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Malaria as a Global Public Health Challenge: Impact, Prevention and measure, Challenges, Treatment and Drug Resistance

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ABSTRACT:

Malaria remains one of the most significant global public health challenges, particularly affecting low- and middle-income countries in tropical and subtropical regions. Caused by Plasmodium parasites and transmitted by Anopheles mosquitoes, malaria poses a serious threat to human health, with children under five and pregnant women being the most vulnerable. Despite global efforts to reduce its prevalence, malaria continues to result in hundreds of thousands of deaths annually, most of them in sub-Saharan Africa. The disease's impact goes beyond mortality, contributing to high morbidity rates, weakened immune systems, and recurrent infections that affect physical and cognitive development, especially in children. Malaria also imposes a considerable economic burden on affected countries by increasing healthcare costs, reducing labour productivity, and hampering economic development. In many regions, repeated outbreaks strain already fragile healthcare systems, diverting resources from other essential health services. Public health interventions—including the use of insecticide-treated nets, indoor residual spraying, effective antimalarial drugs, and improved diagnostic tools—have led to significant reductions in malaria cases in recent decades. However, challenges such as drug resistance, insecticide resistance, and gaps in healthcare infrastructure continue to hinder eradication efforts. In conclusion, malaria remains a pressing public health issue that requires sustained investment, innovation, and international cooperation. Strengthening healthcare systems, expanding access to prevention and treatment, and investing in research are essential steps to reduce the global burden of malaria and move toward its eventual elimination.

Keywords: Malaria, Public health, Drug resistance, Disease eradication

Introduction:

THE IMPACT OF MALARIA ON PUBLIC HEALTH

Malaria is one of the most dangerous infectious diseases in the world. It is caused by tiny parasites called Plasmodium, which exist in six types. The most deadly type is Plasmodium falciparum, mainly found in Africa, while Plasmodium vivax spreads widely outside Africa. Other types are Plasmodium knowlesi, Plasmodium malariae, Plasmodium ovalewallikeri, and Plasmodium ovalecurtisi. These parasites are passed on through the bite of infected female Anopheles mosquitoes. When a mosquito bites a person, its saliva transfers the parasites into the bloodstream. The parasites then travel to the liver, where they multiply. After growing, they return to the bloodstream and cause symptoms like high fever, chills, and headaches. In serious cases, malaria can lead to anemia, organ damage, coma, or even death. Although dangerous, malaria is both preventable and treatable if proper care is given. The risk of getting malaria depends on location, climate, and season. According to the World Health Organization, many big city centers in at-risk countries have low malaria transmission, although nearby areas might still be affected. The risk is lower in places more than 1,500 meters above sea level, yet malaria can occur at altitudes up to 3,000 meters under favourable conditions. Infection is most common at the end of the rainy season when mosquito breeding is high. Preventive measures include using insect repellent, sleeping under mosquito nets, and taking preventive medicines when traveling. Health organizations work worldwide to control malaria by educating people, improving treatment access, and reducing mosquito breeding sites. These efforts have saved millions of lives over the past decades. Continued work is needed to further reduce malaria cases and deaths. Together, governments, communities, and international partners must stay committed to fighting malaria through prevention, effective treatment, and ongoing research to improve health outcomes globally. Every small effort truly counts in saving lives.[1]

HISTORY

Malaria has been known since ancient times, with records from China (2700 BC) and Greece (850 BC). Hippocrates, a famous Greek doctor, was the first to describe malaria-like fevers. However, not much progress was made until the 17th century when T. Sydenham identified different fever patterns

