Ruprecht-Karls-University Heidelberg

Institute of Hygiene

Department of Tropical Hygiene and Public Health

EPIDEMIOLOGY OF MALARIA

IN A HOLOENDEMIC AREA

OF RURAL BURKINA FASO

Inaugural dissertation to obtain the degree of

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Submitted by:
Corneille TRAORE
from Bomborokuy / Burkina Faso

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Dekan: Prof. Dr. med. Dr. h.c. H.-G. Sonntag
Referent: Prof. Dr. rer. nat. H. Becher
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<tr>
<td>ARI</td>
<td>Acute Respiratory Infection</td>
</tr>
<tr>
<td>CNRFP</td>
<td>Centre National de Recherche et de Formation sur le Paludisme</td>
</tr>
<tr>
<td>CRSN</td>
<td>Centre de Recherche en Santé de Nouna</td>
</tr>
<tr>
<td>DDT</td>
<td>Dichloro-diphenil-trichloro-ethane</td>
</tr>
<tr>
<td>DSS</td>
<td>Demographic Surveillance System</td>
</tr>
<tr>
<td>EIR</td>
<td>Entomological Inoculation Rate</td>
</tr>
<tr>
<td>FGD</td>
<td>Focus Group Discussions</td>
</tr>
<tr>
<td>INDEPTH</td>
<td>International Network for continuous Demographic Evaluation of Populations and their Health</td>
</tr>
<tr>
<td>INSD</td>
<td>Institut National de la Statistique et de la Démographie</td>
</tr>
<tr>
<td>ITN</td>
<td>Insecticide Treated Net</td>
</tr>
<tr>
<td>MIM</td>
<td>Multilateral Initiative on Malaria</td>
</tr>
<tr>
<td>PRAPASS</td>
<td>Projet de Recherche-Action pour l’amélioration des Soins de Santé</td>
</tr>
<tr>
<td>SSA</td>
<td>Sub-Saharan Africa</td>
</tr>
<tr>
<td>VER</td>
<td>Vital Events Registration</td>
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<tr>
<td>GIS</td>
<td>Geographic Information System</td>
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1 INTRODUCTION

1.1 History of malaria control

The control of malaria remains one of the world’s greatest public health challenges. First rationale malaria control efforts were only possible after the discovery of the parasite life cycle a century ago. The fight to control malaria through out the world achieved major successes in the 1950s and 1960s after the discovery and systematic use of new tools including residual insecticides, such as dichloro-diphenil-trichloro-ethane (DDT) and new anti-malarial drugs such as chloroquine and amodiaquine (4-aminoquinolines). The application of these effective residual insecticides and drugs led to eradication in parts of the world with low levels of transmission and good infrastructure (WHO, 1999).

Africa was not part of the global eradication effort because of the high malaria endemicity. In addition, infrastructure was not developed, settlements were dispersed and there were few trained people to manage these programmes and financial resources were very limited (Najera et al. 1991).

The global malaria eradication programme was abandoned in 1969, due to technical reasons such as the resistance of the mosquito vector to DDT and resistance of malaria parasites to commonly used drugs (proguanil, pyrimethamine and chloroquine), and to failure of the programme in nearly all of the poor tropical countries. The few demonstration projects that had been set up in Africa had also shown that it was not possible to apply existing vector control measures effectively in such areas of very high transmission intensity.

In 1992, the WHO convened a malaria conference in Amsterdam which gave a new impetus to malaria control efforts and approved a revised Global Malaria Control Strategy (WHO 1993). The strategy enlisted four basic elements for malaria control:

- Early diagnosis and prompt treatment;
- Implementation of selective, sustainable, preventive measures including vector control;
- Early detection, containment, and prevention of epidemics;
- Fostering regular assessment of affected countries’ malaria situation, especially ecological, social and economic determinants of the disease, by strengthening local capacities for basic and applied research.
This new strategy now faces major problems in endemic countries such as:

- Increasing resistance of the malaria parasite to chloroquine and pyrimethamine-sulfadoxine
- Poor coverage of health infrastructure for diagnosis and treatment in the rural areas
- Resistance of the mosquito to insecticides including DDT, one of the few affordable insecticides
- Shortage of well trained personnel, scarce financial resources and finally the major problem with strategic planning for malaria control.

There is thus a need for continuous development of new antimalarial drugs and insecticides, which need to be affordable for the majority of poor populations living at risk for malaria in southern countries. Although it would be a breakthrough if an effective malaria vaccine or more effective vector control tools would become available, this is not likely to happen in the near future. However, the renewed emphasis on tools such as insecticide impregnated bednets, and the improvement of their efficacy and effectiveness by, for instance, using more appropriate fabrics and insecticides, could improve on the state of malaria control in malaria endemic countries especially in Africa (Carnevale et al. 1988; Rozendaal 1989; D’Alessandro et al. 1995; Lengeler and Snow 1996; Lengeler 1998; Lengeler et al. 1998).

The 1999 World Health Report (WHO 1999) declared malaria to be one of the two priority issues in international health, the second was smoking. In the same year, WHO launched the global initiative Roll Back Malaria. This programme is developing a new, sector-wide partnership to combat the disease at global, regional, country and local levels. The Roll Back Malaria initiative calls for well co-ordinated action that makes it an integral part of wider development processes (Roll Back Malaria 2000). These ideas have been taken up, for instance, by the Multilateral Initiative on Malaria, an alliance of organisations and individuals aiming at maximising the impact of scientific research on malaria in Africa, by promoting intensified, co-ordinated international research activities (MIM 1999).
1.2 Global burden of malaria

Malaria is the most important parasitic disease in the world and remains of highest public health importance. In 1994, the global incidence of malaria has been estimated at 300-500 million clinical cases annually, causing 1.5 to 2.7 million deaths each year (WHO, 1997). More than 90% of this malaria burden occurs in sub-Saharan Africa (SSA), where severe malaria disease and death mainly occur among young children of rural areas with little access to health services (Greenwood et al. 1987a; Snow et al. 1999). In SSA malaria accounts for an estimated 25% of all childhood mortality below age of five excluding neonatal mortality (WHO 1997). Recent studies suggest that this percentage might even be higher because of the contribution of malaria as indirect cause of death (Alonso et al. 1991, Molineaux 1997).

According to WHO and the World Bank, malaria is responsible for an annual loss of 35 million disability adjusted life years (DALYs) worldwide (World Bank, 1993). It has furthermore been estimated that about 40% of all fever episodes in SSA are caused by malaria (Brinkmann & Brinkmann 1991).

The epidemiological situation of malaria is worsening with the spread of drug resistance in the parasite and insecticide resistance in the vector. More evidence points to significantly increasing malaria morbidity and mortality is SSA due to the development by Plasmodium falciparum of resistance to existing first-line drugs such as chloroquine and sulphadoxine/pyrimethamine (Trapé 2001).

1.3 Epidemiology of malaria

1.3.1 General considerations

WHO outlined concepts and strategies for each of the eight major endemic settings and malaria paradigms (WHO, 1993). Emphasis was placed on tailoring malaria control to the local situation; i.e. considering the social, ecological and political context of a given area and its overall health and development plans.
Acquisition of information on the burden of malaria relies on advancing our understanding of malaria epidemiology which requires investigation of the complex relationships between the malaria parasite, the vector, the host and the environment (Bloland et al. 1999).

The burden of illness attributable to malaria varies substantially between countries within tropical Africa and even between different regions of the same country. Thus, obtaining information on the burden of malaria by region or district is important so that malaria control interventions, such as insecticide-treated bednet programme, can be targeted at areas where they are likely to be most effective (Greenwood, 1999).

1.3.2 Biological determinants

1.3.2.1 The parasite and its life cycle

Malaria is a disease caused by infection with parasites of the genus *Plasmodium*. Four species of *Plasmodium* (*P. falciparum*, *P. malariae*, *P. ovale* and *P. vivax*) infect humans and lead to disease (Gilles, 1993). *P. vivax* is not common in Africa, especially in West Africa because the Duffy blood antigen (the erythrocyte molecule to which its merozoites bind) being rare in the African population.

Transmission of the *Plasmodium* parasite is mainly from person to person through the bite of a female *Anopheles* mosquito. Rarely transmission can be through accidents, such as transfusion, inoculation of infected blood from one person to another, or transfer through the placenta from an infected mother to her unborn child.

The malaria parasite has an unique life-cycle adapted to man over the years. The life cycles of all *Plasmodium* species transmitted to humans are the same with three reproductive phases. The species differ in the time taken to complete each phase, which is also dependent on the ambient temperature.

An initial phase consisting of a single cycle of sexual reproduction occurring in the female mosquito is known as « sporogony », and produces sporozoites that infect man. At 24°C
sporogony takes 9 and 21 days in *P. falciparum* and in *P. malariae* respectively. When the infected mosquito bites man it injects the sporozoites into the blood.

The sporozoites then travel to the liver where the next phase, a single cycle of asexual reproduction (five to seven days for *P. falciparum*) takes place in the human liver cell called « hepatic schizogony » or « pre-erythrocytic phase » producing merozoites. The merozoites enter the blood when the liver cells burst and invade the red blood cells.

The third or final phase known as « erythocytic schizogony » or « erythrocytic cycle » consists of several cycles of asexual reproduction (each cycle lasting about 48 hours for *P. falciparum, P. ovale* and *P. vivax*, but 72 hours for *P. malariae*) which takes place in red blood cells. This phase produces new merozoites during each cycle which invade new red blood cells and start the erythrocytic cycle again.

However, some of these merozoites differentiate into male and female gametocytes, which are taken up by the blood-sucking female *anopheles* to start the next sporogonic cycle in the mosquito.

### 1.3.2.2 The vector

The *Anopheles* vector is the link between man and the malaria parasite. Because the sexual cycle takes place in the mosquito, it is sometimes called the definitive host. There are about 400 different species of *anopheles*, but there are only about 60 that are vectors of malaria and of these, about 40 are important. The most important vectors in the afrotropical region (Africa south of the Sahara, Madagascar, Seychelles and Mauritius) are the *A gambiae* complex (which includes *A gambiæ, A. arabiensis, A. melas, A. merus, A. bwambæ*, and *A. quadriannulatus*) and *A. funestus* (Service, 1996).

Among the *A. gambiae* complex, *A gambiæ sensu stricto* is the most important malaria vector and it is probably the world most efficient vector (Service, 1996). It breeds in sunlit pools, puddles, borrow pits and rice fields. It bites humans both indoors (endophagic) and outdoors (exophagic), and rests mainly indoors (endophilic) but may also rest outdoors. The other important species of the *A gambiae* complex, *A arabiensis* has similar breeding and biting
habits to *A. gambiae* s.s. except that it tends to occur in drier areas and it is more likely to bite cattle and rest outdoors (exophilic).

*A. funestus*, the other major vector in the afrotropical zone, prefers shaded habitats and breeds in permanent waters, especially with vegetation, such as marshes, edges of streams, rivers and ditches, and rice fields with mature plants providing shade. It bites humans predominantly but also domestic animals, and is exophagic and endophagic.

Because of seasonality in climate, especially rainfall, mosquito abundance and malaria transmission tends to be seasonal. During the wet season, breeding sites are created in stagnant water leading to high mosquito populations and hence increased malaria transmission.
1.3.3 Malaria transmission

1.3.3.1 Vector type and density

The *Anopheles gambiae* complex is the major vector system in Africa and exists only in frost-free regions, or where the minimum temperature in winter remains above 5°C (Snow *et al.* 1999).

In the 1988 entomological survey conducted before the implementation of a bednet trial in The Gambia, 98% of the mosquitoes collected using « knock-down » catches were members of the *A. gambiae* complex (Lindsay *et al.* 1993). However, *A. funestus* also plays an important role in malaria transmission in west Africa.

In the Dielmo site of Senegal, *A. gambiae* s.l. and *A. funestus* represented respectively 62.2% and 36.1% of the 11,685 anopheles collected in 1990-1992. *A. gambiae* s.l. is abundant only in the wet season and *A. funestus* is dominant in the dry season and transmission is ensured alternatively by one or the other species. For *A. gambiae*, a peak of density was observed between July and September during the rainy season, with a maximum of 90.5 bites per person per night recorded in September. In the dry season, the density of this vector was generally low (0.9 bites per person per night). For *A. funestus*, two significant picks were observed: the first just before the rainy season (48 bites per person per night in June) and the second in the middle of the dry season (41 bites per person per night in February) (Trape *et al.* 1994). In this site, the rate of endophagy was 52.7% for *A. gambiae* s.l. and 59.0% for *A. funestus* (Trape *et al.* 1994).

In the region of Bobo-Dioulasso (Burkina Faso), the seasonal transmission of malaria was also mainly due to *A. gambiae* and *A. funestus*, and it varied from one village to the other. In the village Kongodjan, transmission occurs from the beginning of June till the end of December. Maximal registered values are 2.4 infected bites per man per night. Each inhabitant receives an average of 0.63 infected bites every night during the whole transmission period (133 infected bites per man per year). In the village of Tago, the duration of the transmission is shorter, from June to October. Maximal registered values are 1.1 infective bites per man per night. During the transmission period, each inhabitant receives an average of 0.58 infected bites every night (82 infected bites per man per year) (Gazin *et al.*
Another study conducted in the village of Karangasso has found that the majority of the inhabitants receive between 116 and 370 infective bites per person per year (Robert et al. 1988).

In the region of Ouagadougou, the annual entomological inoculation rate (EIR) has been estimated in 1984 at 441.6 in the village of Koubri (Southern of Ouagadougou), 113 in the village of Pabré (Oubritenga province) and 82 in the village of Zagtouli (Western of Ouagadougou) (Hay et al. 2000)

## 1.3.3.2 Sporozoite rates

Traditional method of measurement of presence of sporozoites was to dissect all sampled mosquitoes for their salivary glands and subject them to procedures designed to help reveal potential sporozoites under the microscope (Hay et al. 2000).

Using this technique, an average of 1.43 % of infections was observed in *A. gambiae* s.l. and 1.31 % in *A. funestus* in the Dielmo site. Sporozoite rates were significantly higher in the rainy season than in the dry season and specific identification of the sporozoites shows that in all seasons *A. gambiae* s.l. and *A. funestus* are often simultaneously infected by two or three species of *Plasmodium* (Trape et al. 1994). The same method has permit to find a sporozoite rate of 1.78 % in the village of Kongodjan (Hay et al. 2000).

Nowadays, the enzyme-linked immunosorbent essay (ELISA) techniques, which detect *Plasmodium*-specific circumsporozoite antigens from mosquito head and/or thorax samples, are being increasingly used owing to their greater sensitivity and species specificity (Hay et al. 2000).

Using this method, a sporozoite rate of 1.29 % was found in Dielmo (Senegal), 2.97 % in Barokunda and 17.86 % in Dongoro Ba (The Gambia) (Hay et al. 2000). In Burkina Faso, 4.13 % was found in Karangasso (Hay et al. 2000).
1.3.3.3 Transmission intensity

Transmission and mortality

A few reviews have been focused on the relationship between the intensity of malaria transmission and mortality.

A study in East Africa which compared the pattern of malaria disease in Kilifi (0-60 infective bites per person per year) and Ifakara (10-3000 infective bites per person per year) revealed that children with malaria in Ifakara were younger and that there were three times more severe cases of anaemia, while cases of cerebral malaria were four times more frequent in Kilifi. Despite these major differences the overall rate of severe disease among children under five years were not different (Snow et al. 1994).

