Handbook On Malaria Control In Papua New Guinea

2017

Produced By Rotarians Against Malaria For The National Malaria Control Programme Of Papua New Guinea

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Forward

Papua New Guinea is a developing country with a huge burden of malaria. Outside of Africa, malaria burden in PNG is a very serious public health concern, particularly in the low-lying areas of the country along the coast and islands region where up to 60% of the population is affected by the disease numerous times in a single year. Apart from people getting sick, malaria costs the people and the government of PNG huge sums of money in terms of preventing, controlling and treating the disease as well as all the costs associated at a personal and company level of people being off work and not being productive and the loss of loved ones.

The intention of this handbook is to provide guidance to the health workers, volunteers and others interested in malaria and efforts to control it in Papua New Guinea. It provides basic information on malaria in Papua New Guinea, how to control the disease, who is currently engaged in malaria control activities and experience from other countries. Most importantly, it outlines what health workers and ordinary citizens can do to eliminate malaria in their communities and their families.

In recent years, with the mass introduction of Long Lasting Insecticidal Nets (LLINs) in 2006 and the introduction Rapid Diagnostic Tests (RDTs) for testing malaria and Artemether Lumefantrine for treatment of malaria at health facility level in 2011, malaria in PNG has now been drastically reduced. However, to maintain the gains made and to achieve even further reductions of malaria, we must all work together at government, health service, community and household levels to rid this country of this disease so that it is no longer a public health problem in Papua New Guinea.

The information contained here is not comprehensive and the interested reader and user is urged to refer up to date training materials, guidelines and circulars issued by the National Department of Health for more specific information.

This handbook includes basic facts about malaria, it's transmission in the country, people affected and most at risk and activities to control the disease. It is hoped that after reading this handbook, health workers and others in the field would be encouraged to evaluate their own malaria situations and plan and implement appropriate interventions in their areas to better control the disease and their own personal protection.

We would like to thank the Malaria Technical Working Group of the Department of Health for taking up the challenge and encouraging people to control and eliminate malaria from their communities and subsequently getting rid of malaria from the whole country.

No one in Papua New Guinea needs to suffer from malaria or even die from malaria when it is very easily preventable, curable and can be treated.

I urge all Papua New Guineans to use the strategies outlined in this information booklet to take ownership of your health for a healthier nation.

Thank you

Mr. Michael Malabag, MP
Minister for Health and HIV

Acknowledgements

On behalf of the Papua New Guinea department of Health, I would like to acknowledge the Malaria control program for the publication of this handbook that can be used as an effective tool for use by all stakeholders and partners in our fight against Malaria.

Numerous partners and consultations have been involved in the production of this simple yet very effective tool. To name a few the basic concept for this handbook was developed by Mr. Tim Freeman, Project Manager, Rotarians Against Malaria. The Malaria Technical Working Group (MTWG) under the chairmanship of the Malaria control program manager, Mr Leo Sora Makita, endorsed the idea and contributed to refining the book with major editing carried out by Dr Rabindra Abeyasinghe of the World Health Organisation, PNG.

The following persons also participated in its development, editing through to its finalization, Leo Makita (Malaria Programme Director - National Department of Health), Steven Paniu (Former Deputy Malaria Programme Director - Department of Health), Anna Maalsen (Former Public Health Management Advisor - National Department of Health) and Dr Leonard Nawara, Medical officer for the Malaria Control Program.

A very special mention and acknowledgement must be made to the board of Rotarians Against Malaria (RAM), the Rotary club of Port Moresby, in particular its chairman Mr. Ronald Seddon who had whole heartedly supported the production of this handbook and printing. This fulfils the vision of RAM to see a malaria free Papua New Guinea.

I acknowledge also the numerous others who have contributed in one way or another towards its production.

Mr Pascoe Kase
Secretary

Executive Summary

Malaria remains among the five major causes of hospital admissions and deaths in Papua New Guinea (PNG), accounting for up to 40% of outpatient visits in some areas of the country and historically about 600 recorded deaths annually. Worldwide, malaria kills approximately 650,000 people annually, most of who live in Africa and are children under the age of five. Historically, each year, the National Department of Health in PNG has recorded over 1.7 million clinical malaria cases through its National Health Information System (NHIS). Although this represents figure represents about 25% of the entire population of PNG getting malaria each year, much of these cases were clinically suspected. These figures are based on fever cases reported by the NHIS, which only captures data from hospitals and health centres. This data does not include private health care providers.

Due to the large-scale introduction of Long Lasting Insecticidal Nets (LLINs) in 2006 and Rapid Diagnostic Tests (RDTs) and Artemether Lumefantrine (Mala-1) as a first line treatment for malaria in 2011 malaria has been reduced from about 1.6 million clinical cases of malaria in 2005 to about 990,000 cases of clinical malaria in 2013. Malaria deaths have similarly been reduced from 724 in 2005 to 203 in 2014. Recent studies conducted by PNGIMR (Papua New Guinea Institute of Medical Research) in 2013/14 suggest that malaria prevalence in the general population in PNG now is around 3% down from 6-7% in 2010/11 and about 12-13% in 2009/2010 and that only approximately 20 – 30% of reported malaria cases actually had the malaria parasite in their blood. The results also suggest epidemiology of malaria is diverse in PNG, with some high transmission settings co existing with low and no malaria transmission areas. In lowland coastal areas, the malaria transmission tends to be high and children under five and pregnant women are most at risk to malaria, including severe disease. In highland areas, transmission intensity drops and even adults can be at risk of dying from malaria due to lack of immunity. Understanding these dynamics, as well as other environmental (temperature, rainfall, humidity) and host parasite, vector and host factors is important for proper planning and implementation of sound and evidence based malaria control interventions.

Malaria has significantly impacted development and progress in Papua New Guinea. Apart from the human suffering and misery, each time a person is sick; it costs money in terms of income loss and treatment seeking although diagnosis and treatment at government facilities are free. Also, while the person is sick, they cannot work or go to school which reduces the productivity of the country.

There may also be many misconceptions about malaria among both health workers and the general population. Some people believe for instance that malaria is transmitted through eating rotten food, swimming in the sea or sitting in the sun. Health workers on the other hand have come to believe that most fevers are caused by malaria infections.

This booklet helps to clarify beliefs about malaria and most importantly offers simple solutions to health workers and villagers alike how they can get rid of malaria in the places where they live.

Introduction

Epidemiology has been defined as the basic science of public health. The epidemiological approach to malaria control is based on three main and inter dependent functions (WHO 2011):

1) Describing and measuring the distribution of the disease (who gets malaria, how much of it, where and when)
2) Explaining distribution by its determinant factors (biological, environmental, social, behavioural and economic
3) Predicting changes expected in that distribution from human interventions, in particular from control measures

Therefore, knowledge of local malaria epidemiology in PNG is critical for planning and implementing a sound, evidence based malaria control program, both at national, provincial and district level and even at community level.

Epidemiology of malaria in Papua New Guinea

The disease burden

Historically malaria has been the primary cause of sickness and death in Papua New Guinea (PNG) accounting for up to 40% of outpatient visits in some areas of the country and about 600 recorded deaths annually. Worldwide, malaria kills approximately 650,000 people, most of who live in Africa and are children under the age of five. In previous years, the National Department of Health in PNG records about 1.7 million clinical malaria cases. This represented about 25% of the PNG population getting one episode of malaria each year. These figures are based on fever cases reported by the NHIS and it is possible that systematic parasitological confirmation being rolled out in the country may suggest different trends. Due to the largescale introduction of Long Lasting Insecticidal Nets (LLINs) in 2006 and Rapid Diagnostic Tests (RDTs) and Artemether Lumefantrine as a first line treatment for malaria in 2011 malaria has been reduced to705,000 cases of clinical malaria anddeaths to 186 in 2015.

Table One – Malaria Prevalence Rates As Percentage Recorded By Institute Of Medical Research PNG

Region	Pf 2014	Pv 2014	Mix 2014	Total 2014	Pf 2011	Pv 2011	Po 2011	Mix 2011	Total 2011	Pf 2009	Pv 2009	Po 2009	Mix 2009	Total 2009
Southern	0.02	0.1	0	0.1	1.8	1.8	0.1	0.03	4.4	7.8	2.9	0.1	0.4	11.6
Highlands	0.3	0.3	0.3	0.3	0.3	0	0	0	0.3	7.2	2.5	0.1	0.8	11.4
Momase	2.8	0.7	0.2	3.3	4.2	2	0	0.05	8	10.5	6.7	0.2	1.9	19.8
Islands	2.8	1.1	0.6	3.4	7.4	4.9	0	0.4	14.3	8.2	11.2	0.6	3.4	25.1

Recent studies conducted by PNGIMR in 2013/2014 suggest that malaria prevalence in the general population in PNG is around 3% down from 6-7% in 2010/11 about 12-13% in 2009/2010 and that approximately 20 – 30% of reported malaria cases actually had the parasite in their blood. See Table One. The results also suggest that the epidemiology of malaria in PNG is varied, with some high transmission settings co existing with low and no malaria transmission areas. In lowland coastal areas, the malaria transmission tends to be high and children under five and pregnant women are most at risk to malaria, including severe disease. In highland areas, transmission intensity drops and even adults can be at risk of dying from malaria. Understanding these dynamics, as well as other environmental (temperature, rainfall, humidity) and parasite, vector and host factors is important for proper planning and implementation of sound and evidence- based malaria control services.

Malaria parasites

Malaria is caused by a parasite belonging to the genus *Plasmodium*. There are five species of *Plasmodium* which affect man (*P. falciparum, P. vivax, P. ovale, P. malariae and P. knowlesi)*. Of these, only two (*P. vivax and P. falciparum*) are common in PNG with *P. ovale* and *P. malariae* being rarely found in PNG and usually in combination with *P. falciparum* and *P. vivax*. *P. knowlesi* is essentially a parasite of monkeys which can infect humans as well. It is normally only found in countries in and around Borneo. It is not found in PNG however, it is possible to have imported cases from outside.

These *Plasmodium* parasites are usually found within red blood cells. However, some stages *of P. vivax* and *P. ovale* may additionally infect liver cells.

In Papua New Guinea, the most prevalent species presently is *Plasmodium falciparum followed by P.vivax.* The prevalence of *P. falciparum* is substantial in some places and this is of concern as this is the most dangerous species which can cause severe disease and death if not recognised and treated promptly. Similar to *P. vivax, P. ovale* can also cause relapses which due to the existence of a hypnozoite stage in the liver could cause relapses. It is also noted that *P. vivax* is now recognised as also causing life threatening symptoms for non-immune populations.

The parasites of malaria can only be transmitted from one person to another by certain species of mosquitoes, the Anopheline mosquitoes. However occasionally they can get into another person through the direct passage of blood from one person to another such as during a blood transfusion or through congenital transmission.

Clinical symptoms of malaria

The early symptoms of malaria may not be acute, with symptoms similar to flu, i.e. pains in the limbs and joints, headache, feeling tired, nausea, slight diarrhoea and slight increase in body temperature. Malaria infection is characterized by bouts of intermittent fever, in between which the body temperature returns to normal. Each individual bout of fever repeats within a set time period usually every 48 hours for most plasmodium species. However, the periodicity of bouts of fever is altered due to immunity, infection with multiple species etc.

The clinical picture of a malarial paroxysm of fever is briefly described below.

Cold stage - shivering and feeling of intense cold. Teeth chatter. Pulse rapid and weak, lips and fingers may turn blue (cyanotic). Skin dry and pale with a goose-flesh appearance. Vomiting may occur and children may have fit or seizures. Lasts fifteen minutes to one hour.

Hot stage - Face flushed, skin dry and burning. Headache, nausea and vomiting are common. Pulse is full and bounding. Intense thirst. Temperature of up to 41°C. Lasts 2 to 6 hours.

Sweating Stage - Profuse sweating. Rapid temperature fall below normal levels. Deep sleep and on waking feels weak. Lasts two to four hours.

Classically, these symptoms will repeat themselves every two days (i.e. approximately. every 48 hours), but with multiple infections, high levels of immunity or early intervention with drugs having antimalarials properties this is rarely seen, particularly in places of high transmission such as in the lowlands of Papua New Guinea.

If malaria infections are not detected early and treated with appropriate medications in the correct dosage, severe malaria (SM) develops. These are most likely to develop in falciparum infections but may occasionally be seen in vivax infections also.

Severe malaria manifests in several ways;

For epidemiological purposes, SM is defined as one or more of the following, occurring in the absence of an identifiable alternative cause and in the presence of P*.falciparum* asexual parasitaemia (WHO 2015)..

- *Cerebral malaria:* Drowsiness, multiple fits (more than 2 episodes within 24 hours), impaired consciousness and possibly coma.
- *Low blood glucose:* Blood or plasma glucose < 2.2 mmol/L (< 40 mg/dL)
- *Low red blood cells (Anaemia):* Haemoglobin concentration ≤ 5 g/dL
- *Kidney problem:*
- *Yellow eyes and skin:*
- *Fluid build-up in the lungs (Pulmonary oedema)*: confirmed by x-ray.
- *Abnormal bleeding:* Including recurrent or prolonged bleeding from the nose, gums; vomiting blood (haematemesis) or dark stools (melaena)
- *Algid malaria (Shock):* Skin cold and clammy, breathing shallow, pulse weak and rapid, low blood pressure. Sometimes patient's consciousness may decline.
- Blackwater fever - urine appears black due to haemolysis (breakdown) of the red blood cells.

It must be noted that malaria is a very difficult disease to diagnose, especially *Plasmodium falciparum* malaria, which is often not characterized by the typical symptoms/paroxysms described above. If a person develops fever in Papua New Guinea it is important that a diagnosis of malaria is considered and either confirmed or excluded with the help of laboratory tests such as microscopy or preferably with a Rapid Diagnostic Test for malaria. A delay in seeking treatment or if inadequate and inappropriate treatment is used malaria infection can result in death. The mortality for severe malaria if left untreated reaches 99% (WHO 2015). If a diagnosis of malaria is suspected and no facilities for diagnosis can be made available to the patient within two hours, the WHO now recommends the administration of first line therapy based on a diagnosis of clinical malaria and then refer the patient to the nearest facility with diagnostic capacity as soon as possible. However, whenever possible, the use of antimalarial medicines in the absence of laboratory confirmation of diagnosis in uncomplicated malaria infections is discouraged by the WHO.

Malaria Diagnosis: Clinical, Malaria Microscopy, Rapid Diagnosis Kits and Polymerase Chain Reactions (PCRs)

In terms of how a person is diagnosed, there are basically four main ways. Clinical diagnosis, using a Rapid Diagnostic Test (RDT), microscopy and PCR (polymerase chain reaction) which is mainly used for research purposes.

Before RDTs became widely available, most malaria cases were diagnosed clinically. This is a very unreliable way of diagnosing malaria as many other diseases have the same symptoms as malaria. Such symptoms include fever, headache, weakness, myalgia, chills, dizziness, abdominal pain, diarrhoea, nausea, vomiting, anorexia, and pruritus.

With the introduction of more expensive antimalarial drugs and RDTs becoming available at reasonable prices, PNG like most other countries in the world use RDTs to first diagnose malaria before treatment is given. RDTs are ideal in that they can be performed close to home in settings with no sophisticated infrastructure and can give a result within 20 minutes. RDTs are antigen based tests that have been shown to be capable of detecting >100 parasites/μL (0.002% parasitemia) and of giving rapid results (15 to 20 min). The RDTs main drawback is in its specificity as parasite antigen can persist in the blood of the patient after parasite clearance by chemotherapy thereby producing false positive for six to eight weeks after an original infection of malaria was cleared. They are commercially available in kit form and the ease of performance of the procedures does not require extensive training, equipment, or difficulty in result interpretation. RDTs have the potential to improve the accuracy and time needed for malaria diagnosis particularly for laboratories in low or non-endemic countries, where expertise with microscopy may be limited. However, you need different types of RDTs to test for different species of parasite, so choice of the type of RDT to be used depends on each country. In PNG we use a RDT can detect P. falciparum and also detects other species of parasties but cannot tell if the parasite is *P. vivax, P. ovale* or *P. malariae.*

Table Two. Antimalarials and the Different Parasite Stages Yhey Act Upon.

Drug	Hypnozoite	Asexual blood Forms	Gametocytes	
			Young	Matured
Artemether-lumefantrine	-	++	++	-
Dihydroartemisinin piperaquine	+	++		
Artemether	-	++	+	
Artesunate	-	++	+	
Quinine	-	++	+	
Primaquine	+	+/-	+	
Fansidar	-	+	+	
Chloroquine	-	++	-	

Microscopy remains the gold standard for malaria diagnosis; it is less expensive compared to other laboratory methods but has a low sensitivity. It requires well trained microscopists and when this is not present the result will not be reproducible and un-reliable, there will be variable sensitivity and unacceptably high false-positive rates.

PCR remains the most sensitive of all the methodologies of detecting malaria. Major advantages of PCR values lie in its high sensitivity, with the ability to detect five parasites or less/μL of blood; however, it is expensive and time-consuming and at this present time it remains as a tool for research rather than routine diagnosis.

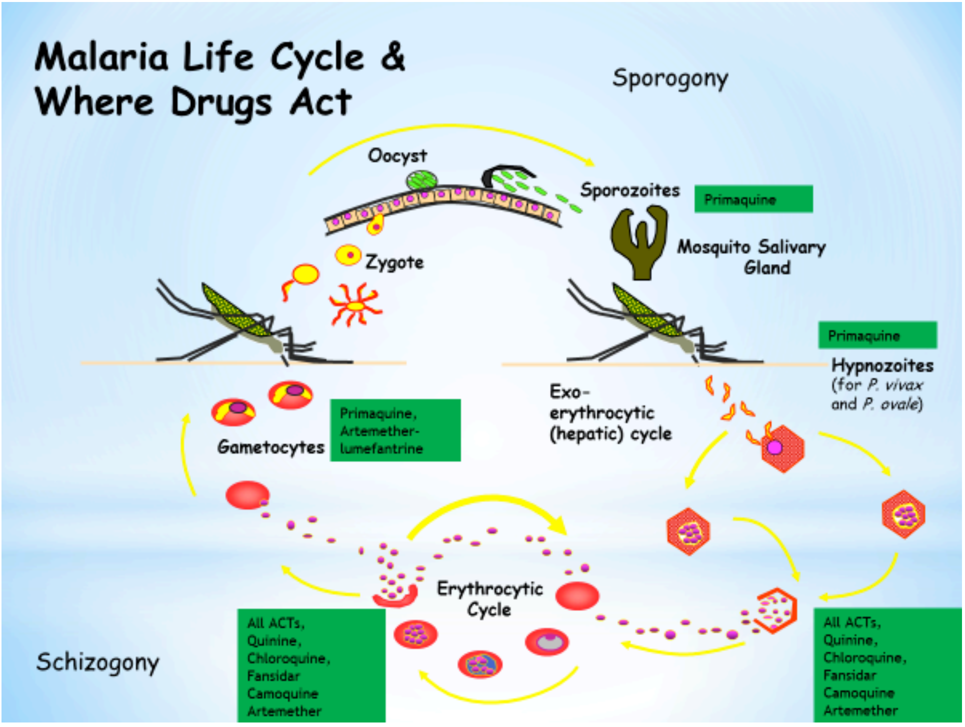

Fig. 1 - Antimalarials And What Section Of The Life Cycle It Targets.

Drug research in malaria often focuses on blood stage parasites because they are responsible for the symptoms of the disease and are easier to manipulate in the laboratory. However different antimalarial drugs are designed to focusing on different areas of the plasmodium life cycle to attack the parasites. Anti-relapse drugs like primaquine focus on the liver stages of the parasite, schizontocidal drugs likes of chloroquine and quinine which are drugs that focus on the Blood stage of the parasite. Arthermether and other Artermisinin derivatives are also schizonticidal drugs but also have some effect on young gametocytes. Gametocytocidal drugs act on the gametocyte stage of the parasite development. Similarly, many of the common antimalarial drugs used have multiple properties and focus on more than one area of the plasmodium life cycle such as primaquine and Pyrimethamine.

Most anti-malarial drugs are unable to destroy mature gametocytes of falciparum, and this means that although a person can be cured of falciparum malaria, the person will remain infective to mosquitoes. Only one anti-malarial drug is known to destroy gametocytes and this is Primaquine. Previously, the only other drug that had an effect on gametocytes had been chloroquine which was able to destroy young gametocytes of *P. falciparum* and all gametocytes of *P. vivax*. However, the recently introduced anti-malarial drugs containing Artemesinin Combination Therapies (ACTs) also destroy immature gametocytes. ACTs therefore not only cure malaria but reduces transmission of malaria, particularly when early treatment is carried out. ACTs have been recently introduced in Papua New Guinea as the first line treatment for malaria by the National Department of Health in the form of Mala-1 which is a combination of Artemether and Lumefantrine.

