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21W.732

MALARIA CONTROL

Abstract

Every year, malaria continues to claim over a million lives around the globe. Attempts have been made to control the disease by eliminating the parasite. However, with a hundred plasmodium species known to cause malaria, eradication of the parasite remains a daunting task. As a result, increased efforts and resources have been channeled towards finding ways of minimizing human-vector contact, thereby controlling the disease. In this review article, methods addressed include use of treated bed nets and curtains, indoor residual spraying, repellents, larvivorous fish and DDT. This article also chronicles the search for the most effective combination of the above methods in combating malaria.

Introduction

Every year, malaria kills 20% of all children under the age of five across the globe. The World Health Organization estimates that 75,000 to 200,000 infants die annually due to malaria, mostly in sub-Saharan Africa. Millions of fatalities are attributed to malaria alone every year; therefore, it comes as no surprise that tremendous resources have been channeled towards eradicating the disease.

Malaria is caused by the single-celled parasite, *Plasmodium*, which is found in the blood of infected humans and *Anopheles* mosquitoes. Most of the 100 known species of the plasmodium parasite are capable of causing malaria (2). The disease is transmitted when a mosquito with the plasmodium parasite bites a healthy human being. Once in the

bloodstream of the human being, the parasites migrate to the liver, where they multiply in the liver cells. They then invade the red blood cells and multiply in the corpuscles before causing them to rupture and release more parasites. This continues unabated unless the person's immune system kills all the parasites in the body (2). If untreated, resulting complications eventually cause death. Malaria vectors thrive in the warmth of the tropics, especially in Africa, South America and Asia.

For a long time, large scale spraying of DDT was considered the standard method of dealing with malaria. However, since the ban on DDT in 1972, due to detrimental effects of DDT on the environment, malaria has been on an upsurge, continuing to claim over a million lives every year. Researchers have been working hard towards finding alternative, and, if possible, better methods of combating the disease. Due to the diversity of the plasmodium species, eliminating the parasite itself has proven challenging to say the least. As a result, over the course of the last few years, researchers have expended greater time and energy in finding ways to minimize human-vector contact, thereby significantly reducing infection rates.

Researchers have investigated traps, treated bed nets and curtains, larvivorous fish, mosquito repellents and indoor residual spraying as possible ways of combating malaria. It has been established that the effectiveness of any one method depends on factors such as location, reception of the native population and ecological effects, such as in the case of larvivorous fish. In addition to the above studies, some researchers have continued investigating DDT use in an attempt to limit its damage to the environment while still realizing its potential as an effective anti-malaria pesticide.

Studies have shown that the success of some methods of mosquito control, such as use of impregnated bed nets, is dependent on certain socio-cultural factors. Social attitudes therefore have to be considered before and during implementation of mosquito control projects. The main mosquito control methods that have been researched upon are discussed below.

Traps

Traps are used to estimate vector population density and as such help determine which methods of dealing with mosquitoes are most appropriate for a given region. In the past, the customary method has been the landing/biting technique, in which a person tries to catch all the mosquitoes that attempt to bite him/her. Recently, a number of traps have been developed by different research and industrial groups as an alternative to the landing/biting method. Recent traps include: the American Biophysics Corporation counter flow geometry trap (ABC CFG), the CDC style light trap (LT) with dry ice, the ABC mosquito magnet (MM) trap, the ABC standard light trap (ABC LT) and the Nicosia and Reinhardt Company Mosquito Attractor Device (N and R trap). Since most of these traps have only been recently developed, there is insufficient data on their efficiency in ensnaring mosquitoes. In a paper published in the Journal of Medical Entomology, Ratana Sithiprasasna and a group of other researchers carried out an evaluation of comparative trapping efficiencies of several light traps and compared these with landing/biting (L/B) in western Thailand(3). Ratana Sithiprasasna and her colleagues found that the landing/biting method was significantly more effective than any of the mosquito traps tested. However, they suggested that after further research, certain traps could become useful substitutes for the traditional landing/biting technique in measuring mosquito population.