In accordance with these findings, studies from the Republic of Congo showed very little variation in malaria mortality despite extreme differences (0.3-100 infective bites per person per year) in malaria transmission intensity (Trape et al. 1996). However, malaria mortality in the Republic of Congo was lower as compared to similar epidemiological settings, and this was attributed to the ready available malaria drugs (Trape et al. 1987, Carme 1996).

Finally, a recent study compared rates of severe malaria in five epidemiological different settings of Kenya and The Gambia. A total of 5556 severe malaria cases were analysed, and the risk of severe disease was lowest among populations with the highest transmission intensities (Snow et al. 1997). However, the results of Snow et al were recently challenged by the documentation of a positive association between the incidence of clinical malaria and EIR even under conditions of very high transmission intensity in young children of rural Tanzania (Kitua 1996, Smith 1998).

Transmission and morbidity

Data on this topic have been published from Senegal, where the numbers of malaria attacks were compared between Dakar (1 infective bite per person per year), Ndiop (20 infective bites per person per year) and Dielmo (200 infective bites per person per year). Despite this major differences in transmission intensity, the cumulative number of malaria attacks by the age of 60 years was pretty similar – 30, 62 and 43 respectively. These fluctuations show that a tenfold decrease or increase in malaria transmission is associated only with a twofold decrease or increase in malaria morbidity (Trape and Rogier, 1996).
This deduction is corroborated by the findings from Tanzania where each 10-fold increase in the EIR correspond to a 1.6-fold increase of incidence of clinical malaria (Smith et al. 1998).

Quantifying the relationship between transmission levels and the incidence of clinical attacks, Trape and Rogier found that for low levels of transmission, i.e. between 0.001 and 0.1 infective bites per person per year, the incidence of malaria attacks is probably directly proportional to the level of transmission in adults as in children. For levels of transmission of 1, 10, 100 and 1000 infective bites per person per year, the data suggest that global malaria morbidity (number of attacks), which is always very high, varies at maximum by a factor of two to three according to the level of transmission (Trape and Rogier, 1996).

1.3.4 Malaria morbidity

1.3.4.1 General considerations

In its mild form, malaria presents as a febrile illness associated with other non specific signs and symptoms. No clinical syndrome is entirely specific for malaria. The fever may be periodic and interspersed with afebrile intervals.

In endemic areas, malaria is usually diagnosed clinically and only rarely confirmed by the presence of the parasite in the peripheral blood. However, in endemic countries there are usually many more asymptomatic carriers of the parasite. Hence even parasitological diagnosis does not necessarily indicate that the malaria is the cause of the disease (Greenwood et al. 1987). Recent work has provided a quantitative framework for the analysis estimating probabilities that fever episodes are indeed of malaria etiology as a function of parasite density (Smith et al. 1994 a,b ; 1995).

Severe life threatening malaria (e. g. cerebral malaria, respiratory distress, severe anaemia, pulmonary oedema, renal failure) and deaths are almost exclusively due to P. falciparum malaria. These complications tend to be the main reasons for hospital admission of young children in endemic areas, but pulmonary oedema and renal failure are rare in children. The
frequency and pattern of distribution of severe forms of *P. falciparum* malaria vary depending on the level of transmission areas (Snow *et al.* 1994, Trape *et al.* 1987).

### 1.3.4.2.1 Malaria incidence

The malaria incidence rate can be estimated from a cohort of newborn children by observing the onset of parasitaemia and clinical symptoms and the use of a mathematical model like the model of Bekessy (Gazin *et al.* 1988).

Using this logistic regression model of Bekessy in a juvenile population of 2 villages in Burkina Faso (Tago and Kongodjian), the authors have obtained a daily incidence rate of 0.010 from January to July, 0.026 from July to September and 0.004 from November to May. Using the same model, a study in Idete village infants, Tanzania, found a crude incidence of 0.021 per day (Kitua *et al.* 1996).

It is well recognized that, in highly endemic areas, newborn infants are relatively protected against mild clinical malaria and severe malaria, compared to older children (Brabin 1990, Snow *et al.*1998). To determine the true incidence of clinical malaria in this age group, appropriate case definitions are needed. Logistic regression has been used to model the risk of fever as a function of parasite density, to estimate the fraction of fever cases that are attributable to malaria (the attributable fraction, AF), and to estimate the sensitivity and specificity of case definitions using different parasites density thresholds (Smith *et al.* 1994, MacGuinness *et al.* 1998).

In a study in southern Ghana, the estimated population AF was 44%, and varied with age and season. For infants, AF was 51% during the wet season and 22% during the dry season; for children over one year of age, AF was 89% during the wet season and 36% during the dry season.

### 1.3.4.3 Malaria parasite prevalence

From cross-sectional surveys, malaria parasite prevalences was found very similar in comparable epidemiological settings of several African countries.
In Idete, Tanzania, 52.1% malaria parasite prevalence in infants was found (Kitua et al. 1996). In The Gambia, malaria parasitaemia was found in 64% of children aged 1-5 years (Alonso et al. 1993). In the Dielmo site of Senegal, a study found an overall 60.3% malaria prevalence of which 92.6% in children and 7.4% in adults (Trape et al. 1994). In the region of Dori, Burkina Faso, a parasite prevalence of 69% was found in children at the end of the rainy season and 24% at the end of dry season (Mouchet et al. 1993). A recent country-wide malaria survey shows an average 35% malaria parasite point prevalence in under-five children of Burkina Faso (Ministère de la Santé, 1997).

In all the African tropical countries, *Plasmodium falciparum* is the most common species responsible for malaria infection.

In a cross-sectional survey in The Gambia, *Plasmodium falciparum* was the predominant species in children, accounting for 96% of all infections (Alonso et al. 1993). During a four-month period of intensive parasitological and clinical monitoring in the Dielmo project, Senegal, 99% of the thick blood films taken in June 1990 from children 2-4 years of age showed the presence of *P. falciparum* trophozoites. Of the 8,539 thick smears examined, *Plasmodium falciparum*, *P. malariae*, and *P. ovale* were respectively observed in 72%, 21.1% and 6% (Trape et al. 1994).

For *P. malariae*, the maximum parasitemia is generally found in children two years of age, while for *P. ovale*, parasitemia is generally very low at all ages (Trape et al. 1994). Assessment of malaria parasitemia in children and adults by microscopy and the polymerase chain reaction in a holoendemic area of Nigeria found that *P. malariae* and *P. ovale* were common in a rural area (26.1% and 14.8%) and that simultaneous infections with *P. falciparum*, *P. malariae* and *P. ovale* are frequent (11.7 % of triple infections) (May et al. 1999).

In Burkina Faso, *P. falciparum*, *P. malariae* and *P. ovale* are observed respectively in 90%, 3-8% and 0.5-2% of malaria cases (Ministère de la Santé, 1993).
1.3.4.4  Malaria clinical prevalence

Field-based epidemiological studies of mild morbidity frequently use fever and specific parasite density thresholds as characterising a clinical event. These events are either detected through cross-sectional surveys (Gazin et al. 1988), active surveillance or passively detected at referral centres. Active surveillance relies on the attribution of a febrile event to the associated parasitaemia (Snow et al., 1999).

But, whatever system is used, the diagnosis of clinical malaria in regions of intense malarial endemicity presents difficult methodological problems. The symptoms of acute malaria are similar to those of many other acute infectious diseases of childhood (Trape et al.1987, Greenwood 1999). Facilities for investigation of suspected cases by microscopy are rarely available; and even when microscopy is possible, the majority of children are parasiteamic for most of the time (Trape et al.1987, Greenwood 1999, Snow et al. 1999). Measurement of parasite density may help in this respect, and threshold values can be determined which differentiate parasitaemia that are likely to be associated with clinical illness from those that are not (Trape et al.1987, Greenwood 1999).

Thus, as high parasite counts are likely to coincide with fever, the proposed approach is to diagnose clinical malaria for fever episodes when the parasite count is above a defined cut-off value (Snow et al 1988, McGuinness et al 1998).

In Burkina Faso, malaria clinical cases have been estimated at 30% of all the cases of fever in the health centres (Mouchet et al. 1993) and in the Nouna district, the proportion was 24.5 % (Ministère de la Santé, 1997b).

1.3.4.4.1 Splenomegaly

Acute clinical episodes of malaria can cause splenomegaly which regresses after the infection has been treated or resolved; but when malaria infections are recurrent, splenomegaly does not regress between attacks, and a high proportion of children resident in malaria-endemic areas have enlarged spleens (Greenwood, 1987a)
Spleen examination is one of the earliest methods for estimation of the amount of malaria in a given locality by determining the proportion of persons with palpable enlargement of the spleen. This method has been introduced by Dempster in India in 1848 and is still commonly used. The objective of the palpation of the spleen is to determine not only the percentage of individuals with demonstrable enlargement of the organ but also the approximate degree of splenomegaly (Gilles 1993).

Two techniques of spleen palpation are used. In one the individual is examined lying down, with the examiner seated on the subject’s right, so that the right hand can explore the splenic region below the left costal margin. The second method, less cumbersome in the field, has the subject standing, with the examiner sitting on a low stool in front of the examined person. The examiner’s right hand gently explores the left side of the abdomen from below the umbilicus towards the costal border. If no spleen is palpable, the subject is requested to breath deeply, while the exploring hand attempts to feel the tip of the spleen by pressing the abdomen under the costal border (Gilles 1993).

The proportion (expressed as a percentage) of enlarged spleens in a sample of the population is known as the spleen rate and is a crude but nevertheless valuable measure of endemic malaria. Usually the spleen rate is determined in children 2-10 years of age; this is because the enlargement of the spleen is greatest when the immune response is building up.

For the determination of the degree of enlarged spleens Hackett’s method of arbitrary classification of the size of the palpated spleen is generally accepted according to the criteria given in the table below (Gilles 1993) :
Table 1  Classification of sizes of the spleen according to Hackett

<table>
<thead>
<tr>
<th>Class of spleen</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Normal spleen not palpable even on deep inspiration</td>
</tr>
<tr>
<td>1</td>
<td>Spleen palpable below the costal margin, usually on deep inspiration</td>
</tr>
<tr>
<td>2</td>
<td>Spleen palpable below the costal margin, but not projected beyond a horizontal line half way between the costal margin and the umbilicus, measured along a line dropped vertically from the left nipple</td>
</tr>
<tr>
<td>3</td>
<td>Spleen with lowest palpable point projected more than half way to the umbilicus but not below a line drawn horizontally through it.</td>
</tr>
<tr>
<td>4</td>
<td>Spleen with lowest palpable point below the umbilical level but not projected beyond a horizontal line situated half way between the umbilicus and the symphysis pubis</td>
</tr>
<tr>
<td>5</td>
<td>Spleen with lowest point palpable beyond the lower limit of class 4</td>
</tr>
</tbody>
</table>

In the Dielmo site, Senegal, the proportion of children 0-1 and 2-9 years of age with an enlarged spleen in dry season was respectively 61% and 87%. In the rainy season, the spleen rate was 89% in children 2-9 years old (Trape et al. 1994). In The Gambia, studies conducted before the ITN trial found an enlarged spleen in 64% of the children aged 1-5 years (Alonso et al. 1993).

Association of splenomegaly with parasitaemia can be variable. In a holoendemic area of southwest Nigeria, spleen enlargement was found in approximately 20% of children with microscopically detectable parasitemia and was positively associated with parasite density (May et al. 1999).

It is known that in malaria endemic areas the prevalence of splenomegaly declines as immunity to malaria is acquired, so that in holoendemic areas, few adults have enlarged spleens (Greenwood, 1987).
1.3.4.5   Severe malaria

Any patient with severe malaria feature is at increased risk of dying, but the exact risk depends on genetics, age, background immunity and access to appropriate treatment. The main clinical manifestations of severe malaria in children are prostration, impaired consciousness, respiratory distress, multiple convulsions and severe anaemia. Severe anaemia is defined as haemoglobin < 5 g/dl or haematocrit < 15% (WHO, 2000).

In African children, cerebral malaria and severe anaemia are the two major clinical features of life-threatening malaria and epidemiological studies have demonstrated that, under conditions of intense, perennial and stable transmission, the incidence of severe anaemia is high while under conditions of less intense, more seasonal and unstable or epidemic transmission, the incidence of cerebral malaria becomes high (Snow et al. 1999).

The mean age of children with these two syndromes is quite different, severe anaemia affects predominantly infants and children below three years of age while the mean age of children with cerebral malaria is higher (about four years) (Brewster and Greenwood 1993, Snow and Marsh, 1995).

Anaemia may develop rapidly during the course of the malaria illness, or may be present in a child with cerebral malaria or any other complication of *P. falciparum* infection. Severe anaemia is often multifactorial, and is attributable to malaria because of parasitaemia and the lack of an adequate alternative explanation (WHO, 2000). It has been reported that the degree of anaemia correlates with parasitaemia and that malaria parasitaemia significantly lowers PCV levels in infants 4-10 months of age (Akum Achidi et al. 1996).

1.3.5   Malaria mortality

Most of the estimated over one million malaria deaths every year are in children up to 5 years old who live in areas of intense transmission of *P. falciparum*, especially in sub-Saharan Africa (WHO, 1996).
1.3.5.1 Assessment of malaria mortality

There are three potentially useful sources of information on levels of malaria mortality in different areas: conclusions drawn from intensive malaria control studies, statistical records rigorously collected, and data from circumscribed populations under continuous demographic surveillance (Snow and Marsh, 1995).

In many parts of rural Africa, measuring malaria mortality from statistical records is difficult since 90% of deaths occur at home and are not registered in any formal way (Greenwood, 1999). Nevertheless, the available data on malaria burden in Africa estimate malaria-specific mortality to be between 6 and 11 per 1000 children under five years per annum (Snow and Marsh, 1995).

Malaria mortality data can be partially collected from cross-sectional studies (Bloland et al. 1999). In rural communities, overall mortality rates can be measured by system of active demographic surveillance, while estimation of cause-specific mortality rates depends upon use of post-mortem questionnaire (Brewster and Greenwood 1993, Greenwood 1999).

This opinion has been developed by a study comparing two approaches for assessing child deaths in a rural area of Burkina Faso: yearly censuses and longitudinal surveillance. It has been shown that surveillance using community informants is the only reliable approach to identify child deaths before six months of age (Diallo et al. 1996).

A demographic surveillance system (DSS), which is now in place in number of developing countries, is a set of field and computing operations to handle the longitudinal follow-up of well-defined entities of primary subjects (individuals, households, and residential units) and all related demographic and health outcomes within a clearly circumscribed geographical area (INDEPTH Network, 2002). In such a system, an initial census defines and registers the target population. Regular subsequent rounds of data collection at prescribed intervals make it possible to register all new individuals, households and residential units and to uptake key variables and attributes of existing subjects. The core system provides for monitoring of population dynamics information on births, deaths, and migrations (INDEPTH Network, 2002).
Longitudinal measurement of demographic and health variables is achieved through repeated visits to all residential units to collect a prescribed set of data. The interval between visits depends on the frequency of the changes in the phenomena under study and on the length of recall intervals for the collected data. For the majority of DSSs, observations are made at 3- or 4-month intervals. This is widely considered an appropriate interval to ensure comprehensive recording of births, deaths, and migrations, which is the minimum requirement for maintaining the coherence of any DSS (INDEPTH Network, 2002).