Primaquine is also the only drug that is able to destroy the liver stages of the *P. vivax* parasite. This is important as the liver stages often remain in the liver to cause recurrent attacks of malaria much later (often several weeks or months afterwards). The only inconvenience with Primaquine is that it needs multiple doses (14 days) to kill off the liver stages and may require testing or continued surveillance for glucose-6-phosphate dehydrogenase (G6PD), as some forms of deficiency with this enzyme can lead to life threatening haemolysis (massive destruction of red blood cells).

Life cycle of the malaria parasite and the impact of environment.

The life cycle of the malaria parasite includes an asexual reproductive stage within humans and a sexual reproduction within the Anopheline mosquito. The main elements of the life cycle are summarized in Fig.1.

1) A non-infected person gets infected when bitten by an infective Anopheline mosquito. The infective stage of the parasite is known as sporozoites; and sporozoites are found in the salivary glands of infective mosquitoes. When a female mosquito has a blood meal from a human, it first injects saliva which contains an anti-clotting agent so that blood will not clog and block its mouthparts. If a mosquito has sporozoites in the salivary glands, i.e. the mosquito is infective, the sporozoites will be injected with the saliva when the mosquito feeds, and the human infection will occur.

2) Sporozoites get carried round in the blood until they reach the liver where they invade the liver cells usually within a few minutes.

3) The sporozoites grow and reproduce within the liver cells, until such time as the liver cells die and burst, releasing parasite stages known as merozoites into the blood. The liver stage takes 5 to 8 days. In *P. falciparum*, each sporozoite produces about 30 000 merozoites. Note: In the case of *P. vivax* and *P. ovale*, some of the sporozoites remain dormant in the liver (hypnozoites) and can reactivate at a later time giving malaria relapses.

4) Merozoites invade and multiply within the red blood cells. Every two days (48 hours), the red blood cells burst and merozoites are released which reinvade other red blood cells (Only in *P. malariae* infections the rupture of red blood cells occurs every 72 hours). After two or three cycles of invading red blood cells, the infected person begins to feel ill as a result of an increasing number of red blood cells rupturing. Fever is mainly caused as the immune systems attempts to neutralize the metabolic by products of parasites being released from the ruptured

red blood cells in to the blood but can also be induced by products of the malaria parasite itself. The time interval from the time a person gets bitten by a mosquito until illness is felt is known as the incubation period and could take approximately 9 to 14 days in *P. falciparum* and 12 to 17 days for *P. vivax*.

5) After several cycles, or about ten days after leaving the liver, the merozoites of *P. falciparum* start producing gametocytes that are infective to mosquitoes. In *P. vivax* infections gametocytes are produced from the first cycle of merozoites development in the blood. Gametocytes can survive in the blood for about three weeks, though some survive up to three months. Gametocytes are so called because they are gametes like sperm and ova, and have two forms - male and female. In *P. vivax* gametocytes are produced from the first schizogonic cycle, but in lesser numbers than in *P. falciparum* infections which forms after about a week.

Fig. 1 shows the main elements of the life cycle of the parasite and Table Two highlights the main characteristics of *P. falciparum* and *P. vivax*. The details below and time lines refer to *P. falciparum* and *P. vivax,* since they are the common species found in PNG.

Table 3. Various Features of *Plasmodium vivax* and *Plasmodium falciparum*

Species	Liver Stage	Incubation Period	Minimum time for sporogony	Duration of a blood cycle
P. vivax	6 - 8 days	12 - 17 days	8 days	48 hours
P. falciparum	5.5 - 7 days	9 - 14 days	9 days	48 hours

6) If an infected person is bitten by a vector mosquito, gametocytes pass into the mosquito's stomach where they fuse to form a "zygote". The zygote then invades the stomach wall and forms a cyst on the outside of the stomach wall. This process takes about 2 days.

7) Within the oocyst the parasite reproduces through asexual multiplication. In *P. falciparum*, each oocyst produces approximately one thousand sporozoites which then migrate to the mosquito salivary glands where the whole cycle can now be repeated.

Important Notes

1) The shortest possible period for the whole life cycle to be completed under optimum environmental conditions is 25 days (9 days in the mosquito plus 16 days in a person). For malaria to become a huge problem in any area, one infected person must infect a huge number of mosquitoes who in turn must infect a large number of other people.

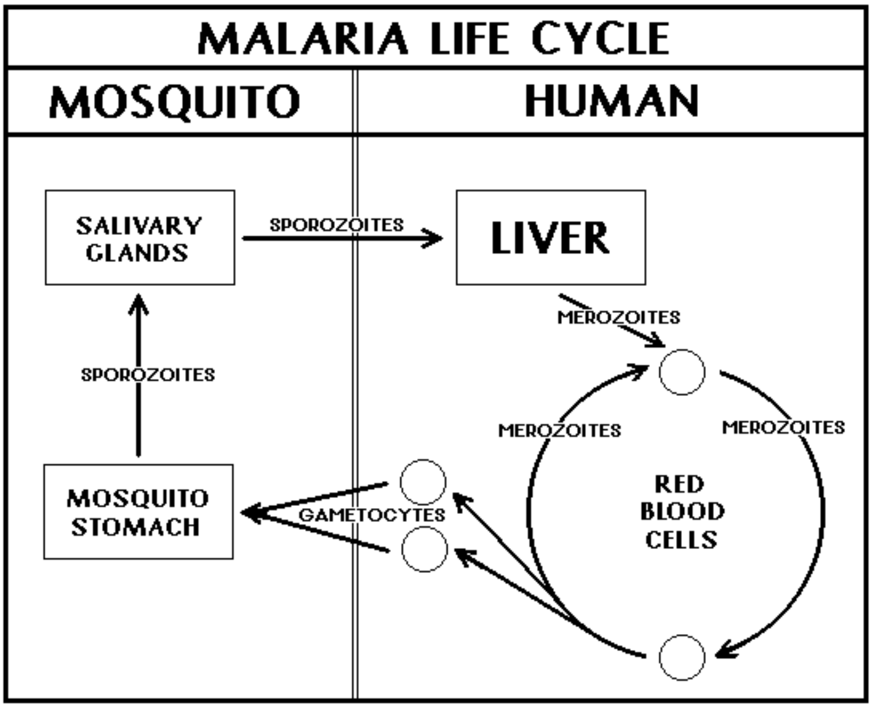

Fig. 2 - Life Cycle of *Plasmodium falciparum*

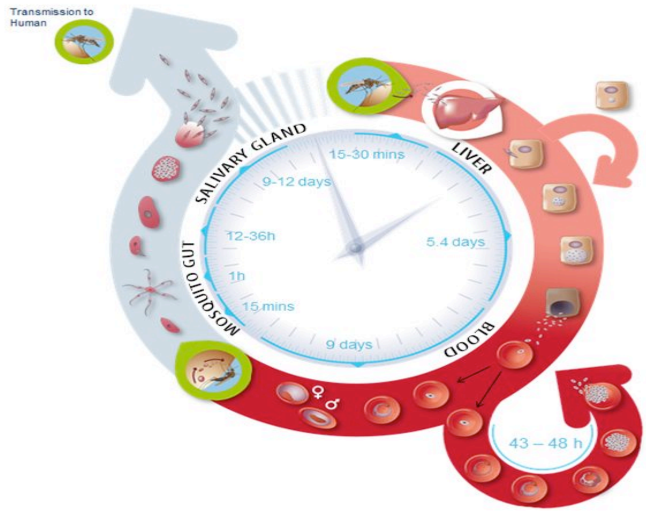

Fig. 3 – Life Cycle And Time Scale Of The Malaria Parasite

2) The weakest part of the life cycle is that within the mosquito. As mosquitoes are cold blooded, the development of the parasite is dependent on environmental temperatures. Fig. 2 shows the sporozoite development times of *P. falciparum* and *P. vivax* within vector mosquitoes. The graph shows that in optimum conditions sporozoite development may take as little as nine days at mean temperatures above 27°C but can take 25 days or more at mean temperatures of below 20°C in *P. falciparum* or 18ºC in P. vivax.

3) Vector mosquitoes generally live for a maximum of 30 days in natural conditions, but the majority die out much earlier. For this reason, it is very unlikely that at temperatures of below 20°C sporozoites of *P. falciparum* can develop before

vector mosquitoes die. Therefore, below mean temperatures of 20°C it is extremely unlikely that malaria transmission of *P. falciparum* can occur, and even up to temperatures of 21-22°C malaria transmission is likely to be extremely slow. Severe outbreaks of *P. falciparum* malaria in countries such as Papua New Guinea are unlikely to be associated with mean temperatures of less than 23°C which do not occur above about 1400 to 1500 metres.

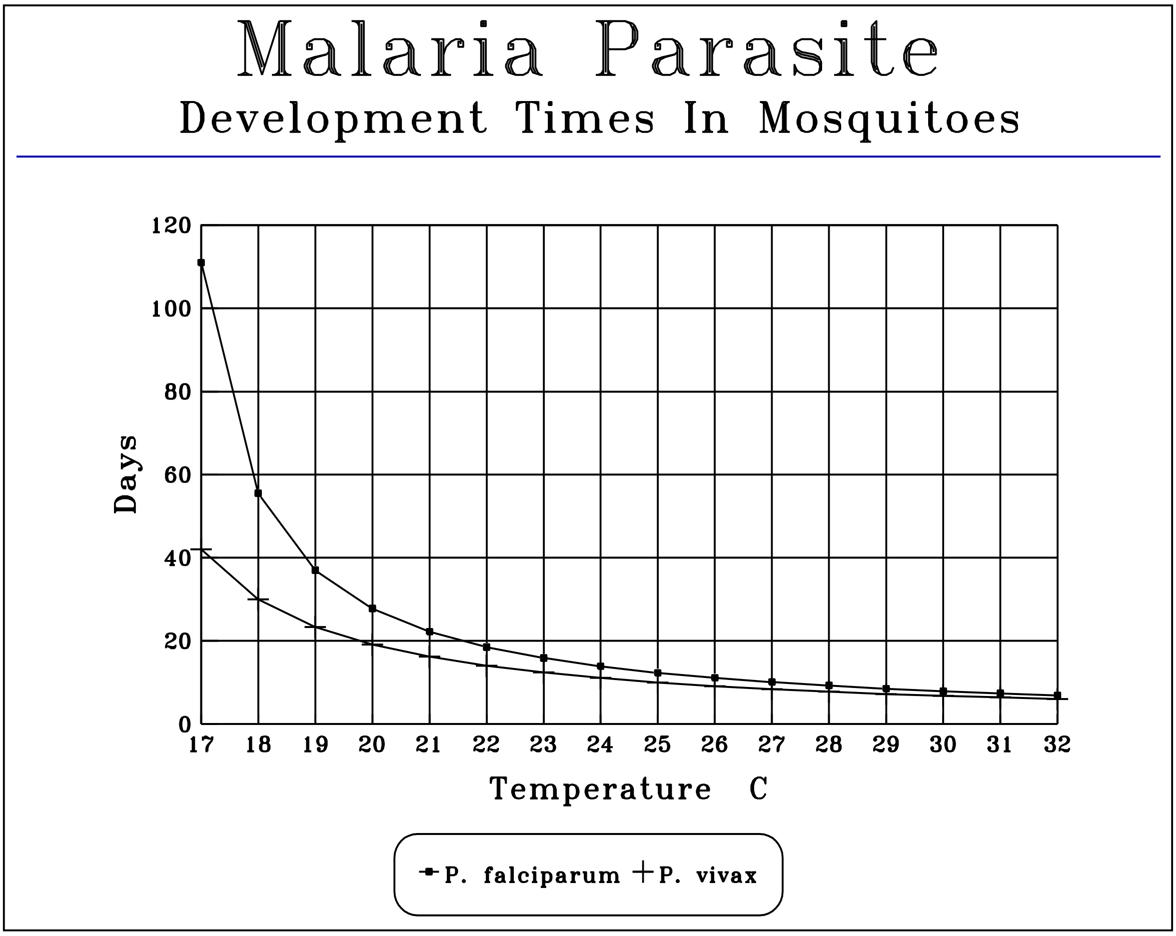

Fig. 4 - Development times of malaria parasite in mosquitoes

4) *P. vivax* parasites continue to develop within mosquitoes at temperatures 2ºC less than *P. falciparum* parasites. Therefore the lowest temperature of continuing development and completion of life cycle for *P. falciparum* is 18ºC, and disease transmission of falciparum malaria can occur up to this temperature. Accordingly vivax malaria transmission can theoretically occur at temperatures higher than 16ºC. It should however be noted that transmission at these temperatures is very inefficient as the parasite development within the mosquito can take a considerable period, during which time the mosquito will reach its life expectancy of about 30 days. As shown in Fig.4 at ambient temperatures above 28ºC this development is completed much earlier and transmission is more efficient as mosquitoes do not need to survive for long periods of time to transmit the disease.

5) The temperature conditions in Papua New Guinea remain ideal for malaria transmission throughout the year in most parts of the country, particularly in the coastal low lying areas. Referring to Fig. 5, it can be seen that average temperatures along the coast in Papua New Guinea are about 27ºC while in the highlands such as in Goroka the average temperature is only 21ºC. Therefore, it can be stated that areas around the coast of Papua New Guinea are ideal for malaria transmission but as one rises into the mountains, the transmission potential is reduced.

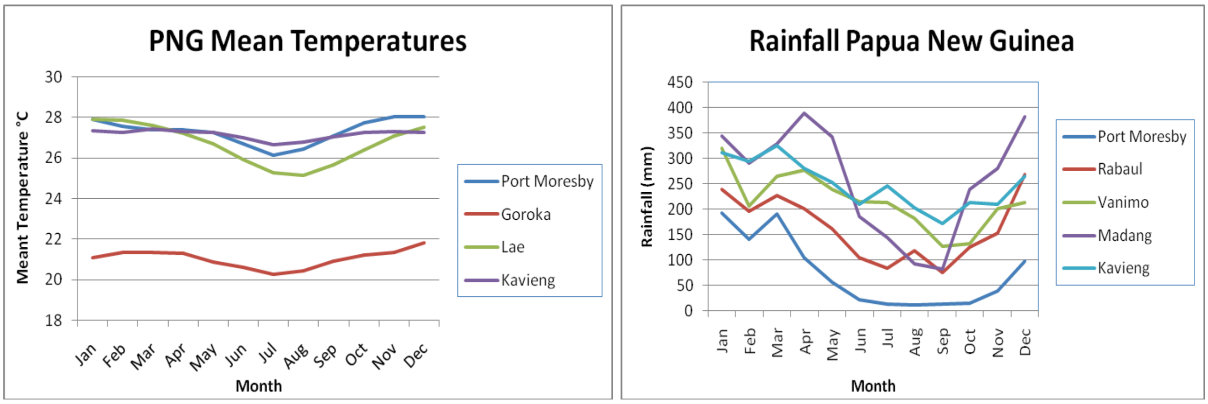

Fig.5 – Mean temperatures and rainfall around Papua New Guinea

6) Around the coastal areas of the country temperatures do not vary very much throughout the year. For example, in Port Moresby, temperatures in July are on average only about 1.9ºC less than in December. Therefore, malaria transmission will be possible throughout the year and fluctuations in intensity of transmission are linked to the availability and abundance of breeding sites, which are mainly determined by rainfall.

Range Of Plasmodium vivax	Endemic Pv								Low Level Pv Transmission												
Range Of Plasmodium falciparum	Endemic Pf				Low Level Pf Transmission																
Temp Based On ADB 1°C per 100 m2	25		24		23		22		21		20		19		18		17		16		15
Temp Based On ADB 1°C per 200 m2	23				22				21				20				19				18
Altitude (m)	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650	1700	1750	1800	1850	1900	1950	2000	2050	2100	2150	2200

Fig.6 – Theoretical limits of malaria in PNG based on temperatures in Goroka and Mount Hagen.

7) Temperature is also influenced by altitude. This can be seen in Goroka in the Highlands which has an average temperature of 21ºC. As one goes higher, temperatures become cooler, generally at a rate of about one degree centigrade for each 100 to 200 m rise in altitude depending on humidity. This is called the Adiabatic Lapse Rate and allows us to make prediction on the presence or absence of malaria in a particular area based on altitude extrapolated from known temperatures at other altitudes[1]. If mean temperatures in Goroka are about 21ºC at 1,600 m in altitude, we can assume that by altitudes of 1800 m, malaria caused by *P. falciparum* is likely to be rare. In fact, if we use 23º C as a temperature where *P. falciparum* malaria can be

[1] Dry Adiabatic Lapse Rate is about 1ºC for every 100 metres in altitude and the Saturated Adiabatic Lapse Rate is about 1ºC for every 200 metres.

freely transmitted, we would be looking at up to altitudes of about 1300 m if we take the mean of the two Adiabatic Lapse Rates. However, in the case of *P. vivax* this would extend to about 1600 m. Above these altitudes, malaria transmission could exist but it would be slow with a theoretical limit of a about 1750 m for *P. falciparum* and 2050 m for *P. vivax.*

8) If we assume 2000 meters as a limit for malaria in Papua New Guinea, we can see by referring to the map of Papua New Guinea in Fig.7, that there are only very few places in Papua New Guinea where it is not possible to find malaria e.g. the high mountainous highland areas of the Highlands Region (About 9% of the population are believed to live above 2000m). Accordingly, it is clear from Fig.7 that of all the provinces, Enga province will have least amount of malaria transmission.

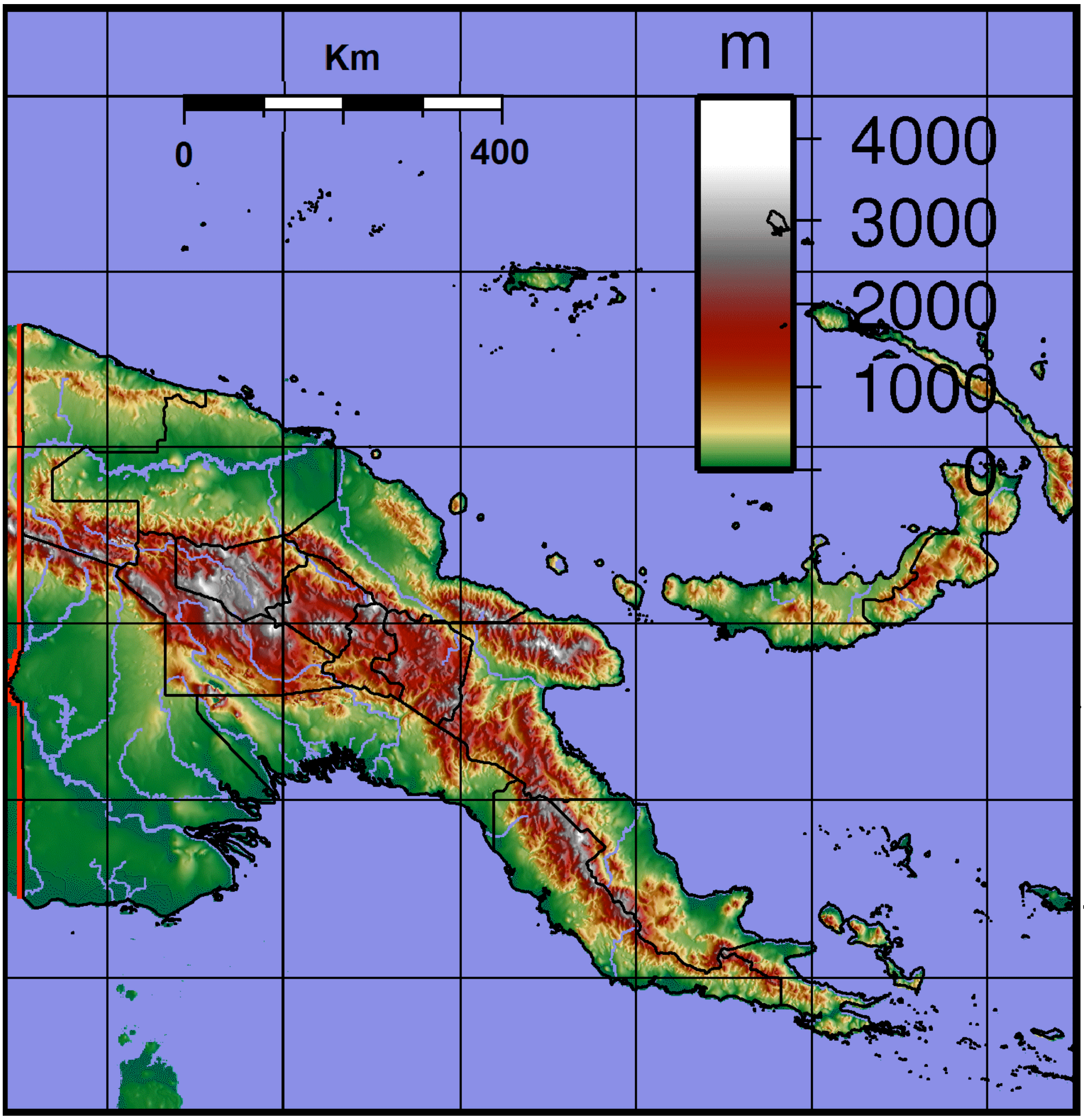

Fig. 7– Map showing altitudes in Papua New Guinea

9) It is also necessary to state, that with Global Warming and with seasonal changes in weather influenced by a variety of factors, temperatures at higher altitudes may rise and outbreaks may occur where there had never been malaria transmission before. These are areas of possible malaria outbreaks. In general, the majority of outbreaks will occur in the zones where malaria barely exists at very low levels, and then suddenly, conditions become much more favourable for a limited time period allowing transmission to increase and an outbreak to occur. In exceptional circumstances however, malaria may occur at higher altitudes than those stated so it is impossible to discount malaria outbreaks in any location without first investigation to prove otherwise. But if in any area, particularly those highland areas where low level transmission is occurring the temperatures were to increase, a malaria outbreak could occur.
10) High temperatures of 35°C and over also disrupt sporozoite development. This means that when temperatures become very hot, transmission may be disrupted. Such high temperatures are not a common feature of Papua New Guinea.
11) Fluctuations in relative humidity also affect the longevity of vector mosquitoes and could impact on malaria transmission.