In spite of the promise of light traps suggested by Ratana et al, the cost of developing traps on a large scale limits their range of application as a means of determining vector population density. Traps are therefore likely to remain a localized phenomenon of malaria research, at least for the next few years.

Oils and Repellents

For centuries, humans have used some form of repellent, such as smoke from burning herbs, to deal with mosquitoes. Natural based oils and plant extracts have been considered as potential insecticides, particularly because the availability of such substances within a local setting greatly reduces cost of large scale manufacture. S. Rajkumar and A. Jebanesan investigated effects of *Solanum trilobatum* (a common shrub in India) both as an oviposition deterrent and a skin repellent (4). The two researchers found the plant extract to be effective in reducing ovipositon of the *Anopheles stephensi* mosquito. When applied to the skin, the plant extract was found to have significant repellent effects, which varied from 70-100 minutes, depending on the concentration of the extract. The two recommended further studies to observe the effects of the plant extract on other mosquito species.

In a separate study done in Thailand, finger root rhizomes, guava leaves' extract and turmeric rhizomes were found to exhibit repellent effects for up to 9 hours(5). These studies provide a promising prospect for development of effective and environmentally friendly anti-malaria insecticides.

Larvivorous fish

The use of fish that predate on mosquito larvae has also been studied as a means of mosquito control. Neeru Singh et al investigated the effectiveness of larvivorous fish,

specifically the *Gambusia spp*, in dealing with Anopheles larvae, but came up with inconclusive results. This was partly due to a lack of similar studies with which to compare their findings (6).

In a separate study conducted by Jennifer Keiser et al, a variety of fish species were used as predators-the most popular being the mosquito fish (*Gambusia affinis*) (7). Other species used included Tilapia spp and *Poecilia reticulata*. On a short term basis, the fish considerably reduced mosquito larvae population. However, the researchers felt that more studies were needed before larvivorous fish could be widely implemented as a form of vector control. This is because introducing foreign species in a water body may adversely affect native fish species and thus interfere with local ecosystems. Studies are also needed to determine how fish populations in water bodies are influenced by temperature, pesticides and chemical pollutants, and how various fish species react to different *Anopheles* species. Therefore, the search for the 'perfect' larvivorous fish is yet to come to a definite conclusion.

Treated bed nets and curtains

In light of the difficulties faced by use of traps and larvivorous fish, treated nets appear more promising in dealing with malaria vectors. In most rural populations, misuse of prescribed drugs by a majority of the population means that the plasmodium parasite develops resistance to drugs over time. Control of the mosquito therefore becomes increasingly important. Consequently, a lot of research has focused on the use of bed nets and curtains and substances with which to treat them. In a study conducted in Northern Ghana by FN Binka et al, insecticide-impregnated bed nets were found to substantially reduce occurrence of malaria in the population, especially in the wet season (8). Another

study carried out in a number of villages in south-central Malawi also showed that curtains treated with permethrin significantly reduced malaria infection rates (9).

As mentioned earlier, introducing treated bed nets and curtains is complicated by human attitudes, since treated bed nets are met with varying responses depending on the recipient population. A good example of the effect of socio-cultural factors can be seen in the study carried out in Northern Ghana. The researchers introduced insecticide-impregnated bed nets in a number of villages and investigated the response of the native population. Villagers' views regarding bed nets were recorded by means of questionnaires. The researchers organized village meetings in which they demonstrated the use and treatment of nets, and advised villagers to treat the nets every six months. F. N. Binka's findings suggest that social attitudes and cultural inclinations are a factor in the success of bed nets. Some of the villagers preferred traditional methods of dealing with the mosquito, such as burning herbs to 'chase away' mosquitoes. Majority of the villagers felt that bed nets were too expensive and thus the former did not plan on purchasing any nets unless they were provided for free. Inaccessibility of treated bed nets in local markets was also a factor that contributed to the low use of bed nets in rural populations. A small fraction of the respondents complained of side effects such as coughing, sneezing, headaches and dizziness that might have been induced by the pyrethroid insecticide that was used to treat the nets. This might have influenced the adoption of the nets.