Deaths of all registered and eligible individuals are recorded, regardless of the place of death. Some DSSs collect more detailed information about deaths to establish the cause of death, generally through the so-called verbal autopsies (INDEPTH Network, 2002).

A verbal autopsy is an interview designed to identify specific medical syndromes, using information about the terminal illness elicited from relatives of the deceased person. The postmortem diagnosis of a syndrome can often be achieved by use of an algorithm based on the presence of certain symptoms and signs, the age of the decedent, and the timing of the onset and duration of symptoms/signs during the terminal illness (Snow et al. 1992).

Epidemiological field studies allow indirect evaluation of verbal autopsy as a diagnostic method. The diagnosis and classification of the causes of death is a process requiring some medical judgment (Gray et al. 1990).

1.3.5.2 Existing mortality data

Large-scale interventions studies with impregnated bednets suggested that malaria contributes to as much as half of all mortality in children aged between 1 month and 5 years living in endemic areas (Alonso et al. 1993; Nevill et al. 1996).

Investigating the cause of deaths in the south bank of the River Gambia, Alonzo et al. found that 26% of all deaths in infants and 41% of deaths of children aged 1-4 years were attributable to malaria.
In the Upper River Division of The Gambia, cause of death was investigated using post-mortem questionnaires and 23% of the deaths in children under 5 years of age were attributed to malaria (Jaffar et al. 1997).

1.3.6 Socio-demographic factors

1.3.6.1 Age dependence of malaria

Many studies have shown that malaria is not a common cause of death among children under the age of 6 months and that in malaria endemic areas, very young infants rarely contract malaria (Alonso et al. 1993, Akum Achidi et al. 1996). This protection has mainly been attributed to transplacentally acquired malaria antibodies, as well as to other biological factors. However, after six months of age, unprotected infants suffer repeated and severe attacks that become milder as they grow older.

Nevertheless, in the study of Idete, a proportion of 5.3% congenital malaria (3 cases of peripheral blood parasitaemia at the age of 5 days) was found (Kitua et al. 1996); and the youngest person who had an attack in the Dielmo study was a two-month-old baby (parasitaemia = 102,000/µl) (Trape et al. 1994).

In a study in Nigeria, first infections were contracted during the second half of the first year of life (Akum Achidi et al. 1996). These findings also showed that malaria parasite rates and densities increased rapidly until the age of 6 months and thereafter decreased gradually until one year of age. Otherwise, the proportion of infected infants increases with age, with a tendency to plateau after the age of 4 months and the prevalence of hyperparasitaemia (parasite density greater than 10,000/µL) also shows an increase with age over the first 6 months in an area of very high transmission intensity (Kitua et al. 1996).

In all areas of high malaria endemicity, the incidence of clinical malaria is highest in young children (under two years of age) with an average of two to six malaria attacks per year (Trape et al. 1994, Rogier et al. 1999) and both the incidence and the severity of the disease decreases considerably thereafter. By the age of five years, immunoprotection is reflected by a
low rate of malaria attacks despite frequently high parasite densities (Akum Achidi et al. 1996).

1.3.6.2 Ethnicity and malaria

Differences in malaria parameters have been found in ethnic groups living in the same area. In the central region of Burkina Faso, the parasitologic data from five cross-sectional surveys in a rural area showed a lower *P. falciparum* prevalence in the Fulani ethnic group for all age groups and lower parasite densities in the Fulani children under 10 years of age. Moreover, the clinical episodes of malaria were markedly fewer among the Fulani than in the Mossi and Rimaibé (Modiano et al. 1996). This was explained by genetic differences between groups. However, it is also likely that cultural and socio-economic differences between ethnic groups contribute to marked differences in malaria risk, e.g. through differences in exposure or through differences in health seeking behaviour (Brinkmann and Brinkmann, 1991).

1.3.7 Climatic and geographical parameters and malaria

Malaria is governed by a large number of environmental factors, which affect its distribution, seasonality and transmission intensity (Snow et al. 1999).

The peak in morbidity and mortality is generally obtained in the rainy season, the time when malaria transmission is at its peak, and the number of deaths during this period has been shown to be over threefold higher than in the rest of the year (Jaffar et al. 1997). In a 3-year prospective study of paediatric admissions to the Royal Victoria Hospital in Banjul, The Gambia, 83% of the 1525 children with cerebral malaria were admitted during the extended rainy season from July to December (Brewster and Greenwood, 1993).

High levels of parasiteaemia are also found much more frequently in the rainy season than in the dry season, and the mean packed cell volumes are lower in the rainy season than in the dry season (Greenwood and Pickering, 1993).
The relationship between malaria vector density and the distance of a settlement from a river is an important indicator of malaria transmission. In The Gambia ITN study, there was an inverse relationship between the numbers of mosquitoes in a village and the distance of settlement from the river (Lindsay et al. 1993).

In a comparative study of the presentation of severe malaria in urban and rural areas of Burkina Faso characterised by different levels of transmission, Modiano and others found that the prevalence of cerebral malaria was higher in the urban sample (53.6% versus 28.9%) while that of severe anaemia was higher in the rural patients (47.4% versus 14.8%). The urban area is characterised by relatively low transmission (1 to 10 infective bites per person per year), while the EIR in rural zones is 50 to 200 infective bites per person per year (Modiano et al. 1998).

1.3.8 Socio-economic parameters

1.3.8.1 Mosquito net use and malaria

A close association has been observed between people’s perception of the cause of malaria and the type of protective measure used. In a longitudinal cohort study in Kenya, 8.5% of the women reported using a bednet regularly, 17.5% burned mosquito coils, 2.7% used an insecticide spray, and 12.1% reported burning dung or leaves. Overall, 67% of the women reported not taking protective measures on a regular basis, and only 5% reported using more than one method regularly (Bloland et al. 1999).

The level of mosquito nets use has been found to be low in communities where bednets were previously unknown. In their studies in Zimbabwe, Vundule and Mharakura (1996) observed a 9% use of mosquito bednets among the respondents studied. This contrasts significantly with a rate of 47% found in Malawi (Ziba et al. 1994).

In West Africa, the use of bednets was found to be high in The Gambia. A study conducted in 73 randomly selected villages in the Gambia found 86% of respondents to be using bednets (Aikins et al. 1993). In the same study, 98% of bednet users were reported to have seen their parents using them in their childhood (Aikins et al. 1993).
The use of mosquito nets has also been found to be higher in urban areas than rural areas. In a KAP study in Douala, Cameroon, mosquito nets were found in 47% of households visited, with 65% of the inhabitants using them. In rural areas, very few mosquito nets were identified (Chambon et al. 1997).

An intervention trial conducted in young children (1-9 years) in a rural area of The Gambia to assess the impact of the traditional use of bed nets on malaria morbidity has found no significant difference in the incidence of clinical attacks of malaria or in any other malariometric measurements between the 2 groups of children (one group sleeping under bednets and the second without bednets). Thus, bed nets were considered not very effective in reducing malaria morbidity in this group of children (Snow et al. 1988).

Several studies on Insecticide Treated Nets (ITN) undertaken in different African and Asian countries have consistently documented significant reduction in the rate of malaria parasitaemia and malaria morbidity (Ranque et al. 1984, Graves et al. 1987, Rozendaal et al. 1989, Nevill et al. 1988, Bradley et al. 1986, Campbell et al. 1987, Snow et al. 1987, Snow et al. 1988).

A major controlled community trial was subsequently carried out in The Gambia (a country with a seasonal malaria transmission pattern and a relatively low malaria transmission intensity of 4-24 infective bites per person per year). In this trial, sleeping under a bednet was associated with 63% reduction in overall mortality and a 70% reduction in mortality attributed to malaria in young children (Alonso et al. 1991). These impressive results have paved the way for the establishment of a National Impregnated Bednet Program in The Gambia. An effectiveness evaluation of this program documented again an overall 25% reduction in all-cause mortality in children aged 1-9 year (D’Alessandro et al. 1995). The results from three further major trials conducted in African regions of very different malaria transmission intensity were published later.

The first one has been carried out at the Kenyan coast among a rural population of children under 5 years of age (10-30 infective bites per person per year). Protection with ITNs was associated with a reduction in all-cause childhood mortality by 33% and severe malaria cases were reduced by 44% (Nevill et al. 1996). The second large study took place in rural northern
Ghana (100-1000 infective bites per person per year). Here, the use of ITNs was associated with 17% reduction in all-cause mortality in children aged 6 months to 4 years (Binka et al. 1996). A third study, which has been carried out in rural Burkina Faso (300-500 infective bites per person per year), was different from the others as impregnated curtains were used instead of bednets. The reduction in all-cause mortality was 15% over the two years of follow up period in children aged 6-59 months, but significant differences were only seen during the first year of the intervention (Habluetzel et al. 1997).

1.3.8.2 Socio-economic status and malaria

The role of environmental risk factors for malaria is an important part of the investigation of community parameters. Many studies have been conducted in this field, but designs and factors’ selection and definitions are often very different. The ownership of some elementary assets is one way of approaching the socio-economic status of households.

It has been found in Peru that the ownership of a radio by the head of the family was not significantly associated with a reduction of the risk of clinical malaria (Guthmann et al. 2001). A similar study conducted in Ethiopian highlands has found no association between the ownership of a radio and malaria incidence (Tedros et al. 2000).

The level of household income has been found to directly influence the purchase and prolonged use of bednets. In their studies on use of malaria preventive measures in Malawian households, Ziba et al. (1994), found respondents with moderate or high incomes compared to respondents from low-income households to be five times more likely to have ever purchased malaria preventive products.

1.3.8.3 Educational level and malaria

One of the most important determinants of human behaviour and knowledge is the formal educational level. It is considered as an indicator for people’s socio-economic status and thus systematically explored in social studies.
Knowledge Attitude Practice (KAP) studies as well as longitudinal studies have shown that women generally have low educational level in malaria endemic countries. In a malaria KAP study in Malawi, 45% of the women interviewed had no formal education and only 3.9 % completed more than 8 years of schooling (Etting et al. 1994).

It has been shown that knowledge of mosquitoes as the cause of malaria increased with education level and that men were more knowledgeable about the correct cause of malaria than women (Aikins et al. 1993).

### 1.3.9 Community knowledge about malaria

In malaria endemic areas with different cultures in Africa, local names of malaria often refer to the main symptoms (Agyepong 1992, Aikins et al 1993, Winch et al. 1996). In The Gambia, the principal name *Fula kajeho* means « Fula hot body » (Aikins et al. 1993). In Ghana, malaria is locally called *Asra* or *Atridi* and several signs and symptoms are used to recognise this disease entity, e.g. headache, yellowish urine, ‘hot body’ (locally called *hedora*) (Ahorlu et al. 1997).

In many endemic areas, while the specific types of fever or malaria symptoms are known, their causes are not associated with the mosquito. In one Gambian study, only 28% of the respondents knew that malaria is transmitted by mosquitoes (Aikins et al. 1993). A comparable percentage was found in Tarkwa, Ghana, where only 25% of mothers interviewed said malaria was caused by mosquitoes and a third of the population had no idea at all what causes malaria (Gyapong et al. 1996).

In two other studies assessing the use of malaria prevention measures in households from Malawi and Zimbabwe, 55% of respondents were reported to have identified mosquitoes as the cause of malaria (Ziba et al. 1994, Vundule and Mharakurwa, 1996).

A wide range of other causes of malaria is given in different areas. In The Gambia, other causes given are: eating too much in the rainy season, Allah (God), rains, drinking too much fresh cows’ milk in the rainy season, or eating mangoes. It has also been reported an old belief among the rural folks that evil spirits causes malaria in children (Aikins et al. 1993).
Studies from Ghana have reported that malaria is perceived as an environmentally related disease caused by excessive contact with external heat which upsets the blood equilibrium, and that many community members did not connect it with mosquitoes in theory or practice (Agyepong 1992, Gyapong et al. 1996).

1.4 Statement of the problem in Burkina Faso

Malaria is a major public health problem in Burkina Faso. A recent review shows an average of 35% malaria parasite point prevalence in children under five years derived from country-wide malaria surveys (Ministère de la Santé 1993). The national Demographic and Health Survey conducted in 1993 concluded that malaria represents 20% of all admissions in hospitals with a case fatality rate of 18%, which is mainly attributed to deaths in children under five years (INSD 1994).

A national malaria control program has been set up in 1993 and implemented, but has not been reviewed since then.

Given the access to formal health services is very limited in rural Burkina Faso (e.g. only about 10% of childhood illness episodes are treated in existing health centres in the CRSN study region), there is an obvious need for more detailed information on the patterns of malaria epidemiology in the community (Sauerborn et al., 1996). So far, such information has only been available for very limited areas of the country.

Since the 1980’s, various studies on chemoprophylaxis and insecticide impregnated materials have been conducted in the country, essentially in the central region around Ouagadougou by the Centre National de Recherche et de Formation sur le Paludisme (CNRFP) and the south-western region around Bobo-Dioulasso by the Centre Muraz (Habluetzel et al., 1997).

Between June 1994 and May 1996, the country participated in a UNDP/WB/WHO supported multicentre study of randomized controlled community trials of impregnated materials which was carried out in different epidemiological settings of Africa. The study realised a 15%
reduction in all cause mortality among children aged between 6 and 59 months associated with the intervention in Burkina Faso (Habluetzel et al. 1997).

Since 1999, the establishment of the Centre de Recherche en Santé de Nouna (CRSN) in the capital of the Kossi province gives opportunity to the Ministry of Health and his partners, to initiate further research on malaria in this rural area.

The implementation of such studies requires relevant data on the microepidemiology of malaria (parasiteamia, morbidity, mortality) and the relation of malaria parameters with its mosquito vector (type, density and behaviour) and with socio-economic indicators.

The present study outlines comprehensive data on the epidemiology of malaria in the study area of the Centre de Recherche en Santé de Nouna (CRSN) located in Kossi Province, north-western Burkina Faso. It is seeking to describe the clinical and parasitological pattern of malaria in young children in this area and to analyse malaria parameters in relation with geographical, entomological and socio-economic indicators.

1.5 Aims of the study

In general, the objective of the study is to contribute to the existing knowledge in the epidemiology of malaria from an endemic area of rural Burkina Faso, Westafrica.

In particular, the research questions are as follows:

1- To determine malaria transmission intensity
2- To determine the pattern of malaria morbidity in young children
3- To describe the association between transmission intensity and malariometric parameters
4- To determine malaria specific mortality in young children
5- To explore the relation of malaria parameters with socio-economic indicators
6- To explore community knowledge, attitude and practice regarding malaria prevention and treatment
7- To assess malaria treatment seeking behaviour
8- To assess the clinical efficacy of chloroquine in uncomplicated falciparum malaria
2 STUDY DESIGN AND METHODS

2.1 Study area

The study was conducted in the research zone of the Centre de Recherche en Santé de Nouna (CRSN), which is situated in Nouna Health District in northwestern Burkina Faso (Figure 1).

The Nouna Health district is located in the Kossi Province, one of the 45 administrative provinces of Burkina Faso, in the north-west of the country adjacent to the border with Mali. Burkina Faso is a landlocked country in the heart of West Africa with a surface area of 274,200 km² and a population estimated at about 11 million inhabitants in 1998. The Kossi province administrative centre, Nouna, is located 300 km from Ouagadougou, the capital of the country.

Since 1992, the Ministry of Health of Burkina Faso and the Department of Tropical Hygiene and Public Health of the University of Heidelberg (Germany) have established a health system research project in this area (Projet Recherche Action pour l’Amélioration des Soins de Santé, « PRAPASS »). In 1999, a national health research centre (Centre de Recherche en Santé de Nouna, «CRSN ») has been developed out of this project.

