Malaria Rapid Diagnostic Test (HRP2/pLDH) Positivity, Incidence, Care Accessibility and Impact of Community WASH Action in DR Congo: Mixed Method Study involving 625 Households

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Abstract

Background Malaria is one of the most prevalent and deadliest illnesses in sub Saharan Africa (SSA). Despite recent gains made towards its control or elimination in past decades, many African countries still have endemic malaria transmission. Thus, the search for disease control strategies is indispensable. This study aimed to assess malaria burden at household level in Kongo central province, Democratic Republic of Congo (DRC), and the impact of community participatory water, sanitation and hygiene (WASH) action.

Methods Mixed method research was conducted in two semi-rural towns, Mbanza-Ngungu (WASH action site) and Kasangulu (WASH control site) between July 2017 to March 2018, involving 625 households (3,712 individuals). Baseline and post-intervention malaria surveys were conducted in 2017 and 2018, respectively, using the World Bank/WHO Malaria Indicator Questionnaire. In addition, an action research consisting of a six-month (September 2017 - February 2018) prospective study was carried out which comprised two interventions: (1) a community participatory WASH action aiming at eliminating mosquito breeding sites in the residential environment and a (2) community anti-malaria education campaign. The latter was implemented at both study sites. In addition, baseline and post-intervention rapid diagnostic test (RDT) for malaria was performed among respondents. Furthermore, a six-month prospective hospital-based epidemiological study was simultaneously conducted using records of patients admitted at health settings located at both study sites.

Results Prevalence of positive malaria RDT among respondents decreased significantly at WASH-action site (38% vs. 20%; $p < 0.05$), but no significant change was observed at the WASH control site. There were 96% of respondents (heads of households) who reported at least one malaria event occurring in the previous six-month period, only 66.5% of them received malaria care at a health setting. At household level, long-lasting insecticide-treated net (LLIN) was the most commonly used preventive measure (55%), followed by mosquito repellent (15%), indoor residual spraying (IRS) (2%), LLIN-IRS combination (2%); however, 24% of households did not use any measures. Mean household malaria incidence decreased at the WASH action site; 2.3 ± 2.2 cases vs. 1.2 ± 0.7 cases ($p < 0.05$), whereas no significant change was noted in control site. Moreover, malaria incidence rate was highest (60.9%) among households living in proximity to grassy and/or stagnant water spots. Low household monthly income (ORa = 2.37; 95%CI: 1.05–3.12; $p < 0.05$), Proximity to high risk area (grassy/stagnant water spots) for malaria (ORa = 5.13; 95%CI: 2-29-8.07; $p < 0.001$), poor general WASH status in residential area (ORa = 4.10; 95%CI: 2.11–7.08; $p < 0.001$) were determinants of household malaria. Furthermore, data collected from referral health settings showed high malaria frequency, 67.4% (1,108/1,645) occurring during the first semester of 2017, including 772 (70%) of pediatric malaria cases and 336 (30%) of cases from Internal medicine departments.

Conclusion Findings from this research suggest the necessity for DRC government to scale up the fight against malaria by integrating efficient indoor and outdoor preventive measures, including WASH intervention in residential environment, and improve malaria care accessibility to reduce malaria burden. This would be a step towards achieving universal health coverage (UHC) in the Congo.

Background

Worldwide, progress has been made towards malaria control and elimination in the two decades. However, many countries of the sub Saharan Africa (SSA) still have endemic malaria transmission. Thus, the search for novel malaria control or elimination strategies is still in progress [1]. Malaria, an infectious disease caused by the protozoan parasites of *Plasmodium* species and transmitted by the *Anopheles* mosquito, is one of the most prevalent and deadliest illnesses in developing countries [2, 3]. The World health Organization (WHO) estimates that the disease has caused 473,000 to 789,000 deaths in the world in 2012, which was lower compared to 1, 000,000 deaths per year reported in the 1990's [2]. Furthermore, it is reported that 90% of malaria-related deaths in the world occur in SSA, 40% of them occurring in the Democratic Republic of the Congo (DRC) and Nigeria. In addition, in SSA, households lose approximately 25% of their total income to malaria-related expenses, suggesting that malaria is a disease that causes or deepens poverty [3–5].

Recently, WHO reports have shown progress made by several countries in reducing malaria burden, and estimated showed that more than 6,000,000 malaria deaths have been averted in SSA between 2000 and 2015 [6]. Nevertheless, the emergence of drug-resistant malaria parasites and pesticide-resistant Anopheles mosquitoes, inaccessibility to treatment for most at risk population, residual and outdoor transmission, the absence of rigorous evaluation of the effectiveness of malaria interventions and the absence of malaria vaccine are among factors that hinder malaria control and elimination programs in most endemic countries [7–9]. Despite a noticeable reduction in global malaria burden in the last two decades, recent trends show stagnation of the progress made and an increase of disease burden in some countries. Additionally, nowadays malaria experts agree that to achieve malaria eradication, interventions should focus not only on the disease prevention, but also on reducing the disease transmission [10, 11].

In fact, most of malaria preventive measures implemented to scale up malaria control are those applied indoor. However, other contributing factors to the disease transmission such as outdoor environmental factors, which increase mosquito population in residential area, are often excluded when designing malaria control interventions. In DRC, apart from challenges related to the availability of and use of malaria preventive measures, issues related to accessibility to healthcare services, including malaria care is another challenge [12]. Our pilot survey conducted in Congolese rural and urban counties showed that poor WASH and low income were associated with malaria [13]. Furthermore, other previous works showed evidence on the effects of malaria on workers' absenteeism, productivity, medical costs [14, 15], population growth, as well as children developmental retardation and premature death [16, 17].

Currently, there is a growing concern about the widespread antimalarial drug resistance in *Plasmodium* parasites, and the disease vector's resistance to most commonly used insecticides in bed nets, which contribute to the failure of malaria prevention programs in most endemic countries such as DRC. In DRC, malaria vector control policy is based on the use of long-lasting insecticide-treated bed nets (LLINs) [18, 19]. A recent study that assessed gene mutations involved in resistance phenomenon to pyrethroid and dichlorodiphenyl-trichloroethane (DDT) - two of most used insecticides against the disease vector -

showed that 85% of *Anopheles gambiae* collected in DRC carried the *kdr* mutations [20]. This, suggests the necessity to find novel approaches susceptible to help scaling up malaria control program in the Congo.