and the healing effects of the cinchona tree bark. The name "malaria" comes from the belief that bad air ("mal-aria") from marshes caused the disease, a term first used in English medical books in 1827. the 19th century when scientists discovered how malaria spreads. Ronald Ross, working in India, and Giovanni Battista Grassi, working in Italy, both found that mosquitoes, specifically *Anopheles* mosquitoes, were responsible for transmitting malaria. Since both India and Italy had high malaria cases, their research was crucial in understanding the disease. Over time, scientists learned that different species of *Anopheles* mosquitoes had unique breeding habits and life cycles, which affected how malaria spread in different regions. This meant that malaria control strategies had to be adapted to fit local environmental, social, and economic conditions. For example, efforts to fight malaria in one country might not work the same way in another due to differences in climate, mosquito species, and human settlements. Malaria treatment has been known for centuries. In ancient China, people used the Qinghao plant (*Artemisia annua*) to treat malaria as early as the 2nd century BC. Later, in the 16th century, Spanish explorers in Peru found that the bark of the cinchona tree (*Cinchona succirubra*) was effective against malaria. In 1820, French chemists Pierre Joseph Pelletier and Joseph Bienaimé Caventou extracted quinine from this bark, which became widely used for malaria treatment. A major breakthrough came in 1970 when Chinese scientist Youyou Tu and her team isolated artemisinin from *Artemisia annua*. This drug proved highly effective against malaria, and Youyou Tu was awarded the Nobel Prize in 2015. Today, artemisinin-based combination therapies (ACTs) are the main treatment for *Plasmodium falciparum*, the deadliest malaria parasite. ACTs combine artemisinin with other drugs to prevent drug resistance, which has developed against older treatments like chloroquine and pyrimethamine[2]. During World War II, DDT was widely used to control malaria, which had affected two-thirds of the world's population. After the war, DDT spraying helped reduce malaria cases, but concerns over environmental and health risks led to its restricted use. Several Nobel Prizes have been awarded for malaria research. Ronald Ross won in 1902 for proving that mosquitoes spread malaria. Charles Louis Alphonse Laveran received the 1907 Nobel Prize for discovering the malaria parasite. Julius Wagner-Jauregg won in 1927 for using malaria therapy to treat paralytic dementia. Paul Müller received the 1947 Nobel Prize for DDT's insecticidal properties. Finally, Youyou Tu won in 2015 for her discovery of artemisinin.

SYMPTOMS

Running nose, cough, and other signs of respiratory infection Diarrhea/dysentery
Burning micturition and/or lower abdominal pain Skin rash/infections

Painful swelling of joints Ear discharge

DIAGNOSIS

Diagnosis of Malaria

Malaria diagnosis involves various methods, including microscopy, laboratory examination, and rapid diagnostic tests.

Microscopy

Microscopy of stained thick and thin blood smears is the gold standard for confirming malaria diagnosis. This method offers high sensitivity, allowing detection of malarial parasites at low densities. It also helps quantify parasite load and distinguish between various species of malaria parasites and their stages.

Laboratory Diagnosis

Laboratory examination involves analyzing stained blood smears under a microscope to identify Plasmodium parasites. Health providers should consider malaria in individuals who have recently traveled to tropical regions or received a blood transfusion and are experiencing symptoms like fever and flu-like signs.

Rapid Diagnostic Tests

Rapid Diagnostic Tests (RDTs) detect circulating parasite antigens. Various types of RDTs are available, some of which can detect multiple parasite species. However, RDTs can be temperature-sensitive and expensive. It's essential to carefully read the user's manual and instructions and follow them meticulously.

Characteristics of Malaria Parasites

Malaria parasites have distinct characteristics, including dark red chromatin bodies, pale purplish-blue cytoplasm, and vacuoles. Infected red blood cells contain developing trophozoites with distinct chromatin dots.

GLOBAL IMPACT

Prevalence

In 2023, around 263 million malaria cases and 597,000 deaths were reported in 83 countries. The WHO African Region was the most affected, with 94% of cases (246 million) and 95% of deaths (569,000). Young children under five were the most vulnerable, making up 76% of malaria-related deaths. Malaria is especially dangerous for children in sub-Saharan Africa (SSA), where mosquitoes like *Anopheles gambiae* spread the disease by biting people indoors at night. Malaria cases tend to rise during certain seasons in many African countries. In 1955, the World Health Organization (WHO) launched a campaign to eliminate malaria, but it failed by 1969 due to mosquitoes and malaria parasites developing resistance to insecticides and medicines. As a result, malaria control efforts slowed, and the disease remained a major cause of childhood deaths in Africa. A breakthrough came in 1993 when a study in The Gambia showed that insecticide-treated bed nets (ITNs) could significantly reduce malaria cases and save lives. Children sleeping under ITNs had 45% fewer malaria-related fevers and a 60% lower death rate. Later studies confirmed that ITNs reduced child deaths and malaria infections by 17%. To strengthen malaria prevention, experts introduced seasonal malaria chemoprevention (SMC), a medicine given to children during peak malaria seasons. Since 2000, over 2 billion ITNs have been distributed, and by 2015, over one-third of SSA households owned at least one ITN. The number of children receiving SMC increased from 120,000 in 2012 to more than 49 million by 2022However, new challenges have arisen. Mosquitoes and parasites are becoming resistant to insecticides and medicines.[4]

LITERATURE REVIEW

1. Abdul-Rahman, et al. (2025).

Communities are at higher risk of malaria due to overcrowding, poor sanitation, and limited healthcare. Lack of proper monitoring leads to more severe cases and deaths. To control malaria, better diagnosis, community health programs, and improved healthcare services are needed. Working together can help reduce its impact effectively.