The CRSN study area is located in the southern and central-eastern parts of the Kossi province and lies between latitudes 12°49’ and 12°96’ north and between longitudes 3°53’ et 4°06’ west. It covers an area of 1,756 km².

The climate is of the Sudano-Saharan type marked by a short rainy season from June to October and a dry season from November to May which includes two parts: a dry, cold and dusty period (November to February) and a dry and very hot period (March to May). The annual rainfall is approximately 700 mm. Throughout the year, the mean daily minimum temperature is approximately 20°C and the mean daily maximum temperature is 40°C.

The vegetation is largely savannah with short trees and two main rivers, Le Mouhoun and Le Sourou, constituting respectively the south-eastern and north-eastern borders of the study area. In the neighbouring villages, fishing and dry season farming are practised. In addition to
this, there are two temporary rivers in the southern and western parts of the area, *Le Vou-hou* and *La Kossi*. Moreover, a lot of gullies conduct rainy water to the rivers.

The population of the CRSN study area is about 60,000 inhabitants, of which 25,000 are living in Nouna city. The other population (35,000 inhabitants) are living in 41 villages of the study area. Residents of the study area are mainly farmers growing millet, sorghum, maize, ground nuts and cotton. They also rear chicken, goats, sheep and cattle.

The main ethnic groups are the *Bwaba* and the *Marka*. The *Mossi* and *Peulh* ethnic groups generally live nearby the settlements of the native groups, where they constitute their specific quarters. Settlements are gathered in the original villages and scattered in the *Mossi* and *Peulh* quarters.

The CRSN study area is served by one district level hospital (in Nouna) headed by a district management team including two medical doctors. The study area is sub-divided into three sub-areas according to the existence of governmental health centres: Bourasso with 18 villages, Koro with 12 villages and Toni/ Dara with 13 villages.

Comprehensive data on the epidemiology of malaria in young children were collected from 6 of the 41 villages of the CRSN study area (figure 1). The villages Bourasso, Sikoro and Kodougou belong to the health centre-defined subarea of Bourasso, while the villages Koro, Seriba and Dionkongo belong to the health centre-defined subarea of Koro. These six villages were purposely selected to represent the rural study population in its socio-cultural, demographic and geographical diversity. They have taken part in a randomised controlled trial (RCT) on the effects of zinc supplementation on malaria morbidity conducted in 18 villages of the CRSN study area in 1999, and they have later been chosen to function as sentinel villages for a major RCT on the long-term efficacy of insecticide-treated mosquito nets (ITN) conducted in the whole rural CRSN study area since 2000 (Müller et al. 2001; Müller et al. 2002). Information on malaria–related knowledge, attitudes and practices have been collected recently from this population (Okrah et al. 2002).

The population of the six sentinel villages and the distance from each village to the nearest river are presented in table 2. The average distance between the Koro subarea villages (Koro,
Dionkongo and Seriba) and the river is 13 km, while the average distance between the Bourasso subarea villages (Bourasso, Kodougou-Mossi and Sikoro) and the river is 1.5 km.

**Table 2**  
Population of the 6 sentinel villages and distance to the river

<table>
<thead>
<tr>
<th>Village</th>
<th>Population (no. Individuals)</th>
<th>Distance to the river (kilometres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bourasso</td>
<td>1757</td>
<td>2.1</td>
</tr>
<tr>
<td>Dionkongo</td>
<td>903</td>
<td>14.9</td>
</tr>
<tr>
<td>Kodougou</td>
<td>1321</td>
<td>1.3</td>
</tr>
<tr>
<td>Koro</td>
<td>2391</td>
<td>8.9</td>
</tr>
<tr>
<td>Sériba</td>
<td>1205</td>
<td>15.0</td>
</tr>
<tr>
<td>Sikoro</td>
<td>1046</td>
<td>1.5</td>
</tr>
</tbody>
</table>

**Sources:** GIS (measurements on scanned maps); DSS (VER 74, July 2002)
Figure 1  Study area in rural Burkina Faso
2.2 Study design

This is a mainly descriptive study on the epidemiology of malaria among young children in rural Burkina Faso. It includes data from methodological different studies conducted in the area at the same time period (1999-2001): (1) entomological study, (2) zinc supplementation study, (3) ITN study, (4) community factors and malaria study, (5) chloroquine efficacy study, and (6) mortality study. Most of these studies have been published already (Müller et al. 2001, Müller et al. 2002, Okrah et al. 2002, Müller et al. 2003a, Müller et al. 2003b, Müller et al. 2003c).

The author of this thesis contributed significantly to planning, field work and analysis of all these studies and combined parts of the original data from the zinc supplementation study and the ITN study for supplementary analysis. Data from all these studies were used according to the research questions outlined in chapter 1.5. In the following subchapters, the single studies are described. Table 3 provides an overview on the studies from which data have been taken for this thesis. Comparisons by season were based on cross-sectional survey results. September, November and December were defined as being representative for the rainy season (high malaria transmission) while February, March and June were considered representative for the dry season (low malaria transmission).
Table 3  
Studies from which data are taken

<table>
<thead>
<tr>
<th>Study</th>
<th>Area</th>
<th>Time period</th>
<th>Sample size</th>
<th>Publication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entomological study</td>
<td>6 villages in CRSN area</td>
<td>09/00 – 07/01</td>
<td>60 households</td>
<td>Submitted</td>
</tr>
<tr>
<td>Zinc study</td>
<td>18 villages in CRSN area</td>
<td>06/99 – 03/00</td>
<td>709 children</td>
<td>Müller et al. 2001</td>
</tr>
<tr>
<td>ITN study</td>
<td>41 villages in CRSN area</td>
<td>06/00 – ongoing</td>
<td>3400 children</td>
<td>Müller et al. 2002</td>
</tr>
<tr>
<td>Community factors and malaria study</td>
<td>10 villages in CRSN area + Nouna town</td>
<td>05 – 06/00</td>
<td>210 households</td>
<td>Okrah et al. 2002</td>
</tr>
<tr>
<td>Chloroquine efficacy study</td>
<td>6 villages in CRSN area</td>
<td>07 – 10/01</td>
<td>120 children</td>
<td>Müller et al. 2003b</td>
</tr>
<tr>
<td>Mortality study</td>
<td>6 villages in CRSN area</td>
<td>01/99 – 12/01</td>
<td>1070 children</td>
<td>Submitted</td>
</tr>
</tbody>
</table>

2.2.1 Entomological study

Entomological surveys have been conducted in the rainy season and in the dry season for the identification of the species of Anopheles mosquitoes, their abundance and their infectivity (human blood index, sporozoite rates) and the annual entomological inoculation rate through systematic pyrethrum spray catches.

Plasmodium falciparum transmission intensity was determined in the six study villages in September 2000 (only Koro subarea), November 2000, March 2001, and July 2001. At these time points spray catches were performed over three days in 10 randomly chosen rooms in each of the study villages inhabited at least by one person sleeping without or with an untreated mosquito net. Spray catches were done between 6.00 and 7.00 in the morning and all collected mosquitoes were transported immediately to the CRSN laboratory in Nouna town for microscopic species determination by an experienced entomologist. Female Anopheles mosquitoes were preserved dry over silica gel and transported to the laboratory of Prof. Chris Curtis at the London School of Hygiene and Tropical Medicine for monoclonal antibody-
based *P. falciparum* CS protein ELISA tests in all mosquitoes collected and for PCR-based species determination in a random subsample of *Anopheles gambiae* s.l. The annual entomological inoculation rate (EIR) per village was calculated using the following formula:

\[
EIR = WM \times SR\text{ in September} \times 91 + VM \times SR\text{ in November} \times 91 + VM \times SR\text{ in March} \times 91 + VM \times SR\text{ in July} \times 91
\]

(WM = vector mosquitoes/person, SR = *P. falciparum* sporozoite rate).

### 2.2.2 Zinc supplementation study

The randomized placebo-controlled trial on effects of Zinc supplementation on malaria morbidity in children aged 6-40 months has been conducted on 709 children (356 intervention group, 353 placebo group) from 18 villages in 1999/2000. During this trial, a longitudinal follow-up of malaria incidence and four baseline malaria surveys have been conducted for the definition of malaria prevalence and its seasonality (spleen rates, PCV values, species-specific parasite rates and parasites densities, malaria morbidity).

Longitudinal follow-up was done primarily in the community, by daily visits to households selected for the trial, 6 days a week, during the whole period of the rainy season (June to November 1999). Each day, fieldworkers have recorded for each child enrolled in the study:

- reported morbidity (main symptoms): fever, cough, diarrhoea, other signs.
- measured axillary temperature
- if temperature \( \geq 37.5^\circ C \), a blood sample has been taken (thin and thick blood film)
- any visit to a health facility (dispensary or hospital; private or public)
- any treatment received.

All children have been visited 4 times by a physician during the four malaria surveys (June 1999, September 1999, December 1999 and March 2000). Each time, a comprehensive clinical examination has been performed (including spleen rates), nutritional status (weight, height, arm circumference) has been assessed, and a blood sample has been taken by finger prick method for thin and thick blood slides preparation in all study children, and for packed cell volume (PCV) determination by micro-haematocrit centrifugation in the field.
Thick and thin blood slides were Giemsa-stained at the Nouna hospital laboratory and transported afterwards to the CNRFP in Ouagadougou for reading. All films were examined by two experienced laboratory technicians using a x 100 oil immersion lens and x 10 eyepieces. In case of significant discrepancy between the results of the two technicians, blood slides were read by a third investigator. Blood films were analysed for the species-specific parasite density per µl by counting against 500 white blood cells and multiplying by sixteen (assuming 8000 white blood cells per µl of blood). Slides were declared negative if no parasites were seen in 400 fields on the thick film. A ten percent random sample of blood films were re-examined at the laboratory of the Heidelberg School of Tropical Medicine, demonstrating an overall 97 % concordance in the diagnosis of *P. falciparum* parasitaemia.

Mild cases of fever (\(T \geq 37.5^\circ\text{C}\)) detected during clinical examination have received standard chloroquine treatment. If the physician diagnosed other causes for fever, those have been treated accordingly. Severe cases of fever and any other medical condition which can’t be treated in the field were referred to the local health centre or the Nouna hospital. Treatment has been provided free of charge for all the study children found to be sick during the clinical examinations.

During the cross-sectional surveys of September 1999 and March 2000, a questionnaire on socio-economic parameters has been addressed to the mothers of study children. The factors investigated, were the ownership by the household of at least one bednet, the use of bednet by the study children, the ownership of a bicycle, a motorcycle, and a radio. Based on the ownership of the last three assets, households have been classified in two socio-economic status:

- High status = ownership of motorbike and/or radio
- Low status = ownership of none of them or only bicycle (bicycle possession was found very usual).

### 2.2.3 ITN study

A longitudinal cohort study on long-term effects of insecticide treated bednets (ITN) on the morbidity and mortality caused by malaria and on overall mortality in children aged 6-60 months has started in June 2000 in the 41 villages of the research zone. All newborn children...
were randomly enrolled in either group A (protection by ITN from 0 to 59 months) or group B (protection by ITN from 6 to 59 months).

Within this study, a prospective follow-up of a subsample of ITN study cohort children from 6 sentinel villages was conducted, including the measure of temperature and the taking of a blood sample by finger prick method for tick and thin blood film preparation in case of fever.

Biannual visits (rainy/dry season) of the subsample of children living in the sentinel villages were organised for the collection of clinical (anthropometric measurements, rates of malaria episodes, anaemia) and parasitological (rates of malaria parasitaemia, parasite density) parameters since the start of the trial. The cross-sectional malaria surveys are conducted as described in the zinc study.

2.2.4 Community factors and malaria study

Medical anthropology research elucidating community-based perceptions, attitudes and behaviour patterns regarding malaria prevention has been conducted in the CRSN research zone in May and June 2000, before the implementation of the ITN study (Okrah et al., 2002). It was an exploratory and descriptive study, using both qualitative and quantitative approaches to data collection. The research team comprised the investigators and four trained interviewers who where familiar with the local settings and the local languages.

Focus group discussions (FGD), individual interviews and key informant interviews were conducted in four of the 10 study villages and in Nouna town. Participants with at least one child below 5 years in their household were selected for the FGD. The discussions dealt with community knowledge of malaria-related concepts, and attitudes and practices regarding malaria prevention and treatment. Key informant interviews were also conducted with medical personnel, local tailors and traders of mosquito nets, users of mosquito nets, traditional healers and ambulant drug peddlers.

Quantitative survey variables and instruments derived from qualitative research. Respondents were sampled through a modified form of EPI (Expanded programme of Immunization) cluster sampling methodology. The CRSN study area was divided first in two clusters, urban
and rural. The urban cluster comprised Nouna town while the rural cluster comprised a random sample of six of the 10 purposely selected villages for the study. In the second stage, the urban cluster was subdivided into seven subclusters and the rural cluster in six subclusters (all six study villages). Overall 210 household were selected proportional to the size of the geographical cluster, and the participating households were finally chosen at random in each cluster. A structured questionnaire was administrated to the heads of the selected households. The questions focused on socio-demographic characteristics, ownership and use of mosquito nets, factors determining the possession and the use of mosquito nets, knowledge and acceptability of insecticide-impregnated mosquito nets and the knowledge and practice of other malaria prevention and treatment methods.

2.2.5 Chloroquine efficacy study

The study was nested into the ongoing cohort study on the long-term effects of insecticide-treated nets (ITN) in young children from the six morbidity observation villages of the Nouna Health District.

Cohort children were consecutively enrolled from July until October 2001 if they fulfilled the following inclusion criteria: age ≥6 months, falciparum malaria (≥37.5°C axillary temperature + ≥5,000 P. falciparum parasites per µl in the absence of another obvious fever cause), absence of antimalarial treatment during past two weeks, informed oral consent. All study children received fully supervised treatment with 25 mg/kg bodyweight of chloroquine (drugs taken from the essential drug stock of Nouna Health District) over 72 hours. Enrolled children were followed clinically over a 14 days period, and a systematic blood slide was taken on day 7-10.

For the evaluation of treatment outcome, we used a modified definition of the WHO protocol for assessment of therapeutic efficacy of antimalarial drugs in areas with intensive transmission (WHO 1996). We defined early treatment failure (ETF) as development of severe malaria on day 1-3 or axillary temperature ≥37.5°C on day 3 in the presence of parasitaemia on day 7-10, and late treatment failure (LTF) as development of severe malaria and/or axillary temperature ≥37.5°C on day 4-14 in the presence of parasitaemia on day 7-10 without previously meeting the criteria of ETF.
2.2.6 Mortality study

The CRSN has developed a well established Demographic Surveillance System (DSS) which prospectively collects data on birth, deaths and migration (Kynast Wolf et al. 2002). The Nouna DSS is based on three procedures (Sankoh et al. 2001; Kynast Wolf et al. 2002):

a) Census:
A baseline census was held in 1992 and collected demographic information on all individuals in the study area. Two control censuses were held in 1994 and 1998.

b) Vital Events Registration (VER):
In 1992, the VER started as a monthly activity. The VERs were carried out by visits of trained interviewers to each village, who asked three key informants if any vital events had occurred since their previous visit. Today, VER interviews are undertaken every three months: six interviewers visit each household and ask about members previously registered or presently living in the household. Both systems are able to identify new vital events, but the latter is likely to be more complete. Registered variables include births, deaths, pregnancies and migrations.

c) Verbal autopsy:
For deaths, the causes are obtained through verbal autopsy which is a commonly used method in the absence of clinical data with however limited sensitivity and specificity (Garenne et al. 2000). Pre-printed post-mortem questionnaires are filled in by the field workers for all the deaths registered during the VER round. They are checked by the supervisors and reviewed independently by two physicians. In case of disagreement on the diagnosis, the judgement of a third physician is taken into consideration and a definitive cause is assigned to the death.