Moreover, despite the United Nations' resolutions calling for accelerating progress towards equitable access to health services some countries of the SSA region, DRC in particular, are still left behind in terms of ensuring primary health care access to populations. To our knowledge, there have been no studies conducted in central Africa region (in DRC in particular) that explored the impact of WASH intervention coupled with anti-malaria education at community level. The present research assessed the spatial malaria risk distribution, disease incidence and evaluated the impact of a community participatory WASH action on household malaria incidence in Kongo Central province, DRC. Additionally, we also searched to determine malaria trend in health settings located at the study sites using hospital-based epidemiological data.

Methods

1. Study design, sites and participants

Mixed method research comprising three distinct studies was conducted in two semi-rural towns of Kongo Central province, DRC, from January 2017 through March 2018. The main study involved 3,712 individuals from 625 households and included: (1) a cross-sectional design (baseline survey) using Malaria Indicator Questionnaire [13, 21] from the World Bank and WHO Malaria Program in Africa and Madagascar; (2) an action research (a 6-month prospective study) consisting of two interventions: community participatory WASH action and malaria education campaign. The latter intervention was implemented in both study sites (Fig. 1a); (3) a prospective hospital-based epidemiological study which was conducted using medical records of patients admitted from 1 January through 30 June 2017 at two randomly selected referral health settings.

In the main study, a two-stage cluster sampling technique was used to randomly select two study sites, at the 'health zone' and municipality (county) levels as shown in Fig. 1b. Loma county (WASH action site) was randomly selected in Mbanza-Ngungu health zone in the town of Mbanza-Ngungu, which is located at 154 km from the capital Kinshasa, with an area of 8,460 km². It has a population of 651,092. On the other hand, Quartier residentiel county (WASH control site) was randomly selected in Kasangulu health zone in the town of Kasangulu; it is located at 33 km from the capital Kinshasa, having an area of 4,680 km² and a population of 194,190 inhabitants.

The following criteria were used to select the county where the study should be conducted: (1) having a referral health setting under the supervision of the health zone medical inspector, and (2) the health setting should have a well-handled patients' records. During the implemen-tation of this study, hospital-based epidemiological data were collected at the health settings located at each study site to determine malaria prevalence trend. In DRC, a health zone consists of primary operational units of the health system and, usually, it covers a population of 100,000–150,000 inhabitants in rural areas and 200,000–250,000 inhabitants in an urban area [22].

All households from selected counties that had at least three members were eligible. Considering a power of 80% ($\beta = 0.80$) for α value of 0.05, we expected to have at least 200 households participate in this research. Within each study site (county), blocks of 50 houses were created; then, data collectors randomly selected every second house on each avenue in each block at selected area. Additionally, only households having at least three members were finally included in the study. In total, 625 households (3,712 individuals) were surveyed, including 316 (50.6%) from the WASH action site (Loma) and 309 (49.4%) from WASH control site (Quartier residentiel).

1. Surveys, interventions and diagnostic procedure for malaria

Surveys were conducted simultaneously at both study sites at baseline and at the end of six-month intervention period, following a schedule that was announced to residents by local health zone staff. The French version of malaria indicator survey (MIS) questionnaire was used in this study. It is a validated questionnaire used by the National Malaria Program of several French speaking African countries to estimate household malaria burden.

MIS comprises an informed consent form and questions related sociodemographic and anthropometric characteristics, household characteristics, past medical history, WASH status, malaria preventive measures, malaria status and care. All household heads participated in the baseline and post-intervention surveys. Additionally, home visits were undertaken by local collaborative research team and Health Zone staff to evaluate WASH status at home and in the living environment, and check indoor and outdoor preventive measures used by household members, and ascertain consistency of their use. A hand-held GPS GIS device was used to collect data on geospatial localization of mosquito breeding sites; that is to estimate the distance between residences and mosquito breeding sites (grassy area, stagnant water spot, garbage spot and river side). We assumed that when a residence was located at less than 200 m from a mosquito breeding site, household members were considered at high risk for malaria.

Anti-malaria interventions comprised the following actions: (1) community WASH action consisting of a weekly participatory hygiene and sanitation transformation (PHAST) was carried out only in WASH action site in order to clean the residential environment and eliminate mosquito breeding spots; (2) community anti-malaria education. The latter was implemented in both study sites after the baseline survey. Education sessions were organized in communities, schools and leaflets that display risk factors and behaviors were being distributed to the participants as well as household heads in each study site. The PHAST approach is a learning methodology commonly used to prevent a broad range of infectious diseases at community level, through improvement of hygiene behaviors and sanitation, and encourages a better community management of water and sanitation services. In this study, PHAST was extended to periodic cleansing of the living environment, by local volunteers and community members.

Furthermore, survey respondents underwent the rapid diagnostic test (RDT) for malaria at baseline and at the end of the study. RDT is a validated diagnostic test with three individual bands that signify the control, the histidine-rich protein 2 (HRP2) and the Plasmodium lactate dehydrogenase (pLDH) antigens. The test allows to diagnose malaria caused by Plasmodium falciparum and other Plasmodium species [23]. All respondents with a positive RDT at baseline received malaria treatment.

Regarding the hospital-based epidemiological study, only patients admitted to internal medicine and pediatric departments of health settings between 1 January through 30 June 2017, and whose records showed final diagnoses were included; records that showed no diagnosis were excluded. For medical records showing comorbidities, the first diagnosis was considered.

3. Statistical analysis

Data are presented as proportions for categorical variables, whereas means and their standard deviations are used for continuous variables. Comparisons within and between study groups were performed using paired t test (for incident malaria incidence cases) and chi-square test (for categorical variables); however, for categorical variables with repeated measures (RDT), McNemar’s test was used. All variables that showed a significant or marginally significant association with household malaria in the bivariate logistic regression analysis were subjected to a multivariate analysis model to determine predictors of malaria. Analyses were performed with the use of Stata software version 15.

Results

1. Baseline characteristics of respondents and households

Table 1
Characteristics of the respondents

Characteristics of respondents	Control site	WASH action site	All respondents
	n = 309 (%)	n = 316 (%)	N = 625 (%)
Gender (%) Male	71 (23)	111 (35.1)	182 (29)
Female	238 (77) *	205 (64.9) *	444 (71)
Age (years; mean +/- SD) 24–50	33.71 ± 8.74	33.86 ± 8.48	33.73 ± 8.68
51–98	60.17 ± 8.51	62.73 ± 9.25	61.27 ± 8.88
Marita status	205 (66.3)	209 (66.1)	414 (66.2)
- Married	22 (7.1)	21 (6.7)	43 (6.9)
- Divorced	32 (10.4)	15 (4.7)	47 (7.5)
- Widower	28 (9.1)	37 (11.7)	65 (10.4)
- Single with child/children	22 (7.1)	34 (10.8)	56 (8.9)
- Single without child			
Education	19 (6.1)	45 (14.2)	64 (10.2)
-No education	37 (12)	48 (15.2)	85 (13.6)
-Primary	203 (65.7)	201 (65)	404 (64.6)
-High school	40 (12.9)	14 (4.5)	54 (8.6)
-College/university	10 (3.2)	8 (2.5)	18 (3)
-Technical/professional school			
Smoking status	306 (99)	284 (89.9)	590 (94.4)
-Never smoked	0 (0.0)	15 (4.7)	15 (2.4)
-Has quit (> 36months)	3 (1)	17 (5.4)	20 (3.2)
-Yes			
Alcohol consumption	257 (83.1) *	207 (65.5)	464 (74.2)
-Never	7 (2.3)	15 (4.7)	22 (3.5)
-Has quit (over 36 months)	20 (6.5)	53 (16.8)	73 (11.7)
-At most 2 glasses/day	25 (8.1)	41 (13)	66(10.6)
-More than 2 glasses/day			

