning System) device to collect data at key points, with GIS software for analysis to identify areas prone to flooding;
- A digital camera (iPhone brand) to capture images in flood-prone areas;
- A field notebook for recording statistics on confirmed cases of diseases reported in various health facilities.

Type of Data

The data in this study is both quantitative and qualitative.

Sampling

Non-probability sampling is a method that involves selecting units from a population using subjective, non-random methods. Due to the challenges in accessing all individuals in flood-prone areas, a non-probability sampling method was used to target the most affected populations. However, this may limit the generalizability of the results.

Choice of Study Environment

The Kwilu River Valley was chosen as the study site due to the high number of confirmed cases of water-borne diseases caused by flooding recorded in the Kikwit North health zone. The Kwilu River Valley, as the administrative and commercial centre of Kikwit, has a dense and diverse population and serves as the epicentre of water-borne diseases in the city.

RESULTS

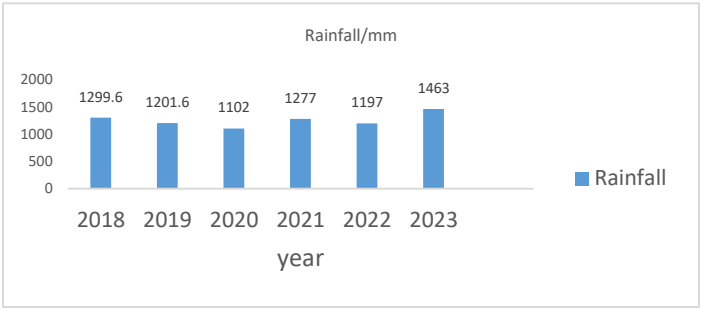
This section presents the results obtained from field and laboratory studies.

Factors Favouring Flooding in the Kwilu Valley at Kikwit

Climatic Hazards

Climatic hazards are the primary factors increasing the likelihood of flooding in the study area. **Figure 2** shows the average annual rainfall in Kikwit from 2018 to 2023.

Figure 2:
Annual rainfall data for the town of Kikwit from 2018 to 2023

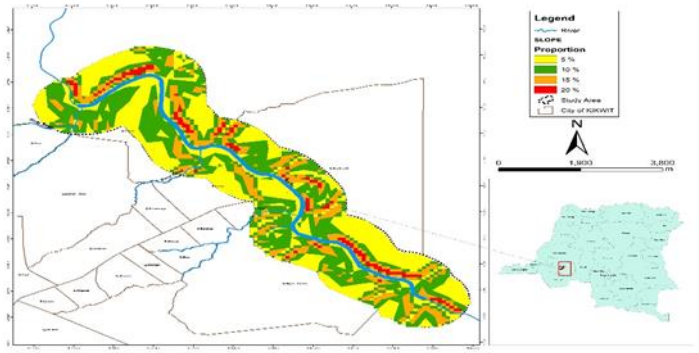


Source: *Meteorological data from Kikwit station.*

Geomorphological Hazards

The geomorphology of the Kwilu River Valley also contributes to flood risks along the river. **Figure 3** illustrates the steep slopes, ranging from 5% to 20%, surrounding the Kwilu Valley. These slopes increase runoff speed, intensify gullying, and funnel rainwater from Kikwit town into the Kwilu Valley.

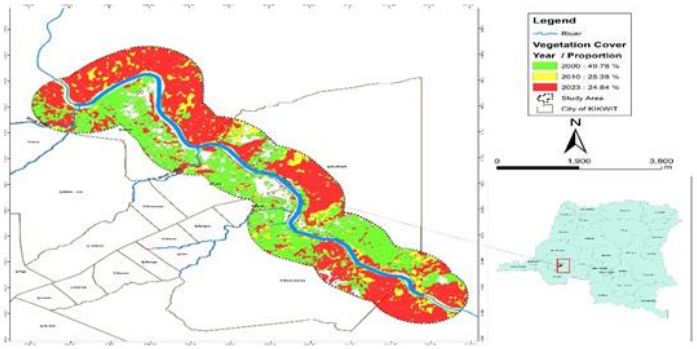
Figure 3:
Geomorphological hazards in the Kwilu River Valley.



Deforestation

The degradation of vegetation cover in the area encourages intense rainwater runoff and accelerates gullying. Vegetation degradation along the Kwilu River significantly impacts flooding risks in the Kwilu Valley. **Figure 4** shows that over time, the primary forest that once covered the Kwilu Valley has given way to secondary forest and, in some areas, has disappeared altogether. Human activities and construction have extended into wetland areas that typically absorb floodwaters, making these areas and human activities increasingly vulnerable to flooding.

