

Physico-chemical parameters of the habitat of molluscs, intermediate hosts of schistosomes, in Kisangani and its surroundings

Sapu, K. J.¹, Abedi, M. M.², Tagoto, T. A.³, Falay, S. D.³, Losimba, L. J.³, & Bobanga, T.⁴

¹Department of Public Health, Faculty of Medicine, University of Bas-Uele, Buta, Democratic Republic of the Congo

²Congolese Government Physician, Ministry of Public Health, Democratic Republic of the Congo

³Department of Public Health, Faculty of Medicine and Pharmacy, University of Kisangani, Kisangani, Democratic Republic of the Congo

⁴Department of Entomology, University of Kinshasa, Kinshasa, Democratic Republic of the Congo

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Correspondence to:

SAPU KANGANGA John
sapujohn49@gmail.com

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ABSTRACT

Introduction

Schistosomiasis, a neglected tropical disease, is caused by *Schistosoma* trematodes and is prevalent in 78 countries, particularly in sub-Saharan Africa. The distribution of these parasites is linked to the presence of their intermediate hosts, freshwater molluscs. The survival and development of these molluscs are influenced by the physico-chemical conditions of their habitat, including water temperature, pH, conductivity, and oxygen levels. Understanding these relationships is crucial for schistosomiasis control.

Purpose

This study aimed to determine the correlation between the physico-chemical parameters of mollusc habitats and the number of molluscs collected within 30-minute intervals in Kisangani, DRC, and its surroundings.

Methods

The research was conducted in five marshy sites in Tshopo Province. Molluscs were collected, and water samples were analysed for temperature, pH, turbidity, conductivity, oxygen saturation, and dissolved oxygen. Mollusc density was assessed by counting the number collected in 30 minutes. Data were analysed using Microsoft Excel and R software, with statistical significance set at 5%.

Results

Mollusc density varied across the sites, with some sites showing high densities and others moderate. Physico-chemical parameters also varied; however, no statistically significant correlation was found between the number of molluscs collected and these parameters.

Conclusion

The study found no significant correlation between mollusc counts and the measured physico-chemical parameters. Factors such as human activity, spatial scale, and other unmeasured environmental variables may influence mollusc abundance. Further research is recommended to explore specific factors affecting mollusc populations in the region.

INTRODUCTION

Understanding the relationships between physico-chemical parameters and intermediate host molluscs is essential for determining their geographical distribution and abundance, as well as for informing public health interventions aimed at effectively controlling schistosomiasis in endemic areas. By modifying environmental conditions, it is possible to reduce mollusc populations and thereby limit the transmission of schistosomiasis (Bakhom et al., 2019).

Schistosomiasis is a neglected tropical disease (NTD) caused by trematodes of the genus *Schistosoma* (S.) (Aubry, 2024; Nwoko et al., 2023; Schistosomiase, 2022). It is endemic in 78 countries worldwide and affects over 229 million people in tropical and subtropical regions, with more than 90% of cases occurring in sub-Saharan Africa. It is estimated to be responsible for approximately 800,000 deaths annually (Aubry, 2024). According to the World Health Organization (WHO), at least 251.4 million people required preventive treatment in 2021 (Nwoko et al., 2023; Schistosomiase, 2022).

Nigeria, Ethiopia, Kenya, Mozambique, and the Democratic Republic of the Congo (DRC) are the five most affected countries in Africa (Kunyu, 2018). The distribution of *Schistosoma* species is directly linked to the geographical range of their intermediate hosts—the molluscs (Hailegebriel et al., 2020; Opisa et al., 2011). Their survival and development are closely related to the physico-chemical conditions of their environment, with key factors including water temperature, pH, electrical conductivity, oxygenation, dissolved oxygen, turbidity, substrate type, and aquatic vegetation (Bakhom et al., 2019).

Scientific literature on the physico-chemical parameters of mollusc habitats in the Kisangani region and its surroundings is scarce. However, this region, with its abundant waterways and wetlands, offers ideal habitats for molluscs. Local populations, who often engage in daily water contact activities (e.g., fishing, agriculture, laundry, and bathing), are at heightened risk of exposure to infectious larvae. Cases of schistosomiasis are regularly reported in several health zones in and around Kisangani. Although studies by Gillet and Wolfs (1954) and more recently by Esol'e et al. (2019) have documented the

distribution of schistosomiasis and its molluscan hosts, they did not investigate the physico-chemical characteristics of mollusc habitats.