2. Okumu, F., et al. (2025)

"Larval Source Management (LSM) reduces malaria but lacks funding due to feasibility concerns. Historical successes and modelling support its integration. Increased investment, policy flexibility, and monitoring can enhance malaria control efforts."

3. Nguyen et al. (2024)

Explored the integration of mobile health (mHealth) tools in malaria case management across Southeast Asia. The pilot program linked real-time diagnostic data to national surveillance systems, improving outbreak response times by 40%. The study concluded that digital health innovations could revolutionize malaria tracking and resource allocation, provided data privacy and training protocols are in place.

4. Ramasamy et al. (2024)

Propose a focused and collaborative strategy to achieve malaria elimination in India by 2030. The study emphasizes the integration of health system strengthening, community engagement, and intersectoral coordination to bridge the gap between policy and grassroots implementation. Their proposal serves as both a policy framework and a call to action, urging stakeholders to focus on innovation, accountability, and equity to close the final gap in malaria control.

5. Mensah and Diallo (2023)

Investigated community-based interventions for early malaria diagnosis using rapid diagnostic tests (RDTs) in Ghana. They found that training local health volunteers to administer RDTs increased early detection by 60%.Their study supports the scale-up of decentralized diagnostic systems to improve access to timely treatment, especially in remote or underserved areas..

6. Bhattarai et al. (2022)

The impact of intermittent preventive treatment (IPT) for malaria among pregnant women in endemic regions of India. The study found that IPT use significantly reduced maternal anemia, low birth weight, and malaria-related complications during pregnancy. With up to 70% fewer malaria cases reported among women who received IPT, the findings strongly support including IPT in standard antenatal care, especially in high-risk tribal and rural areas. The authors recommend strengthening policy implementation and improving awareness among healthcare providers to increase IPT coverage and improve maternal and fatal health outcomes.

7. Kaur et al. (2022)

The advancements in malaria treatment in India, tracing the evolution from traditional herbal remedies to modern pharmacological interventions. The authors discuss the pathophysiology of malaria, diagnostic advancements, and the development of new treatment regimens. Emphasis is placed on the integration of artificial intelligence in developing therapeutic strategies and the importance of adhering to government guidelines. The study also highlights the role of the World Health Organization's Global Technical Strategy 2016–2030 in guiding malaria eradication efforts. This review underscores the need for continued research and innovation in malaria treatment to achieve eradication goals.

8. Krishna et al. (2021)

Conducted a multicentric study to evaluate the therapeutic efficacy of artemether-lumefantrine (AL) in treating uncomplicated *Plasmodium falciparum* malaria across four endemic states in India: Madhya Pradesh, Chhattisgarh, Maharashtra, and Odisha. The study involved enrolling patients diagnosed with uncomplicated *P. falciparum* malaria and administering a standard six-dose regimen of AL over three days, with a 28-day follow-up period to assess treatment outcomes. The results demonstrated a high efficacy rate of AL, with a 98.6% adequate clinical and parasitological response (ACPR) by day 28. The study also reported no significant adverse events, indicating the safety of AL in the Indian population.

9. Ranjha et al. (2021)

Explored the knowledge, attitudes, and practices (KAP) of Mitanins, community health workers in Chhattisgarh, regarding malaria elimination. The research involved a cross-sectional survey of 1,200 Mitanins across various districts, assessing their understanding of malaria transmission, prevention, diagnosis, and treatment. The findings revealed that while a majority of Mitanins possessed adequate knowledge about malaria symptoms and prevention methods, gaps existed in their understanding of diagnostic procedures and treatment protocols. The study highlighted the critical role of Mitanins in malaria control and emphasized the need for regular training and capacity-building programs to enhance their effectiveness. Strengthening the KAP of community health workers like Mitanins is essential for achieving malaria elimination goals in endemic region

10. Okeke et al. (2021)

Examined the effectiveness of insecticide-treated nets (ITNs) in urban versus rural settings in sub-Saharan Africa. Their results showed that while ITN usage was consistent in both environments, malaria incidence remained higher in rural areas due to greater exposure and lack of supplemental interventions. The study recommends combining ITN distribution with environmental management and reduce transmission rates, especially in rural communities.