Characteristics of respondents	Control site	WASH action site	All respondents
Physical activity (≥ 20 min 2x/week)	209 (67.6)	105 (33.2)	316 (50.6)
-No	100 (32.4)	211 (66.8)	309 (49.41)
-Yes			

Table 1
(continued). Characteristics of the households

Household characteristics	**Control site (Kasangulu)**	**WASH action site (Mbanza-Ngungu)**	**All households**
	n = 309 (%)	N = 316 (%)	N = 625 (%)
Sociodemographic characteristics			
Household/family size	126 (40.8)	152 (48.1)	278 (44.5)
1–5	153 (49.5)	148 (46.8)	301 (48.2)
6–10	30 (9.7)	16 (5.1)	46 (7.4)
≥ 11			
Monthly income (US$) < 100	221 (44.38)	277 (55.62)	498 (79.68)
100 or higher	79 (62.20)	48 (37.80)	127 (20.32)
WASH status/ cleanliness of residential environment			
Latrine type (n = 603)	8 (2.6)	5 (1.6)	13 (2.1)
-Appropriate with flushing system	47 (15.2)	99 (31.3)	146 (23)
-Appropriate with manual watering system	68 (22)	54 (17.1)	122 (19.5)
-Inappropriate but covered	177 (57.3)	126 (39.9)	303 (48.5)
-Inappropriate and uncovered	5 (1.6)	14 (4.4)	19 (3)
-No latrine	4 (1.3)	11 (3.5)	22 (3.5)
-Other/ no answer			
Shared latrine? (n = 625) -Yes	49 (22.69)	167 (77.31) *	216 (34.56)
-No	260 (63.73)	149 (36.43)	409 (65.44)

- **Notes**: *, p value less than 0.05.

Household characteristics	Control site (Kasangulu)	WASH action site (Mbanza-Ngungu)	All households
Ecological feature of residence area	42 (13.6)	17 (5.4)	59 (9.4)
- Proximity to river	20 (6.5)	4 (1.3)	24 (3.8)
- Proximity to/residence on mountain/hill	66 (21.3)	88 (27.8)	154 (24.6)
- Proximity to garden, grass/bush	54 (17.5)	92 (29.1)	146 (23.4)
- Proximity – stagnant water spot	20 (6.5)	15 (4.7)	35 (5.6)
- Proximity or residence in slum	38 (12.3)	4 (1.3)	42 (6.7)
- Proximity to river and mountain	49 (15.8)	20 (6.3)	69 (11)
- Proximity – river and slum	11 (3.6)	64 (20.2)	75 (12)
- Nothing particular	9 (2.9)	12 (3.8)	21 (3.4)
-Other/no answer			
Periodic cleansing in residential area	5 (11.6)	10 (3.2)	15 (2.4)
-Yes	304 (98.4)	296 (95.8)	610 (97.6)
-No	0 (0)	3 (1)	0 (0)
-Other/no answer			
Cleanliness of residential area	135 (43.7)	13 (4.1)	148 (23.6)
-Good	139 (45)	222 (70.3)	361 (57.8)
-Acceptable	35 (11.3)	81 (25.6)	116 (18.6)
- Not acceptable	0 (0)	0 (0)	0 (0)
-Other/no answer			
Frequency of mosquito bites	86 (27.8)	134 (42.4)*	220 (35.2)
- High frequency	184 (59.5)	153 (48.4)	337 (53.9)
- Moderate	38 (12.3)	29 (9.2)	67 (10.7)
- No bite or rare	1 (0.3)	0 (0)	1 (0.2)
-Other/no answer			
- **Notes**: *, p value less than 0.05.			

Of the 625 respondents (household heads), 70.9% were females; overall mean age was 33.8 ± 8.8 years. The majority (66.2%) of the respondents were married men and women. Regarding education level, most respondents (64.6%) had high school level, followed by those with primary education level (13.6%), whereas 10.2% were illiterate. Mean household size was 5.9 ± 2.8 members, and almost 80% of them earned less than 100 US dollars a month. About 25% of households used appropriate/acceptable latrines. Baseline survey results also revealed that periodic sanitation intervention was not carried out in the residential area; this was supported by 97.6% of the respondents; 18.6% reported that the general sanitation status in their living environment was unacceptable (11.3% at control site vs. 25.6% at WASH action site) (Table 1).

2. Malaria preventive measures used by household members and RDT results

Long-lasting insecticide-treated net (LLIN) was the most commonly used malaria preventive measure (55% of households), followed by mosquito repellent (15%), whereas indoor residual spraying (IRS) and the combination of LLIN and IRS accounted for 2% each. Strikingly, 24% of households did not use any of the measures as shown in Fig. 2. Regarding malaria testing for household representatives (respondents), results before and after WASH and educational interventions showed no significant change in rate of positive RDT at the control site; however, this rate decreased markedly at WASH-action (38% vs. 20%; $p < 0.05$) (Fig. 3).

3. Malaria incidence and care accessibility among household members

Among the respondents, overall malaria incidence rate (at least one episode) decreased, when comparing the status before and after interventions, 96% vs. 52% respectively ($p < 0.05$) (not shown). Of the 96% of respondents who reported malaria event in the baseline survey, only 66.5% of them received malaria care at a health setting. When considering study sites, malaria incidence rate among the respondents decreased in both the WASH action (98% vs. 47.5%; $p < 0.001$) and WASH control site (94.1% vs. 52.5%; $p < 0.01$).

Furthermore, at household level, mean malaria incidence decreased markedly in the WASH action site (2.3 ± 2.2 vs. 1.2 ± 0.7 cases; $p < 0.05$) following 6-month sanitation intervention period. On the other hand, no significant change was observed in the WASH control site. When comparing both study sites, household malaria incidence was significantly lower in WASH action site than control site ($p < 0.001$) (Fig. 4).