For this study, we analysed post-mortem questionnaires from children aged 0-36 months which have been collected over the period from January 1999 to December 2001 from the six study villages. These were reviewed independently by two physicians of CRSN. In case of disagreement on the diagnosis, the judgement of a third physician was taken into consideration. A definite cause was assigned to one of the following 10 diagnostic categories: acute respiratory infection (ARI), malaria, acute gastroenteritis, malnutrition, meningitis, tetanus, septicaemia, measles, unknown and miscellaneous.
2.3 Malaria morbidity data

Data on malaria morbidity in the six study villages were taken from the data of the zinc supplementation trial (children aged 6-40 months, placebo children only) and the ITN trial (children aged 0-6 months, children without ITN protection only) (Müller et al. 2001; Müller et al. 2002a). Malaria incidence data were available for the main malaria transmission period from July until December 1999 (zinc trial) and for the corresponding period in 2001 (ITN trial). Malaria incidence was calculated through dividing the number of falciparum malaria episodes by the number of days of observation. A falciparum malaria episode was defined as an axillary temperature of 37.5°C or higher with at least 5 000 parasites/µl and no other obvious causes for the fever.

Data on malaria parasite rates and densities, spleen rates and haematocrit values were available from cross-sectional surveys in June 1999, September 1999, December 1999, and March 2000 for children from the zinc trial, and from cross-sectional surveys in March 2001 and November 2001 for children from the ITN trial. Data from February, March and June were considered representative for the low transmission season, and data from September, November and December were considered representative for the high transmission season.

2.4 Data management and analysis

Morbidity and mortality data were entered at the data management department of CRSN and processed using Access© 97. Analysis was carried out using the Epi Info 2000 and Microsoft Excel©. Chi square analysis was performed to test differences in distributions and t tests were performed to compare means.

For community qualitative study data, raw field notes and tape recording were first transcribed and translated. Data were processed and analysed with a software package for qualitative data analysis, using a pre-established code list (ATLAS.ti 1997).

Community quantitative data were analysed with the Statistical Package for Social Sciences (SPSS) for Windows 95.
2.5 Ethical consideration

The study was executed through the established facilities of the Nouna Health Research Centre, a national research centre of the Ministry of Health in Burkina Faso. The malaria related studies conducted in this centre have been approved by the Ministry of Health, Burkina Faso, and by the Ethical Committee of the Medical School, Ruprecht-Karls-University Heidelberg.

The local administrative and health authorities and the local authorities in the villages have been consulted prior to the selection of the villages. They did agree to participate on the study and the selection of the children.

The population have been informed of the risk and benefits of the studies, through village meetings. Oral consent from all the families of cohort children has been a prerequisite for participation.

Sick children were properly treated in the field during clinical investigations, or referred to the next higher health service level when necessary.

Findings of the studies will be shared not only with the local and national health authorities, but also with the population.
3 RESULTS

3.1 Malaria transmission

3.1.1 Vector species and transmission intensity

The overall number of mosquitoes caught was 7,594, of which 6,598 (87%) were malaria vectors. Of the vector mosquitoes, 5,811 (88%) were \textit{A.gambiae s.l.}, 538 (8%) were \textit{A. funestus}, and 249 (4%) were other Anopheles mosquitoes.

\textit{Anopheles gambiae} subspecies analysis in a random subsample of 50 \textit{A. gambiae} s.l. demonstrated \textit{A. gambiae} s.s. being the predominant vector (46/50=92%), beside \textit{A. arabiensis} (4/50=8%). The proportion of \textit{A. funestus} among vector mosquitoes was 6.3 % in September (only Koro subarea), 8.3% in November, 4.3% in March, and 0.2% in July. Mosquito nuisance (bites per person per night) varied largely by village and season (from 14 in September in Seriba to 0.4 in March in Bouarasso).

Of 5,247 \textit{P. falciparum} sporozoite ELISA results, 385 (7.3%) were positive. Sporozoite rates varied largely by village and season, with highest rates observed in September and November (Table 2). The average person in the Koro subarea received 131 infectious bites per year. During November, March and July, the EIR was significantly lower in the Koro subarea compared to the Bourasso subarea (Table 4).
### Table 4  
*P. falciparum* transmission intensity by season and subarea in 6 villages of Nouna Health District, Burkina Faso

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dio</td>
<td>86 (13%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>6 (2%)</td>
<td>92 (4%)</td>
</tr>
<tr>
<td>Kor</td>
<td>111 (9%)</td>
<td>8 (2%)</td>
<td>4 (1%)</td>
<td>16 (7%)</td>
<td>139 (5%)</td>
</tr>
<tr>
<td>Ser</td>
<td>109 (9%)</td>
<td>11 (2%)</td>
<td>10 (3%)</td>
<td>33 (9%)</td>
<td>163 (6%)</td>
</tr>
<tr>
<td><strong>Total 1</strong></td>
<td><strong>102 (10%)</strong></td>
<td><strong>6 (1%)</strong></td>
<td><strong>5 (1%)</strong></td>
<td><strong>18 (6%)</strong></td>
<td><strong>131 (5%)</strong></td>
</tr>
<tr>
<td>Kod</td>
<td>-</td>
<td>123 (11%)</td>
<td>3 (1%)</td>
<td>116 (7%)</td>
<td>242 (6%)</td>
</tr>
<tr>
<td>Bou</td>
<td>-</td>
<td>59 (16%)</td>
<td>0 (0%)</td>
<td>76 (6%)</td>
<td>135 (7%)</td>
</tr>
<tr>
<td>Sik</td>
<td>-</td>
<td>44 (10%)</td>
<td>0 (0%)</td>
<td>22 (5%)</td>
<td>66 (5%)</td>
</tr>
<tr>
<td><strong>Total 2</strong></td>
<td><strong>75 (12%)</strong></td>
<td><strong>1 (0.3%)</strong></td>
<td><strong>71 (6%)</strong></td>
<td><strong>148 (6%)</strong></td>
<td></td>
</tr>
</tbody>
</table>

EIR = entomological inoculation rate; SR = sporozoite rate; Dio = Dionkongo; Kor = Koro; Ser = Seriba; Total 1 = Koro subarea; Kod = Kodougou; Bou = Bourasso; Sik = Sikoro; Total 2 = Bourasso subarea; mo = month; Sept = September; Nov = November

#### 3.1.2 Parasites species

Among all the positives slides analysed from the cross-sectional surveys, the predominant species was *Plasmodium falciparum*, accounting for 91% of blood films in rainy season and 78% in dry season. *Plasmodium malariae* represented 6% in rainy and 18% in dry season, while *Plasmodium ovale* was prevalent in 3% in rainy season and 6% in dry season. Mixed parasitemia represented 5% in rainy season and 18% in dry season.

The corresponding parasite geometric mean densities were 1940 parasites/µl in rainy season and 883 parasites/µl in dry season for *Plasmodium falciparum*, 219 parasites/µl in rainy season and 119 parasites/µl in dry season for *Plasmodium malariae*, 395 parasites/µl in rainy season and 461 parasites/µl in dry season for *Plasmodium ovale.*
3.2 Malaria morbidity

3.2.1 Study children

Malaria incidence data collected through the follow up during the main transmission period were available for 258 children (165 from zinc study and 93 from ITN study). Data for other malaria parameters collected during the cross-sectional surveys fluctuated due to the losses of follow up and the completeness of data collection. Tables 5 and 6 present the number of children included in the analysis by village and season, and by age group and season.

### Table 5 Distribution of study children by village and season

<table>
<thead>
<tr>
<th>Village</th>
<th>Bourasso</th>
<th>Dionkongo</th>
<th>Kodougou</th>
<th>Koro</th>
<th>Seriba</th>
<th>Sikoro</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of children</td>
<td>33</td>
<td>17</td>
<td>19</td>
<td>37</td>
<td>27</td>
<td>27</td>
<td>160</td>
</tr>
<tr>
<td><strong>Rainy season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of children</td>
<td>15</td>
<td>10</td>
<td>24</td>
<td>22</td>
<td>26</td>
<td>25</td>
<td>122</td>
</tr>
</tbody>
</table>

### Table 6 Distribution of study children by age group and season

<table>
<thead>
<tr>
<th>Age group (months)</th>
<th>0-6</th>
<th>7-12</th>
<th>13-18</th>
<th>19-24</th>
<th>25-31</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of children</td>
<td>43</td>
<td>17</td>
<td>31</td>
<td>36</td>
<td>33</td>
<td>160</td>
</tr>
<tr>
<td><strong>Rainy season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of children</td>
<td>19</td>
<td>10</td>
<td>30</td>
<td>35</td>
<td>28</td>
<td>122</td>
</tr>
</tbody>
</table>

3.2.2 Malaria incidence

The average incidence of falciparum malaria per child and per month (from July until December) was 0.21, with substantial variation between villages (Figure 2). Malaria incidence per child and month was significantly higher in Bourasso compared to Koro subarea (0.25 vs.
0.17, p<0.0001) (Figure 2). Malaria incidence per child and per month increased significantly during infancy (0.12 vs. 0.29, p<0.0001) and remained steady afterwards (Figure 3). The malaria attributable fraction for fever was 54% (being lowest in the age group 0-6 month) (Table 7).

**Figure 2** Falciparum malaria incidence per month by village over the main transmission period (7/99-12/99).
Figure 3  
Falciparum malaria fever incidence and malaria incidence by age group

Table 7  
Falciparum malaria (fever + ≥5,000 parasites/μl) incidence per month by age group over the main transmission period.

<table>
<thead>
<tr>
<th>Age group (months)</th>
<th>0-6</th>
<th>7-12</th>
<th>13-18</th>
<th>19-24</th>
<th>25-31</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of children</td>
<td>93</td>
<td>39</td>
<td>54</td>
<td>43</td>
<td>29</td>
<td>258</td>
</tr>
<tr>
<td>Fever incidence/month</td>
<td>0.41</td>
<td>0.40</td>
<td>0.37</td>
<td>0.41</td>
<td>0.28</td>
<td>0.39</td>
</tr>
<tr>
<td>Malaria incidence/month</td>
<td>0.12</td>
<td>0.29</td>
<td>0.23</td>
<td>0.28</td>
<td>0.22</td>
<td>0.21</td>
</tr>
<tr>
<td>Attributable fraction</td>
<td>29%</td>
<td>73%</td>
<td>62%</td>
<td>68%</td>
<td>79%</td>
<td>54%</td>
</tr>
</tbody>
</table>
3.2.3 Malariometric parameters by village and age group

3.2.3.1 Malaria parasite prevalence and density

*Plasmodium falciparum* parasite prevalence by village and season shows an average value of 68% in the dry season and 83% in the rainy season. The highest values in dry season and rainy season are found in Bourasso (83% / 93%) and Sikoro (74% / 92%) (Figure 4).

![Figure 4](image_url)  
*P. falciparum* parasite prevalence by village and season

Parasite prevalence by age group has nearly the same values in children aged 0-6 in both seasons (≈55%). In dry season, it remains nearly unchanged in the 7-12 months (47%) before an increase in the older age groups is observed. In rainy season, its increases sharply in the 7-12 months (100%) before getting nearly stable for the other age groups (Figure 5).
Severity of malaria infection was determined by the geometric mean parasite density in children with a positive blood film. The values of mean density by village and season is given in table 8. The overall mean density in rainy season was nearly threefold higher than the one in the dry season (2187 vs 808). The highest density in dry season was found in Seriba (1006), while in the rainy season the highest density was in Kodougou (4881).
Table 8  Geometric mean parasite density by village and season

<table>
<thead>
<tr>
<th>Village</th>
<th>Bourasso</th>
<th>Dionkongo</th>
<th>Kodougou</th>
<th>Koro</th>
<th>Seriba</th>
<th>Sikoro</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of children</td>
<td>33</td>
<td>17</td>
<td>19</td>
<td>37</td>
<td>27</td>
<td>27</td>
<td>160</td>
</tr>
</tbody>
</table>
| Mean P. falcip.
Density/µl    | 970     | 791       | 713      | 801  | 1106   | 972    | 883   |
| **Rainy season**|       |           |          |      |        |        |       |
| No of children| 15      | 10        | 24       | 22   | 26     | 25     | 122   |
| Mean P. falcip.
Density/µl    | 3054    | 1599      | 4881     | 2235 | 1263   | 853    | 1940  |

3.2.3.2  Clinical malaria prevalence

*Plasmodium falciparum* clinical malaria prevalence (fever + ≥ 5000 parasites/µl) derived from cross sectional surveys is presented by age group and season in figure 6. Zero clinical prevalence has been found in children aged 0-6 months. In rainy season the highest clinical prevalence is found in age group 7-12 months (40%), thereafter it decreases sharply until age group 19-24 (20%) before being nearly stable (≈5%). In dry season the peak of clinical prevalence (6%) is situated in the children aged 19-24 months. The number of children available for the analysis by age group was small, particularly for the age group 7 to 12 months (17 in dry season and 10 in rainy season).
3.2.3.3 Hematocrit values

Haematocrit values were significantly lower during the rainy season compared to the dry season (28.3% vs. 31.7%, p<0.0001) (table 9, Figure 7). The lowest values were registered in the villages of Seriba and Sikoro (27%) while the highest was found in Dionkongo in rainy season as well as in dry season (34%) (Table 9)
### Table 9
Mean hematocrit values by village and season

<table>
<thead>
<tr>
<th>Village</th>
<th>Bourasso</th>
<th>Dionkongo</th>
<th>Kodougou</th>
<th>Koro</th>
<th>Seriba</th>
<th>Sikoro</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of children</td>
<td>33</td>
<td>17</td>
<td>19</td>
<td>37</td>
<td>27</td>
<td>27</td>
<td>160</td>
</tr>
<tr>
<td>Mean hematocrit</td>
<td>30%</td>
<td>34%</td>
<td>33%</td>
<td>30%</td>
<td>31%</td>
<td>34%</td>
<td>31%</td>
</tr>
<tr>
<td><strong>Rainy season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of children</td>
<td>15</td>
<td>10</td>
<td>24</td>
<td>22</td>
<td>26</td>
<td>25</td>
<td>122</td>
</tr>
<tr>
<td>Mean hematocrit</td>
<td>28%</td>
<td>34%</td>
<td>28%</td>
<td>29%</td>
<td>27%</td>
<td>27%</td>
<td>27%</td>
</tr>
</tbody>
</table>

![Figure 7](image-url)  
**Figure 7**  
Mean hematocrit by age group and season
3.2.3.4 Spleen rates

Enlarged spleen rates by village and season are presented in figure 8. The overall rate is higher in rainy season (77%) than dry season (67%), but in the village of Dionkongo and Sikoro the rates of dry season are higher than those of rainy season.