Another example of the influence of socio-cultural factors on malaria control can be seen in the study carried out in south central Malawi (9). Before the introduction of the treated curtains, most of the villagers used natural methods to deal with mosquitoes since nets were unaffordable. Village workers were trained to help with the project. Majority of

the villagers adopted the curtains. The nature of village leadership was found to be related to adoption percentages: villages with conservative leadership were less likely to adopt the curtains.

A separate study conducted by Collins Ahorlu et al in southern Ghana clearly portrays the effect that social attitudes have on efforts to control malaria. In this study, socio-cultural determinants of treatment delay for childhood malaria were investigated (10). The findings suggest that poverty, lack of knowledge of the root cause of malaria, magico-religious beliefs and lack of access to drugs were some of the reasons why most children were not treated within the first 48hrs after symptoms appeared. The researchers felt that focusing on educating the public on the cause of malaria was less of a priority as compared to emphasizing prompt and effective treatment, as the latter is a surer way of minimizing fatalities.

Indoor Residual Spraying and DDT

Indoor Residual Spraying is defined as: "application of long acting chemical insecticides on the walls and roofs of all houses in order to kill adult vector mosquitoes that land and rest on these surfaces (11)." Before the 1970s, DDT was extensively used for agricultural purposes, especially on large farms. On most occasions, DDT was applied on a large scale using airplanes. With time; however, public concern on the effect of DDT on the environment led to a ban of DDT use in 1972 in the USA. Following the ban, numerous studies have been conducted to determine the detrimental effects of DDT. Most of the initial findings found a relation between DDT and cancer and prenatal disorders, and other environmental effects (12). This has led to a significant decline in use of DDT in most countries. However, over the past few years, the World Health Organization has

proposed the reintroduction of DDT as an anti-malaria pesticide, citing articles that show the effectiveness of DDT in controlling vector populations. The WHO argues that if used in a controlled manner and on a much smaller scale than was the case before the 1970s, DDT still remains the most effective tool that exists against malaria. However, there remains a considerable risk of misuse and so the WHO proposes adoption of a coordinated and well organized approach if DDT use is to be environmentally friendly (11).

Recently published studies support the assertion by the WHO that DDT remains effective. One study in India found that controlled use of DDT led to a significant reduction in the number of malaria cases, with an even more remarkable drop in cases among infants (13). A study in KwaZulu Natal revealed that DDT use, when used in combination with prompt treatment and improved vector control, was highly effective in reducing mosquito populations in the area (14).

Amid talk of phasing out DDT in India, Gunasekaran et al introduced indoor DDT spraying in 54 villages in India. The chemical was found to remarkably reduce malaria incident rates when used in controlled amounts (15). In a research study carried out in the Solomon Islands, residual spraying using DDT was also found to considerably lower malaria infection rates (16)**.** The results of some studies also suggest that there are other chemicals that are also effective when used for Indoor Residual Spraying. A research study conducted in Thailand also shows the effectiveness of DDT as a repellent, especially when combined with other insecticides (17)**.** A study in Central India found that a pyrethroid insecticide, when combined with early diagnosis and treatment, was more effective than DDT when used for indoor residual spraying (6). This was because vectors in the area,

such as *Anopheles culicifacies* had developed resistance to DDT. The chemical's use is therefore limited to areas where vectors have not developed resistance.