4. Household malaria incidence according to residential area

Each study site was divided into areas of low and high risk for malaria. Households living in proximity (distance less than 200 meters) to river, stagnant water/grassy spot were considered at high risk; whereas those whose residences were located at higher altitude or far from river, grassy area and water posts were considered at low risk for malaria.

Results showed that malaria incidence rate was markedly higher (83%) among households with residences located at high risk areas as compared to those living in low risk areas (83% vs. 17%, respectively; $p < 0.001$). Moreover, malaria rate was highest (60.9%) among households living in proximity to grassy and/or stagnant water spot (Fig. 5a, b).

5. Determinants of household malaria (baseline survey)

The multivariate analysis with adjustment for age, gender and occupation showed that household malaria was positively associated with household size (ORa = 1.39; 95%CI: 2.62–4.89; $p < 0.05$), proximity of residence to high risk area for malaria (ORa = 5.13; 95%CI: 2.29–8.07; $p < 0.001$) and the frequency of mosquito bites (2.68; 95%CI: 2.84–4.17; $p < 0.05$), whereas inverse association was found between household malaria and income status (OR = 2.37; 95%CI: 1.05–3.12; $p < 0.05$), also between household malaria and general WASH status in the residential environment (ORa = 4.10; 95%CI:2.11–7.08; $p < 0.001$) (Table 2).

Table 2
Preditors of household malaria (multi-variate analysis)

Predictors	**ORa (SD)**	**95% CI**	**p-value**
Age (< 40 y. vs. 40 or older)	1.03 (0.02)	0.98–1.07	0.184
Gender (M vs. F)	0.27 (0.21)	0.05–1.27	0.099
Household size (2–5 vs. > 5)	1.39 (0.16)	2.62–4.89	< 0.05
Education level (Low vs. high)	0.88 (0.27)	0.48–1.62	0.701
Living environment (high risk vs. low risk)	5.13 (0.9)	2.29–8.07	< 0.001
Income status (US$) (< 100 vs. 100 or higher)	2.37 (1.42)	1.05–3.12	< 0.05
General WASH status (poor vs. good)	4.1 (0.5)	2.11–7.08	< 0.001
Mosquito bite (frequent vs. less frequent)	2.68 (0.27)	2.84–4.17	< 0.05

-Notes: multiple logistic regression model was performed with adjustment for age, gender, occupation.

6.*Malaria trend in internal medicine and pediatric departments at referral hospitals*

Figure 6 shows the disease distribution at the two referral health settings located at study sites. Overall malaria frequency was high, 67.36% (1,108/1,645), followed by respiratory diseases (21.22%; 349/1,645) and other conditions, including gastrointestinal disorders (11.43%; 188/1,645) (Fig. 6a). Pediatric malaria was more frequent in health settings located at the study sites, 69.67%, whereas of the disease (malaria) accounted for 30.33% of patients admitted to internal medicine departments (Fig. 6b).

Furthermore, high rate of malaria was observed at both study sites: 61.35% at Loma county in Mbanza-Ngungu and 73.92% at quartier residentiel in Kasangulu (Fig. 6c). Although malaria rate remained high throughout the first semester (2017), disease rate was highest between April (83.37%) and May (85.37%); it was also high in February (77.9%), whereas it decreased to 61.36% in June, which corresponds to dry (cold) season in DRC (Fig. 6d).

Discussion

This study was carried out in two Congolese towns, Mbanza-Ngungu and Kasangulu, in the western province of Kongo central which is considered a malaria endemic area. The trend of RDT positivity among the respondents (household heads), household malaria incidence in the main intervention and control sites before and after a six-month intervention period and related determinants were investigated. It was found that overall prevalence of malaria RDT + as well as that of self-reported (at least one disease episode) decreased significantly among the respondents. Strikingly, of the 96% of respondents who reported incident malaria, about 33% did not have access to malaria care at a health setting; they mostly relied on self-medication which is a common practice in poor Congolese communities.

In fact, amidst severe economic crisis in the country caused in part by the longstanding armed conflicts, and due to poverty, unemployment, lack of national health insurance and universal health care system in DRC, accessibility to quality health care is still a mere dream for many Congolese households [13]. Additionally, the issue related to household income might explain the considerable rate (24%) of household that did not use any preventive measures against malaria. In SSA region, health inequalities have been previously reported to be influenced by socioeconomic status. For example, a study conducted in rural Kenya [24] showed higher malaria prevalence among poorest individuals than in less poor ones.

In the present study, high malaria incidence was observed (with two cases or more per household) in the previous 6-month period prior to implementing interventions, according to baseline survey results. Similarly, this fact was evidenced by results from the hospital-based epidemiological study that revealed high malaria morbidity in both study sites. On the other hand, the baseline survey also showed higher malaria incidence among households living in areas with highest risk for disease transmission, whereas it significantly decreased in the WASH action site where PHAST intervention was implemented. This outcome implies the importance of maintaining the residential environment clean and free of mosquito breeding sites to reduce the risk of disease transmission through mosquito bites.

Our study also showed association between malaria and household income status, with members of household earning less than 100 $USD having higher risk for malaria. A recent systematic review and meta-analysis conducted by Degarege and colleagues [25] also confirmed this fact. Similarly, another study by Tasting et al. [26], which focused on pediatric malaria, showed that the odds of malaria infection were higher in poorest children as compared with the least poor ones, suggesting that socioeconomic development could be an effective and sustainable intervention against malaria. Obviously, households with low income have difficulty to regularly afford the cost of effective anti-malaria preventive measures.

Nonetheless, despite being a valuable contribution that provides novel insights on malaria risk distribution according to residential environment, accessibility to preventive measures and malaria care, as well as the role of community involvement in the fight against this deadly disease, the present work neither explored the role of vector (malaria parasite) resistance in disease incidence at our study sites. Future investigations should consider this important issue that contribute to the endemic status of malaria in sub Saharan Africa.

Conclusion

This study explored environmental and sociodemographic factors associated with household malaria in DRC. Findings suggest the role of community involvement in the fight against malaria, particularly in terms of promotion of clean living environment through interventions that reduce mosquito population and the risk of disease transmission. In DRC, malaria endemic country, the use of indoor preventive measures such as LLIN and IRS might not be enough to control the disease. According to our findings, LLIN and IRS users and non-users were equally exposed to malaria due to high disease risk (numerous mosquito breeding sites, high population in the living environment). There is a necessity for DRC health policymakers to consider integrating indoor and outdoor preventive measures, with the involvement of communities for an efficient malaria control. Furthermore, DRC government should make primary health care accessible to its population in effort towards achieving universal health coverage.

Data availability

The study data are available from the corresponding author.