The mosquito vectors

Mosquitoes are small flying insects with two wings and are related to flies. Female mosquitoes suck blood before laying eggs as blood is needed for egg development. Male mosquitoes do not bite people and feed on plant juices.

A vector is any animal that transmits a disease-causing agent from one host to another. Mosquitoes transmit a variety of diseases in man besides malaria including Yellow Fever, Dengue, filariasis (elephantiasis). In Papua New Guinea, mosquitoes account for the transmission of malaria, filariasis, dengue, chikungunya and Japanese Encephalitis.

Mosquitoes have a four-stage life cycle which lasts a minimum of one week from egg to adult. The adult mosquito after emergence can survive 3 – 4 weeks depending on existence of favourable environmental factors. In situations where effective vector control measures are in place or the environmental conditions are not favourable, this duration of life is considerably reduced and the potential for malaria transmission is reduced.

1) Eggs are laid in water by female mosquitoes. The eggs float on the surface of the water.
2) Eggs hatch to form "larvae" ("larva" singular) which grow in four stages (instars) like many other insects such as butterflies and beetles.
3) The larvae grow in water and change into "pupae" which is a resting stage. The pupae are able to move around but they do not feed. Within the pupae the larvae change into adults.
4) The pupae hatch out to form adult mosquitoes.

Mosquitoes can be divided into two groups known as Anophelines and Culicines (Figs 6 and 7). It should be noted that ONLY Anopheline mosquitoes are able to transmit malaria.

There are many species of mosquitoes in Papua New Guinea. Of the Anopheline mosquitoes, only three species are important which all belong to a group of mosquitoes known as the *Anopheles punctulatus* group. Within this group, on the species *An. farauti* is made up of a number of sub species (at least eight), three of which transmit malaria in PNG.

<u>Table Three</u>
Major Characteristics Of Malaria Vectors In PNG

Species	Sub Species	Breeding Sites	Distribution	Biting
Anopheles farauti	*An. farauti s.s*	Brackish water coastal streams, swamp	Coastal areas 1-2 km from the coast	Early night biter and also tends to be zoophylic
	An. farauti		Sepik and Ramu River plains	
	An. hinosorum		10-100km from the coast	
An. koliensis		Breeds in seepage areas such as the edge of forests	Low density but everywhere in the country except along the coast	Later night biter
An. punctulatus		Temporary clear water such as found in tyre tracks	Inland and highlands	Later night biter

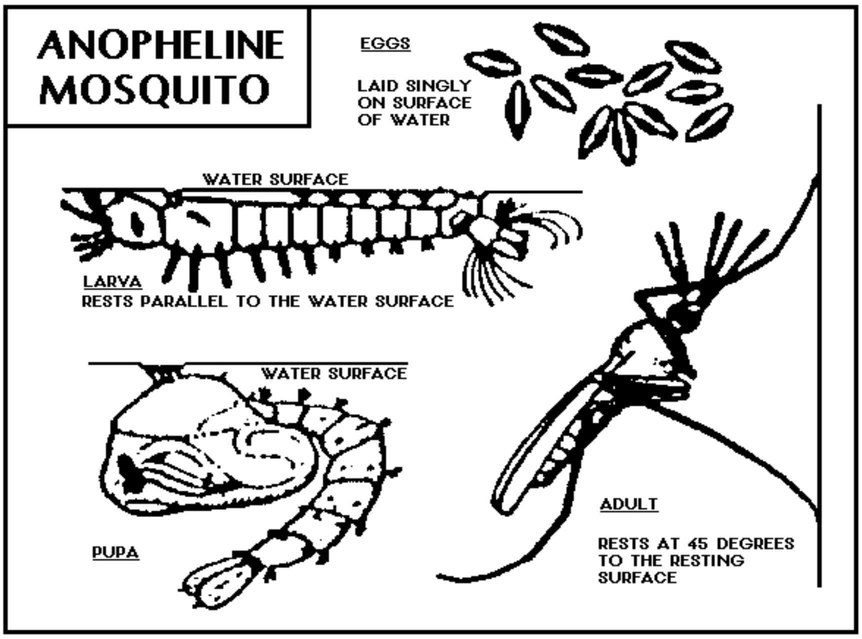

Fig. 8 - Anopheline Mosquito

All mosquito eggs, larvae and pupae can be seen with the naked eye (Fig. 6) Culicine larvae are often more difficult to see than Anophelines (especially in muddy water) because they rest under the water surface. Mosquito larvae are easy to distinguish from other animals living in water because they wriggle rapidly like a snake when disturbed. When disturbed they swim to the bottom of the water and can remain like this for several minutes so the best way to look at them closely is to catch them with a large soupspoon (scoop).

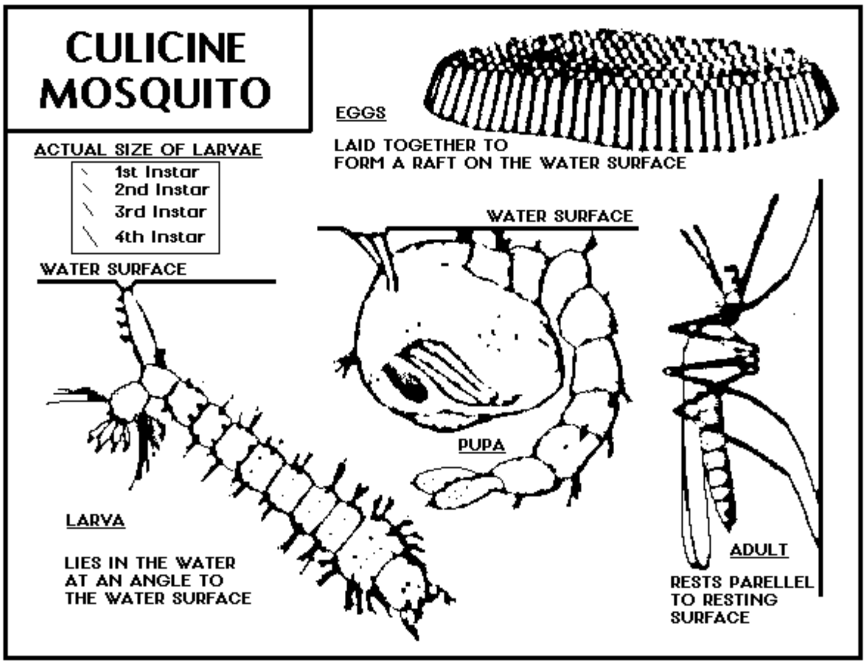

Fig. 9 - Culicine Mosquito

Adult Anopheline mosquitoes are easily distinguishable from adult Culicine mosquitoes because they do not sit parallel to their resting surface. They are also usually slimmer in build and the head is in line with the rest of the body: the head of Culicines is normally held at an angle to the rest of the body.

It is not possible to distinguish between the different species of the *Anopheles punctulatus group* without specialised laboratory techniques. For confirmation of actual species within a complex, it is necessary to do detailed investigations.

However, for practical purposes, if you find *Anopheles* mosquitoes where malaria transmission occurs, then it doesn't really matter which species you are dealing with as they all need to be destroyed. Also, in normal practice, such as environmental control, it is good practice to destroy all mosquito larvae, Anopheline or Culicine, because, without such effort, local communities will not appreciate any control activities carried out. When a person is being bitten at night by mosquitoes, it is impossible to tell in the dark whether it is a good mosquito or a bad mosquito, though, culicine mosquitoes are normally stated as being more noisy flyers than anophelines.

It should be noted that a female vector mosquito usually bites a person every third day so that throughout its life time it is unlikely to bite more than ten people. For it to transmit malaria it must usually bite a person with malaria very early on in its life. At most, a single infective mosquito is unlikely to infect more than six or seven people throughout its life. Conversely, a single infected person can infect several hundreds of mosquitoes. This being the case, it is just as important for a person infected with malaria to protect themselves from mosquito bites as a person without malaria. The person already infected with malaria can infect many more people.

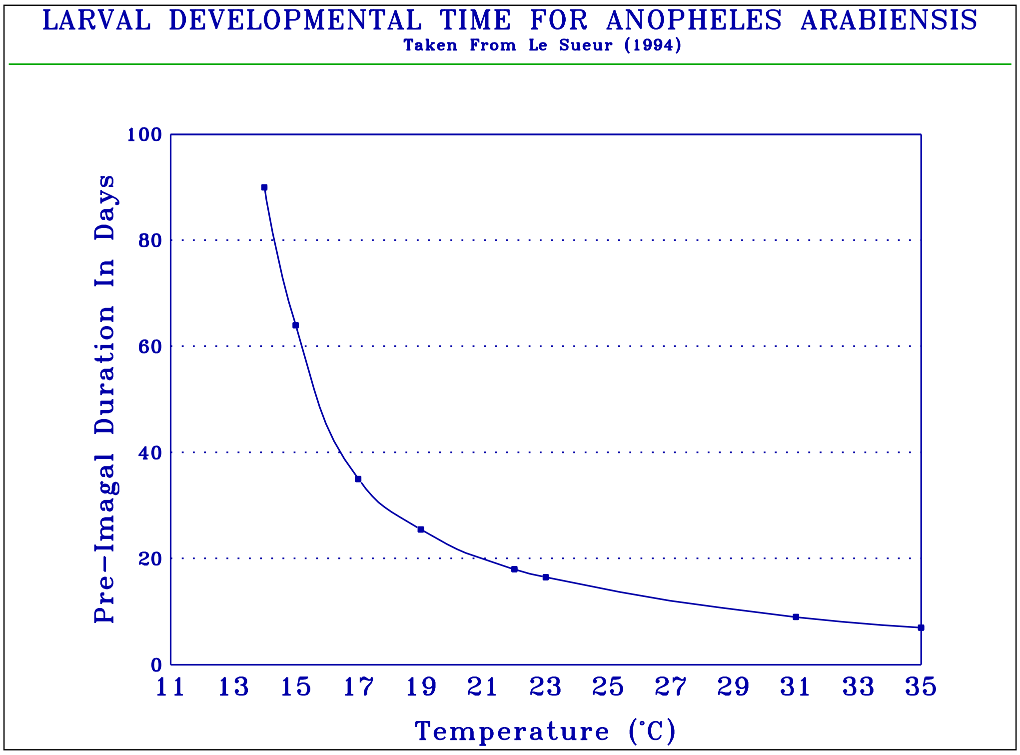

Fig. 10 – *An. arabiensis* larval developmental times

Factors affecting the distribution of malaria vectors

The major factors affecting mosquito breeding and hence malaria transmission are temperature and rainfall. In Papua New Guinea, rainfall is very variable from one area to another, but by referring to Fig. 3, it can be seen that most areas in the country have some rainfall throughout the year with the driest period being between to July and September. Ambient temperatures are also suitable in most parts of the country throughout the year, except in the mountains of the highland areas. The only places where temperatures are never likely to be suitable for malaria transmission are in the high mountains above 2,200 m which are shown in the map of Fig.5 as white or grey.

Temperature

Temperature affects not only the growth of the parasite in the mosquitoes, but also the speed in which mosquitoes can grow. Fig.8 shows that the larval developmental time for the African vector mosquito *Anopheles arabiensis* larvae. The development time of local malaria vector mosquitoes in PNG would be similar to the times illustrated in fig. 8 and the graph shows that development may take as little as seven days in optimum conditions at mean daily temperatures of 35°C to sixty days at mean daily temperatures of 15°C. In Papua New Guinea, for practical purposes, it should always be assumed that mosquito larvae for most of the year are taking as little as seven days to develop from egg to adult.

Sometimes at lower temperatures, the development of larvae is so slow that it is possible to find huge populations of larvae breeding with no adults to be found anywhere because they have all died off. At low temperatures, not only does development take a long time, the survival of the larvae also becomes more difficult as there is a much greater period during which the larvae are exposed to natural hazards such as predators. Due to these factors, mosquito breeding in high mountains of the highlands is likely to be very slow or non-existent. Similarly, high temperatures (above 35°C) experienced during heat waves inhibit mosquito breeding.

The importance of these figures is that it helps us understand the epidemiology of malaria and thus allows us to destroy malaria in the most efficient way. Since we are aware that mosquitoes may breed in seven days, it means that if we are carrying out a larval control programme, all mosquito breeding sites need to be checked weekly.

Altitude

PNG is located close the equator and temperature mainly depends on altitude. In most parts of the lowlands there is perennial transmission, with only limited seasonality. Transmission is less intense on some of the islands such Autonomous Region Bougainville and in the drier areas along the south coast (including Port Moresby). These south coast areas are the only ones that exhibit marked seasonality, with transmission virtually stopping during the dry season. As altitude increases, transmission decreases significantly becoming unstable at an altitude of 1200 – 1600 metres. Intense transmission is then limited to local epidemics, which generally coincide with the end of the rains and start of the dry season (April – July) and can be associated with a high incidence of relatively severe morbidity. Above 1600 metres temperatures generally tend to be low for local malaria transmission. However, this may be changing with global warming thought to be a key factor involved in the recent alarming increases in transmission at higher altitudes.

An estimated 94% of PNG's 8 million population live in areas that are classified as endemic for malaria. About 56% live at altitude below 1200 metres where malaria transmission is stable, 12% live at altitudes between 1200 and 1600 metres where malaria transmission is unstable (epidemic prone) and a further 23% live at altitudes between 1600 and 2000 metres where no significant malaria transmission occurs. However, the situation is complicated by the fact that many people with houses at relatively high altitude have gardens at lower altitudes where they sometimes (seasonally) sleep to protect their crops. Thus, without detailed knowledge of an area, it is difficult to identify which villages have no risk of malaria.

Substantial heterogeneities in malaria epidemiology are found not only along broad environmental gradients, but also between villages only a few kilometres apart and between different clusters of houses within the same villages. Some of these variation is accounted for by drug and mosquito net (LLIN) usage patterns and nutritional differences can also play a role. Local heterogeneity in the spectrum of vectors present and their densities is also thought to be important. In the highlands, one village can have endemic malaria, while a neighbouring village is malaria free, and epidemics tend to be localised rather than affecting large areas.

Rainfall

As stated Papua New Guinea has rainfall throughout the year with the driest period between July and September in most parts of the country. This means that opportunities for mosquito breeding occur throughout the year in most parts of the country.

Since vector mosquitoes such as *Anopheles farauti breed* in small puddles, they are very susceptible to rainfall. If rains are too little, puddles dry up before one week, and where rainfall is very heavy and frequent, puddles get washed away. The ideal balance is infrequent but heavy showers which contribute to maximising mosquito breeding. Accordingly, the intensity of malaria transmission can vary considerably from one year to the next depending not only on the amount of rainfall, but also on the pattern of rainfall.

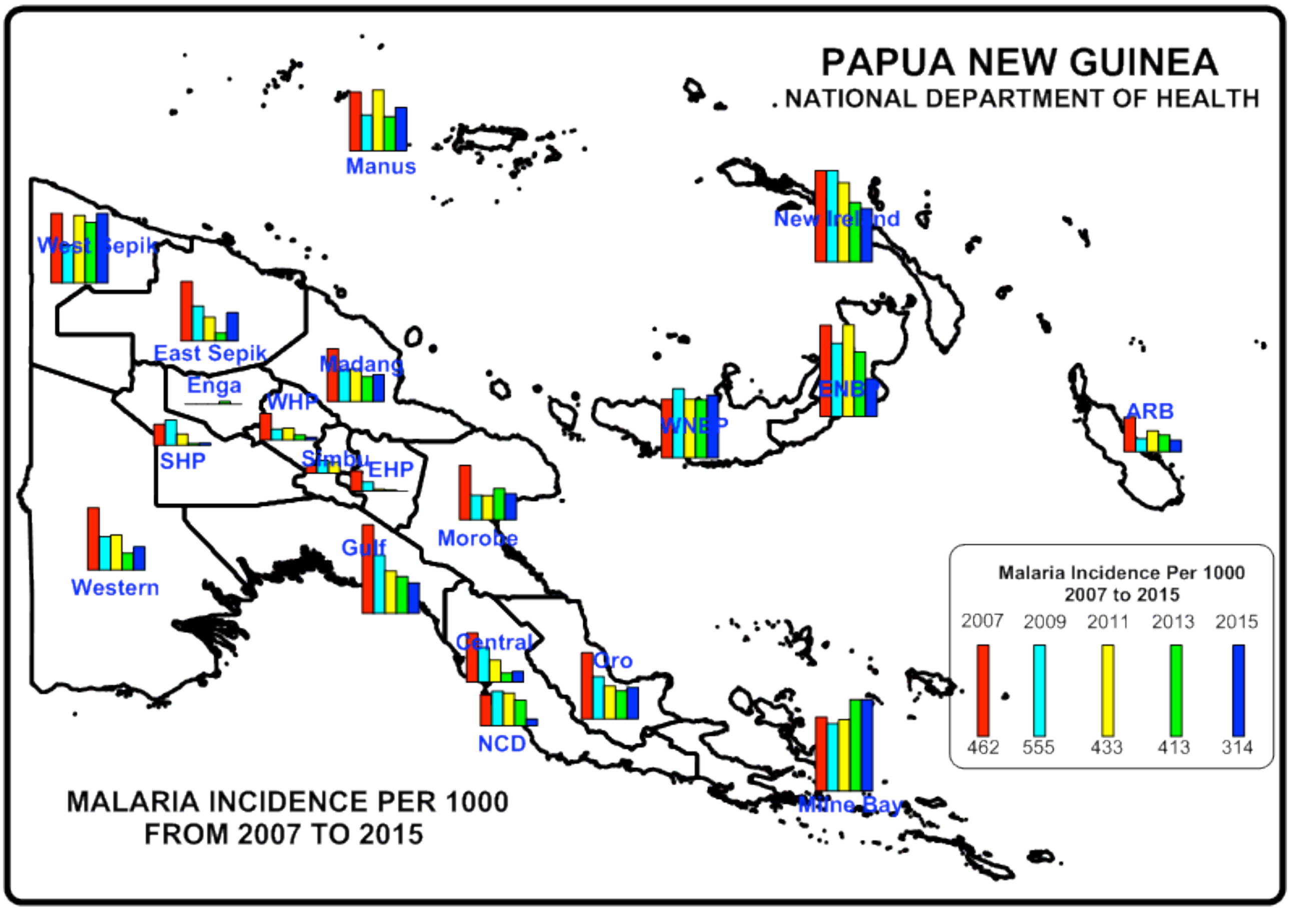

Fig. 11 – Malaria Incidence IN PNG From 2007 To 2015

Malaria may also be affected by floods. During a flood, malaria is not likely to be a problem, but after the floods recede, many puddles of water will exist where malaria mosquitoes can breed.