Aim And Objective

AIM:- To assess and understand the impact of malaria on public health, focusing on its effects on individual health, healthcare systems, and socio-economic development, particularly in malaria-endemic regions.

Objective:-

1. To analyse the economic consequences of malaria on individuals, families, and national healthcare systems.

2. To examine the challenges in malaria prevention, diagnosis, and treatment, including drug and insecticide resistance.

3. To explore the role of climate change and environmental factors in influencing malaria transmission and outbreak patterns.

4. To recommend sustainable strategies for reducing the burden of malaria and improving public health outcomes.

PLAN OF WORK

1. Epidemiology of malaria
2. Symptoms and Diagnosis
3. Impact on public health
4. Preventive and measure
5. Treatment and drug resistance
6. Program and polices

Epidemiology of malaria

India has made major progress in reducing malaria, especially between 2000 and 2019, but the disease still remains a serious problem. In 2019, there were around 5.6 million malaria cases in India, according to a WHO report. Malaria cases usually rise during the summer and rainy monsoon seasons. About 95% of people in India live in areas where malaria is common. However, 80% of malaria cases are found in just 20% of remote and hard-to-reach communities. One study using PCR tests found malaria rates as high as 35% in some areas, showing that traditional methods like microscopy and rapid tests often miss many cases. In southern India, especially around Bengaluru, the most common malaria parasite is *Plasmodium vivax*, which can also cause severe illness and even death. A study there showed that most patients had mild malaria, possibly due to early treatment or past exposure. While *P. falciparum* used to be more common, *P. vivax* is now becoming dominant in many regions. Still, in some parts of India, *P. falciparum* remains the main cause of malaria. India has 47% of the world's *P. vivax* cases, with 90% of all Indian malaria cases coming from just seven states. Travelers returning from India have also spread malaria to other countries.[5]

IMPACT OF MALARIA ON PUBLIC HEALTH

Malaria is a major public health concern worldwide, affecting 2.4 billion people in 100 countries. In areas where malaria is common, like Africa, almost everyone is at risk and gets infected repeatedly. Those who survive childhood infections develop some immunity. However, in areas with low infection rates, people don't develop immunity due to limited exposure.

The impact of malaria is significant, leading to:

- Loss of life
- Reduced productivity
- Increased school absence
- High treatment costs
- Negative effects on social and economic growth

Understanding the importance of malaria is crucial, especially in regions where it's common. It's not just about the number of cases, but also the overall impact on individuals and communities. .[6]

Economic Burden

The economic burden of malaria was calculated by adding up the costs of:

- Resources used by healthcare providers
- Resources used by households
- Lost productivity due to illness or caregiving This calculation was done for:
- Uncomplicated malaria
- Severe malaria
- Children under 5 years old
- All ages.

Household Costs of Malaria

Direct costs: medical care, treatments, diagnostic tests, consultation fees, travel costs, food, and telephone expenses

- **Indirect costs**: lost productivity due to illness or caregiving, including missed work, agricultural activities, housework, and school attendance

Malaria in Pregnancy

- Pregnant women are more likely to develop severe malaria, which can lead to high morbidity and mortality rates.
- Malaria during pregnancy can cause abortions, stillbirths, and low birth-weight babies.
- Pregnant women with no or low immunity are at higher risk of malaria complications.
- Mortality due to cerebral malaria in pregnancy is 40%, twice the mortality rate in non-pregnant individuals.

Community-Based Studies on Malaria in India

Community-based studies are crucial to understanding the impact of malaria on women and children in India. There is an urgent need for community-based studies in India to understand the impact of malaria on women and children. These studies should focus on:

Quantifying morbidity and mortality due to malaria

- Understanding healthcare-seeking behavior of women and children
- Assessing awareness and utilization of medical facilities
- Identifying barriers to accessing healthcare services
- Reliable diagnosis of malaria is difficult in remote rural areas.
- Longitudinal studies and village reporter systems can help overcome this challenge.
- Surveys should be conducted to determine attitudes towards malaria treatment and prevention.
- Health education campaigns are necessary to improve awareness and utilization of medical facilities.
- Women's attitudes towards community health workers and government health workers should be assessed.[7]

PREVENTION AND MEASURE

1. Use of Long-Lasting Insecticidal Nets (LLINs**)** while sleeping.
2. Wearing **long-sleeved clothing** in mosquito-prone areas.
3. Elimination of mosquito breeding sites (like stagnant water).
4. Regular cleaning and covering of water containers.
5. Active health education and awareness campaign.