Abbreviations

HRP2
histidine-rich protein 2
IRS
indoor residual spraying
LLIN
long-lasting insecticide-treated bed net
MIS
malaria indicator survey
PHAST
participatory hygiene and sanitation transformation
pLDH
plasmodium lactate dehydrogenase
SSA
sub Saharan Africa
UHC
universal health coverage
WASH

water, sanitation and hygiene

Declarations

Ethics approval and consent to participate

Participation was voluntary based on the willingness of community leaders and household heads to take part in this study. Prior to implementing this research, informed consent from was obtained from each household head, and ethical approval was also obtained from the School of Public Health of the University of Lubumbashi and the Faculty of Medicine of William Booth University in DRC. All medical procedures performed in this study were in accordance with the Helsinki declaration regarding the use of human subjects in research.

Consent for publication

Not applicable.

Availability of data and materials

The datasets analysed during this study are available from the corresponding author on reasonable request.

Competing interest

The authors have no conflict of interest related to this study.

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Authors' contributions

- NRN, RW, SK, MI, SMJM and SN participated in the conception and writing of the research protocol and data analysis;
- RW, NRN, TH, TS (1), EPM, TS (2), NC and BAM participated in the implementation of the study activities and data collection process;
- KW, NRN, SI, BAM, TH, AHM and MI performed the data analysis and interpretation.
- All authors proofread the manuscript.

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Figures

Fig.1a

Health zones and study sites in Kongo central province, DR Congo

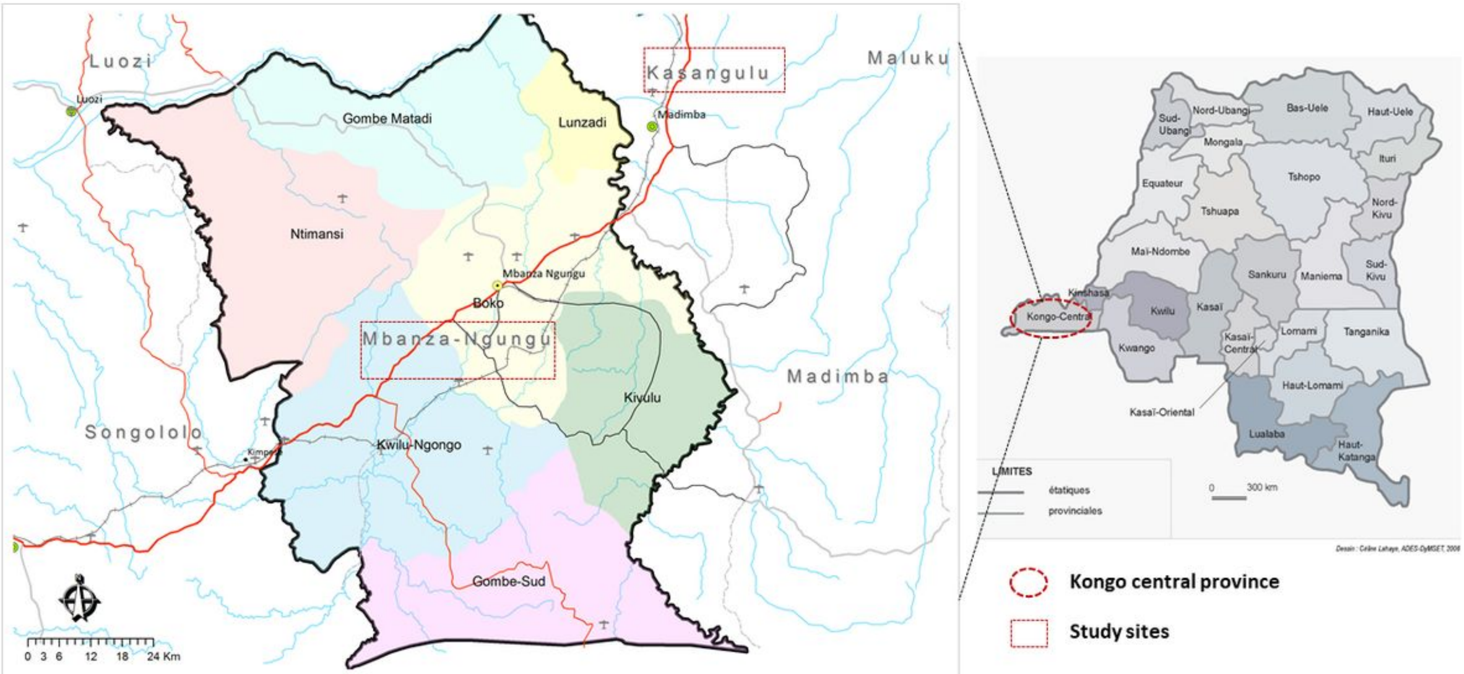

Figure 1

Maps of DR Congo (a) showing the study area in Kongo central province and main study flow chart RDT, rapid diagnostic test for malaria; WASH, water, sanitation and hygiene.