The combination of both rainfall and temperature give the overall pattern of malaria in PNG which is shown in Fig.9 for the period 2005 – 2011. Fig.9 also shows the trends of malaria in the last few years which will be discussed later. The graph shows that malaria can be as little as 36 per thousand people in places such as Enga and as much as 628 malaria cases per thousand people in West New Britain.

Malaria transmission dynamics are affected by many other factors in addition to rainfall and temperature. Even with similar rainfall and temperatures patterns, malaria incidence may be very high in one village and practically nonexistent in another adjoining village close by. Besides temperature and rainfall, there are many other factors that control malaria transmission in any given locality and these are discussed below.

Other factors affecting malaria transmission

Surface Soil Types

Where sandy soil surfaces exist, water soon drains away discouraging mosquito breeding sites. Clay soils on the other hand will hold water and mosquito breeding sites may remain for long periods of time.

Topography

Flat areas are more likely to have malaria problems than hilly areas as flat areas retain water, and hilly areas allow runoff. Much of the coast of Papua New Guinea is flat and considerably swampy. Swamps afford numerous habitats for mosquito breeding. Mountainous areas however allow quick runoff of water which means that much water can drain away.

Man-mosquito contact

For malaria transmission to take place, people must come into contact with infected mosquitoes and vice versa. Some relevant facts are as follows:

1) The malaria vector mosquitoes of Papua New Guinea only feed during darkness. Mosquitoes that bite during the daytime are not normally anopheles. Any activity that is carried out after darkness, particularly in the vicinity of breeding sites increases the risk of transmission. High risk activities include fetching water and bathing, as in both these cases, people are travelling to where the water is and the mosquitoes are breeding. In such circumstances, mosquitoes never need to find hosts, as the hosts come to them instead. One new common factor in PNG is people sitting outside watching videos often to late hours of the night. This is ideal for malaria carrying mosquitoes biting and transmitting malaria.

2) Some mosquito species are often reported as flying long distances, e.g. several kilometres. While this may be the case, it is usually found that most mosquitoes biting within a household are breeding close by, and probably rarely more than half a kilometre from their breeding sites. Thus, the further away people's dwellings are from potential breeding sites of mosquitoes the better. This applies to both single houses and where a city is situated. All places in which people live should be places as far away as possible from places such as swamps or other areas where water is situated, particularly standing water or very slow moving streams.

3) Without water, malaria vector mosquitoes cannot survive and breed. Without mosquitoes malaria cannot be transmitted.

Assessing Malaria Transmission Potential

Using some of the information contained in this manual it is possible to create models of various areas and calculate whether malaria transmission is possible within a given area and how much of a problem it might become. By looking at soil types, topography, rainfall patterns, temperature and people's behaviour in an area in relationship to mosquitoes, is it possible to understand the biggest problems within an area, and once understanding this, it is then possible to design interventions which best tackle the problem identified.

There are also many other factors that can be looked at when investigating malaria transmission within an area. Such factors include:

Changes in environmental conditions

One of the major factors that affect malaria transmission is the environment. In some places where previously malaria may have been a small problem, due to changes in the environment or Global Warming, the malaria problem can get much worse. Often these problems are related to water projects that increase mosquito breeding sites, but other changes in environment can be equally problematic such as cutting down trees in forests and agricultural project such as paddy cultivation, hydropower projects and irrigation projects etc.

Water is usually the key to malaria transmission, and water management, often the key to controlling malaria. Confounding the problems with water projects or environmental changes is human activity. Both need to be considered when looking at ways to control malaria in any given area. It should also be noted that mosquito larvae are also very susceptible to predators. Therefore, mosquito larvae tend to live and survive in places which are protected from predators. Potentially, any body of water may breed mosquitoes and the only way to confirm this is by scooping up water and looking for the larvae.

Types of Water Bodies

Swamps

Swamps are mentioned first as swamps are very common in Papua New Guinea, particularly along the coast. Swamps create thousands potential "niches" for mosquito breeding. This situation is compounded as *A. farauti* can live in brackish (salty) water which allows them to survive in the inner parts of mangrove swamps where the water is not too salty i.e. where fresh water has mixed with sea water.

Dams

While it is unusual for mosquitoes to breed in dams due to being devoured by a large number of predators including fish, a number of situations can arise where dams become problems.

When reservoirs created by dams first fill, they often fill rapidly creating a large temporary expanse of water without predators. In this situation mosquitoes might breed in increasing numbers due to the new availability of breeding sites. Before a new dam is to be constructed in the tropics, its possible impact on malaria and the environment should be considered.

Even after reservoirs created by dams become full, there are often numerous small places where mosquitoes might breed: at the edges where animals leave footprints which fill with water leaving a small separated puddle of water: in weeds where these become very dense excluding fish and other predators from entering and in the case of earth dams where seepage occurs through the dam wall often forming marshy ground below the dam wall.

Rivers

Rivers can contribute to increased mosquito breeding when the water level within them rises and also as they dry up during dry periods. When water levels in rivers fall, it tends to leave many water puddles at the edges. If these pools remain for over a week before the river rises again, many of these puddles could become successful mosquito breeding sites. This could be a particularly problem with *An. farauti* in Papua New Guinea along the coast where rivers rise and fall with the tide, particularly spring tides where water levels rise very high. As already mentioned *An. farauti* can breed in brackish water, so when spring tides occur and the sea level starts to retreat, numerous small pools of water may be left.

The impact of rivers is particularly noticeable in countries with dry periods. In such countries, it is common to find more malaria among populations living in close proximity to the river than among populations that live away from the river.

Irrigation schemes

Irrigation schemes should not cause any difficulty normally, but irrigation systems in open channels (especially earthen channels) may become mosquito breeding sites if not properly maintained. Additionally water pooling along the channels for several days at a time could contribute to vector breeding.

Temporary pools

Temporary pools can form nearly anywhere, especially where soils are clay and the terrain is flat. However, local changes in environment can produce temporary pools in very dangerous places.

Human activity

Any activity that occurs around water at night in malarial areas must be considered potentially dangerous in terms of malaria transmission. Such activities bring people into contact with vector mosquitoes when they are most active. Fetching water and bathing have already been mentioned as high risk activities. Other activities may include:

Brick making

Brick making is usually done with close access to water, but worse still, this activity increase breeding sites because it involves the digging of holes or borrow pits as they known in the case of brick building. Borrow pits are one of the classic breeding sites of many *Anopheles* mosquitoes.

Guarding fields at night

In many places people will sleep out at night to protect their crops from wild animals or thieves. This problem is particularly bad if it is carried out in a swamp area or forest fringe area where mosquitoes are numerous.

Fishing and hunting

Fishing may be carried out at night for a variety of reasons, sometimes because fishing may be illegal in some places. If the fishing is carried out near the side of a river or lake, then contact with vector mosquitoes is likely to occur.

Hunting similarly can be a problem at night depending on how the hunting is carried out. If the hunters are in the forest away from water then there is no problem, but if they are stalking their prey at watering points, these same watering points are likely to be sites of intense mosquito breeding.

Immunity

Immunity refers to the body's ability to fight an infectious agent before a person gets sick or to mitigate the consequences of the infection. With many diseases full immunity or protection is acquired after one exposure to the disease (e.g. measles). This is not the case with malaria.

Sero-epidemiological studies indicate that immunity to malaria is slow to develop, taking several years in sub-Saharan Africa despite repeated bites from infected mosquitoes. Young children appear to have insufficient immunity to infection and to mild and severe disease. Children between the ages of 5 and 10 develop an immunity to severe disease but still suffer from mild disease, and it is not until adolescence that immunity to disease is established though still may suffer from mild attacks of malaria. Immunity to infection is never acquired, and adults living in malaria endemic areas, although rarely sick from malaria, often carry the parasite albeit at lower levels than children (Pierce J, 2009).

Immunity to malaria is not life long. Even should a person become fully immune to malaria, he must remain living in a malarial area to maintain this immunity. If a person with immunity to malaria then lives in a non-malarial area for a long time (up to 6 months and above) they are likely to lose their immunity! This is particularly important for Papua New Guineans who have left the country and gone to live in places like Australia, America or Europe. Loss of immunity may also be a problem while malaria continues to go down in PNG as people are no longer re-infected by malaria and their immunity is not maintained.

Immunity can be compromised. The immune system which protects people from malaria can also get weak if the body is not very strong or has immune deficient diseases such as HIV/AIDS. Whenever a person is made less strong, such as having malnutrition, or perhaps is suffering from another disease such as flu, the immune system is not so strong, and consequently, they may suffer from a malaria attack which is worse than normal.

During pregnancy, women are much more prone to malaria than at other times which can lead a normal episode of malaria becoming much worse, or becoming complicated. This situation is more likely during the first pregnancy.

Drug resistance

Drug resistance in malaria refers to the ability of a parasite strain to survive and/or multiply despite the administration and absorption of a drug given in doses equal to or higher than those usually recommended but within tolerance of the subject" (WHO, 1973). This implies that the drug must gain access to the parasite or the infected red blood cell for the duration of the time necessary for its normal action (WHO, 1986).

Due to high levels of treatment failure and resistance reported to chloroquine in Papua New Guinea, the National Department of Health changed the first line treatment of uncomplicated falciparum and vivax malaria to Artemether + Lumefantrine (AL), an Artemisinin Combination Therapy (ACT) in 2009. Artemether-lumefantrine (AL) is the first-line ACT on the current national malaria treatment guideline. AL was initially packed specially for the NDOH as Mala-1, but now the drug is available under different trade names such as Coartem® or Lumartem®.

The mechanism of resistance development is through either the "de-novo" selection of a genetic change or make up which confers resistance to the parasite, or through the preferential transmission of acquired resistant organisms (WHO). This latter method is referred to as the selective pressure. It means when a parasite population containing resistant organisms is exposed to a concentration of anti-malarial drug sufficient to kill the susceptible, but *not* the resistant parasites, these will be selected and transmitted preferentially.

The use of oral artemisinin monotherapy may result in selection pressure causing the emergence of resistance to artemisinin and its derivatives. It is therefore important that only nationally recommended combination therapies are used and all oral monotherapies are stopped altogether. If resistance happens to develop and establish in PNG, this may result in treatment failures and possibly high malaria fatalities. It is important to note that resistance to Artemether has been observed on the Thailand Cambodian border. It is very important that it should not reach PNG.

It is important to stress though that drug resistance does not mean treatment failure. Drug resistance is one reason for treatment failure. Increasing treatment failure rates in a facility may be strongly suggestive of a developing drug resistance. Therefore, it is important that treatment failures be monitored and reported promptly to health authorities.

ACT should be taken for uncomplicated infections only following laboratory confirmation of malaria infection. An exception to this may be made if the condition of the patient is strongly suggestive of malaria and access to laboratory facilities will not be available for more than two hours. In such situations where diagnosis has been confirmed and a complete course of Mala-1 (AL) has been taken for three days, if the symptoms of the disease do not go away or return within a few days, it is necessary to return to consult with a health worker as this may be indicative of treatment failure. Such suspicion of treatment failure should be confirmed by microscopy and the health worker should make a thorough investigation to ascertain if the patient has taken the complete course of treatment as prescribed and the patient has been able to retain the treatment. Such an investigation will help determine if the situation is due to resistance or due to other circumstances which may be responsible for the non clearance or reappearance of signs and symptoms.

In deciding whether it is necessary to use alternative second line treatment it should be established if;

1) The patient returns within 14 days of treatment.
2) The patient concerned has actually taken a full course of drugs. It is still fairly common for people to take only an initial couple of doses from the course of treatment and then stop as they feel better.
3) There are other factors that might have caused the anti-malaria drugs to fail such as vomiting or internal problems which might stop the drug being absorbed properly.
4) The case being dealt with may not be malaria at all if not confirmed with a blood slide.
5) Having other drug treatment failure cases being reported in the area.

The most important thing about drug resistance is to educate health care workers and patients that should patients not get better within a few days of treatment they should be instructed to return to the health institution immediately. Health care workers should be trained on how to manage such patients.

Malaria surveillance

Health information regarding the number of malaria cases detected, their treatment outcomes is extremely important. Without such data, it is difficult to plan disease control activities and make the best use of available resources. In Papua New Guinea where there are limited resources, it is important to spend those resources in the places they are most needed, and without health information, such priorities cannot be made.

Clinical malaria morbidity and mortality data is collected monthly from every health centre in the country and is collated nationally. Malaria data is also collected monthly at hospitals, and laboratories also keep data of laboratory examinations which are also collected to national level. Other data collection systems also exist in some localities which help to give more information.

A Health Information System (HIS) is very important in the identification of malaria outbreaks. It is very important that all malaria data at each health facility in the country is collected. A copy of the data should be kept at the facility level after a copy of the data is sent to the provincial level or higher as appropriate.

As malaria can be a fatal disease, by plotting or graphing malaria data each month and each year, local trends of malaria can be observed. By doing this, one should be able to spot trends and often have warning of when malaria is becoming a bigger problem than usual.

From a clinical point of view malaria situation in an area can be determined through morbidity related data (Incidence Rates, Prevalence Rates, Blood Slide Positivity Rates and Out-Patient and In-Patient figures from health centres) and mortality related data (number of deaths due to malaria, number of deaths in children under 5 years due to malaria).

The following sections demonstrate the strengths and weaknesses of each type of data and how it can be used to increase the knowledge about malaria in any given area, and how this data can be compared with other areas.

Malaria Outpatient Figures

Clinical malaria outpatient figures are usually collected in PNG and by themselves are not particularly useful without laboratory confirmation unless collected over many years. As malaria is often confused with other diseases such as flu, clinical malaria figures are often more a measurement of fever in the community than anything else. However, in certain areas and at certain times of the year, malaria accounts for most of the fevers being presented at health centres, so by measuring fever, you are measuring the trends of malaria.

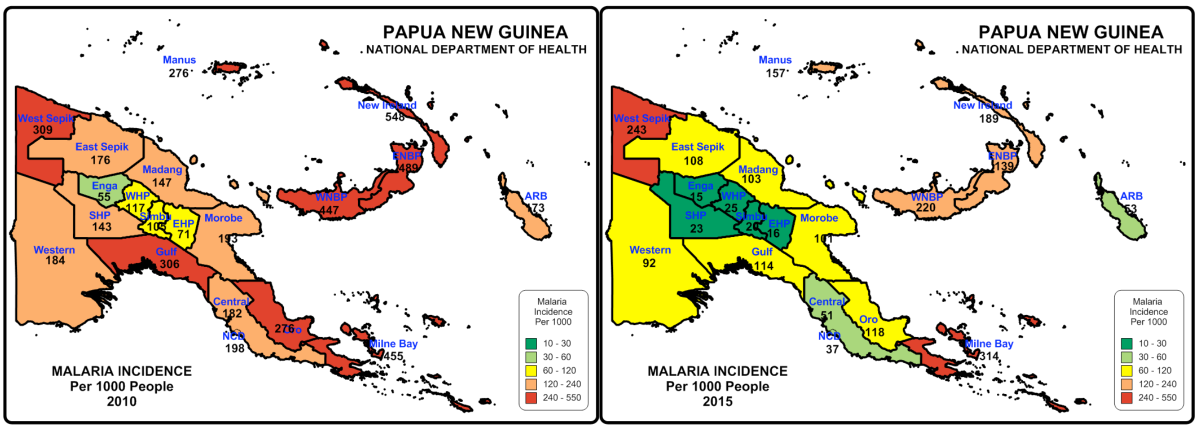

Fig. 12 – Malaria incidence by Province 2010 and 2015.

Even when malaria is confirmed or otherwise, malaria out-patient cases will never really represent what is happening in a community as malaria cases are also dependent on the percentage of people in a community who attend health facilities. However, people who normally attend a health facility are likely to remain fairly constant from one year to the next, so any increases or decreases in clinical malaria is likely to represent increases or decreases in malaria transmission in an area. Thus out-patient malaria cases will be representative of the trend in malaria transmission in an area.

Therefore, it is very important to record and plot clinical malaria cases on at least a monthly basis so that a base line can be observed. If malaria then increases dramatically above this baseline in a particular month then further investigation is needed. This is particularly important in countries that are prone to malaria epidemics, such as Papua New Guinea. Documenting malaria cases can become even more useful where a laboratory exists. If a blood slide positivity rate is calculated, then monthly cases of *P. falciparum* can be estimated more accurately.

The malaria incidence recorded in all the provinces for 2010 and 2013 are shown in Fig. 9. From these maps, it is therefore possible to measure trends of malaria in the country. Looking at these two maps together, it is possible to conclude that malaria in all provinces decreased from 2010 to 2013 with the biggest decreases occurring in the East Sepik, Oro and Southern Highlands. To see a trend over a longer period, one can use a graph or map as shown in Fig.8 where the incidence of several years has been plotted for each province. Both Fig. 8 and Fig. 9 show a gradual decrease of malaria over the last five years which are believed primarily to be a result of the introduction of Long Lasting Insecticidal Nets (LLINs) throughout the country.

In-patient figures and deaths

In-patient figures do not measure the amount of malaria in a community, rather the severity of malaria in a community. In Papua New Guinea, malaria cases are not usually hospitalised unless they suffer from severe malaria. As there are few referral hospitals in Papua New Guinea, severe cases seen in a hospital can provide an understanding regarding disease transmission in the area and access to treatment.

Deaths due to malaria are difficult to measure as malaria parasites may be found in people who die from other causes where the immediate cause of death is not due to malaria. However, wherever possible, it is necessary to determine the number of deaths due to malaria. In many situations where adequate diagnosis is not available a lot of deaths are attributed to malaria, especially if the deceased had fever in the period preceding death.

It is important where possible to quantify the total number of deaths in a community, particularly amongst the under fives where malaria is such a big problem. As malaria is such a big killer, if total mortality rates in Under Fives are observed, and there is a change in the number of children dying in a particular time, it is very possible that malaria could be one of the major contributing factors.

Incidence rate

Incident Rate is the measure of the number of new infections of a disease measured over a specific period of time, usually annually. The most common method is the number of new cases per thousand population over a period of a year. However, equally, Incidence Rates can be measured over a week, a month, or whatever seems suitable to the disease and what is happening on the ground.

Clinical incident rates normally assume that every one who gets sick goes to a health centre. One way of deriving more accurate incidence figures for malaria is by estimating the catchment population that is known to use a particular health center. This may be several villages which are usually located near to a health center and then by recording the number of new cases from each of these villages in a year it is possible to estimate a reasonably accurate Incidence Rate.

Incidence rate is a much better estimate of malaria in a community than the total number of cases reported. This is because the Incidence Rate takes in to account the change in population size in a community.

Incidence rates for a given area by themselves are valueless unless they can be compared with incidence rates from other areas to get a comparative idea of what your calculated incidence rates really mean. For example, 30 cases of malaria per thousand population per year may be a very high estimate for Europe but not for Africa, where malaria cases are very high. This would be a very low figure for Africa or PNG. Therefore, one must always compare the incidence rates with other areas or over time in the same locality to get a measure of the severity of the disease in a community.

However, for routine monitoring and surveillance, accurate Incidence Rates are not normally calculated but information from health institutions are collected, so that the out patient department (OPD) figures (which substitute for Incidence Rates) can be compared from one year to the next. In this way, increases or decrease of malaria can be observed and monitored and the impact of interventions assessed.

In Papua New Guinea, malaria out-patient cases are collected monthly from all health centres and collated at district, provincial and central level. Dividing these out-patient figures by the population totals allows for estimating the clinical incidence rate. in the clinical incidence rate for Papua New Guinea at provincial level is depicted in Fig. 9 for the years 2010 and 2013.

The incidence rates may also be used to determine the malaria situation in respect of different age groups. In places where malaria is a very great burden and immunity is acquired quickly, incidence rates are higher in the under five age group than in other age groups. Where malaria is less and immunity is acquired more slowly, incidence rates in the five to fourteen age group are comparatively similar to the under fives. Where malaria is absent malaria incidence rates in all age groups remains the same. Unfortunately for Papua New Guinea, in the past, data was not collected by age and therefore age specific incidence rates could not be calculated. This is now changed, and specific incidence rates by age group can now be calculated from data collected in the monthly National Health Information System.

Table Three shows data collected from some villages in Central and NCD Provinces. The village are arranged in order of incidence with one village Adio (near Kabuna) having the highest recorded incidence of malaria in Central and NCD.

More importantly, it can be seen in these villages of high incidence that the number of malaria cases being recorded in children as a percentage of the population, is much higher than in adults. In Adio also, it can be seen that the relative incidence in 5-9 Age Group is higher, so this means that the young children are generally protected better. Overall, as seen in Adio and other villages such as Inika, Dua No 1, Hereparu and Kivori Kui, children have higher incidence than adults which means that malaria is active in these areas and the adults are reaching some kind of immunity.