Objective

This study aimed to determine the correlation between the physico-chemical parameters of mollusc habitats and the number of molluscs collected over a 30-minute sampling period in Kisangani and its surrounding areas.

METHODS

Study Area

The study was conducted in five marshy sites in Tshopo Province: the Onane River in the Wanierukula Health Zone (00°28'40.84"N 25°41'11.01"E); the Tomboli-Mboli stream in the Yakusu Health Zone (00°34'39.59"N 25°01'32.84"E); the Kakole River in the Tshopo Health Zone (00°43'05.42"N 25°18'37.18"E); the water conduits behind the Governor's Office (00°31'14.49"N 25°11'51.74"E); and the ANR station (00°30'47.18"N 25°10'48.41"E) in the Makiso-Kisangani Health Zone.

These sites were selected based on their known association with human schistosomiasis and the presence of molluscs, as identified by local knowledge. Data were collected from May 10 to May 17, 2024. The geographical coordinates of each site were recorded using a Global Positioning System (GPS) device.

Figure 1.
Health Zones of Research

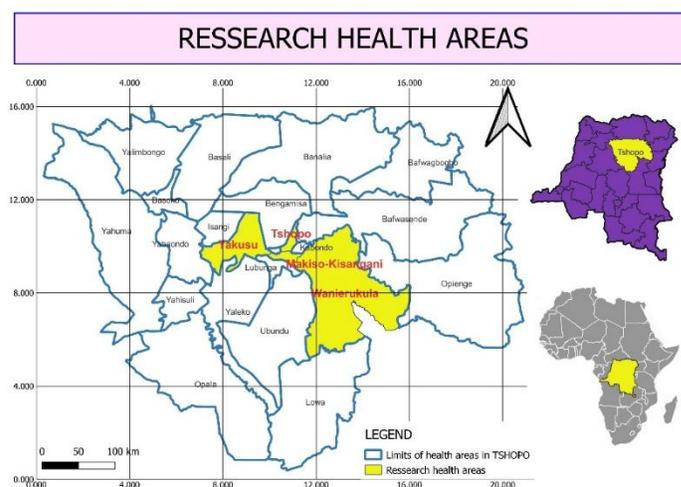
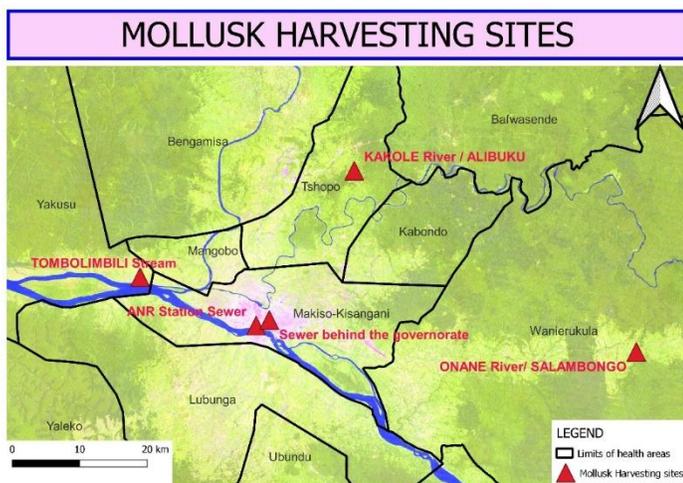


Figure 2:
Location of Snail Collection Sites



Study Design

This was a descriptive cross-sectional study involving mollusc collection and the measurement of physico-chemical parameters of their aquatic habitats. All sampling and measurements were conducted between 9:00 a.m. and 11:00 a.m. at each site.

Materials Used

After molluscs were collected, a ComboR multiparameter probe was used to measure six physico-chemical parameters of the water: temperature, pH, turbidity, conductivity, oxygen saturation, and dissolved oxygen. Molluscs were counted and then transferred to the Entomological Service of the Parasitology Laboratory at the University Clinics of Kinshasa for taxonomic identification in a separate study.