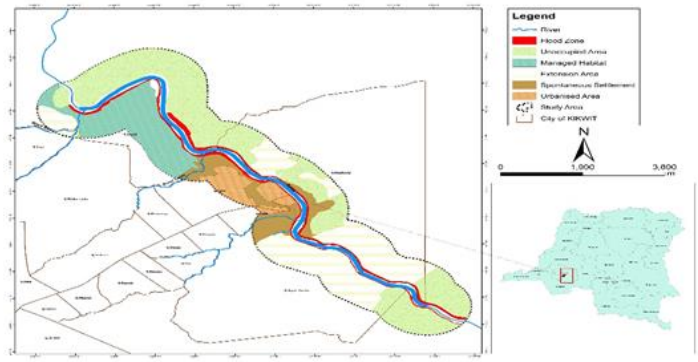
Figure 4:
Vegetation cover dynamics in the Kwilu River Valley at Kikwit.



Flood Zones in the Kwilu River Valley at Kikwit

This section identifies the flood zones within the study area. **Figure 5** shows the areas prone to flooding in the Kwilu River Valley. All areas along the Kwilu River act as catchment zones for rainwater from Kikwit due to climatic (heavy rainfall) and geomorphological (slope over 15%) hazards, poor urban planning, and the socio-environmental vulnerability of the population.

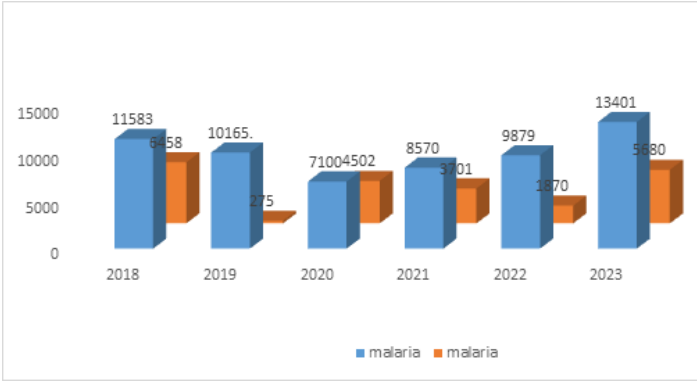
Figure 5:
Location of flood zones in the Kwilu River Valley



Risk of Water-Borne Diseases

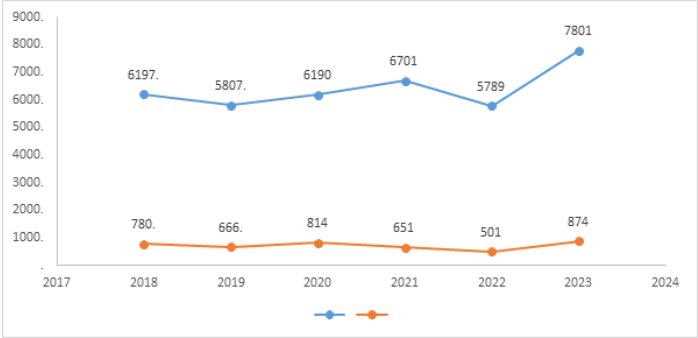
This section presents the recorded cases of water-borne diseases linked to flooding in the study area. **Figure 6** indicates that malaria is the most frequently recorded disease in flood-prone areas, with 13,401 confirmed cases in 2023, including 5,680 severe cases.

Figure 6:
Recorded cases of malaria in the Kwilu Valley.



Diarrhoea is also prevalent, with 7,801 confirmed cases reported in 2023, of which 874 were severe (see **Figure 7**).

Figure 7:
Statistics on confirmed cases of diarrhoea in the Kwilu River Valley.



Following floods in the Kwilu Valley, some residences remain flooded with stagnant water, creating breeding sites for larval development and proliferation. Cleaning flooded plots is challenging, and the lack of sanitation facilities explains the rise in positive malaria cases, particularly during flood periods along the Kwilu River. **Figure 8** illustrates stagnant water in a plot following the floods.

Figure 8:
Stagnant water in a plot following the floods of November 2023 in the Kwilu Valley

In addition to malaria and diarrhoea, many residents of the Kwilu Valley in Kikwit also suffer from pneumonia. Figure 9 shows that 854 cases were recorded in 2018, with 156 classified as severe.