However, in villages such as Beriena and Forestry Brown River, incidence rates are similar in both children and adults. This signifies that malaria transmission is still happening in these areas but not to a degree whereby the adults are gaining immunity.

In other places, such as Kuriva, Apanaipi and Brown River malaria cases in adults are generally much higher than in children. This would generally signify that malaria is being imported into these areas rather than being transmitted within the area.

In general, the higher the incidence, the higher the level of acquired immunity. When incidence falls low, immunity tends to disappear.

Analysing data in this way also gives clues into the transmission of an area. June Valley and ATS have been included in this table. Both have very low malaria incidence rates, but the fact that child rates of malaria are higher than adults, this suggests that some transmission of malaria is still occurring in these areas, albeit in very localised areas.

Prevalence rates

A prevalence rate is the amount of a disease in the population at a given moment in time. To determine such a rate, factors like population do not need to be known.

To determine prevalence rates a survey needs to be carried out. A survey may be an active survey or a passive survey. An active survey is a type of survey where someone goes out to look for disease cases and is the usual way of carrying out a prevalence survey. This is opposed to a passive survey, when disease cases are monitored as and they come into a health facility i.e. one passively sits waiting for data to arrive.

The type of survey actually carried out depends on what type of information you would like to receive. The types of information that you may wish to find out are;

- How much malaria is actually being transmitted within a locality? For this purpose, it is often better simply to sample only small children e.g. under nines, as children rarely move out of a locality. Adults on the other hand are mobile and may acquire the disease from outside the locality and lead you to believe that transmission is acquired locally, when in reality it was acquired elsewhere.

- How much immunity is present in the population? This can be indirectly assessed by determining the intensity of malaria amongst the different age groups. To do this you must measure the age structure of the population and sample different age groups accordingly.

To determine prevalence rates for malaria the following needs to be done.

- A population must be randomly selected and all persons within this group surveyed whether they are sick or not, which in the case of malaria, means taking a blood slide or doing a Rapid Diagnostic Test (RDT) for malaria.

Table Four
Analysis Of Incidence In Some Localities In Central And NCD In 2015

Village	Relative Incidence 0-4 (14%)	Relative Incidence 5-9 (14%)	Relative Incidence 10-15 (12%)	Relative Incidence Adults(60%)	Relative Incidence <15 (40%)	Overall Incidence (Per 1000)	Population
Adio	235	705	480	288	473	362	243
Inika	0	196	685	205	274	233	146
Bereina	35	114	331	146	152	148	2,013
Dua No. 1	45	180	210	94	142	113	318
Hereparu	0	118	275	69	124	91	242
Kuriva	26	56	101	91	59	78	3,301
Kivori Kui	36	179	125	50	113	75	798
Idoido	76	76	178	53	107	75	375
Forestry Stn. B/River	52	43	50	54	48	52	3,008
Inawi	58	42	58	41	52	45	1,720
Amo Amo	0	24	83	33	33	33	600
Kivori Poe	39	39	60	18	45	29	1,106
Waima	14	27	16	28	19	24	3,132
Inawaia	7	22	67	10	30	18	1,986
Apanaipi	16	0	19	19	11	16	885
Eboa	0	16	9	21	8	16	1,777
ATC (NCD)	14	11	4	5	10	7	4,024
Nine Mile Settlement	2	0	4	10	2	7	9,380
June Valley	11	4	4	3	6	4	4,000
8-Mile Settlement	3	2	0	1	2	1	15,054

- It is not necessary to take a lot of slides, 100 per area is recommended as a preliminary survey, particularly where prevalence results are expected to be high as in Papua New Guinea. Further slides could be taken if the results are ambiguous. However, if you wish to get an age structure for malaria, then it is best to allocate a number of slides for each age group as mentioned before.

- All people who are surveyed should be recorded by sex, age, address and any clinical symptoms of malaria.

- There are many ways of selecting people for a survey, each with their merits and disadvantages. For example

    - A village could be visited, and all people within each household found should be tested or have a blood slide taken whether they are sick or not. If only a certain number of subjects need to be tested or slides need to be taken, then keep testing or taking slides from all people in each age group in each house visited until an age group is complete. Then in successive houses, take only the age groups required.
    - In communities where school attendance is high a very quick and simple way of making a prevalence survey is to visit a school and sample a complete class of children from selected age groups. This often allows a wide area to be sampled at one time but, it must also be remembered that with such a survey, if children are sick with malaria, they may be absent from school which will lower the prevalence rate.

It is most important with prevalence data to record all the circumstances around which the survey was carried out, i.e. the date on which the survey was carried out, the exact locality, and the type of the survey that was carried out e.g. school survey, house by house etc.

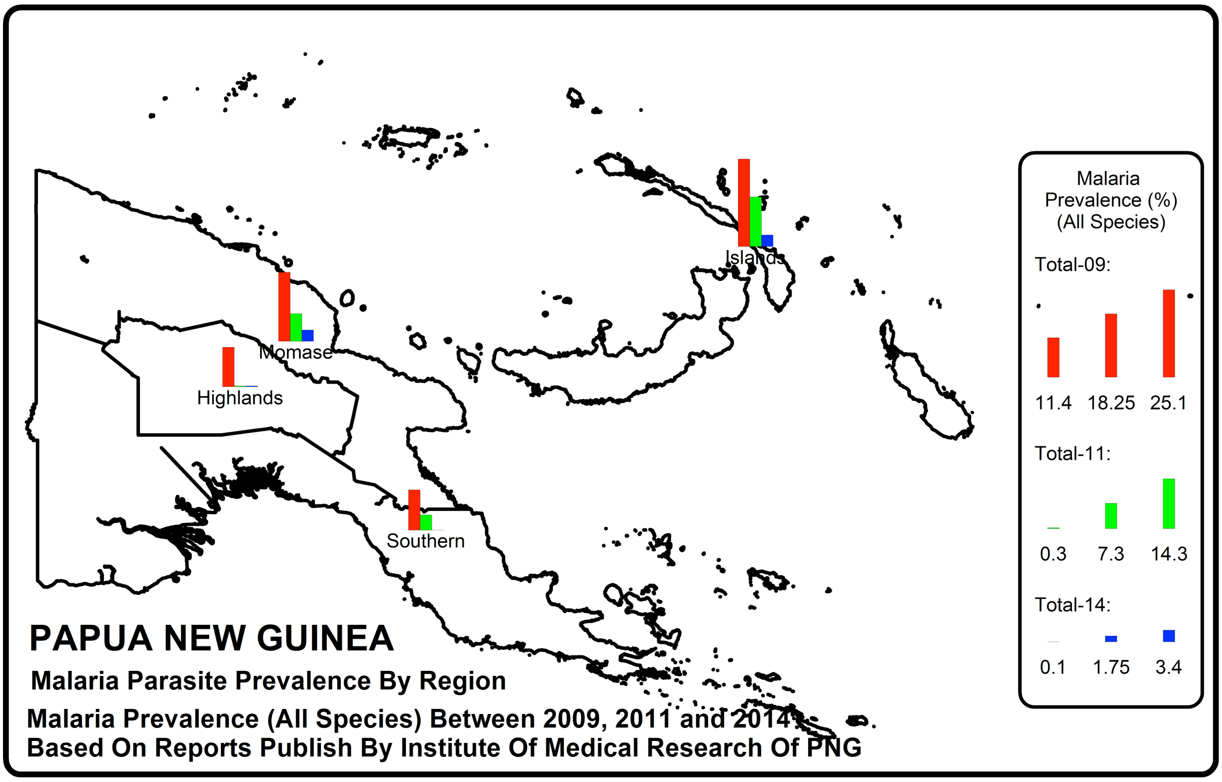

Fig. 13 – Map showing the prevalence of malaria in PNG as recorded by the PNG IMR in 2009, 2011 and 2014.

For prevalence rates to be useful for monitoring malaria, they need to be carried out regularly. For example, schools could be sampled once or twice a year at specific times of the year. By doing this, it is possible to monitor if malaria is going up or down.

Interpreting prevalence rates

If one looks at a prevalence rate one must take into account the time of year and the parasite rates in different age groups. The following points can be made

1) If malaria parasites are found in children it is usually indicative of malaria transmission being present at the time or prior to the survey. As noted earlier, very young children can retain malaria infections for a long time if untreated and this being the case, high rates of malaria in children represent malaria in an area, but not necessarily at the time of the survey.
2) If parasites are found predominantly in adults it is usually indicative that transmission is not occurring in the area of the survey but rather that the cases are imported from elsewhere.
3) If prevalence rates are higher in children than in adults, this usually indicates that malaria is endemic to the area - the lower rates in adults indicates some degree of immunity to malaria due to continual exposure.
4) If parasite rates are equal in all age groups, this indicates a fully susceptible population and often indicates that malaria has recently been imported into the area. This is the situation usually found where a malaria outbreak occurs.
5) Areas where *P. falciparum* predominates as compared to other species are the areas which should get highest priority in terms of malaria control, particularly areas where prevalence rates in adults are similar to children. The higher the prevalence rate in children the higher the priority for malaria control should be as *P. falciparum* can be fatal.

It is not necessary to take prevalence rates in all parts of Papua New Guinea, but wherever possible, samples should be taken from all representative types of areas i.e. at different altitudes and particularly differing agricultural practices e.g. rice growing areas as well as non rice growing areas.

When interpreting prevalence rates one must also be aware of the focal nature of malaria. One village may have a higher prevalence of malaria, while another only a short distance away may have a significantly lower rate of malaria.

Fig. 13 shows the prevalence rates recorded by IMR in 2009 and 2011 by region. This shows that the overall prevalence rates for *P. falciparum* was 7.2% to 10.5% and *P.vivax* 2.5% to 11.2% depending on the region. However, by 2011, P. falciparum has reduced to 0.3% to 7.4% and P. vivax 0% to 4.9%. See also Table One.
Taking Fig. 10 and 11 together, it can be seen that the malaria epidemiology for PNG is not simple. Malaria prevalence in the Highlands is the only place where P. falciparum prevalence is higher in children than adults which is suggestive of a high transmission area. In the Islands Region and Momase prevalence in the 5-14 age

group is higher than in children under fives which suggests that immunity in PNG takes a long time and is not achieved before the age of five.

Slide Positivity Rate

This is often the most commonly quoted malaria figure from a health centre and often the least useful, particularly if it is based on blood slides alone. It is usually quoted as a percentage, i.e. the total number of positive slides divided by the total number of slides examined and then multiplied by a hundred. It is basically a measure of the number of actual malaria cases over what you might think is malaria.

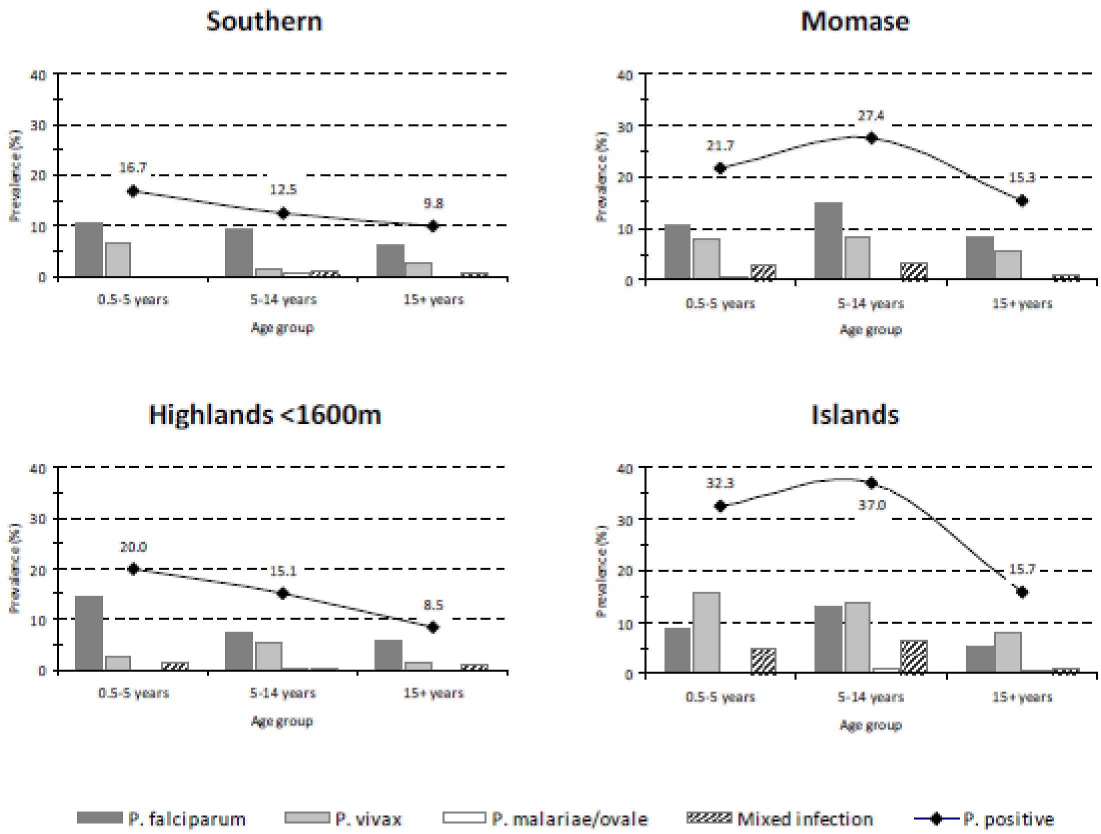

Figure 6-1: Parasitaemia prevalence by age group and region

Fig. 14 – Graphs taken from IMR Report From 2010

The Slide Positivity Rate is an indication of the degree of suspicion clinicians have in respect of malaria when dealing with febrile patients. Malaria is a difficult disease to diagnose, particularly *P. falciparum*, so the Slide Positivity Rate should not be used as a tool to measure the performance of any given clinician, though some clinicians are better at diagnosing malaria than others.

The Slide Positivity Rate can be a simple indicator of the degree of malaria in a population at any given time, but any conclusions should consider other factors which could affect the SPR.

At a local level, SPR can help analyse malaria figures at a health centre. Fig. 12 shows the clinical cases and the slide positivity rate at the Malaria Centre in Badili in Port Moresby. In the first graph, clinical malaria cases each month look completely random. However, when one looks at the slide positivity rate, a clear seasonal picture of malaria emerges malaria cases peek from January to July of each year suggesting that malaria in Port Moresby is linked to the rainy season.

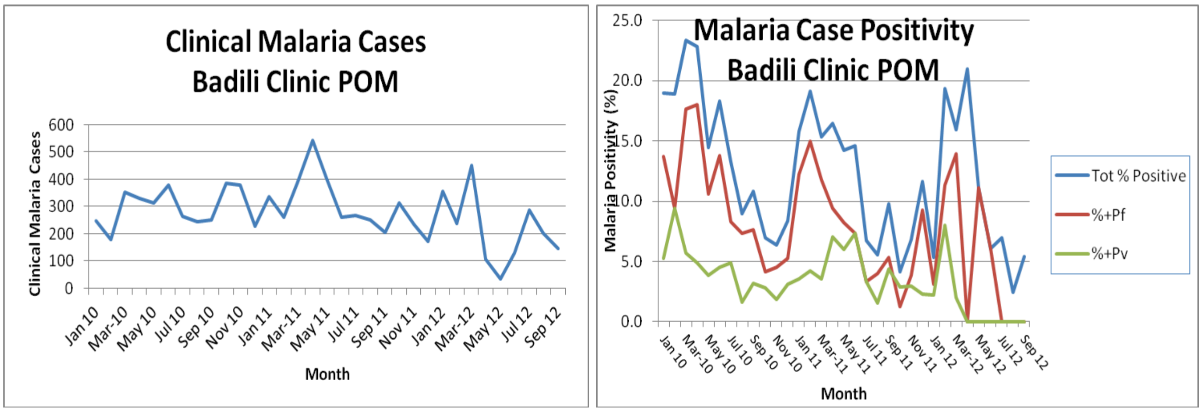

Fig. 15 – Clinical Malaria and Malaria Positivity Rates At Badili Malaria Centre

If laboratory services are available to take slides of all suspected malaria cases, then the data collected can be used to help calculate a real malaria incidence rate through any given area.

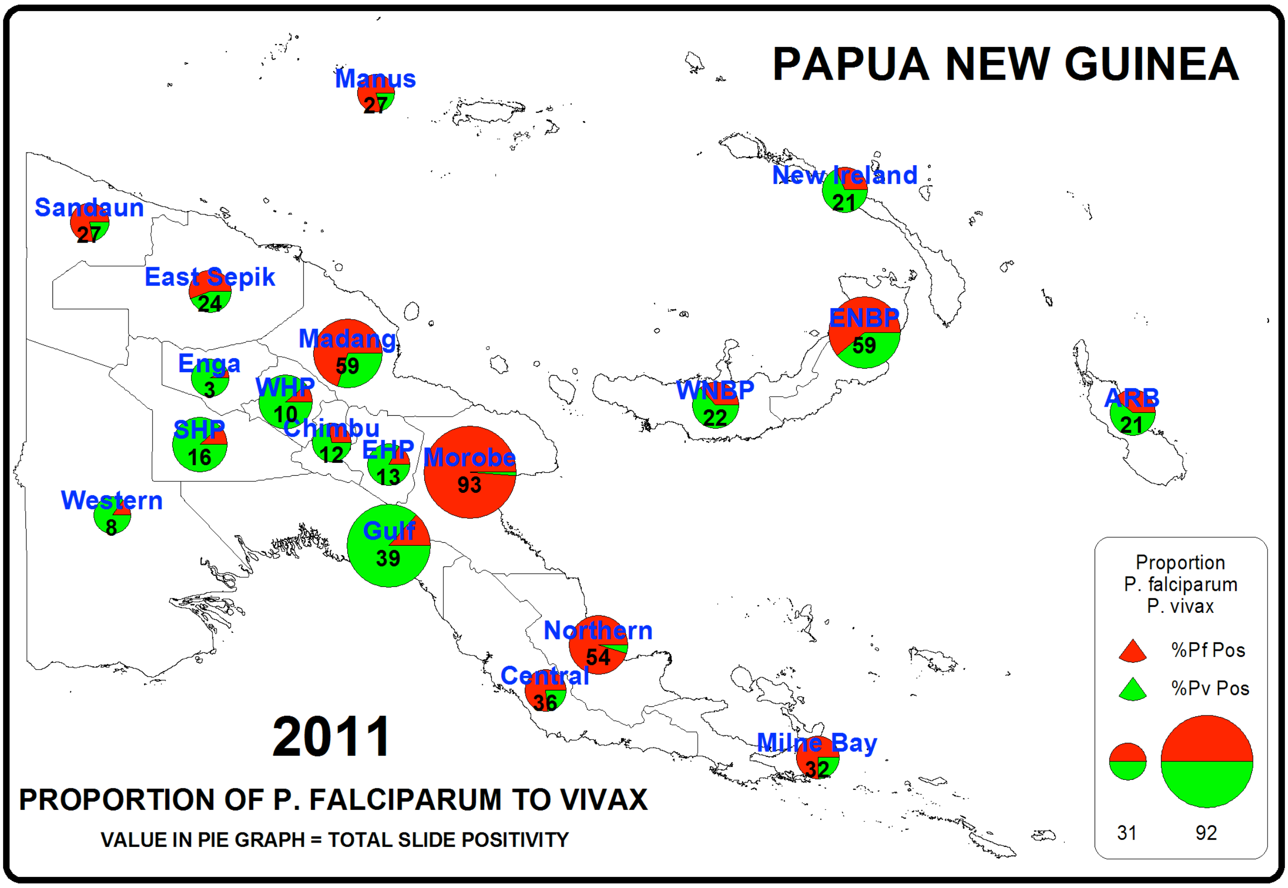

Fig.16 – Malaria Slide Positivity Rates in Provinces of PNG in 2011

Data collected from the country can be presented as in Fig. 16. This map shows the overall positivity rate for each province (black numbering under the name of each province) together with the proportion of *P. falciparum* to *P. vivax* in each province.

Fig. 16 clearly shows the differences between malaria in the different provinces. The highlands have low Slide Positivity Rates and high levels of *P. vivax* as compared with *P. falciparum.* Conversely, the coastal areas and the New Guinea Islands, particularly New Britain and Manus, have relatively high Slide Positivity Rates and high proportions of *P. falciparum.*

However, all data needs to be looked at with a little bit of caution. It can be seen from this Fig.13 that Morobe is recording 93% positivity and practically no *P. vivax*. This is unlikely to be true as it is almost impossible to get such high positivity rates even in the middle of a malaria outbreak. Therefore, analysis of Morobe Province should take all other available data into consideration before getting a clear picture of malaria on the ground.