Mollusc density was assessed using the method developed by Sellin and Simonkovich, which involves counting molluscs collected by a single investigator within a 30-minute period. Sites were categorised as follows: low density (1-10 molluscs), medium density (11-50), and high density (more than 50) (Poda et al., 1994).

Variables of Interest

1. **Number of molluscs collected in 30 minutes** (Poda et al., 1994).
2. **Physico-chemical parameters** of the water at the mollusc collection sites:
 - a) **Turbidity (ppm)**

Turbidity varies with the presence of colloidal materials (e.g., clay, debris, microorganisms) and humic substances from decomposed vegetation, as well as pollution. Suspended solids (SS) give the water a cloudy appearance and block light penetration needed for aquatic life (Admin, 2022; Khodja & Brahimi, 2021). High turbidity can reduce algae availability, clog mollusc gills, and disrupt their habitat. Normal turbidity values should be below 10 NTU; levels above 25 NTU are potentially harmful to molluscs (Henley et al., 2000).

b) Temperature (°C)

Water temperature affects dissolved oxygen, which is essential for aquatic organisms. Higher temperatures reduce dissolved oxygen, impairing self-purification and potentially eliminating species. Molluscs generally thrive in water between 10 °C and 25 °C; extreme or abrupt changes can be lethal (Admin, 2022; Haszprunar, 2020).

c) Conductivity

Water conductivity, measured in $\mu\text{S}/\text{cm}$ or mS/cm , indicates the presence of ions or pollutants. It helps detect anomalies such as organic pollution. Acceptable conductivity ranges for freshwater molluscs are typically between 150 and 500 $\mu\text{S}/\text{cm}$ (Admin, 2022; Davis et al., 1981). Conductivity affects molluscs' osmotic regulation.

d) pH

Measured with a pH meter, this parameter indicates the water's acidity or alkalinity. Most molluscs prefer water with a pH between 6.5 and 8.5. Extreme pH values can be toxic (Admin, 2022; Haszprunar, 2020).

e) Oxygen Saturation

Oxygen saturation above 80% supports mollusc growth and activity. Levels below 60% cause stress; below 30% are hypoxic and often lethal (Diaz & Rosenberg, 2008; Environmental Research Center, University of Technology et al., 2015).

f) Dissolved Oxygen

Molluscs require 5–6 mg/L of dissolved oxygen. Levels below 3 mg/L are harmful. Low oxygen levels are often found in stagnant or polluted waters (Haszprunar, 2020). While mollusc tolerance varies by species, extreme deviations are generally harmful (Strong et al., 2008).

Data Processing and Analysis

Data on mollusc numbers and water physico-chemical parameters were entered into Microsoft Excel 2019 and analysed using R software (version 4.4.0). A scatterplot with a regression line illustrated correlations between mollusc counts and physico-chemical variables. Kendall’s non-parametric tau correlation was used due to non-normal distribution (Shapiro-Wilk test: $W = 0.756$; $p = 0.034$) and a small number of sites with tied values. Statistical significance was set at 5%. Mapping of snail collection sites was conducted using QGIS 3.36 software based on field-collected coordinates.

Ethical Considerations

All procedures in this research adhered to ethical standards. Ethical approval and relevant field authorisations were obtained.

The study was approved by the Vice-Dean in charge of Research, Faculty of Medicine and Pharmacy, University of Kisangani, DRC (No FMP/76/2024).

RESULTS

Number of Molluscs Collected in 30 Minutes and Mollusc Density at Different Sites

Table I:
Distribution and Density of Molluscs at Different Sites

Health Zone	Site	Molluscs Collected (30 min)	Density
Makiso-Kisangani	ANR Water Conduit	34	Moderate
Makiso-Kisangani	Governor's Water Conduit	90	High
Tshopo	Kakole River	90	High
Wanierukula	Onane River	82	High
Yakusu	Tombolimboli Stream	32	Moderate

As shown in Table I, mollusc density was highest at the Onane River, Kakole River, and Governor’s Water Conduit, where 82, 90, and 90 molluscs were collected within 30

minutes, respectively. In contrast, the Tombolimboli Stream and ANR Water Conduit had moderate mollusc densities, with 32 and 34 molluscs collected, respectively.