Figure 9:
Recorded cases of typhoid in the Kwilu River Valley in Kikwit.

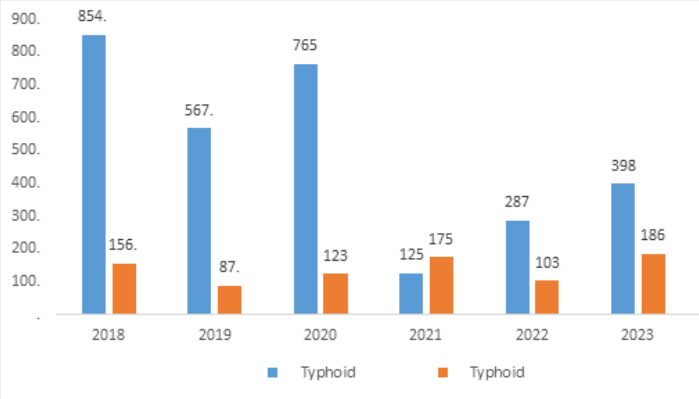


Figure 10 shows that 2023 had the highest number of recorded typhoid cases, with 11,850 cases reported in health facilities within the study area. The year 2020 followed with 9,200 cases, 2019 with 9,112 cases, 2018 with 7,933 cases, and finally, 2022 with 765 positive cases. Commercial establishments, including makeshift restaurants, are frequently affected by flooding, contaminating facilities and degrading health standards.

Figure 10:
Statistics on cases of pneumonia registered in the Kwilu River Valley in Kikwit.

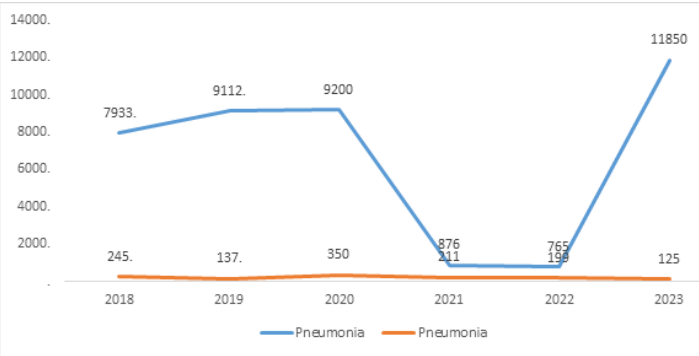


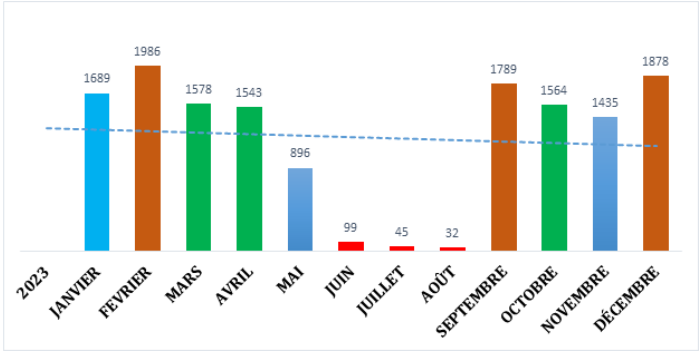
Figure 11 depicts the flooding of Office National de Transport (ONATRA) facilities in the Kwilu Valley at Kikwit, Democratic Republic of Congo. This situation exposes the facilities to high humidity, increasing the health risk of pneumonia.

Figure 11:
Flooding of ONATRA facilities on the banks of the Kwilu River in Kikwit, November 2023.

Assessing the Health Risk of Flood-Related Water-Borne Diseases

This section assesses the health risk associated with water-borne diseases due to flooding and explores the link between rainfall and the number of cases recorded in the study area. Figure 12 shows that malaria incidence was highest in February, September, and December 2023, while it was lowest in June, July, and August. January, March, April, and October had relatively consistent incidence rates.

Figure 12:
Incidence of malaria in 2023.



Comparative Analysis of Water-Borne Diseases and Climatic Data

The data was manually checked for consistency before entry and analyzed using R software. Relationships between variables were assessed using the Chi-square (Chi^2) test, as well as odds ratios (OR) and their 95% confidence intervals. Variables were deemed significant if their odds ratio was greater than 1, the lower bound of the 95% confidence interval exceeded 1, and the p-value was ≤ 0.05. Adjustments were made using the Mantel-Haenszel

test. The significance level for this study was set at $p < 0.05$, and the bivariate analysis considered key variables that explain water-borne diseases under the two climatic contexts (rainy and dry seasons).