It should also be noted that it is now compulsory that health centres test all suspected malaria cases with a Rapid Diagnostic Test (RDT). For lots of reasons, RDTs are generally more accurate that blood slides and whenever malaria is suspected, all patients should request an RDT test which can give a result within 15 minutes.

Malaria as a percentage of other diseases

One methodology of measuring the burden of malaria is by comparing the number of cases treated for malaria with overall numbers of people treated for all other diseases. Fig. 17 shows the number of people going to a health facility compared with the provincial population, and of those cases, the percentage which are being reported as malaria.

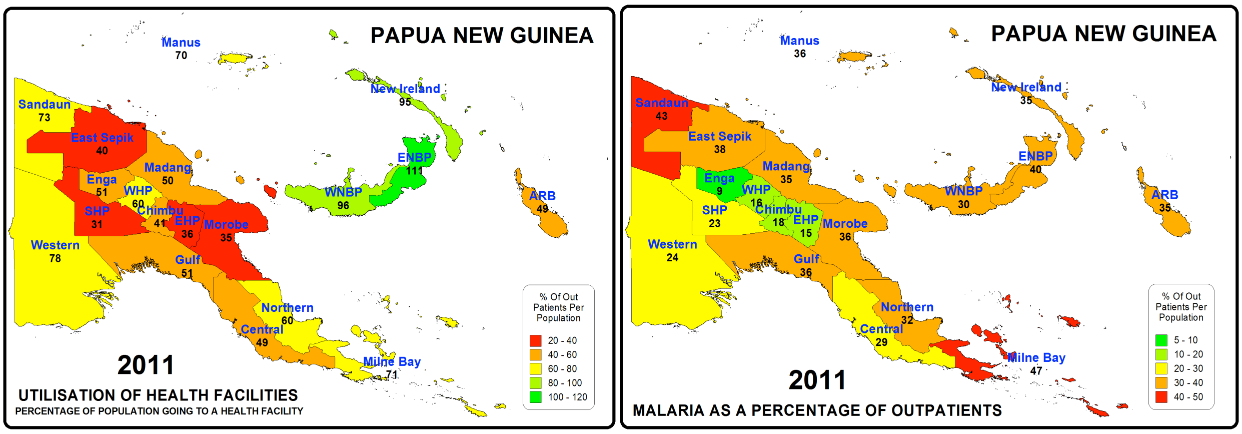

Fig. 17 – Utilisation Of Health Centres and Malaria As A Percentage Of Out Patients in 2011

It is clear from Fig. 14, that in the New Guinea Islands, utilisation of the health facilities is very high compared with other places in the country but they also report the highest number of cases of malaria as a percentage of the population. Conversely, a number of the highlands provinces have low utilisation of health centres and low reporting of malaria. This suggests however, that malaria cases are probably under reported in the highlands areas.

In summary

- Health centres should keep monthly records of all patients investigated and treated for malaria. The use of anti malaria medicines without a confirmatory diagnostic test (either microscopy or RDT) is discouraged for all uncomplicated malaria patients. The data collected should be collated and shared with the provincial and national malaria authorities on a monthly basis. It will be beneficial if these figures can be plotted on a graph monthly.
- Health information data should be reviewed regularly so that trends can be investigated and changes in malaria transmission observed. This activity should be most encouraged at a health centre level, as these are the people who will ultimately have to deal with any given problem when it occurs.

Malaria As A Clinical Problem

Clinical impact

Malaria is a major health problem in Papua New Guinea. It is estimated that many people in the country contract the disease several times a year. This is confirmed by the fact that malaria is one of the most common diseases seen in outpatient figures for health facilities throughout the country.

Apart from sickness, malaria also causes several hundred deaths every year, particularly amongst young children.

The economic impact of malaria is not limited to costs associated with treatment and prevention alone. Malaria also impacts on school attendance, work attendance and reduces productivity of the population. In addition exposure to repeated attacks of malaria, especially young children may also have life long impact on both physical and mental development of children as they grow up.

If laboratory services are available to take slides of all suspected malaria cases, then the data collected can be used to help calculate a real malaria incidence rate through any given area.

Methods of malaria control

Malaria can be controlled through many different interventions. All malaria control methods can be categorized under one of five categories as listed below. What should be most remembered, is that malaria can be controlled locally and often with little or no money if people are willing to help themselves. Effective and sustainable malaria control cannot be achieved by the use of any one of these methods in isolation. They should be used in appropriate and cost-effective combination based on the intensity of transmission in a given locality and a full understanding of the local epidemiology.

1. Methods to prevent mosquitoes feeding on man

   - Mosquito Repellents
   - Physical Barriers - clothes, un treated mosquito nets and wire screens
   - Mosquito fumigants - mosquito coils, vapours, mats
   - House siting i.e. choosing an area free of mosquitoes
   - Avoiding breeding sites of mosquitoes after dark (behavioural avoidance)

2. Destruction of adults mosquitoes

   - Residual Insecticides on walls, insecticide treated mosquito nets, clothes and curtains
   - Insecticidal fogging
   - Domestic Animal treatment

3. Destruction of mosquito breeding sites by environmental manipulation and modification methods

   - Filling in of mosquito breeding sites
   - Draining swamps and other water bodies
   - Altering river courses
   - Covering water sources
   - Altering banks to make them steeper and deeper
   - Covering the water in wells or toilets with polystyrene balls
   - Removing or adding shade plants
   - Addition or removal of water weeds
   - Periodic flooding by making the water level go up and down and flushing

4. Destruction of mosquito larvae

   - Insecticides
   - Predators such as *Gambusia* fish, dragonflies and frog tadpoles
   - Parasites - Nematodes, fungi and bacteria

5. Control of malarial parasite

   - Early diagnosis and treatment
   - Prophylactics (Preventative Drugs)

Methods to prevent mosquitoes feeding on man

For malaria transmission to occur, a healthy person needs to be bitten by an infective malaria vector mosquito. Prevention of mosquito bites is the simplest form of control on an individual basis. The process works two ways: healthy people pick up the disease from infected mosquitoes, and non-infected Anopheline mosquitoes pick up the disease from infected people having gametocytes in their blood. The reduction of man/mosquito contact is therefore important for people who do not have the malaria parasites, but also important for those who currently have malaria or are carrying gametocytes due to incomplete or late treatment. In terms of transmission a single infected person is much more dangerous than a single infected mosquito. An infected person may infect several hundred mosquitoes, but a mosquito can only infect perhaps up to seven people in a lifetime.

Mosquito repellents

A mosquito repellent is any substance that is applied to the skin or clothes which repel mosquitoes and stops them biting. Repellents are a particularly useful form of malaria prevention because they protect a person from mosquito bites both inside and outside the house. A limitation of repellants applied directly on the body is that they are washed off due to bathing or when in contact with water and hence will need to be reapplied. There are a number of commercial repellents available worldwide, but very few presently in Papua New Guinea. Repellents include

- **DEET** (Chemical Name: N,N-diethyl-m-toluamide or N,N-diethly-3-methyl-benzamide)
- **Picaridin** (KBR 3023, Chemical Name: 2-(2-hydroxyethyl)-1-piperidinecarboxylic acid 1-methylpropyl ester)
- **IR3535** (Chemical Name: 3-[N-Butyl-N-acetyl]-aminopropionic acid, ethyl ester)
- **Citronella oil**

Citronella oil is a natural product and possibly one the oldest of the repellents used by mankind. It has a very strong smell but only lasts about sixty to eighty minutes meaning that it must be repeatedly re-applied. DEET is one of the most tested repellents and can last for up to 5 - 6 hours. Picaridin, appears to be nearly as good as DEET, but with a shorter duration of action and less irritability.

Unless there is more information to the contrary, only DEET and Picaridin appear to last a long time (over six hours), and for this reason, it is likely recommended that only repellents containing DEET or Picaridin be used and promoted unless a person is sensitive to DEET or Picaridin. Overall, however, it appears that DEET still remains the most effective and safe repellent on the market.

DEET comes in many different types of formulations from oils, creams, aerosols, Vaseline and solid formulations. All these formulations should have a fairly similar repellence and the major difference between any of them is price which is often based on the strength of the repellent. The other major consideration is portability because many of the different repellents can leak, especially the oils. For a repellent to be of use one should be able to carry it around so it is available whenever necessary, especially outside.

It should be noted that:

- While all repellents containing DEET are very good, one will always find people who say it does not work for them: do not be misled by such people, as repellents do work for the majority of people. If a repellent does not appear to work for a particular person you should always recommend that they try a different formulation.

- Repellents can cause an allergic reaction in some people especially on the face: sometimes the problem is in the formulations in which case recommend another DEET formulation, or it may be the DEET so it may be necessary to recommend another repellant not containing DEET.

- DEET and other synthetic repellents only work over a very short distance. It is necessary therefore to use the repellent on all exposed parts of the body, and even clothes (especially socks) where biting is intense. There is no known substance that can work over a large distance to repel mosquitoes besides fumigants discussed later.

- Repellents such as DEET are "plasticisers" meaning they attack types of plastics such as watch faces. Avoid rubbing repellents on plastics.

- Bathing will wash off repellents. It is recommended that people using repellants in malarial areas are encouraged to reapply them after taking a bath.

Natural repellents are some of the cheapest forms of self protection which most people in Papua New Guinea could probably afford. People are encouraged to seek natural and local remedies to ward of insect bites. A limitation of most herbal repellents is that their repellent efficacy is limited normally only for a few hours. The crushed leaves, extract of seeds or bark of these plants can be rubbed on the skin. At present little is known about natural repellents in Papua New Guinea.

For all repellents, it is recommended that they are applied when it gets dark, once again if bathing in the evening, and immediately before sleeping as the repellent may last until the morning.

Physical barriers

Physical barriers are anything that keep mosquitoes physically away from people and these include screens, curtains, mosquito nets and clothing. Apart from clothing, most mosquito barriers are a type of mesh which allows air to circulate: the right size of mesh is a bit of a balancing act between what allows the most air to pass through and what keeps out insects. To enhance their effectiveness they can be treated with insecticides which also allows for a bigger size mesh and more air (see next section).

1) Screens

Screens are usually made of metal or plastic and are used in window frames or doors where they need to be tight fitting to be effective. While screening is expensive, if well maintained they will last for years and represent a good investment.

2) Curtains

These can be hung over windows or doors. Most curtains are not tight fitting, and to enhance their effect as a deterrent to mosquitoes, they can be sprayed with insecticides so that the mosquitoes are killed as they try to find a way to enter the house.

3) Mosquito nets

This is the most common form of barrier method. To improve the effect of barriers such as mosquito nets, they can be impregnated with an insecticide which kills mosquitoes as they try and find a way into the net. They are usually expensive in the short term for rural people, but if looked after properly they can last for a period of 3 – 5 years and provide protection not only to the individual sleeping under the net, but to the community at large if a high proportion of people in the community are sleeping under treated nets. Thus insecticide treated mosquito nets not only protect people sleeping under the net but by also killing off vector mosquitoes can reduce local transmission of malaria. Unlike spraying houses, insecticide treated mosquito nets do not rely on mosquitoes resting on the walls of the houses, and are therefore more likely to kill mosquitoes.

Mosquito nets treated with insecticide have now become the recommended form of malaria control worldwide. Papua New Guinea was one of the first countries to recognise the preventative and control aspects of treated nets. Insecticide Treated Nets (ITNs) have now been replaced with Long Lasting Insecticidal Nets (LLINs) which do not need retreatment as the insecticide should last at least five years or twenty heavy washes.

4) Clothing

Clothing acts as a barrier to mosquitoes biting, though some mosquitoes seem capable of biting through almost any clothing and therefore clothing which is loose fitting i.e. not lying against the body is likely to be more effective than thick tight clothing. The other difficulty with clothing is that most malaria transmission occurs in very hot places and it is difficult to persuade people to wear long clothes which cover the body. In this respect, once again loose fitting clothing is more suitable by giving both air to the body and a gap between the clothes and the body through which mosquitoes cannot reach. To enhance this effect, clothes can also be treated with insecticide in the same way as mosquito nets which both kill and inhibit mosquito biting.

The only difficulty with clothing is that it is difficult to protect exposed parts of the body such as the face and hands except by the use of repellents.

Mosquito fumigants

A fumigant is any substance that when burned or heated releases smoke or vapours which repel and sometimes kill mosquitoes.

Traditional fumigants include the burning of selected tree leaves, or other parts of plants, etc. These traditional smokes serve to dispel mosquitoes resting inside houses or in close proximity to residential compounds. However, the most commonly used fumigants today are commercially available mosquito coils, sticks or vapourises. Mosquito coils are made of a variety of natural and synthetic insecticides which tend to inhibit mosquito biting, repel mosquitoes and in a few cases actually kill them. Generally though, fumigants are not that effective and in the long term are very expensive. They can only be used indoors and there is some evidence that continual use can cause respiratory problems in some individuals.

Another alternative that is now available are electrical heating devices that heat small pads (vapour mats) of insecticide. These are a much better alternative than mosquito coils for people who have electricity as they do not produce smoke and are therefore not as irritant. One pad may last several hours so it is often possible to set one going just before sleeping and it will still be working when daybreak comes: the pads change colour when they are no longer effective. To overcome the problem with electricity, some of these devices use a candle or paraffin wick.

The major problem with fumigants is that they are effective only when used indoors and are relatively expensive when compared with other personal methods of protection that can be used continuously over long periods of time. In this respect, insecticide treated mosquito nets represent a much cheaper option.

Selecting a location for house building

The closer a house is situated to a potential mosquito breeding the greater the chance of vector mosquitoes entering into houses. Therefore, for practical purposes it is always better to situate a house as far away as possible from mosquito breeding grounds (i.e. at least one kilometre), but this is rarely practical as people traditionally build houses in close proximity to a water source. It is always better to site a house upwind of a breeding site so that vector mosquitoes are not inadvertently carried with the wind. It is therefore helpful to determine the prevailing wind patterns before selecting a location for a house. In the long run, it is generally cheaper to site living quarters away from breeding grounds than to control mosquitoes in areas near to breeding grounds.

Avoiding breeding sites of mosquitoes after dark

As malaria vector mosquitoes mainly bite at night, and human activity that occurs at night in the vicinity of a mosquito breeding site will increase the chances of man vector contact. Malarial areas are usually hot, so activities such as water fetching are often carried out at night. Also, bathing usually requires privacy so many people also bath at night. Both of these activities involve water, and often water which is suitable for mosquito breeding such as rivers, river beds and dams. Other such activities may include people sleeping out of doors when guarding fields or crops at night.

People should adopt the practice of using repellents if they do have to move around at night in areas where mosquito breeding is likely to occur. It may also be good to destroy or modify such breeding sites so no mosquitoes are around in such situations.

Destruction of adult mosquitoes

Residual spraying of insecticides

Insecticide formulations can be divided into two types; those types which have a residual action i.e. long lasting for several months and those which have a knockdown or short lasting action generally for a few hours. The latter will not be considered in depth as they are generally expensive and are not considered suitable for malaria control.

Residual insecticides are cheaper in the long term as some may last up to a year when applied to walls or other surfaces. These are the types of insecticides that can be used for residual house spraying for malaria control purposes.

DDT (dichloro-diphenyl-trichloroethane) was the first insecticide used for residual spraying and it belongs to a group of insecticides known as the organochlorines. This was a very cheap long lasting insecticide, but had to be abandoned as a residual spray as many malaria vectors developed resistance to this insecticide. Additionally it was found to be harmful to the environment and fauna. Although still used in countries such as South Africa and Zimbabwe, it is generally considered environmentally unfriendly as it persists in the environment and may contaminate food crops which cannot be used for export..

The organochlorines were followed by the organophosphates of which Malathion and Fenitrothion were the key insecticides and these continue to be used by several countries at present. Safer newer insecticides belonging to the pyrethroids group are now favoured for use in malaria control for spraying houses and treating mosquito nets. These insecticides while being extremely toxic to insects are very safe to people. One of these synthetic pyrethroids lambda cyhalothrin is earmarked for use in the highlands of PNG for malaria outbreak control.

The synthetic pyrethroids are very useful for treating mosquito nets because, even if they do not kill the mosquitoes, they will repel them and often knock them down. This factor is extremely important when mosquito nets have become damaged and there are small holes in them. With the insecticide, mosquitoes will still not attempt to enter through these small holes, nor will they bite a person through the netting. Similarly, in the case of knockdown, while the mosquitoes do not actually die, they are actually knocked down onto the floor, and before they recover, they may be picked up by ants.

There are a number of synthetic pyrethroids now available for malaria control and treating nets and other materials. The synthetic pyrethroids include Deltamethrin, Lambda cyhalothrin, Alpha cypermethrin, Cyfluthrin and Etofenprox. These particular insecticides are known to last from three months to a year, and in the case of mosquito nets, more than a year if the mosquito net is not washed. One other synthetic pyrethroid which should be mentioned here is Permethrin. This insecticide is not used usually on walls, but it still commonly used for the treatment of Long Lasting Insecticidal Nets (LLINs) such as (Olyset LLIN).

Older classes of insecticides are also available, especially organophosphates (Malathion and Fenitrothion) and Carbamates (Bendiocarb), but generally they are more expensive or do not last as long. Also, since they are more toxic than the pyrethroids they are reserved for residual spraying of dwellings and not generally used for treatment of netting materials.

As in the case of DDT vector mosquitoes are gradually developing resistance to pyrethroids in some countries. To reduce the risk of this happening some countries are combining the use of treated mosquito nets with indoor residual spraying of insecticides belonging to the group of organophosphates or carbamates. These insecticides are very good, but they do not last as long as synthetic pyrethroids (generally three months) which mean that they require much more frequent applications.

The other problem with synthetic pyrethroids is that while they are very safe to humans they are particularly toxic to fish. They should not be sprayed anywhere near rivers and ponds holding a lot of aquatic life. This is particularly important when treating or re-treating mosquito nets or curtains. After treatment, the remaining packets of these insecticides should be thrown away down a latrine or rubbish dump, but never thrown away into water where fish might be.

In countries which suffer from malaria outbreaks, residual house spraying can work quickly and extremely well if the mosquitoes are indoor biting and indoor resting. If this is the case during an outbreak, whole households will get sick within a short period of each other and breeding sites will often be found in close proximity to houses. If transmission is occurring elsewhere, residual house spraying will have no effect at all, and this is usually indicated if only certain people within households are getting sick.

It is recommended that anyone wishing to use insecticides for treating nets, curtains or spraying their houses, they should first contact the Malaria Control Department at the National Department of Health in Port Moresby for advice before purchasing and insecticide.

Treatment of mosquito nets

In the last twenty years Insecticide treated mosquito nets (ITNs) became the favoured way of controlling and preventing malaria worldwide. ITNs were treated with insecticide and needed to be retreated every year. In recent years, ITNs have been replaced by Long Lasting Insecticidal Nets (LLINs) which are factory treated with insecticide that can last 3 – 5 years or at least 20 washes in a washing machine with modern detergents.

World Health Organisation Approved LLINs In 2015

Name Of LLIN	Name Of Company	Description
DawaPlus 2.0	Tana Netting	Deltamethrin coated on polyester
Duranet	Clark Mosquito Control	Alpha-cypermethrin incorporated into polyethylene
Interceptor	BASF	Alpha-cypermethrin coated on polyester
Lifenet	Bayer Crop Science	Deltamethrin incorporated into polypropylene
Magnet	VKA Polymers Pte Limited	Alpha-cypermethrin incorporated into polyethylene
Netprotect	Bestnet Europe Limited	Deltamethrin incorporated into polyethylene - NB WHOPES approval presently withdrawn.
Olyset	Sumitomo	Permethrin incorporated into polyethylene
PermaNet 2.0	Vestergaard Frandsen	Deltamethrin coated on polyester
PermaNet 2.5		Deltamethrin coated on polyester with strengthened border Interim
PermaNet 3.0		Combination of deltamethrin coated on polyester with strengthened border (side panels) and deltamethrin and PBO incorporated into polyethylene (roof)
Royal Sentry	Disease Control Technologies	Alpha-cypermethrin incorporated into polyethylene
Yorkool	Yorkool International Co Ltd	Deltamethrin coated on polyester

NB – There are always new WHO Approved LLINs being approved and this should be checked on the World Health Organisation Website http://www.who.int/whopes/en/

Many studies have shown ITNs or LLINs give high protection against malaria. A treated net is supposed to have a 50% protective efficacy against malaria. This compares with only a 25% efficacy for a normal untreated mosquito net.