Fig.1 b

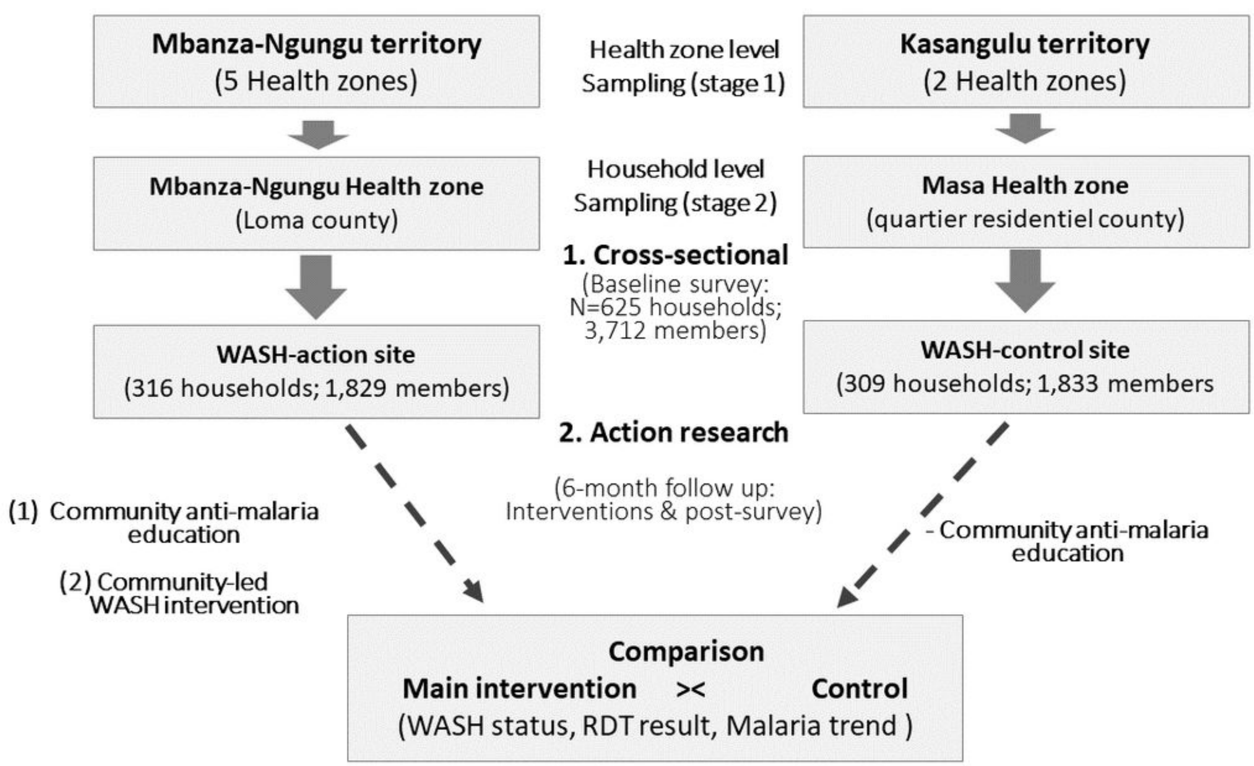

Figure 2

(b) comprising both study designs of the main study (Source of original maps: Celine Lahaye, ADES-DyMSET (2006) and CAID – DR Congo (Cellule d' Analyse des Indicateurs de Developpement), 2017) RDT, rapid diagnostic test for malaria; WASH, water, sanitation and hygiene.

Fig.2

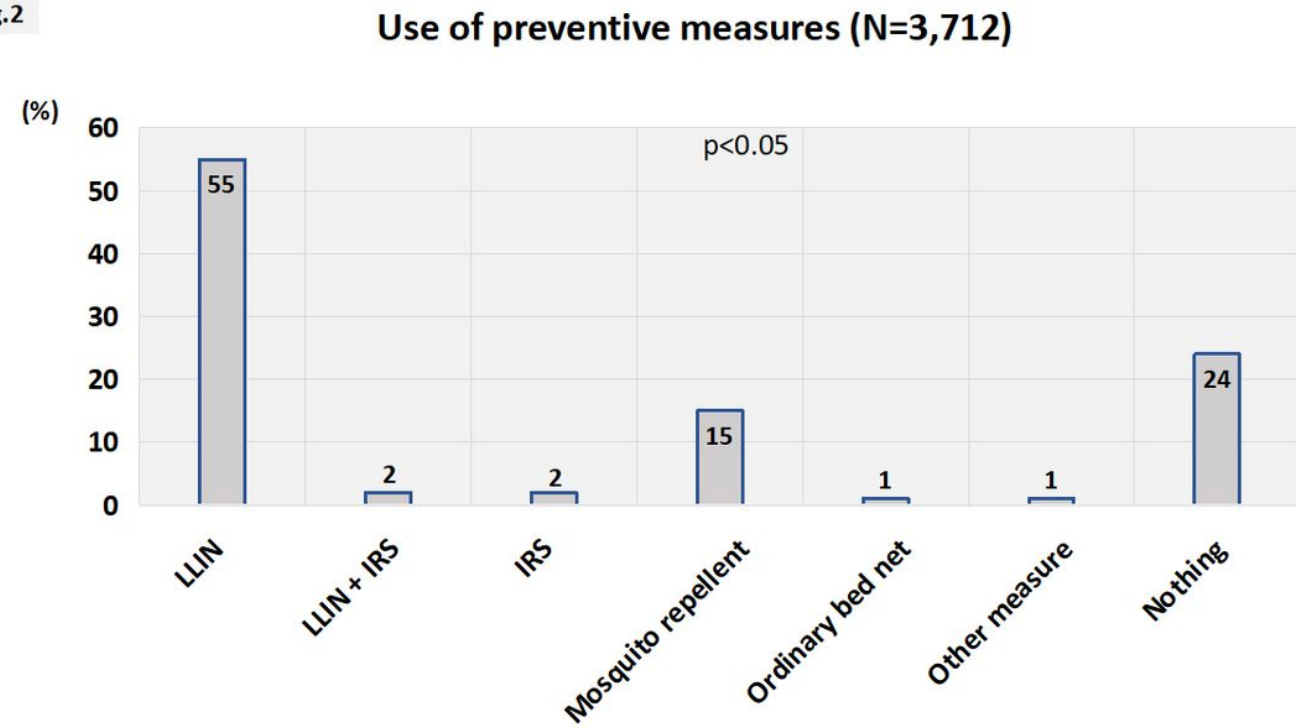

Figure 3

Malaria preventive measures used by household members IRS, indoor residual spraying; LLIN, long-lasting insecticide treated net. The figure shows that LLIN was the most used anti-malaria measure (55%) in households followed by mosquito repellent (15%), whereas 24% of households did not use any preventive measure ($p<0.05$).