Table 1:
Relationship between malaria cases and rainfall data for 2023

	Rainfall data for 2023		Ddl	P	S
	Dry season	Rainy season			
December	0,00%	100%	1	0,001	TS
February	0,00%	100%	1	0,001	TS
July	67%	0,00%	2	0,082	**
August	43%	0,00	2	0,063	**

Comparative analysis using the Chi-square test indicates a significant association between months of heavy rainfall (December, February) and increased malaria cases, as shown by the probability of 0.0147 (1.37%) compared to the study's significance threshold of 0.05 (5%). Specifically, $p = 0.001 < 0.05$. Conversely, months in the dry season (July and August) did not exhibit a significant relationship with water-borne diseases ($p = 0.082$ and $0.063 > 0.05$).

DISCUSSION

The results of this study are compared with findings from other researchers to gain a comprehensive understanding of factors that favour flooding in the Kwilu River valley at Kikwit. Regarding natural hazards that contribute to flooding, this study found that the River Kwilu valley is surrounded by steep slopes ranging from 5% to 20%, with an annual average rainfall exceeding 1,000 mm. Unlike findings from Ozer (2022) in similarly flood-prone areas in Senegal, where waterborne diseases were less common, this study highlights a high prevalence of malaria and diarrhoea in Kikwit. Residents relocating from eroded, higher-altitude areas are confronted with flooding risks in lower-altitude regions, thus facing both erosion and flood risks depending on altitude.

The study further demonstrated significant degradation of vegetation cover in the Kwilu River valley. These findings align with those of Musibono (2022), who asserts that the degradation of gallery forests increases flood risk, especially in urban areas. Along the River Kwilu at Kikwit, the gallery forest has been entirely destroyed by human activities, disrupting the wetlands' structure and function. These wetlands previously acted as an ecotone between terrestrial and aquatic ecosystems, absorbing excess water during flood periods.

In terms of waterborne disease risks, the study recorded multiple waterborne diseases reported by local health facilities, with malaria being the most prevalent in the Kwilu River valley at Kikwit. Although our findings are consistent with Kikozokozo et al. (2022), this study indicates higher incidences of typhoid than expected, likely due to inadequate health infrastructure in the region. These results are further corroborated by Kambembo (2022), who identified stagnant water as a primary factor in the proliferation of larval breeding sites, predominantly located outside houses in low-altitude areas. Kambembo (2022) attributes this phenomenon to ecologically favourable conditions, including dissolved oxygen, temperature, conductivity, pH, turbidity, and the depth of larval breeding sites, particularly beneficial for *Aedes* species.

On a socio-economic level, the study's findings are consistent with Mbola et al. (2022) in Kikwit, who observed that the health risks from waterborne diseases substantially impact the socio-economic well-being of the population, disrupting commercial activities and reducing income. Flooding is a significant public health issue that disrupts multiple development sectors, sometimes resulting in loss of life in Kikwit (Kikozokozo et al., 2021). Similarly, Nienie et al. (2020) concluded that flooding in the Kwilu River valley at Kikwit contaminates drinking water sources, thereby increasing waterborne disease transmission risks.

The management of living conditions in Kikwit's River Kwilu valley plays a crucial role in the emergence and re-emergence of waterborne diseases. As a result, we recommend developing a new urban planning framework and implementing a flood management policy incorporating early warning systems, community health education, and infrastructure improvements in high-risk areas.

CONCLUSION

This study has shown that the health risks associated with waterborne diseases due to flooding in the River Kwilu valley are substantial. Consequently, there is an urgent need to establish effective disease surveillance to support

public health prevention and control efforts. Future research should focus on longitudinal studies to monitor the long-term health impacts of flooding. Immediate actions should prioritize enhancing drainage systems and strengthening local healthcare infrastructure to mitigate the health risks associated with flooding.

Ethics Approval: Ethical approval for this study was obtained from the Ethics Committee, School of Public Health, University of KInshasa, Democratic Republic of the Congo (ESP/CE/031/2024)

Conflict of Interest: None declared.