![Figure 8: Spleen rate by village and season](image)

The distribution of enlarged spleen rates by age group and season shows in rainy season no enlarged spleen in children aged 0-6 months (0%) while all the children of the age group 7-12 months have enlarged spleen (100%). In dry season 90% of children aged 13-18 months have enlarged spleen (figure 9).
3.2.4 Malariometric parameter comparison by subarea

While in the dry season no differences were seen in malariometric parameters between the Koro and Bourasso subareas, in the rainy season the prevalence and parasite density of *P. falciparum* was significantly higher in Bourasso compared to Koro subarea. Haematocrit values were slightly higher in Bourasso compared to Koro subarea during the dry season, but the opposite pattern was observed in the rainy season (table 10).

*P. falciparum* parasite prevalence (p=0.03, p=0.02) and density (p<0.0001, p<0.0001) were positively associated with age during rainy season surveys, respectively (table 11).
Table 10  Malariometric parameters by subarea and season in young children of 6 villages of Nouna Health District, Burkina Faso

<table>
<thead>
<tr>
<th>Subarea</th>
<th>Bourasso</th>
<th>Koro</th>
<th>Total</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry season</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of children</td>
<td>79</td>
<td>81</td>
<td>160</td>
<td>n. s.</td>
</tr>
<tr>
<td><em>P. falciparum</em> prevalence</td>
<td>58 (73%)</td>
<td>50 (62%)</td>
<td>108 (68%)</td>
<td>n. s.</td>
</tr>
<tr>
<td>Mean <em>P. falcip.</em> density/µl</td>
<td>909</td>
<td>901</td>
<td>905</td>
<td>n. s.</td>
</tr>
<tr>
<td>Mean hematocrit</td>
<td>32.1%</td>
<td>31.2%</td>
<td>31.7%</td>
<td>n. s.</td>
</tr>
<tr>
<td>Spleen rate</td>
<td>58 (73%)</td>
<td>49 (61%)</td>
<td>107 (67%)</td>
<td>n. s.</td>
</tr>
<tr>
<td>Rainy season</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of children</td>
<td>64</td>
<td>58</td>
<td>122</td>
<td>p&lt;0.0001</td>
</tr>
<tr>
<td><em>P. falciparum</em> prevalence</td>
<td>58 (91%)</td>
<td>43 (74%)</td>
<td>101 (83%)</td>
<td>p&lt;0.0001</td>
</tr>
<tr>
<td>Mean <em>P. falcip.</em> density/ml</td>
<td>2 879</td>
<td>1 690</td>
<td>2 224</td>
<td>p&lt;0.0001</td>
</tr>
<tr>
<td>Mean hematocrit</td>
<td>27.6%</td>
<td>29.0%</td>
<td>28.3%</td>
<td>n. s.</td>
</tr>
<tr>
<td>Spleen rate</td>
<td>50 (78%)</td>
<td>45 (77%)</td>
<td>95 (78%)</td>
<td>n. s.</td>
</tr>
</tbody>
</table>

Dio = Dionkongo; Kor = Koro; Ser = Seriba; Kod = Kodougou; Bou = Bourasso; Sik = Sikoro
Table 11  Malariometric parameters by age group and season in young children of 6 villages of Nouna Health District, Burkina Faso

<table>
<thead>
<tr>
<th>Age group (months)</th>
<th>0-6</th>
<th>7-12</th>
<th>13-18</th>
<th>19-24</th>
<th>25-31</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of children</td>
<td>43</td>
<td>17</td>
<td>31</td>
<td>36</td>
<td>33</td>
<td>160</td>
</tr>
<tr>
<td><em>P. falciparum</em> prevalence</td>
<td>55%</td>
<td>47%</td>
<td>68%</td>
<td>78%</td>
<td>83%</td>
<td>68%</td>
</tr>
<tr>
<td>Mean <em>P. falciparum</em> density/ml</td>
<td>315</td>
<td>766</td>
<td>1.047</td>
<td>1.441</td>
<td>1.471</td>
<td>883</td>
</tr>
<tr>
<td>Mean hematocrit</td>
<td>33%</td>
<td>30%</td>
<td>30%</td>
<td>29%</td>
<td>34%</td>
<td>31%</td>
</tr>
<tr>
<td>Spleen rate</td>
<td>19%</td>
<td>71%</td>
<td>90%</td>
<td>83%</td>
<td>85%</td>
<td>67%</td>
</tr>
<tr>
<td><strong>Rainy season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of children</td>
<td>19</td>
<td>10</td>
<td>30</td>
<td>35</td>
<td>28</td>
<td>122</td>
</tr>
<tr>
<td><em>P. falciparum</em> prevalence</td>
<td>53%</td>
<td>100%</td>
<td>83%</td>
<td>89%</td>
<td>89%</td>
<td>83%</td>
</tr>
<tr>
<td>Mean <em>P. falciparum</em> density/ml</td>
<td>197</td>
<td>2.999</td>
<td>4.513</td>
<td>2.675</td>
<td>3.858</td>
<td>1.940</td>
</tr>
<tr>
<td>Mean hematocrit</td>
<td>28%</td>
<td>28%</td>
<td>26%</td>
<td>28%</td>
<td>27%</td>
<td>27%</td>
</tr>
<tr>
<td>Spleen rate</td>
<td>0%</td>
<td>100%</td>
<td>93%</td>
<td>74%</td>
<td>86%</td>
<td>77%</td>
</tr>
</tbody>
</table>

3.3 Malaria mortality

Over the three-year period of January 1999 to December 2001, 118/1070 under-three children died in the six villages (table 12). The proportion of deaths reported for the Bourasso and Koro subarea correspond to a yearly mortality rate for the age group 0-36 months of 31.2 and 42.5 per 1000, respectively. These rates are not significantly different (p=0.08).
Table 12  Mortality by subarea and age group in young children of 6 villages of Nouna Health District, Burkina Faso (1999-2001)

<table>
<thead>
<tr>
<th>Age at death (months)</th>
<th>Bourasso</th>
<th>Koro</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-6</td>
<td>13</td>
<td>17</td>
<td>30</td>
</tr>
<tr>
<td>7-12</td>
<td>15</td>
<td>16</td>
<td>31</td>
</tr>
<tr>
<td>13-18</td>
<td>8</td>
<td>11</td>
<td>19</td>
</tr>
<tr>
<td>19-24</td>
<td>6</td>
<td>13</td>
<td>19</td>
</tr>
<tr>
<td>25-36</td>
<td>9</td>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>Total (%)</td>
<td>51/545 (9.3)</td>
<td>67/525 (12.8)</td>
<td>118/1070 (11.0)</td>
</tr>
</tbody>
</table>

A verbal autopsy questionnaire was available from 94/118 (80%) of the deceased children (56 from the period July to December, 38 from the period January to June). Malaria (42/94, 45%), acute gastroenteritis (23/94, 25%) and ARI (9/94, 10%) were the most frequent post-mortem diagnosis (table 13). The largest number of deaths occurred in early infancy. The number of malaria deaths was already high in infancy and decreased thereafter. The majority of malaria deaths (23/42) was associated with convulsions and/or coma, only 4/42 had signs of severe anaemia and another 4/42 had signs of dyspnoea during the final stage of the illness. Seventeen malaria deaths were diagnosed from the Bourasso sub-area compared to 25 malaria deaths from the Koro sub-area.
Table 13  Causes of deaths by age group in young children of 6 villages of Nouna Health District, Burkina Faso

Age (months)  Cause of deaths

<table>
<thead>
<tr>
<th></th>
<th>MAL</th>
<th>ARI</th>
<th>GE</th>
<th>Others</th>
<th>Missing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-6</td>
<td>9</td>
<td>4</td>
<td>4</td>
<td>12</td>
<td>1</td>
<td>29</td>
</tr>
<tr>
<td>7-12</td>
<td>11</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>13</td>
<td>18</td>
</tr>
<tr>
<td>13-18</td>
<td>9</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>19-24</td>
<td>6</td>
<td>1</td>
<td>9</td>
<td>2</td>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>25-36</td>
<td>7</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
<td>9</td>
<td>23</td>
<td>20</td>
<td>24</td>
<td>118</td>
</tr>
</tbody>
</table>

MAL=malaria; ARI=acute respiratory infection; GE=gastroenteritis

3.3  Demographic, environmental and socio-economic factors

3.4.1  Age and sex dependence of malaria

Age dependence of malaria has been shown already in the previous chapters on malaria morbidity and mortality.

No difference was found in malirometric parameters regarding the sex of children as presented in table 14.
Table 14  Distribution of malaria parameters by sex and season

<table>
<thead>
<tr>
<th>Sex</th>
<th>Female</th>
<th>Male</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry season</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of children</td>
<td>83</td>
<td>77</td>
<td>160</td>
</tr>
<tr>
<td>P. falciparum prevalence</td>
<td>71%</td>
<td>65%</td>
<td>68%</td>
</tr>
<tr>
<td>Mean P. falciparum density/µl</td>
<td>884</td>
<td>880</td>
<td>883</td>
</tr>
<tr>
<td>Mean hematocrit</td>
<td>31%</td>
<td>30%</td>
<td>31%</td>
</tr>
<tr>
<td>Spleen rate</td>
<td>70%</td>
<td>64%</td>
<td>67%</td>
</tr>
<tr>
<td><strong>Rainy season</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of children</td>
<td>67</td>
<td>55</td>
<td>122</td>
</tr>
<tr>
<td>P. falciparum prevalence</td>
<td>85%</td>
<td>82%</td>
<td>83%</td>
</tr>
<tr>
<td>Mean P. falciparum density/µl</td>
<td>2088</td>
<td>1792</td>
<td>1940</td>
</tr>
<tr>
<td>Mean hematocrit</td>
<td>27%</td>
<td>28%</td>
<td>27%</td>
</tr>
<tr>
<td>Spleen rate</td>
<td>77%</td>
<td>76%</td>
<td>77%</td>
</tr>
</tbody>
</table>

3.4.2  Ethnicity and malaria parameters

The distribution of malaria parameters (parasite prevalence and density, hematocrit and spleen rate) by ethnicity and season is presented in table 15. No significant differences were found between the principal ethnic groups.
**Table 15** Distribution of malaria parameters by ethnicity and season

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Bwaba</th>
<th>Dafing</th>
<th>Mossi</th>
<th>Others (Peulh &amp; Samo)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of children</td>
<td>51</td>
<td>71</td>
<td>28</td>
<td>10</td>
<td>160</td>
</tr>
<tr>
<td>Parasite prevalence</td>
<td>77%</td>
<td>61%</td>
<td>69%</td>
<td>80%</td>
<td>68%</td>
</tr>
<tr>
<td>Geometric mean density/µl</td>
<td>1042</td>
<td>766</td>
<td>539</td>
<td>896</td>
<td>789</td>
</tr>
<tr>
<td>Mean hematocrit</td>
<td>30%</td>
<td>28%</td>
<td>33%</td>
<td>32%</td>
<td>31%</td>
</tr>
<tr>
<td>Spleen rate</td>
<td>70%</td>
<td>64%</td>
<td>64%</td>
<td>75%</td>
<td>67%</td>
</tr>
<tr>
<td><strong>Rainy season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of children</td>
<td>42</td>
<td>52</td>
<td>20</td>
<td>8</td>
<td>122</td>
</tr>
<tr>
<td>Parasite prevalence</td>
<td>92%</td>
<td>80%</td>
<td>90%</td>
<td>87%</td>
<td>85%</td>
</tr>
<tr>
<td>Geometric mean density/µl</td>
<td>1485</td>
<td>1400</td>
<td>5294</td>
<td>2654</td>
<td>2252</td>
</tr>
<tr>
<td>Mean hematocrit</td>
<td>27%</td>
<td>28%</td>
<td>28%</td>
<td>29%</td>
<td>28%</td>
</tr>
<tr>
<td>Spleen rate</td>
<td>72%</td>
<td>82%</td>
<td>90%</td>
<td>75%</td>
<td>81%</td>
</tr>
</tbody>
</table>

**3.4.3 Environmental parameters**

Seasonal variations of malariometric parameters have already been presented in the chapters on malaria morbidity and mortality.

**3.4.4 Socio-economic factors**

**3.4.4.1 Mosquito net use in study children**

Mosquito net protection of young children by village and season is presented in table 16. The overall net use is 9% in dry season and 16% in rainy season, with substantial variation between villages.
**Table 16** Mosquito net use by village and season

<table>
<thead>
<tr>
<th>Village</th>
<th>Bourasso</th>
<th>Dionkongo</th>
<th>Kodougou</th>
<th>Koro</th>
<th>Seriba</th>
<th>Sikoro</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of children</td>
<td>33</td>
<td>17</td>
<td>19</td>
<td>37</td>
<td>27</td>
<td>27</td>
<td>160</td>
</tr>
<tr>
<td>Mosquito net use</td>
<td>11%</td>
<td>0%</td>
<td>7%</td>
<td>8%</td>
<td>20%</td>
<td>16%</td>
<td>9%</td>
</tr>
<tr>
<td><strong>Rainy season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of children</td>
<td>15</td>
<td>10</td>
<td>24</td>
<td>22</td>
<td>26</td>
<td>25</td>
<td>122</td>
</tr>
<tr>
<td>Mosquito net use</td>
<td>0%</td>
<td>0%</td>
<td>35%</td>
<td>14%</td>
<td>33%</td>
<td>0%</td>
<td>16%</td>
</tr>
</tbody>
</table>

### 3.4.4.2 Socio-economic status of study population

The distribution of malaria parameters by socio-economic status in March 2000 is presented in table 17. No differences was found between high and low status.

**Table 17** Malaria parameters by socio-economic status (March 2000)

<table>
<thead>
<tr>
<th>Economic status</th>
<th>No.children</th>
<th>Prevalence (%)</th>
<th>Density (µl)</th>
<th>Hematocrit (%)</th>
<th>Spleen rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>107</td>
<td>78</td>
<td>5011</td>
<td>29</td>
<td>81</td>
</tr>
<tr>
<td>High</td>
<td>21</td>
<td>76</td>
<td>6026</td>
<td>29</td>
<td>76</td>
</tr>
<tr>
<td>Total</td>
<td>128</td>
<td>77</td>
<td>5519</td>
<td>29</td>
<td>79</td>
</tr>
</tbody>
</table>

### 3.5 Community knowledge about malaria

Most of the study population was within the age range 20-40 years and the great majority was illiterate. All respondents in the qualitative research with the exception of two FGD
participants and four key informants were farmers, with different ethnic background. While roughly half of the participants of the qualitative interviews and discussions were females, the great majority (87%) of the heads of households interviewed during the survey were males. Of those, 80/120 (38%) were from Nouna town and 130/210 (62%) were from the six villages. The distribution of ethnicity was as follows: Bwaba 71/210 (34%), Marka 55/120 (26%), Mossi 46/210 (22%), Samo 26/210 (12%), Peulh 9/210 (4%) and others 3/210 (1%). Most respondents were married (190/210 = 90%) and most were in monogamous union (137/190 = 72%)

3.5.1 Knowledge and perception of malaria

Malaria is commonly translated by all the ethnic groups as ‘Soumaya’, which is a Dioula word meaning, ‘a state of feeling cold’. It is also known as ‘Hinro’, and ‘Djokadjo’ in the Bwamu language. ‘Hinro’ is interpreted to have the same meaning as ‘Soumaya’, while ‘Djokadjo’ is interpreted as yellow eyes. The disease is further known as ‘Sai’, among the Peulh and Samo ethnicities. Sai has the same meaning as ‘Djokadjo’.