Physico-Chemical Parameters of the Sites

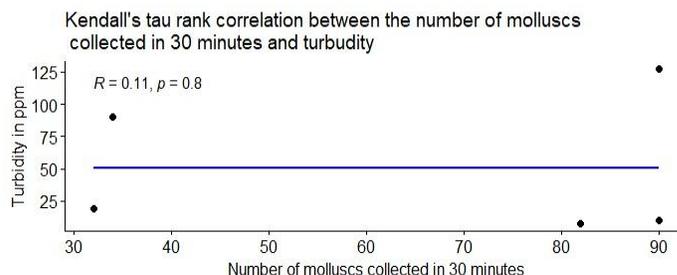
Table 2:
Physico-Chemical Parameters of Mollusc Collection Sites

Site	Turbidity (ppm)	Temp (°C)	Conductivity (µS/cm)	pH	Oxygen Saturation (%)	Dissolved Oxygen (mg/L)
ANR Water Conduit	90	29.0	323	5.6	40.0	2.90
Governor's Water Conduit	127	28.7	370	5.1	44.5	3.19
Kakole River	9.8	26.0	63.2	5.1	73.0	6.10
Onane River	7.6	26.2	72.4	5.1	82.0	6.20
Tombolimboli Stream	19.0	26.6	32.3	5.5	40.2	2.98

Turbidity ranged from 7.6 ppm at the Onane River to 127 ppm at the Governor’s Water Conduit, both of which exhibited high mollusc densities. Temperature varied from 26.0°C at Kakole River (high density) to 29.0°C at ANR Water Conduit (moderate density). Conductivity ranged from 32.3 µS/cm at Tombolimboli Stream (moderate density) to 370 µS/cm at Governor’s Water Conduit (high density). pH ranged from 5.1 at Governor’s Water Conduit, Kakole River, and Onane River (high densities) to 5.6 at the ANR Water Conduit (moderate density). Oxygen saturation ranged from 40.0% (ANR) to 82.0% (Onane). Dissolved oxygen levels ranged from 2.90 mg/L (ANR) to 6.20 mg/L (Onane).

Correlation Between the Number of Molluscs Collected and Physico-Chemical Parameters

Figure 3:
Correlation diagrams between the number of molluscs and physico-chemical parameters