Even if a net is not a long-lasting net, synthetic pyrethroid insecticides will last 6 to 12 months on a net providing the mosquito net is not washed. However, with the Long-Lasting Treatments, the insecticidal efficacy will be greatly increased and the insecticide should last at least five years and or 20 washes.

At present, there are several WHO approved LLINs manufactured by ten companies on the market. If purchasing LLINs, you should only purchase LLINs which have been approved by WHO, as WHO approval indicates that the LLINs have been tested and found to be efficacious and have met rigorous international standards.

Most of the LLINs distributed by the NDOH and RAM in Papua New Guinea are Permanet 2.0.

Thermal fogging

Fogging can be a useful method of killing adult vector mosquitoes where vector densities are found to be very high during a malaria outbreak. Fogging machines atomise the insecticide to produce a cloud of insecticide which looks like smoke. The insecticide can now penetrate every hidden corner in a household or village and kill off every mosquito around.

The advantage of fogging is that it leaves a profound impact on householders as the method is very noisy and produces clouds of vapours. The trouble is that fogging is generally expensive and generally the effect is not long lasting. But if one wishes to make a political statement, that health care services actually care, then fogging is the most likely method of malaria control that a community will remember in the future.

Destruction Or Modification Of Mosquito Breeding Sites

Environmental control refers to any method which either destroys mosquito breeding sites or modifies them in such a way that mosquitoes (in particular vector mosquitoes) are inhibited from breeding. Most of the methods are common sense, but others require a detailed knowledge of the breeding habitats of the particular vector mosquito one is trying to destroy. However, for practical purposes, it is normally better to destroy all mosquito breeding sites in any given area as people do not appreciate the effects of their activities if they continue to be bitten, albeit by other species of mosquito. Outlines of some of the methods used for modification or destruction of breeding sites are as follows;

Filling in of breeding sites

Any water body large or small which is like to retain water for more than a week should be filled in if it is not being used for any other purpose. If there are too many puddles as will be found in some swampy areas of Papua New Guinea where it rains throughout the year, it is then important that local villagers can identify mosquito larvae, and in this way, they destroy the puddles that are breeding mosquitoes. In practice, it will be found that where there are many puddles, only a few will actually be mosquito breeding sites.

Modifying or draining swamps and other water bodies

Swamp draining is one of the most successful methods of destroying vector mosquito breeding sites in many parts of the world. With small swamps, this can actually be carried out by villagers, but for larger swamps, it is usually necessary to find an engineer who can properly survey the swamp so that they can be drained in the most efficient manner.

It is important to note that proper water management will contribute to reducing mosquito breeding. Swamp management will not only reduce mosquito breeding, but can also contribute to increasing agricultural output by increasing rice production.

The draining of swamps also improved access to villages located in these places as roads could be built in the swamps where previously roads could not be built.

Altering river courses

Rivers that meander normally slow down on the inside of bends and speed up on the outside of bends. In this situation silt is deposited on the inside of bends while eroding away the outside of the bends. In this type of situation, puddles can be formed with the changing of the river bank, and one way to stop this problem is to straighten out the river or stream so that it remains fast flowing along its length.

Altering river banks

As rivers become silted, dry up or recede during the dry season or animals drink from various water sources, the banks of the river become gradually become shallower and shallower. During this process many small puddles are formed which become isolated from the main body of water and become ideal breeding sites for mosquitoes. This situation can easily be dealt with by deepening the edges of the water body by removing the silt near the edge of the water and at the same time filling in the puddles on the actual edge. This allows predators in the water to deal with the larvae naturally.

Use of polystyrene balls

Sometimes abandoned wells or borrow pits may become flooded and serve as breeding sites for mosquitoes. In this case they can be treated with small polystyrene balls. If the whole water surface is covered with these balls, mosquitoes do not breed.

Use of shade plants

This method has been very successful in other countries where malaria vector mosquitoes breed in shady places. However, to use this method of malaria control successfully one must know the breeding habits of the local mosquitoes very well. Often by changing the shade, one might destroy the breeding site of one type of mosquito and then make it ideal for another type of mosquito.

Addition or removal of water weeds

Various types of water weed may encourage mosquito breeding by affording protection to larvae, while other types of weed inhibit larval breeding by forming dense mats on the surface of the water so that the larvae cannot get to the surface to breath.

One such weed that encourages larval breeding is the filamentous algae known as *Spirogyra*. This weed forms tangled masses of thin strands of vegetation through which larvae can easily move through but is too tangled for anything much larger such as fish. Wherever this algae is found it should be removed. On the other hand, if one is trying to control mosquitoes using fish such as *Gambusia* fish (mentioned below), the presence of *Spirogyra* within water bodies would allow many mosquito larvae the opportunity to survive.

Periodic flooding and draining

This is particularly suitable for slow moving streams which tend to form stagnant pools along their length. A small dam can be built which is broken weekly to flush out all the small pools below the dam. Flushing is also important in irrigation canals. Irrigation canals should always have water moving though them quickly at least once a week to discourage mosquito breeding.

Important Notes On Environmental Control

- Before any environmental control activity is undertaken it should be ascertained if there is a problem in the first place. Often water bodies that look like potential breeding sites are not actual breeding sites as they have enough predators to control the breeding naturally.

- As many mosquito species can breed within a week in ideal conditions, it is important that all environmental control activities which are temporary in nature are monitored on a weekly basis and previous control activities repeated when necessary.

- People often complain that mosquitoes are biting and there are no apparent breeding sites in the vicinity. As mentioned previously, most mosquitoes entering houses are usually coming from close by and one method of tracking down potential breeding site is to wait for evening and listen for frogs. Frogs normally need moisture to survive and if their calls can be heard it means that water is very close by so one only needs to follow the sounds of the frogs.

- Environmental control methods should always be considered in preference to any other control method. While environmental methods can be expensive in either equipment or time, they are generally the most permanent.

- Many environmental control methods can be ideal for villagers as it costs nothing to carry out except time. Many of the above methods can be carried out by school children and should be incorporated into school activities wherever possible.

- As a general rule, most mosquitoes do not probably fly more than about half a kilometre from water. Therefore, most mosquitoes coming into a house to bite are coming from very near. If all these breeding places are destroyed or altered, mosquitoes should disappear, and with them malaria. However, for this to be effective, a large area must be cleared at the same time with everybody helping. Wind may also bring in mosquitoes from long distances, though if the wind is too strong the mosquitoes will not fly. However, it is believed that most mosquitoes stay within a fairly small area, with only a few migrating. Therefore, by destroying breeding sites in the vicinity of dwellings a considerable reduction in the number of mosquitoes coming to the house can be achieved.

The local population can contribute to this effort by reporting the existence of mosquito breeding sites to the local health authorities, who can then advise on the best course of action.

Destruction of mosquito larvae

This covers any method that can directly destroy the larvae in their breeding sites and is generally known as larviciding.

Insecticides

There are several different insecticides that can be used for larviciding. Probably the best is known as Abate (temephos). Abate is registered by WHO as being suitable and safe enough to use in water that might be used for drinking by both people and animals. Abate has also a huge advantage that it is generally selective in action and safe to other types of fauna at recommended application levels.

Some points should be noted

- Organic material normally soaks up insecticide. When using an insecticide in organic matter, one usually has to apply more insecticide to get the same affect.

- Even though certain larvicidal insecticides may theoretically continue to work for periods of over a week, it is still usually necessary to spray weekly. There are very few water bodies that remain completely stagnant from one week to the next, and usually any insecticide applied is either washed out or soaked up by organic matter.

- Larviciding is generally a slow method of control and is not usually suitable for quick results such as required in a malaria outbreak situation as it kills only larvae leaving adults to continue transmission. If larviciding were the only method used to control an outbreak it might take six weeks to see a reduction in cases (Some adults might be expected to live for another four weeks, plus another two-week incubation period of the last people to get bitten by infected mosquitoes).

- Finally, if the use of larvicides is being planned, it is best to get advice from the National Malaria Programme at the National Department of Health.

Predators

These include some species of fish, dragonflies and frog tadpoles. Most open bodies of water usually have enough predators to deal with mosquito larvae but occasions do arise where this is not the case and these are usually man made in origin such as disused burrow pits, wells, fish ponds, swimming pools etc. If such bodies of water must contain water then they should be stocked with fish, but it must always be remembered, that if the pool is not concrete lined then the edges must be continually dealt with in case small protected pools are formed at the edges which might breed larvae.

In Papua New Guinea one might consider fish as a control method where there are large bodies of water which are breeding mosquitoes. One fish used in many parts of the world including PNG is *Gambusia affinis*. *Gambusia* is a very small little fish about three to six centimetres long which has a voracious appetite for mosquito larvae. It has been introduced into many countries in the world including Iran, Russia, Afghanistan, India and PNG. To use these fish is a matter of collecting them from the wild and putting them when and where one needs them. In the case of PNG, it is reported that *Gambusia* can be collected from the drainage channels of Port Moresby and other large towns.

The use of fish such as *Gambusia* is very important where there is much permanent water that remain for long periods of time.

Gambusia affinis

Parasites

These include nematodes, fungi and bacteria. For mosquitoes, the most common parasite used are bacteria which are used as a larvicide. *Bacillus thurungiensis* (Bti) (this is actually a toxin produced by the bacteria, there are no live bacteria) is the most common one found commercially, but care should be used in applying these bio-larvicides as the Bti works as a stomach poison to the larvae and so need to be ingested. For this reason Bti may not work as expected if the larvicide is not in the area where the larvicide is applied. For example, if the mosquito larvae tend to feed on the surface of the water but the larvicide sinks to the bottom, it will not work. Like all larvicides it needs to be used in still water.

Control of malarial parasites

Drugs can be used either curatively or preventively. In this section curative drugs will not be covered as this is adequately covered elsewhere.

In many parts of the world, preventive drugs (prophylactics) are used by people to prevent malaria. Preventive drugs are particularly important for vulnerable population groups living in endemic areas (pregnant mothers) and for people who normally live in non malarious areas of the world and who visit or work in malarial areas.

Anyone wishing to take prophylactic drugs should consult with local medical staff, particularly pregnant women in Papua New Guinea, to find out which is the most recommended antimalarial drugs for malaria. This is particularly important for pregnant women, as many antimalarial drugs are dangerous when used during pregnancy.

For visitors to Papua New Guinea, it is best to consult with the Malaria Control Unit in the National Department of Health in Port Moresby or the World Health Organisation for which is the most recommended drug of choice for prophylactic use in Papua New Guinea.

Two points should be noted about prophylactics

- No prophylactic in the world is 100% effective. Prophylactics should never be used as the only form of malaria prevention.
- When using a prophylactic and one does catch malaria, the symptoms are usually much less severe and less life threatening than if no prophylactic had been used.

Using insecticides

Individual application of insecticides as residual sprays in dwellings by individuals and organizations is not recommended. Organizations wishing to carry out such spray operations are advised to seek advice from the Malaria Programme of the National Department of Health.

Integrated malaria control strategy

Malaria control is complex and past efforts to control the disease in many countries have failed due to dependence on a single method of control such as residual house spraying or treatment. This single approach has inevitably resulted in failure. Malaria transmission is often influenced by human activities and ignorance. Adopting the optimal combination of methods available in a given location allows for the effective control of the disease in a cost-effective manner. This approach is termed an integrated approach to malaria control and is dependent on using several methods of control in combination.

For practical purposes then, it is always best to come up with a malaria policy which covers all aspects of malaria control with a timetable of who does what and when.

A malaria policy should contain the following components

1) Treatment/Drug Policy including prophylaxis for vulnerable groups
2) Diagnostics Policy (Use of Laboratories and Rapid Diagnostic Test kits)
3) Health Information Policy
4) Health Education Policy
5) Malaria Vector Control and Prevention Policy
6) Malaria Outbreak Response Policy.

The malaria policy should also include

1) WHAT activities should take place.
2) WHEN the various activities should take place.
3) WHO should ensure that the activities occur.

4) WHO actually carries out the activities.
5) WHERE the activities should take place.
6) HOW those activities should be carried out.

Conclusions

Malaria is a disease which involves a mosquito that transmits a parasite from one person to another. Knowing this simple fact allows malaria to be controlled in a variety of ways.

Depending on the environment and the different vectors, malaria epidemiology can be diverse. Understanding the relationship of people, mosquitoes and environment in any given area, gives information about the best way to tackle malaria in that given situation.

There are a few points which need noting.

- No one method of controlling malaria is applicable in all situations.
- It is unlikely, even in ideal situations that malaria transmission will ever respond to one single type of intervention.
- To effectively control malaria, one must use a combination of several different methods of malaria control which necessarily include elements of parasite control, vector control and education.

Although people in Papua New Guinea consider malaria as an ever present problem, and perhaps very difficult to deal with than in other parts of the world, the correct strategy and efforts will contribute to changing this opinion.

For the present, while Papua New Guinea gets money from the Global Fund to distributed nets throughout the country, there are still many other things that people can do for themselves. This handbook gives information, that hopefully if applied, allows a person, even without money, to do something for themselves, so that they can protect both themselves and their family from this terrible disease.

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ANNEX ONE

MALARIA OUTBREAKS

A Malaria Outbreak can be defined as a situation where malaria cases rise above expected level or threshold for a particular period of the year and in a given locality. However, in the case of Papua New Guinea, it is very difficult to say whether malaria is higher than normal as there is so little existing malaria data so few people know exactly what “expected or threshold” is.

If one cannot establish what “threshold” for malaria is, then one should look at the circumstances where people feel the need to cry for help and the situations which may give rise to this.

In many countries malaria outbreaks are declared when

- An increased number of deaths are recorded in a community and suspected to be malaria.
- Severe and complicated cases of malaria appear at a health centre.
- The number of malaria cases seen at a health centre rise sharply.
- Febrile patients are more than usual at a health centre and too many for health centre staff to cope with.
- A health centre is experiencing many cases of malaria and does not have the drugs to deal with them.

To determine that transmission is higher than normal for that time of year, health workers will need to examine past records, if they exist. When **malaria cases are higher than normal, increased malaria cases by themselves is no sign for alarm unless people become critically ill or die or there are too many people for the local health facility to deal with.** However, wherever an increase of malaria is noted, the situation should be monitored in case the situation becomes worse later.

Malaria outbreaks in Papua New Guinea have not been reported often except in the highland provinces. The outbreaks in the highlands are usually self-limiting as the conditions in the highlands are not conducive to sustaining high levels of malaria transmission, except for short periods of time. These outbreaks have traditionally occurred in PNG between about 1200-1500m in altitude in such places as the Wagi Valley.

The possible causes of malaria outbreaks or increases in malaria in PNG are:

- A change in malaria transmission potential brought about by changes in the environment e.g. increased irrigation, increased rainfall, changes in cultivation and deforestation and climate change resulting in increased temperatures in an area.
- People coming in for late treatment to health centres. This often results in death or severe malaria cases.
- People not taking full course of antimalarial drugs.
- People living a long distance away from a health centre which also results in late treatment seeking behaviour.
- People from a malarial areas coming into an areas which was previously non malarial.

- People coming from a non malarial area into an area which is malarial i.e. non immunes coming into an area where some immunity already exists in the local population.
- Lack of antimalarial drugs in a given area, either in the public or private sector.
- Drug resistance. This results in people returning to health centres again after being treated.
- Sub standard drugs. This has the same effect as drug resistance.

Investigating a malaria outbreak

When investigating a malaria outbreak the following facts should be determined. Where possible these facts should be determined even before a site visit is carried out as many situations may be sorted out without a site visit thereby reducing costs.

- Who is affected, where and since when?
- What are the reasons why a malaria outbreak is being suspected or declared and whether the reasons are relevant or not? This is to give an understanding of what motivates people to report a problem.
- Are there suspected malarial deaths or severe malaria cases being recorded?
- If severe malaria cases are being recorded, how are they being dealt with i.e. treated at source, being referred without primary treatment etc?
- Is there any blood slide confirmation that the suspected malaria cases being seen are malaria, and in particular *P. falciparum*?
- Are the malaria cases being seen higher than normal or perceived to be higher than normal where data does not exist?
- Are the suspected malaria cases being seen too many for the local health staff to deal with?
- Are the suspected malaria cases coming from an area a long way from a health centre or close to existing health structures?
- Do health centre's have drugs to deal with the situation? What drugs are available in terms of first, second and third line treatments?
- In the area where there is a malaria outbreak, is there a selling of malaria drugs in the private pharmacies or by retailers?
- Where drugs are available, are people returning for further treatment after taking antimalarials?

If the information given suggests a site visit, then the following needs to be done. In all cases, it must be remembered that the most urgent priority is that people should not die. The best way to ensure this is with health education which stresses early treatment, with a FULL COURSE of a recommended antimalarial. Knowing the answer to some or all of the above questions also allows you to travel to a suspected malaria outbreak location with some of the essential items required e.g. drugs.

- When visiting the site of a malaria outbreak, one should take at least one very experienced microscopist or RDTs (Rapid Diagnostic Tests) with all the equipment necessary to carry out a survey. Determining that malaria is the cause of the fever outbreak should be the first step in establishing a malaria outbreak.

- When visiting any area, all political and social expectations should be observed. If necessary visit all relevant political structures at each level and explain your business briefly, particularly with local health authorities. In the case of the local health authorities, they should be asked to accompany any evaluation team in all stages of any investigation. In all cases, confidentially should be assured and informed consent obtained.

- Existing laboratory records should be examined where they exist and all *P. vivax* and all *P. falciparum* cases should be recorded by month against the total number of slides examined. Where possible these should be compared with Out-Patient Figures where they exist. It is also imperative that an analysis of all positive cases be made by village so that the focal point of the malaria outbreak can be determined.

  A table such as follows should be completed for final report purposes. The number of slides or RDTs examined for each village is also important as it gives an indication of the number of people reporting from a particular area. Also recording such information is important in final reports when one has to justify control measures and expenditures.

Week						
Village	No. of fever patients	No. of Slides or RDTs Examined	No. of Pv cases	No. of Pf cases	%Pv	%Pf

- It is also very important that the slides suggesting a malaria outbreak are cross checked by your experienced microscopist. Many malaria outbreaks in the past have been false alarms due to incompetent microscopists. For this reason, it is always better to take RDTs for surveillance purposes.

- If it is established that there is actually a malaria problem in the area concerned, then it is necessary to decide on what type of action needs to be taken. The first thing to be undertaken if possible is have a team carry out a prevalence survey in the area concerned. The prevalence survey is particularly important where malaria is suspected but there are no existing records to confirm the situation. This is done to give an indication of the severity of the situation as well as a matter of record for the future.

- The malaria prevalence surveys should be carried out in two or three of the suspected malaria villages and if possible one other surrounding village. It is important that this survey be completely randomised with sick and non sick people included. This survey will give a good indicator of the severity of the problem in the area. Survey teams should also carry antimalarials and treat all positive patients with a full course of antimalarials.

- If a health centre occurs in the area of the outbreak and it does not have laboratory facilities or RDTs, it is strongly recommended that at least 100 suspected malaria cases have a blood slide taken for microscopy or are tested by RDTs. From this a blood slide positivity rate can be calculated and the level of malaria at a health centre level calculated. All suspected cases of malaria, even at this stage, should be treated presumptively with antimalarials if RDTs are not available, or in the case of microscopy, given a full course of treatment even before their slide is read, unless, slides can be read quickly and a result given within 1 hour.

- If prevalence rates and Blood Slide Positivity Rates confirm malaria in an area, then all future suspected cases of malaria should be treated presumptively unless there are enough RDTs to test everyone.

- While survey teams are conducting an active survey, other factors still need to be taken into account. As people can die of malaria, the treatment of cases is always more important than control activities.

1) Are people from this area seriously ill, getting complicated malaria or dying?
2) Are treatment facilities available in the areas?
3) Do the treatment facilities have enough staff to deal with the number of cases being seen?
4) Are sufficient antimalarial drugs readily available in the area?

From this kind of information it can then be decided what types of inputs are needed to help in this situation in terms of treatment. The optional inputs for treatment are health education materials, extra clinical staff, a temporary treatment centre and drugs. Transport is also often necessary to carry very sick patients, but this is usually very difficult and costly to organise.

It must be said that wherever possible, existing health structures should be used as this is the most efficient use of resources and to add further resources e.g. extra treatment centres, are extremely expensive. For example, if drugs are in short supply, simply supply extra drugs. In many cases, the only input that is needed is advice.