Malaria control efforts focus on two main methods recommended by
WHO: Insecticide-treated nets (ITNs) and indoor residual spraying (IRS) reduce malaria. Integrated Vector Control (IVC) combines two or more mosquito control methods, such as insecticide-treated nets (ITNs), indoor residual spraying (IRS), larval source management (LSM), or environmental management. It focuses on children under five and pregnant women, as they are more vulnerable to severe malaria complications
WHO: Insecticide-treated nets (ITNs) and indoor residual spraying (IRS) reduce malaria. ITNs Impact: Prevented 663 million cases (2000-2015); pyrethroids were widely used.
Resistance Issues: Mosquito resistance to pyrethroids is rising, reducing ITN effectiveness New Solutions: New insecticides introduced to improve control and manage resistance.
IRS Importance: Effective in high-transmission areas and long-standing spraying programs. IRS Evolution: Shift from DDT (1950s-60s) to pyrethroid-based IRS (2000s)
Insecticide Resistance: Over-reliance on few insecticides is risk
Cost Implications: New insecticides are expensive but essential for malaria control.[8]

Malaria Challenges

Malaria control in India faces three major challenges: difficulty in implementing and managing control programs, growing resistance in mosquitoes to insecticides, and resistance of malaria parasites to medicines. India, being the second most populated country, struggles to provide effective healthcare to everyone. Though indoor spraying with insecticides like DDT and the use of insecticide-treated bed nets have helped reduce malaria in the past, mosquitoes have started developing resistance to these chemicals, especially in rural areas. This makes current control methods less effective over time.Similarly, the malaria parasite, especially *Plasmodium falciparum*, has become resistant to older medicines like chloroquine. As a result, new treatments like artesunate combined with other drugs are now used. However, there are signs that resistance to these newer treatments may also be developing, especially in the northeastern regions of India. Monitoring and tracking this resistance is difficult, especially since resistance can spread silently before treatment failure becomes obvious. To successfully fight malaria, India needs better disease surveillance, more research on how resistance spreads, and stronger health systems to keep up with changing threats. Without these efforts, it will be hard to maintain control over malaria in the long term.[9]

Drug Resistance

Malaria parasites are becoming resistant to many common anti-malarial drugs like chloroquine, amodiaquine, and mefloquine, making treatment harder, especially in Africa and Southeast Asia. Chloroquine, once the most affordable drug, now fails in up to 80% of cases. Artemisinin-based therapies remain effective, but selling artemisinin alone worsens resistance. Many anti-malarial drugs sold are poor-quality or fake. Drugs with long-lasting effects can help prevent reinfection but also increase resistance. Using similar drugs over time can make resistance worse, as seen with chloroquine and piperaquine. This makes it harder to develop new treatments before resistance spreads further. A malaria vaccine, RTS,S, offers 30–50% protection, yet better vaccines are needed.[10]

Climate Change

Malaria remains a major global health challenge, climate change is making the fight harder. Rising temperatures, rainfall changes, and humidity impact mosquito survival and malaria transmission. Climate change has expanded mosquito habitats, increasing the risk of malaria outbreaks, even in regions where it was previously eliminated. To tackle this growing threat, health systems must use advanced tools like artificial intelligence, predictive modelling, and GIS mapping. However, these technologies are not widely used in lower-income countries. Rapid urbanization and environmental changes worsen the situation, making preventive action crucial. By using science and technology, we can strengthen health systems and reduce the impact of climate change on malaria.[11]

Inadequate Health System

Primary health care centers did not have enough staff or proper facilities to provide good medical services, including accurate malaria diagnosis. To improve this, key areas need attention: training health workers to enhance their skills, hiring more staff, strengthening leadership and supervision, improving the supply of medical materials, and ensuring quality control in institutions. Additionally, better patient referral systems are needed.[12]