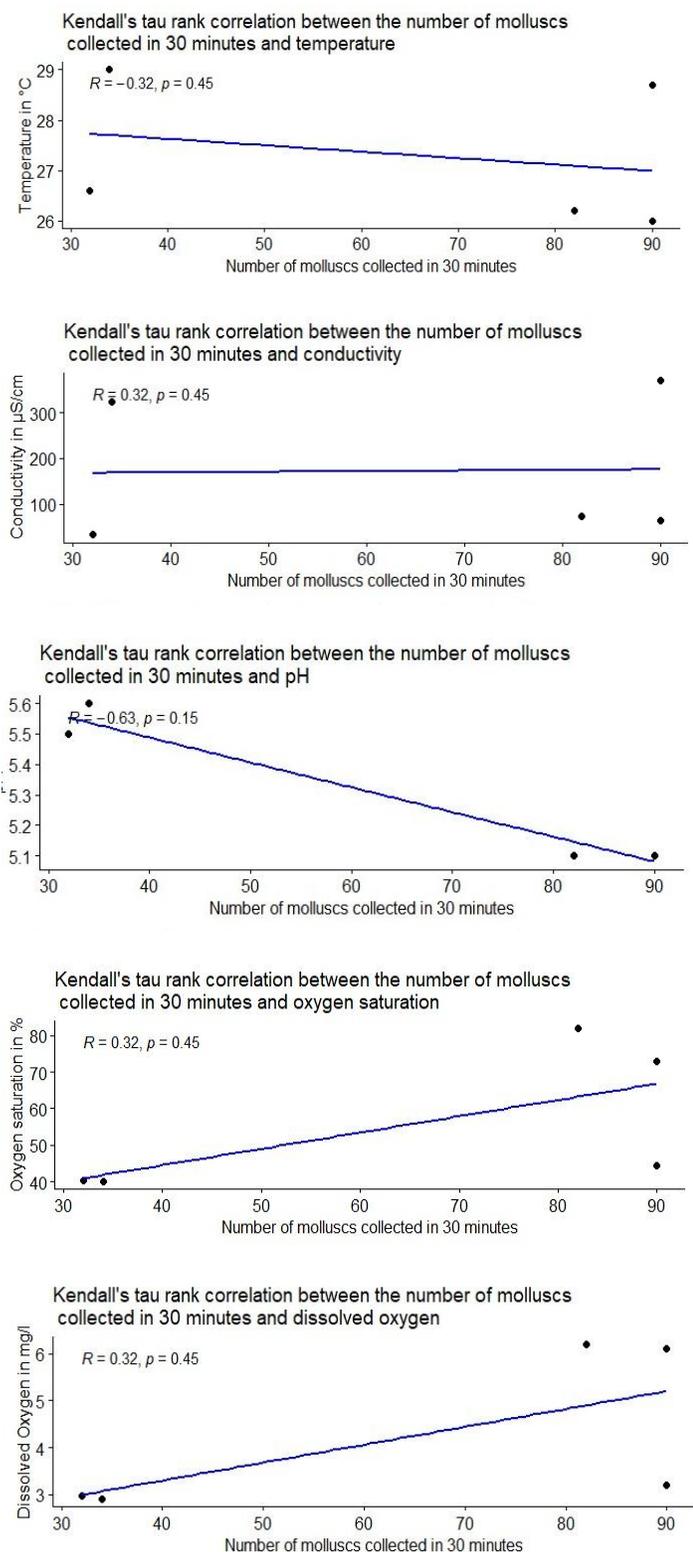


Figure 3 shows that the regression line between mollusc count and turbidity is nearly horizontal, suggesting no linear trend. A decreasing trend is suggested between

mollusc count and temperature, as well as between mollusc count and pH. In contrast, mollusc numbers appear to increase with conductivity, oxygen saturation, and dissolved oxygen. However, Kendall’s tau correlation test results showed no statistically significant relationships between the number of molluscs collected and any of the physico-chemical parameters (turbidity, temperature, conductivity, pH, oxygen saturation, or dissolved oxygen) at the 5% significance level ($p < .05$).

DISCUSSION

Mollusc Numbers and Density at Different Sites

The Onane, Kakole, and Governor’s Water Conduit sites recorded high mollusc densities, while the ANR and Tombolimboli sites exhibited moderate densities. This pattern may be attributed to human activity in these areas, particularly defecation, urination, and bathing, which enrich water bodies with organic matter and promote algae growth—a primary food source for molluscs (Comment prendre soin d’un escargot d’eau: 12 étapes, 2024; Les escargots – Aquariophile facile, 2021).

Physico-Chemical Parameters of the Sites

Turbidity did not appear to influence mollusc density in this study, contrasting with findings by Bakhoun et al. (2019) in Senegal. The discrepancy may stem from our smaller number of sites ($n = 5$) and single-time sampling, compared to their multi-site, biweekly approach. Future studies with a broader scope in Tshopo may yield more definitive results.

Temperature values ranged from 26.0°C to 29.0°C, with an average of 27.3°C—higher than the 18.7°C reported by Bagalwa et al. (2023) in rivers of South Kivu. This variation may reflect differing regional climatic conditions, as also noted by Grogala et al. (2014) in Côte d’Ivoire. Temperature is a key determinant of aquatic biological processes such as growth and reproduction.

Conductivity ranged from 32.3 to 370 $\mu\text{S/cm}$, but mollusc density did not follow a clear pattern relative to conductivity. This contrasts with Davis et al. (1981), who found a positive correlation in North America. The variation in our findings may reflect the adaptability of molluscs to different local environments. As Strong et al.