- In all cases, the most important aspect of any anti malaria campaign is health education. People must be educated that:

  - There is a problem with malaria in the area and malaria if untreated can kill.
  - Anyone feeling sick should look for treatment within the first 24 hours of onset of symptoms.
  - If anyone has already been treated but still does not feel well, then they should return to the nearest health facility to explain what has happened.
  - If they are prescribed with antimalarial, or buy their own drugs, it is very important to take a full course of the drugs supplied.

- To aid in these health education messages it is strongly advised that all village and community leaders are involved from the outset. Wherever possible, one should also use other agencies (including the private sector) if they work in the area.

- If it is deemed absolutely necessary to create extra treatment posts due to existing health services being far away, then it is highly recommended that a temporary health post(s) be set up in the most affected villages. When a post is set up, people should be encouraged to come to the health post, not the other way around. There is a tendency for health staff to go from house to house looking for malaria cases - this takes up much time and is wasteful of both resources and time. When a health post is set up, local leaders should be informed (including the church), so that they can inform local inhabitants.

- If it is felt that local inhabitants are not responding, then a team can go from house to house to inform people directly, but treatment should only occur at the health post. Only if a patient is seriously ill and cannot move should they be treated at home.

- If there are many affected villages, a treatment centre can move from one village to another, spending a short time at each village until all suspected malaria cases are treated. Before moving to another village though, the village must be pre-warned.

- **All treatment during a malaria outbreak should be free. Cost sharing is likely to result in people seeking late treatment.**

- Whatever the circumstances, treatment outposts should be maintained only untill the outbreak is brought under control and then responsibilities should be passed over to local health staff.

- In all cases of treatment the following messages should accompany treatment:

  - A full course of treatment should be followed.
  - If after completing treatment they feel ill, they should return for advice.
  - Advice on any protective measures that might be appropriate in that situation.

- Where many cases of severe malaria (e.g. cerebral malaria) are being seen and there is a transport problem, extra treatment facilities might need to be considered. One option is to bring an experienced doctor to the area.

- The most important aspect of any malaria outbreak is to ensure that it does not occur again. This involves strengthening infrastructure, increasing health education and in some continuing control activities into the future.

Malaria control in outbreak situations

Malaria control options are usually expensive and do not have an immediate affect on a malaria outbreak. If a malaria control strategy is carried out and it is perfect, it will be at least two weeks before any noticeable reduction in malaria is noted. This is because, when a malaria control activity is initiated, there will still be many people already infected and it will take two weeks before all these people show symptoms. It will be only after two weeks that the effects of reducing transmission will be noted.

The major aspect of malaria control is to stop malaria transmission. The major problem with malaria outbreaks in Papua New Guinea is that they usually occur at the end of the malaria season in March and April when it stops raining. In many times during the past, a malaria outbreak was only recognised at the point where malaria transmission stops of its own accord, as the disease surveillance system was very weak. Recently the disease reporting system has been strengthened considerably and this is expected to change with the availability of RDTs at all health facilities.

Malaria control methods in outbreak situations

The options given below are only suggestions and may not be available for implementation as equipment and insecticides may not be available in the required location during an outbreak.

Adult mosquito control

If malaria transmission is still deemed to be very intense and likely to last for some time then the option of residual spraying should be considered. This will require spray pumps (usually 8 litre compression sprayers) and insecticide which is known to last at least six or more months.

Where temperatures are suitable and indoor resting mosquitoes are suspected of causing the outbreak, the use of indoor residual insecticide spraying is advocated. Since adult mosquito control will be very expensive, it should be focussed on the most affected areas - to find these areas, good surveillance is required. Another option for adult control is the distribution of LLINs among the population living in villages affected by the outbreak.

Mosquito larval control

Larval control is not usually advocated for outbreak control as its affects are much slower than with adult control. Using larval control only, does not normally affect the adult mosquito population, so transmission would not stop until all adults have died. However larval control can be used to supplement adult control through indoor residual spraying or distribution of LLINs.

Prevention of mosquito bites

Prevention of mosquito bites is part of a health education package given to people during a malaria outbreak, and more importantly as health education in the prevention of future outbreaks.

All LLIN distribution programmes in outbreak locations should be at no cost to the residents of affected villages.

Summary of an outbreak response

- It is always better to detect a malaria outbreak early before it becomes a serious problem. Good surveillance data should be reviewed regularly at all levels of the health system starting with individual health centres.

- Health centres should be encouraged to report without delay suspected malaria outbreaks to higher authorities for further investigation. Situations to be reported should include a large increase in malaria cases, many severe malaria cases,Blood Slide Positivity Rates higher than normal and when many cases appear not to respond to malaria treatment. It is for this reason that Health Centres should always do a RDT test each time someone is suspected of having malaria and also record all cases tested in the RDT Register Book together with the place where the patient lives.

- All reports should be investigated and where necessary the area affected visited. Reports that occur during the period from April to June are more likely to be malaria outbreaks than at other times of the year. Reports at other times of the year will probably be some other problem such as influenza outbreaks.

- Before any intervention takes place all aspects of a suspected outbreak should be investigated. The level of inputs should be proportional to the size of the problem. The most important aspect to determine is whether the problem is actually malaria, and if it is malaria, how big is the problem and exactly where and what the problem is.

- In any response to a malaria outbreak, priority should always be given to treatment to prevent deaths. Control or prevention comes afterwards when treatment services are working properly.

- Ensure that drugs are available at all levels of the health system.

- Wherever possible use existing health infrastructure and keep external inputs to the minimum as they are costly and may be needed elsewhere.

- If it is necessary to have extra outreach clinics, consider using local volunteers to help who can be trained in basic malaria treatment.

- Health information should be given the highest priority to inform people that they should seek immediate treatment when feeling ill. This should be followed later by information on taking full course of treatment and returning to a health centre if drugs do not appear to be working - this is usually best administered at health centre level when people come to get drugs.

- At the end of any outbreak it is extremely important to ensure that it does not occur again the following year. A health education campaign for the whole community would be appropriate in terms of rapid treatment seeking behaviour and malaria prevention.

Preventing malaria outbreaks

Malaria Outbreaks are usually the result of something in the environment changing or breaking down. If malaria control activities are good, treatment services available and people are carrying out malaria preventive activities and seeking prompt treatment, malaria outbreaks will not occur.

In PNG where preventive services are not strong, malaria outbreaks will occur, particularly in mountainous areas where immunity is not developed. Similarly, health information and malaria surveillance systems are weak in PNG and as such, it is almost impossible to detect a malaria outbreak before they occur.

However, even in PNG, malaria outbreaks can be kept to a minimum with few or no deaths if health education of early treatment seeking behaviour is emphasized and clinical services staffed and operating with adequate anti malaria medicines and RDTs.

To aid this situation, the authorities and implementing partners could conduct health education campaigns through the churches and government outreach services to remind people that early treatment seeking within the first 24 hours since the onset of fever saves lives, especially in children under 5 years.

Similarly, the authorities need to ensure that there are adequate antimalarial drugs at all levels of the health system available at all times of the year.

Annex Two

Community based malaria (CBM) projects

Summary

Community Based Malaria (CBM) projects are those where local communities take up malaria control in their immediate surroundings. The projects are normally based on larval control carried out on a weekly by communities on a voluntary basis using a variety of larval control methods. The idea of the programme is to eliminate all breeding sites and thereby mosquito breeding within at least two kilometres of where people are living.

Such projects have been carried out in many countries with great success, and in some cases, reducing malaria practically to zero.

CBM projects require dedicated community mobilisers who are able to get communities to participate on a voluntary basis at no cost. For the most part, the project would supply educational inputs on vector breeding sites and other aspects of malaria epidemiology and sometimes equipment necessary for application of larvicidal insecticides (spray pumps) and larvicides. Occasionally other tools required for clearing of breeding sites are provided, but often these are found from within the communities.

Such CBM projects can be stand alone projects as detailed above or may be combined where possible with distribution of LLINs or education regarding the use of LLINs. CBM projects may also be combined with community based treatment of malaria.

CBM projects are about mobilising communities to deal with malaria by themselves using simple, affordable and locally available tools and methods of malaria control. Such CBM projects should offer a variety of malaria control options which are suitable for every social group, so that even the poorest in a community can do something for themselves. Some options for malaria control only cost time and labour, something that even the poorest person can offer. CBM projects are more successful in rural communities, as it is more difficult to obtain sustained commitment from urban communities.

Why CBM projects?

- Malaria is a huge problem and few countries have the resources to deal with malaria effectively at a governmental level.
- There is a belief that the malaria problem is so big, that only large sums of money can deal with it. With this attitude people often ignore existing resources that might help.
- There is a belief that malaria control should only be carried out by government agencies and that individuals or communities can only help minimally e.g. purchasing or treating mosquito nets.

Keys to success

- The key to success is having a fully educated community in all aspects of malaria control. In this respect, communities should be dealt with as equal partners and not as ignorant participants, which means that they must be consulted in all aspects of any project including giving feedback on results of any intervention.
- People do not do things for nothing. However the reward does not have to be financial, often a pat of the back for a job well done is enough. One must find the minimum motivation needed, but money should never be the motivation. Once a financial reward is used in participation, community effort will be lost once money runs out.
- Good community mobilisers are a necessity and the choice of the right people critical.
- Do not expect immediate results from communities. Some communities respond quickly, while other communities take time, and often need to see success in other communities before they will fully participate. Patience is the key to success.

Field notes

- Community Mobilisers do not need a background in malaria, but they must be able to read and write, have a capacity to learn, willing to work hard, and most importantly, be able to integrate themselves with rural communities.
- Community Mobilisers should be taught in all aspects of malaria control, particularly methods related to mosquito breeding site eradication. Destroying mosquito breeding sites requires for the most part only labour which is free and few other inputs.
- Apart from Community Mobilisers, no one should receive any type of payment for any services rendered in the community. Once any type of payment is given, all future activities will collapse.
- Where mosquito nets, insecticides and repellents are available, Community Mobilisers can sell these products to communities.

Start of operations

- At the beginning of the project, selected villages should be visited and all relevant authorities visited to explain the project. Such authorities should include Ministry of Health officials, and district and village authorities.
- All members of the community should be educated in all aspects of malaria epidemiology and control, particularly, mosquito larval identification. Children should be given priority as they normally know where all water bodies and hence mosquito larvae can be found.
- Villages and villagers should be arranged into clusters for spray pump distribution on a weekly basis if larviciding is deemed necessary. All activities related to larval control must be carried out weekly.
- Community mobilisers should become completely familiar with the areas in which they work and know for themselves all the breeding sites which the community will control.

Day to day activities

- Community mobilisers should visit all communities frequently to ensure that activities are being carried out and to sort out problems and discuss all issues relating to malaria. Education is not a one time process, but an ongoing exercise. As time progresses, visits can become less and less, but in most cases should never exceed once a month. Communities need to feel that they are being monitored and need encouragement. If this does not happen they will lose interest. The reward is congratulation for a job well done and the resultant decrease in mosquitoes if the work is carried out well.
- It is important that community mobilisers constantly ask community members if they have mosquitoes biting them at night. This is particularly important after activities have started so that activities can be monitored. If mosquitoes are present, particularly when communities claim that they are larviciding, then it is most important to identify local breeding sites and thoroughly check them to make sure that mosquitoes have been killed. It should be remembered that, after the start of larvicidal activities, it will take at least one month for all mosquitoes to disappear, even if all larvicidal activities have been carried out correctly. This is because, even if all mosquito larvae are killed, adult mosquitoes may still live for another month. However, after one month, if larviciding has been done properly, all adult mosquitoes should have disappeared.

Equipment needed

- Pressure spray pumps where larviciding is needed. Spray pumps should be supplied on the basis of one pump being able to cover several villages in one week. Pumps should be shared between adjacent villages so each village is able to use the spray pump for one day each week.
- Transport and diaries for community mobilisers. Transport could consist of motorbikes or bicycles depending on area to be covered.
- Larivicide - the usual recommended larvicide is Temephos (Abate®) which is an organophosphate insecticide. Usually this will come in containers of 25 litres which will then have to be put into smaller bottles of about one litre. One litre of Temephos will spray about six hectares of water so this should last an extremely long time.

Larval control for CBM projects

Larval control was selected as the method for vector control during CBM projects for the following reasons.

- Larvicides are cheaper than residual insecticides but application is labour intensive. However in CBM projects labour is supplied by the community, and hence not costly to obtain.
- Larval control requires full participation of the community on a regular basis (once a week) which keeps the people engaged and focused on the project.
- The problem to be dealt with (i.e. mosquito larvae) can easily be recognized by communities, even small children. When walls are sprayed with insecticide, people rarely see dead mosquitoes - the results of residual spraying is indirect,

and rarely are all mosquitoes destroyed or seen to be destroyed by the community. With larval control, people can see the fruits of their labour immediately i.e. dead mosquito larvae. Better still, if the larval control is done properly, mosquito bites can disappear altogether. This builds a causal relationship between action and results. Communities need this to demonstrate to themselves that their activities have been worthwhile.

Larval control has usually been the choice of control in urban setting and often people criticise larviciding in rural areas where breeding can be extremely numerous. However, it must be said, that once a community is mobilised, thousands of puddles no longer become a huge problem as there are thousands of villagers to deal with them.

Keeping records

While it is important for Community Mobilisers to keep records of their activities, it is equally important to keep a check on mosquito densities and malaria. Keeping track of mosquitoes could be done with entomologists catching mosquitoes in a locality (usually not feasible due to staff shortages), or simply by asking villagers about the mosquito biting nuisance at any given time. As stated, if this type of programme is carried out properly, mosquitoes should for the most part disappear.

Where possible, it is also important to measure malaria. Community based malaria control is still a new concept in PNG, particularly the use of larvicides within a community situation. Measuring malaria therefore justifies a programme to the community, the local health authorities and most importantly to governments so that such programme can receive funding and expand.

The simplest way to measure malaria is by the use of prevalence surveys over several years. Better still, where a health centre exists locally which keeps health records, village malaria incidence rates can be measured on a yearly basis starting with as many years prior to your programme as possible. Collecting data from the past allows you to evaluate your programme much more quickly than if no such data existed. This is now made easier as all health centres have a RDT or Microscopy Register Book for all malaria tests carried out. Using this register, it is very easy to monitor the malaria in any health centre catchment area i.e. where patients use a particularly health centre.

Being able to show such data, particularly to communities, will mobilise the communities more. Such data gives communities pride that the activities they carry out are worth while. Without such input, such projects will eventually fail through lack of proof and impetus.

Conclusions

Many people die each year as a result of malaria, and in most cases, the deaths are a direct result of ignorance in not knowing how to deal with this disease. Community participation allows many issues, including malaria, to be dealt with in what otherwise might appear to be hopeless conditions.

This is not to say that community participation will answer all problems. However, where resources are absent or inadequate, community participation allows some kind of action to take place where otherwise there would be none, and where it is done properly, results can be impressive.

In PNG, where there are large areas of swamps, the draining of swamps in the vicinity of communities will contribute to a significant reduction in mosquito densities and disease burden. It should however be remembered, that while local communities can deal affectively with small swamps, it is always better to get a qualified engineer to tell you how to deal with bigger swamps.

Annex Three

Urban malaria control projects

Background

Urban in the context of this document refers to any built up area where a lot of people may live. This can include villages, towns and cities as well as settlement areas.

While malaria can thrive in both rural and urban areas, and many of the problems of mosquito breeding similar in both types of setting, urban environments have their own special difficulties. In urban areas, by virtue of high concentrations of people, many diseases, including malaria, can build up and spread quickly through the population.

In well planned urban areas, malaria and mosquitoes are rarely a problem, but in unplanned, or badly planned urban setting, mosquitoes and malaria can abound. The major problems usually relate to water and sanitation, or rather, lack of good sanitation facilities and ignorance of the population in the best way to dispose of waste water and the storage of water for drinking purposes.

In the urban areas of Papua New Guinea and particularly in settlements most of the malaria is acquired in villages or rural areas and brought by people who come and settle for short or long periods of time.

However, malaria in urban areas is relatively easier to control than in rural areas as the problems tend to be much more concentrated in proportion to the population affected and accessibility is not an issue as in the rural areas of PNG. In rural areas, mosquito breeding sites are spread out and numerous in comparison to the people affected and accessibility is often a problem to remote communities.

Malaria control in urban settings

Since the first use of DDT in the early 1940's as a residual insecticide, malaria control has depended largely on residual house spraying, till the introduction of insecticide treated mosquito nets. Residual house spraying remains extremely effective in many situations against malaria but is expensive, especially in urban settings as the surface areas to be sprayed are much larger than in sparsely populated rural areas. More importantly, it does not deal with the issue of mosquito breeding. Traditionally, urban malaria control has dealt with environmental issues which include measures to reduce mosquito breeding and breeding sites as opposed to simply dealing with adult mosquitoes.

Good urban environments are well planned environments, or at least should be well planned, and this being the case, opportunities for mosquito breeding, or opportunities for any type of disease to flourish should be minimised. In urban settings it is better to concentrate on environmental issues and not simply the destruction of adult mosquitoes, unless an outbreak requires urgent control measures. In such outbreak situations the preferred emergency action would be thermal fogging and residual spraying to rapidly destroy adult mosquitoes.

Mosquitoes however can take as little as one week to grow from egg to adult. To stop mosquito breeding, all suspected breeding sites of mosquitoes need to be destroyed, modified to minimize breeding or treated with larvicides or other larval control material on a weekly basis.

Using Temephos

Temephos usually comes as a 50% EC (Emulsifiable Concentrate). One litre of Temephos can cover about five to ten hectares of water depending on dosage rate.

It is recommended that Temephos be applied at a rate of 5 ml of Temephos per ten litres of water, and using a fan nozzle, be sprayed at a rate of one metre per second. The fan of the nozzle should be positioned to give a swath of about one metre. Where higher dosages of Temephos are required, e.g. in heavily polluted water, instead of adding more insecticide to the spray pump, water can be double sprayed to give a double dose of insecticide. Nozzles should give an output of about 20 ml per second. This would give an application rate of 50 grams per hectare which is suitable for clean water. 100 grams per hectare is required for polluted water.

When spraying insecticide, it is always important to return 24 hours later to ensure that the dosage rate is correct and that all mosquito larvae have been killed.

Final Points

Like Community Based Control, it is very important that all malaria cases in urban areas are investigated so that mosquito control activities can be focalised in areas of difficulty. Like rural health centres, all urban health centres also have RDT or Microscopy Register Book from which all malaria test results are recorded including where the patients are coming from and if they have travelled from outside of the urban environment.

For example, from the RDT records taken in Port Moresby we can say that in 2016 there were 595 positive malaria cases of which 475 lived in Port Moresby and of which only 235 claimed not to have travelled outside of Port Moresby. **Annex Four**

Annex Four
Malaria control activities which can be carried out by school children

Malaria is an easy disease to understand: it involves mosquitoes which breed in water, people infected with parasites and people without parasites coming together with infected mosquitoes.

Experience has shown that even young school children are able to recognise mosquito larvae once they have been demonstrated. Many of the prevention and control activities described earlier are simple in nature and can be practised by all ages of people. Since school is the place where learning often starts the following activities can easily be carried out by any school in the country. If these activities are carried out at school, it could be hoped that they would be taken back to the children's households and parents. In addition they may become part of their everyday lives in later life.

1) Teach children to recognise mosquito larvae

Mosquito larvae can easily be collected and reared in the classroom until they emerge as adults. It is recommended that adults are killed when they emerge.

2) Have children survey all water bodies around a school for mosquito larvae on a weekly basis

Larval surveys can easily become part of a weekly school routine in the same way as cleaning classrooms. Suggested method is to send children away from the school for a distance of about one kilometre (twenty minutes' walk) and as they walk back, to search every puddle, pool and pond they can find. When finding larvae they should destroy the breeding site but also bring some larvae back to show their teacher before destroying the breeding site (if possible) in which the larvae were found. If some breeding sites are too difficult for the school to deal with then they should be reported to the local health authorities for necessary action. It is also very helpful to make maps of all the breeding sites so the school knows where it should concentrate its activities.

3) Recording sick children with malaria

Whenever children get fever or get sick with fever associated-illnesses, they should be encouraged to seek malaria test (diagnosis) and treatment immediately.

4) Recording temperature and rainfall data

Where a school has a minimum and maximum thermometer and a rain gauge it is easy to record average daily temperatures and daily rainfall. Keeping this data allows children to see how malaria develops and falls off with temperature changes and rainfall. In most rural schools in malarial areas, teachers stay at the school. The above activities not only teach children to prevent malaria but it also protects the teachers.

5) Carrying health messages to their homes

School children can be used to carry key malaria control messages such as "sleeping under a treated net every night protects you and the family from malaria" to their parents and homes. It is also important that they take the message of destroying all mosquito breeding sites around their home.