TREATMENT AND DRUG RESISTANCE

Antimalarial Drugs

Drug/Combination	Targeted Species	Mode of Action	Use
Chloroquine	*P. vivax*	Inhibits parasite digestion inside RBCs	First-line treatment
Artemisinin-based therapies (ACTs)	*P. falciparum*	Rapid action against blood stages	Severe malaria
Primaquine	*P. vivax*, *P. ovale*	Kills liver stage (hypnozoites)	Prevents relapses

Self Treatment

The CDC (Centers for Disease Control and Prevention) advises travellers to take malaria prevention medicine instead of relying on self-treatment. However, those who skip prevention, use the wrong drug, or need a weaker option are at higher risk of infection. Travelers in remote areas may carry atovaquone-proguanil for emergency self-treatment, but not if using it for prevention. Quinine-doxycycline is a less ideal backup. Self-treatment is only temporary, and seeing a doctor quickly is essential.

Malaria In Children

 Tetracycline and Doxycycline Are Not Safe for Young Children These antibiotics should be avoided in children under 8 years old.

They can deposit in bones and teeth, causing permanent tooth staining, weaker enamel, and slower bone growth. Because of these risks, doctors prefer alternative treatments.

 Clindamycin with Quinine as an Alternative

- When treating malaria in young children, clindamycin combined with quinine is a safer option.
- This avoids the risks linked to tetracycline and doxycycline.

 Mefloquine

suggests it for children over 6 months old, it is safe for children who weigh more than 5 kg. The most common side effect is vomiting, but otherwise, it is generally well tolerated.

Primaquine

Health authorities in the US and Canada do not specify a minimum age for primaquine.

- This suggests that it is considered safe for children when G6PD deficiency is ruled out.

Malaria in Pregnancy

- High Risk: Malaria can cause miscarriage, stillbirth, premature birth, low birth weight, and newborn death.
- Treatment for *P. falciparum*: Quinine + clindamycin is safe and recommended in chloroquine-resistant areas.
- Quinine Risks: Can lower blood sugar, but benefits outweigh the risks.
- Avoided Medications:
    - Atovaquone-proguanil & mefloquine (not recommended unless necessary).
    - Tetracycline & doxycycline (unsafe in pregnancy).
    - Primaquine (dangerous for G6PD-deficient babies).
    - *P. ovale* & *P. vivax* Treatment: Chloroquine or mefloquine weekly until delivery.
- After Delivery: Primaquine treatment is required.

Chloroquine

Chloroquine is a medicine that was originally developed to treat malaria, a disease spread by mosquito bites. Malaria is caused by parasites that enter the bloodstream and infect red blood cells. Chloroquine works by killing these parasites and stopping the infection from spreading in the body.

Hydroxychloroquine

Hydroxychloroquine is very similar to chloroquine, but it has one extra hydroxyl group (a small chemical change). According to a study by Tett, Cutler, Day, and Brown, this small difference does not change how the medicine works in the body in any important way.

So, hydroxychloroquine does not work in places where chloroquine resistance is common (where chloroquine is no longer effective).

For prevention (prophylaxis), hydroxychloroquine is taken the same way as chloroquine:

- Adults take one 400 mg tablet (which contains 310 mg of the actual working part, called the base).
- Maximum dose is one tablet.
- Children should be given 5 mg per kg of body weight.

Mefloquine

Mefloquine is a medicine used to prevent and treat malaria. It is similar to an older medicine called quinine

- Mefloquine works against Plasmodium falciparum and Plasmodium vivax, the parasites that cause malaria.
- It also works on chloroquine-resistant strains of P. falciparum (these are tougher types that don't respond to older treatments).
- It can kill the gametocytes (a stage of the parasite) of P. vivax, P. ovale, and P. malariae, which helps stop the spread of malaria to other people.

Quinine Sulphate –

Quinine sulphate kills malaria parasites that are inside red blood cells, especially during a stage called the "schizont phase.

- Stops the parasite from making proteins and energy.
    - Blocks the parasite from removing toxic waste (heme), which builds up and kills it.

Pyrimethamine and Sulfadoxine –

These two drugs are used together and work better as a team. They stop the malaria parasite from making folate, a vitamin it needs to grow.

- Pyrimethamine blocks an enzyme called DHFR.
- Sulfadoxine blocks another enzyme called DHPS. By stopping both enzymes, they prevent the parasite from surviving in red blood cells.