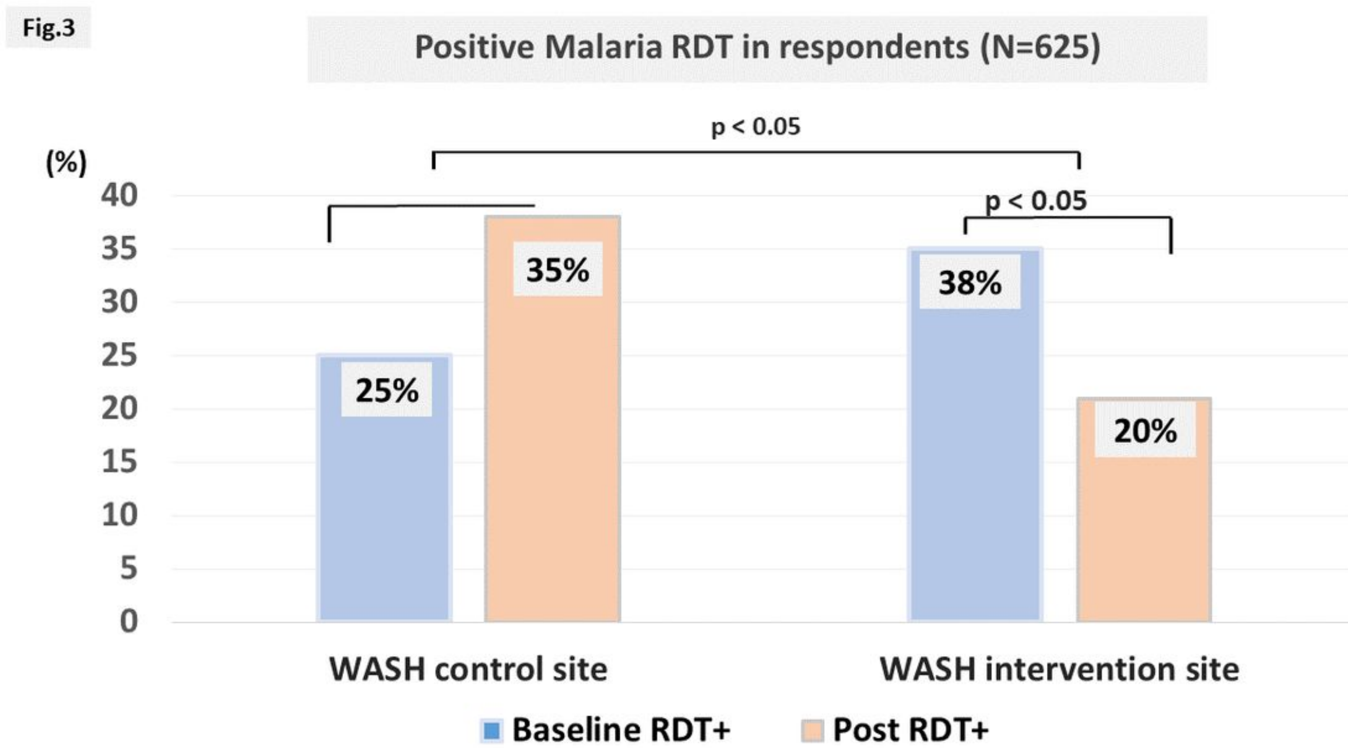

Figure 4

Prevalence of positive RDT for malaria among the respondents NS, not significant; RDT+, rapid diagnostic test for malaria; WASH, water, sanitation and hygiene. The figure shows a significant decrease of prevalence rate of positive RDT at WASH action site (38% vs. 20%; $p<0.05$) as compared to baseline RDT result.

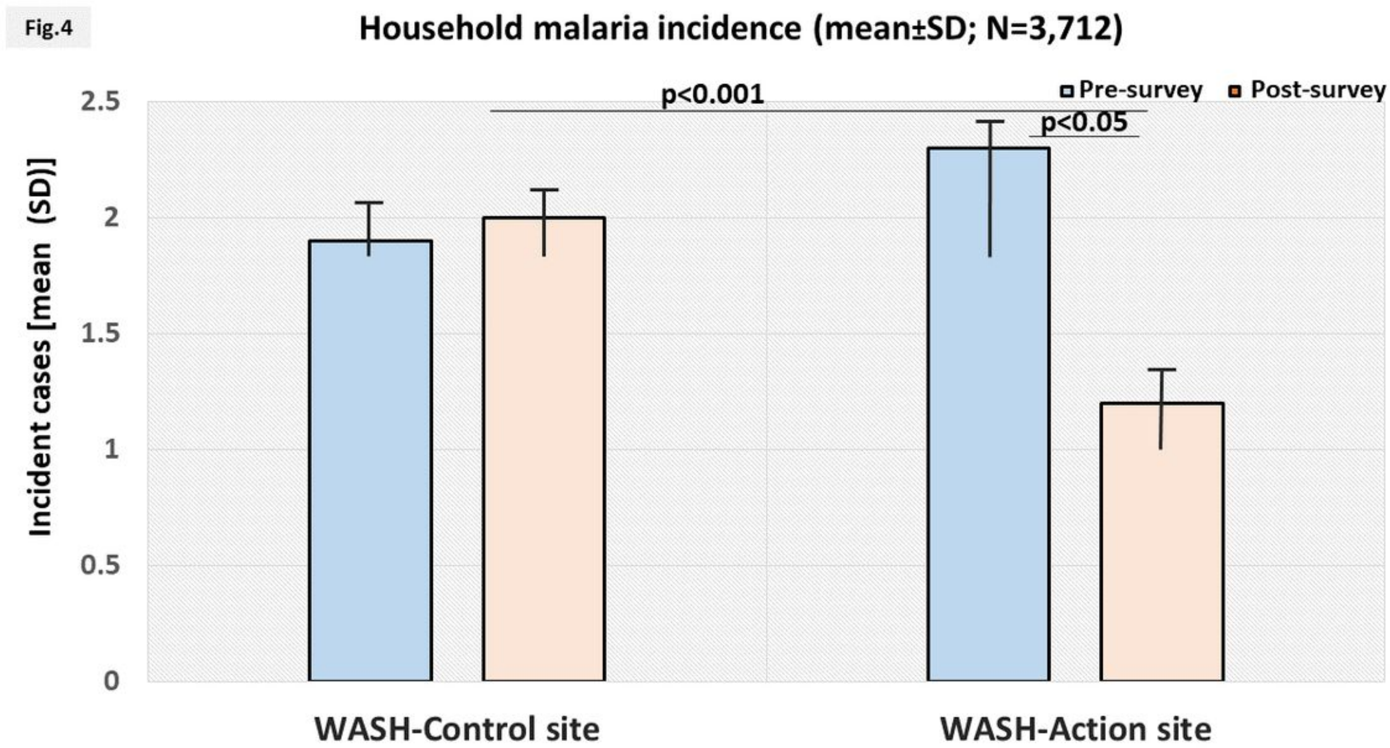

Figure 5

Trend in malaria incidence among households before and after interventions SD, standard deviation; p, p-value. The figure shows a significant decrease in incident malaria cases (mean values) among household members at WASH action site following interventions (p<0.05).