The name malaria or ‘soumaya’ is used for a number of ailments, making it, according to the majority of respondents, ‘the mother of all diseases’. It thus encompasses many other diseases like, meningitis, headache, diarrhoea and stomach pains. A statement supporting the above concept of malaria among the local communities has been summarised as follows:

‘When we hear of soumaya, it is a serious illness. Even as you are talking about it, we are not at ease, because it is the mother of all illnesses. All illnesses which have not yet developed, begin to appear when you have soumaya, headache, backache, constipation, all come from soumaya.’ (Male discussants of Dionkongo village, May 10, 2000)

In view of this, malaria is known to be caused by many factors other than mosquitoes and to manifest in many signs and symptoms, different from the biomedical knowledge.

Malaria is furthermore known and perceived as a very serious disease among all the ethnic groups in terms of the problem it provokes. Generally, it is perceived as a true, ‘vrai’ problem and ‘very wicked to man’. The disease further frightens and embarrasses many of the
respondents because of its frequency of occurrence, severity of impact coupled with the lack of means, ‘manque de moyens’ to address it. The Medical officer responsible for the district, holds that malaria ‘is the major cause of morbidity and mortality among infants and children under five years in Nouna Health District’.

The disease is perceived to result in death of children ‘soumaya is a big thing because many of our children are losing their lives from it’. It is furthermore known to results in severe health, economic and social consequences on affected victims and the entire community. These include social stress, fatigue and the inability to work.

Malaria is also perceived as an important disease due to the financial strain it brings. Particularly, it is said to attack them at the high time of agricultural activities when people have depleted all their stockpiles of food and have no money or even the energy to work.

3.5.2 Knowledge of causes and transmission of malaria

The study found a diverse knowledge among respondents about the causes and transmission of malaria. While some of these are similar to the common knowledge on malaria epidemiology, others are entirely different. Most respondents identified mosquitoes as the main cause of malaria. ‘The big cause of malaria is the mosquito’. Some members of the literate women group in Nouna town even know the female anopheles as the vector responsible for malaria ‘It is said through the bite of the mosquito, which transmits malaria from a sick person to a healthy person’.

Apart from mosquitoes, dirty water, poverty, lack of means, seasoned foods, fatigue, hard work are also found to cause malaria. This broader perception of the causes of malaria among respondents can probably be due to their perception of malaria as a broader disease term. The various causes and transmission mechanisms of malaria identified in the study has been summarized in table 18 below


<table>
<thead>
<tr>
<th>Perceived causes of soumaya</th>
<th>Perceived causal mechanisms involved</th>
<th>Number of times mentioned during FGD (n=10)</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mosquitoes</td>
<td>Sucking blood Deposition of dirty water under the skin of victims</td>
<td>10</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Poverty and lack of means</td>
<td>Inability to provide good care, to prevent disease or to purchase treatment</td>
<td>10</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Poor personal and environmental hygiene</td>
<td>Favours indirectly the growth of various parasites</td>
<td>6</td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>Fruits (i.e. mangoes), shea nut, leaves of fresh beans, sugary foods, condiments (i.e. Maggi)</td>
<td>Eating food items considered cold in term of property</td>
<td>6</td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>Kono (bird)</td>
<td>Flies over village or house at night</td>
<td>5</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Fatigue</td>
<td>Weakening of the body</td>
<td>4</td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Dirty food</td>
<td>Eating</td>
<td>3</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Dust</td>
<td>Entering one’s chest</td>
<td>2</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Cold, particularly cold rains</td>
<td>Cold temperatures, rain water falling on “chilling” persons</td>
<td>2</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Inheritance + environmental factors</td>
<td>Sick mother gives birth to sick child</td>
<td>1</td>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>

From the table, the knowledge of malaria transmission is related to its perceived cause. Among those who perceive malaria to be caused by mosquitoes, malaria is also transmitted through the transfer of blood from sick persons to healthy persons:

"There are also a lot of mosquitoes here, if they bite you, after biting a sick person, you know that the sickness has come. The wicked soumaya does not leave any part."
Malaria is furthermore perceived to be transmitted through the deposition of dirty water by the mosquito under the skin of victims. ‘The mosquitoes which live in water, when they bite you, they leave the water under your skin. That can also give you soumaya’ (women focus group discussants of Samo ethnic group, May 11, 2000).

The other mechanisms of malaria transmission identified are, the eating of dirty food, ignorance of malaria prevention methods among community members and lack of sensitization on the part of health workers to communities on the appropriate malaria preventive measures. Interestingly, one minority opinion was that malaria is transmitted through a combination of genetic and environmental factors.

### 3.5.3 Malaria prevention and treatment

Specific malaria prevention measures reported during the FGD were the use of chloroquine for pregnant women, the use of mosquito nets, the evacuation of dirty water, and the use of a specific plant (Djioula: Fariwêgné yiri) as a mosquito repellent in rooms. The most frequently mentioned specific practice against mosquitoes reported from participants in the survey was the use of mosquito coils (142/210 = 68%). Mosquito coils and insecticide sprays were sold, under various brand names, in the local markets. Most of the measures against mosquitoes targeted at the perceived mosquito nuisance rather than for malaria prevention.

A statement from a key informant, a health officer, is summarized below:

‘As for the preventive measures in general, it is individual protection. At the moment, where we can say something better is only with pregnant women. All the rest, we can not say that any measure is in place’ (key Informant, Nouna, May, 28, 2000).
Malaria treatment was often reported to be a combination of both modern and traditional methods. Depending on the type of malaria and its severity, people usually started with some traditional therapy, followed by modern treatment in case of failure. For serious disease, the nearest health centre was the most frequently cited option.

Malaria was reportedly cured with “anti malaria drugs” such as chloroquine, paracetamol and aspirin, which were bought from merchants or governmental health services. Although there was evidence for incorrect dosages in several instances, perceived effectiveness was emphasized by many respondents:

’We often treat malaria by taking anti malaria drugs. That is to say, you can even have the germ in the organism, but if you take anti-malaria products, it totally neutralize the germ, that is the case’ (male focus group discussants of the Bwamu ethnic group, Nouna, May 12, 2000).

Regarding the use of traditional herbs, six different types of herbs are found. These comprise flowers of eucalyptus plants, acacia, citronella, pawpaw, guava and leaves and roots of the neem tree. The use of these herbs is found to be high among all study discussants. Treatment, however, comprises various combinations of the herbs. The most commonly mentioned combinations are eucalyptus plants with acacia and neem leaves. These different herbs are reportedly boiled and the concoctions drank, bathed and or perfused depending on the perceived severity of malaria.

The effectiveness of these herbal treatments is, however, uncertain. Some respondents such as male focus group discussants of nokui- mossi village believe that the herbal treatment was effective: ‘…as for me, the herbs cure us a lot from soumaya and other illnesses...’. Others are of a contrary opinion. One key informant and a traditional practitioner believed that the effectiveness of herbal treatment is a matter of chance. According to him,

’.. when one has soumaya, we uproot the leaves and bath…it is a question of chance. For some people it works, others use the traditional plants in vain and go to the hospital.’ (key Informant, traditional practitioner, Denissa- Mossi, May 30, 2000).
The uncertainty about the effectiveness of herbal treatments is found to result in a combination of both modern and herbal treatments in curing malaria. The usual pattern is the use of herbal treatment as a starter and then a follow up with modern medicine when that failed. The type of resort adopted first, however, depends on the type of malaria and its perceived severity. For malaria infections perceived to be serious, participants prefer the health facility as the first resort.

3.5.4 Mosquito net prevalence, characteristics and use

Forty-nine percent (103/210) of community study respondents reported at least one bednet in their household. The distribution of respondents according to the number of bednets owned has been shown in figure 10 below. The figure shows that 44 (21%) respondents have only one bednet. Twenty-seven (13%) have only two bednets. Thirty-two (15%) have three or more bednets.

![Figure 10](image_url) Percentage of respondents owning a certain number of bednets
About two-thirds of the nets were rectangular, white and synthetic, of various origins and sold in local markets (figure 11). The materials are usually imported from Europe and Asia, and the mosquito nets produced by local tailors. Some were locally made mosquito nets and curtains, made from tick cotton. These were particularly preferred by older individuals, as a means to provide warmth during the colder periods of the year. Most mosquito nets were used for more than 3 years (60/103 = 58%). Seventy-three percent (75/103) of respondents used their mosquito nets only during the rainy season, only 12/103 (12%) used their nets throughout the year.

![Figure 11](image)

**Figure 11** Characteristics of bednets owned by respondents

Adult men were the group who reportedly used mosquito nets most often (35/103 = 34%), followed by mothers with young children (20/103 = 19%) and elderly persons (17/103 =17%) (Table 19).
Table 19  Mosquito net use in households

<table>
<thead>
<tr>
<th>Persons using bednets</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children under 15 years alone</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Young children and their Mothers</td>
<td>20</td>
<td>19</td>
</tr>
<tr>
<td>Adult men alone</td>
<td>35</td>
<td>34</td>
</tr>
<tr>
<td>Adult women alone</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Elderly persons</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>Couples</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Other</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>103</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

The above findings as described are confirmatory to earlier findings from the focus groups. In the latter, respondents who mentioned the use of bednets in their homes also indicated that adults mostly use them. A statement echoing the above assertion has been summed as follows:

‘...it is not everybody who sleeps under mosquito nets. In my house there are both women and children, but there are those who use mosquito nets and those who don’t. .. it is me and my mother who use mosquito nets. The children sleep like that.’ (male discussants of the Nokui Mossi village, May 11, 2000).

The majority of bednets are also used during the raining season. This is true for 75 (72.8%) respondents owning at least one bednet. A further 12 (11.7%) respondents use their bednets throughout the year and 11 (10.7%) use theirs during the raining and cold seasons. Only 3 (2.9%) respondents use their bednets during the cold season alone.
3.6 Malaria treatment seeking behaviour

Detailed information on morbidity and treatment seeking behaviour was available from 1,848 disease episodes recorded over the six-months observation period in 666/709 children from the zinc supplementation study (median 3 episodes, range 0-9).

Of these, 1,640/1,848 (89%) were fever episodes (median duration 4 days, range 1-96), and 894/1,640 (55%) of fever episodes were attributable to malaria.

Of recognized fever episodes, 1,386 were treated. Overall, 2,228 treatment were provided during these fever episodes. The distribution by place of treatment is given in figure 12.

![Figure 12](attachment:image.png) Proportions of treatment by treatment seeking place
Treatment seeking at formal health services (health centre/hospital) was largely influenced by location of the household. The highest frequencies of health centre/hospital visit per child during the six months study period were in the villages with an existing health centre (1.7 in Bourasso and 0.8 in Koro) and in a village close to a hospital of the neighboring district (1.7 in Nokui-Bobo).

Overall, the mean number of health centre/hospital visits per child during the six months study period was 0.5, ranging from 0.03 and 0.07 in the villages of Sampopo and Cissé respectively to 1.7 in Bourasso and in Nokui-Bobo. While there were no differences in the overall number of mean treatments per child between the two study sub-areas of Bourasso and Koro, the mean number of health centre/hospital visits in Bourasso sub-area was higher compared to the Koro sub-area (0.8 vs 0.3).

Moreover, there was no association between the length of fever episodes and visiting a health centre or hospital, but children with ≥38.5 °C temperature were more likely to visit a health centre or hospital compared to children with <38.5°C (19% vs 12%). Of the few fever episodes with reported convulsions, 4/11 (36%) were treated at a health centre or hospital.

The distribution of the 2.228 treatments provided during 1.386 fever episodes is presented in the table 20.
Table 20  Proportions of the 2,228 treatments provided during 1,386 fever episodes in young children of 18 villages of rural Burkina Faso

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Frequency (n = 2,228)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloroquine</td>
<td>1,180</td>
<td>53%</td>
</tr>
<tr>
<td>Antipyretics</td>
<td>426</td>
<td>19%</td>
</tr>
<tr>
<td>Traditional remedies</td>
<td>283</td>
<td>13%</td>
</tr>
<tr>
<td>ORS</td>
<td>56</td>
<td>3%</td>
</tr>
<tr>
<td>Tetracycline</td>
<td>45</td>
<td>2%</td>
</tr>
<tr>
<td>Quinine</td>
<td>43</td>
<td>2%</td>
</tr>
<tr>
<td>Ampicillin/Amoxicilline</td>
<td>30</td>
<td>1%</td>
</tr>
<tr>
<td>Cotrimoxazole</td>
<td>29</td>
<td>1%</td>
</tr>
<tr>
<td>Sulfadoxine-Pyrimethamine</td>
<td>4</td>
<td>0.2%</td>
</tr>
</tbody>
</table>

While most of the chloroquine and antipyretics were available at the household/village level, quinine treatment was observed in similar proportions at household level, and most antibiotics (except tetracycline) and the few treatments with pyrimethamine-sulfadoxine was mainly reported from health centre/hospital level (table 21).
Table 21  Proportions of fever treatments provided at household/village level compared to health centre/hospital level by treatment category in young children of 18 villages in rural Burkina Faso

<table>
<thead>
<tr>
<th>Treatment category</th>
<th>Household/village</th>
<th>Health centre/hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloroquine</td>
<td>1049/1.180 (89%)</td>
<td>131/1.180 (11%)</td>
</tr>
<tr>
<td>Antipyretics</td>
<td>369/426 (87%)</td>
<td>57/426 (13%)</td>
</tr>
<tr>
<td>Traditional remedies</td>
<td>283/283 (100%)</td>
<td>0/283 (0%)</td>
</tr>
<tr>
<td>ORS</td>
<td>26/56 (46%)</td>
<td>30/56 (54%)</td>
</tr>
<tr>
<td>Tetracycline</td>
<td>45/45 (100%)</td>
<td>0/45 (0%)</td>
</tr>
<tr>
<td>Quinine</td>
<td>22/43 (51%)</td>
<td>21/43 (49%)</td>
</tr>
<tr>
<td>Ampicilline/amoxycilline</td>
<td>3/30 (10%)</td>
<td>23/30 (90%)</td>
</tr>
<tr>
<td>Cotrimoxazole</td>
<td>5/29 (17%)</td>
<td>24/29 (83%)</td>
</tr>
<tr>
<td>Pyrimethamine-sulfadoxine</td>
<td>0/4 (0%)</td>
<td>4/4 (100%)</td>
</tr>
</tbody>
</table>

3.7  Clinical efficacy of chloroquine

A total of 120 children were recruited and there was no loss to follow-up: The mean age was 10.4 months (range 6-15), and the male/female ratio was 0.71. Mean temperature on day 0 was 38.7°C (range 37.5 –40.7) and mean *P. falciparum* density was 38 400 (range 5.500-287.000).

On day 7-10, 32/120 (27%) children were still parasitaemic (mean *P. falciparum* density 3.620, range 50-23.000). The overall treatment failure rate was 12/20 (10%), with 6/120 (5%) being ETF and 6/120 (5%) being LTF. None of the children developed severe malaria, and there were no differences in parasitological and clinical failure rates between villages (Table 22).
Table 22  Parasitological and clinical failure rates of chloroquine treatment in young children with uncomplicated falciparum malaria (fever + ≥5,000 parasites/µl) in six villages of rural Burkina Faso.