Doxycycline –

Doxycycline is actually an antibiotic, but it also helps treat malaria when used with other antimalarial drugs like quinine.

- Works during the red blood cell stage of the malaria parasite.
- Slowly kills the parasite.
- Doesn't affect the earlier or later stages of the parasite's life.
- It is processed in the liver.

Atovaquone and Proguanil

These two are combined into one tablet and work together:

- Atovaquone blocks the parasite's ability to make energy by stopping a part of its mitochondria (its power center).
- Proguanil stops the parasite from making DNA by blocking an enzyme needed for that process. Together, they kill the parasite effectively.

Artemether and Lumefantrine

This combo is very powerful against malaria:

- Artemether quickly kills parasites by producing chemicals that damage them.
- Lumefantrine stays in the body longer and helps kill any leftover parasites. Together, they clear the infection and reduce the chance of it coming back.[13]

Artemisinin-based combination therapies (ACTs)

 Effect: improves cure rates, and slows drug resistance.

 Benefits: Reduces malaria transmission in low-transmission areas; more research needed for high-transmission regions.

 Challenges: High cost, lack of awareness, safety concerns in pregnancy, misuse, supply issues, and weak post-marketing surveillance.

 Recent Progress: Increased uptake in the last two years due to global and local efforts.

 Funding Issues: The Global Fund supports ACT expansion, but delays in fund distribution slow implementation.

 Affordable Alternatives: Dihydroartemisinin-piperaquine (Artekin) is a cheaper option, suitable for widespread use.

 Need for Investment: More funding for research, healthcare infrastructure, and expert training in malaria-endemic countries.[14]

MALARIA VACCINATION

RTS, S/AS01 and R21 are the only malaria vaccines approved by WHO.

Both vaccines are based on the circumsporozoite protein (CSP) to provide partial protection. Using sporozoites or asexual-stage parasites as antigens can offer broader protection against multiple strains.

 Enhancing Vaccine Efficacy:

- R21 vs. RTS, S: R21 contains more CSP, reducing immune response to the hepatitis B surface antigen (HBsAg) carrier and improving effectiveness.
- Engineered Antigens: Modified antigens (e.g., AMA1 with RON2L) boost immune response and neutralize diverse parasite strains.

 Challenges:

- Prior malaria exposure or existing infection may weaken immune response to vaccines.
- Refining antigens and adjuvants alone may not fully overcome this issue.

 Future Strategies:

- Modulating the immune system to counter malaria-induced immune suppression.
- Potential treatments like DON (glutamine analogue), CD47, and interleukin-15 complex have shown success in severe malaria cases.[15].

PROGRAMME AND POLICIES

Global And Local Effort To Control Malaria

The World Health Organization (WHO) has implemented comprehensive malaria control programs that have significantly impacted public health globally. These programs focus on reducing malaria transmission and mortality through various strategies:

1. Vector Control: WHO promotes the use of insecticide-treated bed nets (ITNs) and indoor residual spraying (IRS) to reduce mosquito populations. For instance, between 2000 and 2015, these interventions contributed to a 60% reduction in global malaria mortality rates.
2. Antimalarial Medications: The organization recommends artemisinin-based combination therapies (ACTs) as the first-line treatment for Plasmodium falciparum malaria, improving patient outcomes and reducing transmission.
3. Surveillance and Rapid Response: WHO emphasizes strengthening health information systems to detect and respond to malaria cases promptly, preventing outbreaks and ensuring effective resource allocation.
4. Vaccination: In recent years, WHO has endorsed malaria vaccines, such as the R21/Matrix-M developed by Oxford University and the Serum Institute of India. This vaccine has shown 75% efficacy in the first year and is being distributed in high-burden countries like Nigeria. [16]

5. WHO's "High Burden to High Impact" Initiative Focuses on 10 worst-affected African countries + India, which together account for 70% of malaria cases worldwide.

Aims to increase political commitment, improve data usage, and enhance coordination for better malaria control.

Future Strategies and Innovation

Improved insecticides, Mass drug administration in high-risk areas

The RTS, S vaccine, though partially effective, is being tested for large-scale use.