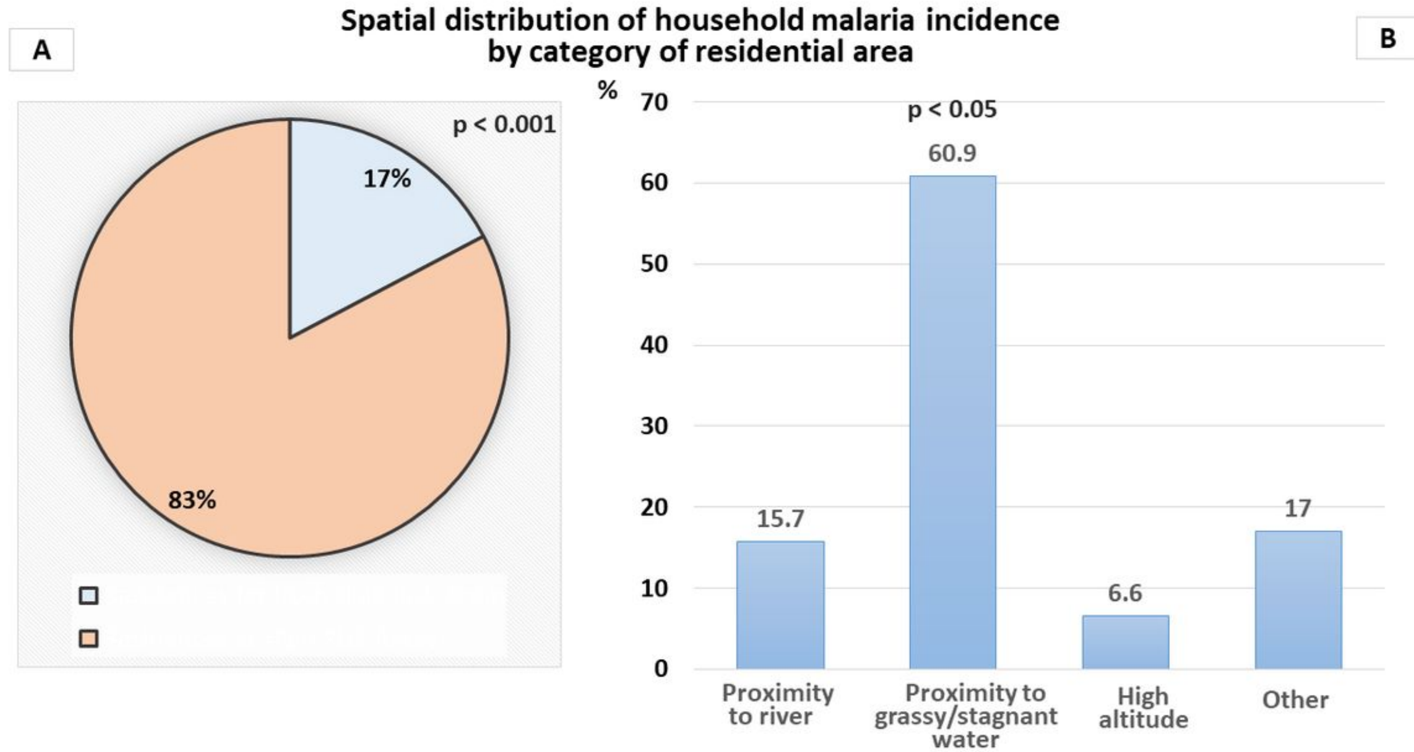

Fig.5 a,b

Figure 6

Spatial distribution of household malaria incidence by malaria risk category of residential area (a) and the proximity of the residence to risk geographical area in relation to malaria risk (b) The figure shows that higher malaria incidence was found among households living in proximity to high malaria risk areas such as grassy areas/stagnant water (60.9%) and residences near river (15.7%).

Fig. 6

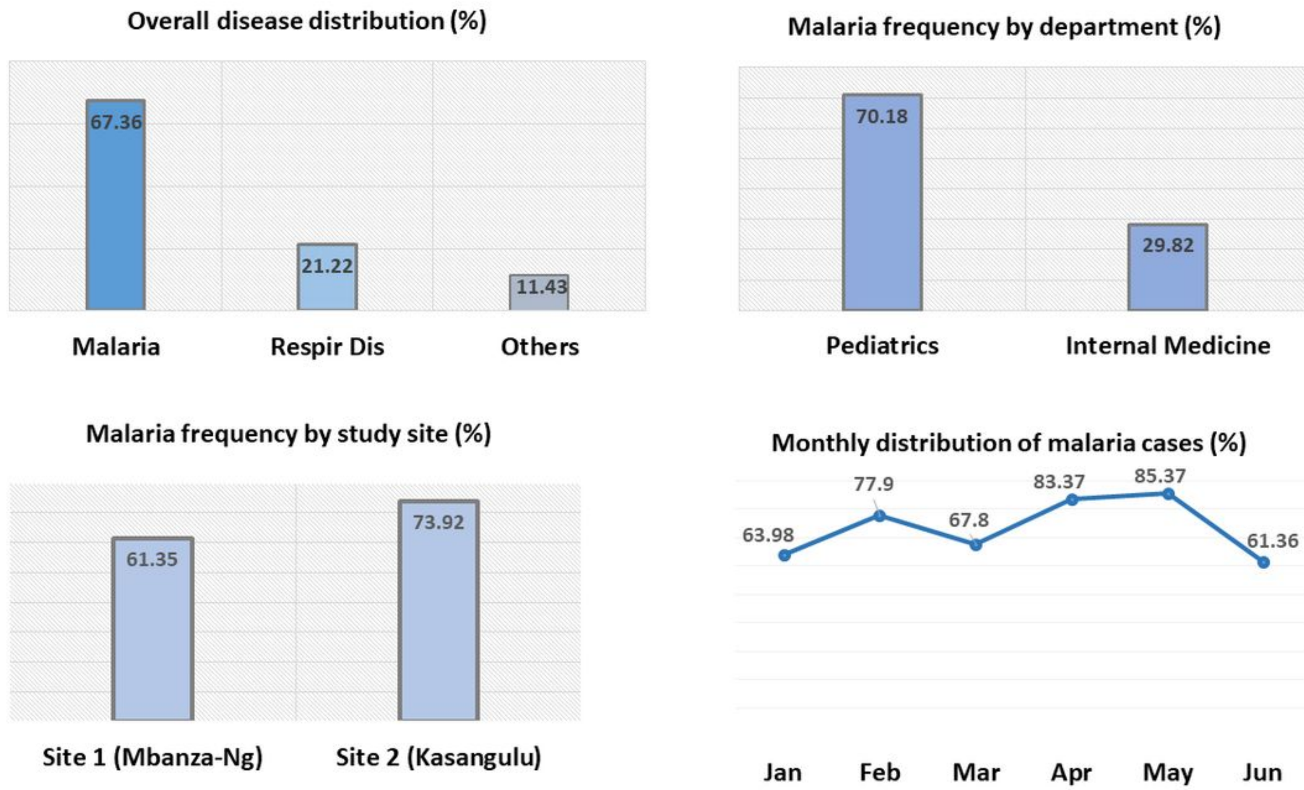

Figure 7

Hospital-based malaria incidence trend at referral health settings located in study sites, Kongo Central province, DR Congo Figure 6 shows high malaria incidence rates in the two referral health settings that participated in this study (Fig.6a), in pediatric departments (Fig.6b), study sites (Fig. 6c). When considering hospital-based monthly incidence rate in first semester of 2017 (Fig.6d), malaria was more frequent in February, April and May which correspond to months with high pluviometry in western area of DR Congo.