<table>
<thead>
<tr>
<th>Village</th>
<th>Parasitological failure</th>
<th>Clinical failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Koro*</td>
<td>8/25</td>
<td>5/120</td>
</tr>
<tr>
<td>Seriba</td>
<td>4/16</td>
<td>2/120</td>
</tr>
<tr>
<td>Dionkongo</td>
<td>7/18</td>
<td>2/120</td>
</tr>
<tr>
<td>Bourasso*</td>
<td>5/27</td>
<td>1/120</td>
</tr>
<tr>
<td>Sikoro</td>
<td>7/27</td>
<td>2/120</td>
</tr>
<tr>
<td>Kodougou</td>
<td>1/7</td>
<td>0/120</td>
</tr>
<tr>
<td>Total</td>
<td>32/120 (27%)</td>
<td>12/120 (10%)</td>
</tr>
</tbody>
</table>

* Village with a health centre
4 DISCUSSION AND CONCLUSIONS

4.1 Discussion of the study

4.1.1 Methodology and design of the study

This study has some limitations. Firstly, entomological data were not available in Bourasso subarea during the height of the rainy season (September). Thus, our assumption of a major difference in transmission intensity between the two subareas is based on extrapolation from the other three entomological surveys. Secondly, as we have not collected information on all possible confounding factors, the observed differences in malaria parameters by subarea could also be attributed to other factors. Thirdly, the data for the first age group were from the year 2001 and the data for all the other age groups were from 1999, making results not fully comparable. Finally, the number of children in subgroups were often small, which needs to be taken into account in the interpretation of statistical comparisons. Despite these limitations, we believe that our data are quite characteristic for the epidemiology of malaria in the area, making them particularly valuable for contributing to the ongoing discussion regarding the relation between malaria transmission intensity and morbidity/mortality.

4.1.2 Malaria transmission

The average malaria transmission intensity in the rural Nouna study area is similar to the situation reported from other areas of western and central Burkina Faso, and from other west African countries confirming the high malaria endemicity in most parts of the country (Gazin et al. 1988, Boudin et al. 1991, Habluetzel et al. 1997, Hay et al. 2000). As in other Westafrican regions, *P. falciparum* is the dominant parasite being mainly transmitted through *A. gambiae* and *A. funestus* (Boudin et al. 1991, Greenwood and Pickering 1993, Coetzee et al. 2000). Our data demonstrate that malaria transmission in the study area is intense and perennial, but with marked seasonal fluctuation.

We have shown a considerable variation in malaria transmission intensity between study villages. Annual EIRs varied from about 100 in Dionkongo to more than 1000 in Kodougou after extrapolation for the Bourasso subarea. This is mainly explained by the Bourasso sub-area village’s proximity to the two main rivers in the area and supports the evidence for an
association between malaria vector density and the distance of a settlement from a river (Lindsay et al. 1993).

4.1.3 Malaria morbidity

Our findings on significant associations between transmission intensity and malaria incidence, prevalence and density provides further evidence for a likely benefit of interventions aimed at reducing transmission intensity even in holoendemic areas of SSA (Smith et al. 1998, Smith et al. 2001).

The high proportion of fever cases having been attributed to malaria both on the rainy and the dry season reassure the policy of presumptive malaria treatment for rural West African areas of high transmission intensity and is thus in contrast to findings from urban areas (Oliver et al. 1991).

The mean hematocrit values were significantly lower in children of all age groups during the wet season compared to the dry season surveys. This could have as an explanation that malaria is a major cause for anaemia development (Akum Achidi et al. 1996, Kahigwa et al. 2002). However, we have evidence from our data that these findings may at least partly be confounded by other factors, in particular malnutrition (Müller et al. 2003c).

4.1.4 Malaria mortality

We recognized malaria as the main cause of deaths in our limited case series. However, it has to be taken into consideration that the diagnosis was based on the rather unspecific tool of verbal autopsy (Snow et al. 1992, Todd et al. 1994). Most deaths with a postmortem diagnosis of malaria occurred in the second half of infancy, which supports the evidence for children in this age group being particularly vulnerable for severe malaria disease and death in areas of high transmission intensity (Binka et al. 1994, Kitua et al. 1996, Bloland 1999). Our finding of malaria deaths typically being associated with signs of cerebral malaria supports our observations from an earlier postmortem series (Müller et al. 2003a). These findings provides some further evidence for different clinical manifestations of severe malaria in areas
of seasonal compared to areas with a more perennial malaria transmission pattern (Slutsker et al. 1994, Snow et al. 1994).

4.1.5 Risk factors for malaria

Entomological data from the study villages show that in rainy season the average EIR of the Bourasso subarea is tenfold the one of the Koro subarea. The Bourasso area has the highest malaria incidence particularly in Kodougo and Sikoro. Moreover, in the rainy season, malaria is more prevalent in the Bourasso subarea. These findings support the evidence for the intensity of malaria transmission being associated with distance from the river (Lindsay et al. 1993).

4.1.6 Community factors associated with malaria

Soumaya, the local equivalent of malaria, is considered a widespread and important health problem in northwestern Burkina Faso. As particularly young children of this area are experiencing a number of soumaya episodes during each rainy season, a significant additional burden is put on families at the time when agricultural work is most demanding and resources are most limited (Sauerborn et al. 1996; Müller et al. 2001). Soumaya manifests through various signs and symptoms. Although the majority of our study population knew that mosquitoes cause malaria, other natural and supernatural causes for malaria were frequently stated during interviews. These local perceptions of malaria are strikingly similar to findings from other malaria-endemic areas of SSA (Makemba et al. 1996; Ahorlu et al. 1997; Minja et al. 2001; Tarimo et al. 2000).

As in much of SSA and depending on accessibility, costs and perception of the entity as a “normal” or an “out of order” illness, malaria symptoms in our study area were usually first treated with traditional herbal remedies and/or available western drugs (Deming et al. 1989; Guiguemde et al. 1999, Ruebush et al. 1995; Djimbe et al. 1998; Nsimba et al. 1999; Hausmann Muella et al. 2000; Thera et al. 2000). Only in case of non-response or clinical deterioration, and depending on distance to the next health care facility, as well as on funds
and time available for transport and treatment, patients visited health centers. Although it is reassuring that western drugs are more effective as compared with traditional treatment, the fact that most villages in our study area are several kilometers away from the next health centre results in the great majority of illness episodes not being seen by trained health staff.

Prevention of mosquito bites through use of specific repellent plants, burning of mosquito coils and use of mosquito bednets is common. However, as also reported from many other places in SSA, these measures are primarily targeted against nuisance of mosquitoes and not against malaria (Aikins et al. 1994; Von Bortel et al. 1996; Zimichi et al. 1996).

There are great variations in the proportions of households using mosquito nets in malaria-endemic communities of the SSA (Zimicki 1996). While some countries such as The Gambia have a strong tradition of using mosquito nets for several purposes, mosquito net use is not very common in Ghana and Malawi (Binka et al. 1994; D’Alessandro et al. 1994a; Ziba et al. 1994). The households of CRSN study area demonstrate intermediate rates of mosquito net ownership in the SSA context. Our findings confirm the higher mosquito net ownership rates in urban compared with rural areas observed in other SSA countries (Zimicki 1996).

In our study area the majority of existing mosquito nets were used by adult males heads of households instead of those at greatest risk for severe malaria, namely young children and pregnant women. A predominance of mosquito nets use by male adults has also been observed in other SSA countries like Ghana and Tanzania, while in The Gambia young children and pregnant women were more frequently protected with mosquito nets than older children and non pregnant adults (Aikins et al. 1994; D’Alessandro et al. 1994b; Zimicki 1996). We also found that only a minority of households which own mosquito nets in our study area use them throughout the year. This supports similar findings regarding the influence of seasonal variation on mosquito net use from other SSA countries (Winch et al. 1994; Zimicki 1996; Binka & Adongo 1997). These findings have to be taken into consideration during the design of information/education/communication (IEC) messages within the framework of ITN programs.
4.1.7 Malaria treatment seeking behaviour

The majority of fever cases in study children received some form of treatment, with multiple treatment being common and most treatment taking place at the household/village level through left-over drugs from former illness episodes, drugs bought from shops or the minority of functioning village health workers, and through treatment by traditional healers. Only a minority of treatments took place at the health centre/hospital level, and the frequency of such visits was associated with sub-area and distance to the health centre/hospital as well as with more severe illness presentation. Treatment was usually with chloroquine, the official first-line treatment for uncomplicated malaria in Burkina Faso, often accompanied by antipyretics (mainly paracetamol) and traditional remedies. These findings support similar observations from other malaria endemic regions of SSA and point the importance of the accessibility to formal health services in rural SSA (de Francisco et al. 1994, McCombie 1994, Ahorlu et al. 2000, Thera et al. 2000). While most of antibiotic treatment in young children was provided through the formal health sector, tetracycline treatment took place at household/village level. This observation is disturbing and calls for better education on the dangers of antibiotic treatments in general and tetracycline treatment in the case of children in particular in respective communities.

4.1.8 Clinical efficacy of chloroquine

The first cases of in vitro and in vivo chloroquine resistance in Burkina Faso were seen in 1983 and 1988 respectively, and reported clinical failure rates after use of chloroquine for treatment of uncomplicated malaria in children were around 5% in the early 1990s (Guigemdé et al. 1994). Our finding of a low chloroquine clinical failure rate in a representative group of young children from Burkina Faso provides further evidence for chloroquine remaining sufficiently effective after many years of resistance occurrence in parts of West Africa (Guigemdé et al. 1994; Brasseur et al. 1999; Plowe et al. 2001).
4.2 Conclusions

We have demonstrated malaria being the major cause for morbidity and mortality in children aged 0-3 years living in a holoendemic rural area of Burkina Faso, with children aged 6-12 months being at highest risk. Cerebral malaria is the main cause of malaria-related deaths in these young children, and most children die in the villages without having been seen by a health worker.

As chloroquine has been shown to still being an effective first-line treatment drug in falciparum malaria in rural Burkina Faso, malaria control efforts should concentrate on early treatment of young febrile children through the mothers in the villages and appropriate referral to the peripheral health centers in case of non-response. However, the future development of chloroquine resistance needs careful monitoring also in Burkina Faso, and new combination therapy schemes may replace single drug treatments in the future in Africa.

Mosquito nets and in particular insecticide-treated mosquito nets are a new and promising tool for malaria control also in Africa. Our data so far support the evidence for a positive association between malaria morbidity and transmission intensity in African areas of high malaria endemicity. Thus, there is currently no evidence to withhold the protection with ITN of young children even in areas of high malaria transmission intensity.
The epidemiological situation of malaria in the world remains a major threat to public health. In Africa, the global malaria eradication program of the 1950s was not implemented due to high malaria endemicity, poor infrastructure and lack of financial resources. After the failure of the global eradication approach, in 1992 WHO changed to a malaria control strategy based on early diagnosis and prompt treatment, implementation of selective, sustainable, preventive measures including vector control and strengthening local capacities for assessment of malaria situation and its determinants in the affected countries.

In 1994, the World Health Organisation estimated the global incidence of malaria at 300-500 million clinical cases annually, causing 1.5 to 2.7 million deaths each year. Today, more than 90 percent of malaria morbidity and mortality is in Sub-Saharan Africa (SSA), where malaria accounts for an estimated 25% of all childhood mortality below age of five. Recent studies suggest that this percentage might even be higher because of the contribution of malaria as an indirect cause of death. This epidemiological picture of malaria is worsening with the spread of Plasmodium falciparum resistance to existing first-line drugs such as chloroquine and sulphadoxine/pyrimethamine and vector resistance to insecticides.

The goal of this study was to contribute to the existing knowledge in the epidemiology of malaria in a high-transmission area of rural Burkina Faso. The study has included data from six methodological different studies conducted in the area over the period 1999-2001: (1) entomological study, (2) zinc supplementation study, (3) ITN study, (4) community factors and malaria study, (5) chloroquine efficacy study, and (6) mortality study. All data on malaria morbidity and mortality have been collected in children under the age of three years from 6 of the 41 villages of the CRSN study area. These six villages were purposely selected to represent the rural study population in its socio-cultural, demographic and geographical diversity. The main findings were:

- Malaria transmission in the study area is intense and perennial, but with marked seasonal fluctuations. A. gambiae complex is the predominant vector, while A. funestus is only of minor importance. The area is holoendemic for malaria according to spleen and parasite rates. The entomological inoculation rate varies from 100-1000 per person per year.
• The average incidence of falciparum malaria per child and per month was 0.21 over the main transmission season (July-December). *Plasmodium falciparum* parasite prevalence was 68% in the low transmission season and 83% in the high transmission season.

• Malaria transmission intensity was higher in the Bourasso subarea, which is closer to the rivers, compared to the Koro subarea. In the high transmission season the prevalence and parasite density of *P. falciparum* was significantly higher in Bourasso compared to Koro subarea. The Bourasso subarea also had the highest malaria incidence.

• Based on the verbal autopsy diagnosis, 45% of deaths in young children were attributed to malaria and the majority of children had signs of cerebral involvement before death. There were no significant differences in mortality rates between Koro and Bourasso subarea.

• Malaria was perceived as a widespread and important health problem, putting a huge burden on families. The majority of the study population knew that mosquitoes cause malaria, but other natural and supernatural causes for malaria were also stated.

• Traditionally; the population used specific repellent plants, burning of mosquito coils and use of mosquito bednets against mosquito nuisance. Forty-nine percent of households owned at least one bednet.

• Malaria symptoms were usually first treated with traditional herbal remedies and/or available modern drugs. In case of clinical deterioration, patients visited the health centres if they had funds for transport and treatment costs.

• The chloroquine clinical failure rate was 10% in young children of the study area.

In conclusion, this study has demonstrated that malaria is the major cause of morbidity and mortality in children aged 0-3 years living in a holoendemic rural area of Burkina Faso. As chloroquine is still sufficiently effective as first-line treatment drug in falciparum malaria in Burkina Faso, malaria control efforts should concentrate on early treatment of young febrile children through their mothers in the villages and on appropriate referral to the peripheral health centers in case of non-response. In addition, protection of all young children with ITN should be promoted in the malaria endemic areas.
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Traoré C, Somé F, Yasomé Yé, Kouyaté B, Becher H, Müller O. Malaria in young children of rural northwestern Burkina Faso: association between transmission intensity and malaria morbidity and mortality. Tropical Medicine and International Health (submitted)
Name: Corneille TRAORE  
Date and place of birth: 15th April 1957, Bomborokuy, Burkina Faso  
Marital status: Married, 3 children  
Father: Etienne TRAORE  
Mother: Adèle TRAORE  

**Education**  
1964-1970 Ecole Primaire Publique de Bomborokuy  
1970-1974 Petit Séminaire Saint Paul de Tionkuy  
1974-1975 Collège Charles Lwanga, Nouna  
1975-1978 Collège de Tounouma, Bobo-Dioulasso  
1978-1986 Faculté des Sciences de la Santé, Université de Niamey, Niger (MD)  
1990-1991 Faculté de Médecine, Université de Montpellier I, France  
  (Diplôme de Socio-Economie de la Santé)  
1998-1999 Institut Regional de Santé Publique de Cotonou, Bénin  
  (Master of Public Health)  

**Professional experience**  
1987-1988 General Duty Medical Officer, Hôpital Yalgado Ouedraogo, Ouagadougou  
1998-1990 District Medical Officer, Gourcy, Yatenga Province  
1992-1995 Provincial Director for Health, Tougan, Sourou Province  
1995-1998 Health Planning Direction, Ministry of Health, Ouagadougou  
2000-2003 Scientist, Centre de Recherche en Santé de Nouna, field work for dissertation (Department of Tropical Hygiene and Public Health, University of Heidelberg)
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