Funding and Commitment

- Funding for malaria control has stagnated, slowing progress.
- More investment is needed from donor agencies and malaria-affected countries.
- Balance between elimination efforts and control in high-risk regions is crucial.
- Strengthen surveillance and data collection.
- Improve public health policies based on research.[17]

Malaria Control Programs In India:

National Vector Borne Disease Control Programme (Nvbdcp)

The National Vector Borne Disease Control Programme (NVBDCP) is the central agency tasked with controlling all vector-borne diseases in India, including malaria. Functioning under the Directorate General of Health Services, Ministry of Health and Family Welfare, NVBDCP is responsible for formulating technical guidelines, setting policies, and monitoring the implementation of malaria control activities.

1. **Disease Management**

Early detection and complete treatment of malaria cases.

Annual Blood Examination Rate (ABER) target: ≥10% of the population.

2. **Integrated Vector Management (IVM):**

- Reduction of vector populations through environmental and chemical interventions.
- Distribution of insecticide-treated bed nets (ITNs) in high-risk areas.

3. **Supportive Interventions:**

Behaviour change communication, capacity building, and program monitoring & evaluation.

4. **Innovative Initiatives**

- Under the National Rural Health Mission (NRHM), Accredited Social Health Activists (ASHAs) have been trained to:
  - Conduct rapid diagnostic tests (RDTs).
  - Administer antimalarial drugs at the village level.

5. **Monitoring and Evaluation**

- NVBDCP carries out fortnightly household surveillance for malaria.
- The National Institute of Malaria Research (NIMR), under the Indian Council of Medical Research (ICMR), provides technical support by:
  - Evaluating new insecticides and diagnostic tools.
  - Conducting clinical trials.
  - Monitoring resistance patterns in parasites and vectors
  - Ensuring quality assurance an RD [18]

PUBLIC AWARENESS AND EDUCATION

Public awareness campaigns, like national awareness days, can help prevent the spread of infectious diseases by getting people interested and informed. Insecticide-treated nets (ITNs) are one of the best ways to prevent malaria. This support is helping to improve malaria testing in hospitals and healthcare centers and provide ITNs to communities. Special malaria teams, made up of health workers, distribute the nets and give advice on malaria prevention. Community media played the biggest role in spreading malaria awareness, using different publicity materials.

- Posters and bulletin boards in village clinics and township hospitals.
- Monthly malaria information published in newspapers by health authorities.
- Educational materials like exercise books for students.
- Shopping bags, aprons, and cups printed with malaria messages for the general public.

- Leaflets and banners for workers traveling to malaria-prone areas.
- Only few villagers got malaria knowledge through community media, suggesting the need to expand these efforts to reach more people, especially in remote areas.

Factors Affecting Malaria Awareness:

- Location & Malaria History: People living in areas with more malaria cases and those who had suffered from malaria knew more about the disease.
- Education & Income: Those with more than 9 years of education and middle-income households had higher malaria awareness

Age & Distance to Hospitals:

Older people knew more about malaria, likely because they experienced past outbreaks

- Needs More Attention
- People with less than 9 years of education.
- Residents in remote areas who don't receive malaria information.[19]

CONCLUSION

Malaria remains a major public health concern, especially in tropical and subtropical regions with limited access to healthcare. Despite progress in prevention and treatment, the disease continues to cause significant illness and death, particularly among children under five and pregnant women. The health consequences of malaria are severe. Repeated infections weaken the immune system, hinder child development, and increase maternal and infant mortality. Pregnant women face higher risks of complications, including anemia and low birth weight, which can lead to long-term health issues for both mother and child. Beyond health, malaria imposes a heavy economic burden. Families face medical expenses, lost income, and reduced productivity. At the national level, malaria drains healthcare resources, limits workforce capacity, and hinders economic development. In highly affected areas, it contributes to cycles of poverty and slows progress in education and social welfare. Efforts to control malaria—such as insecticide-treated nets, indoor spraying, antimalarial drugs, and improved diagnostics—have led to notable improvements. However, challenges like drug and insecticide resistance, climate change, and weak healthcare infrastructure continue to threaten progress. Addressing malaria effectively requires a comprehensive approach that includes stronger health systems, continued research and innovation, community awareness, and consistent global support. Collaborative efforts between governments, health organizations, and local communities are essential to reduce transmission and improve outcomes. In conclusion, malaria's impact on public health is deep and wide-reaching. It affects not only individual health but also economic stability and development. Sustained action is vital to control and eventually eliminate the disease. Reducing the burden of malaria will contribute significantly to global health equity and the achievement of broader development goals.

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