(2008) explain, mollusc tolerance varies significantly across species and habitats.

pH values in this study ranged narrowly from 5.1 to 5.6, all below the 6.59–7.5 range reported by Bakhoum et al. (2019). This could be attributed to differences in water body type—our study sampled small rivers and wastewater conduits, whereas theirs examined a major river system (Senegal River).

Dissolved oxygen is directly influenced by temperature and photosynthetic activity in aquatic ecosystems (Sanaa, 2006). Its availability affects mollusc distribution and reproduction. In aquatic systems, algae and aquatic plants are vital oxygen sources that support mollusc respiration (Aminot & Chaussepied, 1983).

Correlation Between Mollusc Numbers and Physico-Chemical Parameters

The observed non-significant trends in the correlation graphs—both positive and negative—may be due to random variation given the small sample size. While some relationships may indicate underlying patterns, others might reflect non-linear interactions. These findings align with those reported by Bagalwa et al. (2023) in Katana, South Kivu, but diverge from the significant correlations found by Bakhoum et al. (2019). Again, the difference may be due to the limited scope and sampling frequency in our study.

Limitations

This study's limitations include the small number of geographically separated sites and the reliance on single-time sampling. Security concerns related to the deadly ethnic conflict between the Mbole and Lengola tribes restricted broader data collection. Additionally, potentially important factors—such as substrate type and aquatic vegetation—were not measured, although they may significantly influence mollusc populations.

CONCLUSION

This study provides valuable information on the physico-chemical parameters of the habitats of molluscs, the intermediate hosts of schistosomes, in Kisangani and its surroundings.

The findings reveal the absence of a statistically significant correlation between the number of molluscs collected in 30

minutes and the physico-chemical parameters of the different sites. Although the lack of a clear relationship is intriguing, it could be attributed to several factors. These include the spatial scale of the study, which may limit the ability to detect small-scale correlations, as well as unmeasured environmental variables—such as vegetation cover, water flow, and sediment composition—that could play important roles in mollusc distribution and abundance.

Further research is needed to investigate the specific factors influencing mollusc abundance in Kisangani and its environs.

Recommendations

To effectively combat schistosomiasis in Kisangani and surrounding areas, a multidimensional approach is essential. Environmental interventions should include the following:

Surveillance and Monitoring

- **Regular malacological surveillance:** Establish a system for the routine monitoring of mollusc populations in at-risk sites, including mollusc counting and identification of host species.
- **Monitoring of physico-chemical parameters:** Continue to monitor water parameters to better understand their influence on mollusc population dynamics and to inform targeted interventions.

Mollusc Habitat Management and Modification

- Line city water pipelines and regularly clean riverbanks to make these habitats less favourable for mollusc survival.

Improved Access to Water, Sanitation, and Hygiene (WASH)

- Provide safe drinking water sources (e.g., boreholes, standpipes) to reduce community reliance on potentially contaminated water bodies.
- Construct and promote the use of adequate latrines to prevent the contamination of water sources with human excreta containing schistosome eggs.
- Implement proper wastewater and solid waste management systems to prevent the pollution of aquatic environments.

Education and Behaviour Change

- **Community awareness:** Educate local populations about the schistosomiasis lifecycle, the role of molluscs, transmission pathways, and prevention strategies.
- **Promotion of healthy behaviours:** Encourage latrine use, discourage open defecation and urination, and reduce direct contact with infested waters (e.g., by wearing protective footwear or avoiding swimming in known at-risk areas).
- **Community participation:** Involve local communities in the planning and implementation of interventions such as canal cleaning and mollusc surveillance.

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Ethical Approval: The study was approved by the Vice-Dean in charge of Research, Faculty of Medicine and Pharmacy, University of Kisangani, DRC (N° FMP/76/2024).

Conflicts of Interest: None declared.

ORCID iDs:

Sapu, K. J.¹: <https://orcid.org/0009-0007-7321-5300>
 Abedi, M. M.²: Nil identified
 Tagoto, T. A.³: <https://orcid.org/0000-0003-1012-6769>
 Falay, S. D.³: <https://orcid.org/0000-0003-0746-9090>
 Losimba, L. J.³: <https://orcid.org/0000-0002-2110-4488>
 Bobanga, T.⁴: <https://orcid.org/0000-0002-4885-2750>

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