ORCID iDs:

Munduku, M. O.[1]: Nil identified
Kikozokozo, K. D. [1]: Nil identified
Kilensele, M. T.[1]: Nil identified
Banganga, G. G.[2]: Nil identified
Kalela, I. T.[1]: Nil identified
Bondo, B. S.[1]: Nil identified
Musibono, E. D.[1]: Nil identified
Mpuru, M. B.[3]: Nil identified

REFERENCES

Hec-Ras, Abidi, S., Hajji, O., Essaleh, W., Ezzine, A., & Hermassi, T. (2019). Cartographie du risque inondation de la Haute Vallée de Medjerda. *Journal International Sciences et Techniques de l'eau et de l'Environnement*, *IV*(1), Décembre.

Kakesa, J. P. (2024). *Risques et implication anthropique dans le déclenchement des phénomènes hydro-géomorphologiques dans la ville de Kikwit, RDC* (Doctoral thesis, Department of Geosciences, University of Kinshasa).

Kikozokozo, M., & Bisimwa, D. (2022). Evaluation des risques de réémergence de l'épidémie du virus Chikungunya dans la vallée de Mont Ngafula à Kinshasa, RDC. *Annales Africaines de la Médecine*, *16*(1).

Kikozokozo, M., Mangala, R., & Yenga, K. (2021). Caractérisation de types des gîtes larvaires d'Aedes sp à Kinshasa-Mont Ngafula après l'épidémie de Chikungunya de 2018-2019. *Congo Sciences, Journal en ligne de l'ACASTI et du CEDESIRK*, *9*(3), Novembre.

Kitadi, M., Kwilu, D., & Nku, B. (2022). La qualité bactériologique des eaux consommées dans la ville de Kikwit et son impact sanitaire sur la population: Cas des quartiers Lumbi et Ndeke zulu de la Commune de Nzinda. *International Journal of Latest Research in Humanities and Social Science (IJLRHSS)*, *5*(5), 33-37. Retrieved from www.ijlrhss.com

Mbola, M., & Ntambwe, M. (2021). Urban-rural poverty and environmental conservation. Paradoxes des dirigeants et des dirigés: Etude critique sur la production de charbon de bois dans la ville de Kikwit et ses environs. *Revue Mouvements et Enjeux Sociaux - Revue Internationale des Dynamiques Sociale, M.E.S.*, (118), 18 January 2022.

Munduku, O. (2021). Analysis of urban aspects of housing in the Ngulu-Nzamba district in the city of Kikwit, DRC. *International Journal of Latest Research in Humanities and Social Science (IJLRHSS)*, *4*(4), 18-27. Retrieved from http://www.ijlrhss.com/paper/volume-4-issue-4/2-HSS-988.pdf

Musibono, E. (2022). *Politiques environnementales toxiques en République Démocratique du Congo: Le paradoxe congolais*. ERGS-Kinshasa.

Mutungu, L. (2022). *Les acteurs et les facteurs du phénomène d'érosion ravinante dans la ville de Kikwit (Province du Kwilu, République Démocratique du Congo). Perspectives d'aménagement durable* (Doctoral thesis, Faculty of Science and Technology, University of Kinshasa).

Nienie, B. , Lay, N., Tshiala & Poté, J. (2020). Conception on the issue of access to drinking water, a major concern for the town of Kikwit in DR Congo, *Congolese magazine of Human and Social Sciences*. https:/www.doi.org/10.59189/crsh506263

Ozer, P. (2022). Evolution pluviométrique et relation inondations-évnements pluvieux au Sénégal. *Bulletin de la Société Géographique de Liège*, *42*, 27-33.

Selhorst, P., Sheila, M., De Smet, B., Marien, J., & Anthony, J. (2020). Molecular characterization of virus during the 2019 outbreak in the Democratic Republic of the Congo. *Emerging Microbes &*

Infections, *9*. https://doi.org/10.1080/222175120201810135

Vuni, A., Pangu, S., Mabiala, P., Lelo, F., Aloni, J., Malaisse, F., & Nzau, M. (2022). Eléments d'appréciation d'un bassin versant en vue d'un contrat de rivière: Cas de la Kalamu à Boma (Kongo Central, RD. Congo). *Geo-Eco-Trop*, *46*(1), 43-61.

Wilson, A. L., Courtenay, O., Kelly-Hope, L. A., Scott, T. W., Torr, S. J., et al. (2020). The importance of vector control for the control and elimination of vector-borne diseases. *PLoS Neglected Tropical Diseases*, *14*(1), 1-31.

World Health Organization. (2020). *Vector-borne diseases: Key facts*. Retrieved from https://www.who.int/newsroom/fact-sheets/detail/vector-borne-deseases