Multiple Strategies

With malaria mortality rates still disconcertingly high, it comes as no surprise that studies have been carried out to determine the effect of using different mosquito-control methods simultaneously. In a study carried out in Equatorial Guinea, researchers investigated the effect of using both insect treated nets (ITNs) and Indoor Residual Spraying (IRS) to combat malaria vectors (18)**.** Up to the beginning of the last decade, use of treated nets had been the main method by which malaria was kept under control in the country. When an IRS campaign was introduced in 2004 in the island of Bioko in Equatorial Guinea, it was found that infection rates dropped by 50%. However, the success of this two-pronged attack on malaria was found to depend on presence of skilled personnel and adequate financial backing. In the Thailand study, the repellent effects of DDT, deltamethrin and lambdacyhalothrin were investigated (17). High vector mortality rates were found when DDT was used in association with the other chemicals.

For a long time, pyrethrum based insecticides were the traditional mode of dealing with mosquitoes. Recently, however, a resistance to pyrethroid insecticides has been noted in certain *Anopheles* species. Studies have therefore been conducted to investigate the effects of using more than one insecticide/repellent. In one study by Cedric Pennetier et al, a repellent (DEET) was used in conjunction with a non-pyrethroid insecticide (propoxur) (19). The combination was found to be effective against *Anopheles* species that were both non-resistant and resistant to pyrethroid insecticides.

Another multiple-strategy approach was carried out in Northern Vietnam, in which Mesocyclops (an omnivorous arthropod that feeds on mosquito larvae) was used in water storage tanks. This was done together with large scale communal clean ups that were held regularly in the region. This program proved remarkably effective in reducing the vector population, which breeds mainly in large water bodies. It is interesting to note that majority of the natives in the area were willing to participate in the project, and this had a significant impact on the project's success rate (20).

In Mali, insect treated nets (ITNs), insecticide spraying and mosquito coils were used in a large scale malaria prevention program. The program proved significantly successful at reducing malaria infection rates. It was noted that most people used sprays and coils, mainly due to cost constraints, lack of knowledge of ITNs and unavailability of net treating services in many rural areas. (21)

In Eritrea, a combination of IRS, larvicidal activities and malaria case management was used to combat malaria between 2000 and 2004 (22). Due to increased vector resistance to chloroquine, the drug was used together with sulfadoxine-pyrimethamine. Malaria infection rates over the 4 year period fell drastically. It was noted that the drop in infection rates was closely related to the amount of DDT used for IRS and the number of insect treated bed nets (ITNs) distributed. This suggests that of all the methods used, ITN and IRS were the most effective. The findings of the Solomon Islands study also found that residual spraying using DDT was much more effective when used together with impregnated nets-malaria infection rates went down by two thirds. However, this resulted in increased implementation and sustenance costs was a negative consequence and so the

researchers recommended further studies to find out which combination would prove to be most cost effective.

Another malaria control strategy was investigated by Romir et al (23) in Madagascar, whereby yearly residual spraying was used in conjunction with a program by means of which antimalarial drugs were made significantly more available to rural populations. This strategy also proved effective in keeping vector population at a minimum, and thereby reducing infection rates.

Conclusion

At present, DDT remains our best large scale option against malaria. However, it remains to be seen whether countries will allow for a reintroduction of a chemical that has been the cause of so much controversy over the past four decades. With the malaria vaccine not yet at hand, it is clear that more research is needed in the proper introduction and management of DDT, bed nets and insecticide-treated curtains in large rural populations. Identifying environmentally friendly ways of controlling vector populations in malaria prone regions remains one of the major challenges that researchers have to face.

The use of multiple mosquito control methods simultaneously has been shown to be almost always more effective, but this is hampered by increased costs (16). More research is therefore needed to find the most cost effective and environmentally friendly combination of malaria control strategies. Once this has been done, defeating malaria will only be a matter of time.

References:

1. World Health Organization Website
2. National Institute of Health Website
3. Evaluation of Candidate Traps as Tools for conducting Surveillance for Anopheles Mosquitoes in a Malaria-Endemic Area in Western Thailand. By Ratana Sithiprasasna, Boonsong Jaichapor, Somporn Chanaimongkol, Patcharee Khongtak, Tarnthong Lealsirivattanakul, Somsak Tiang-Trong, Douglas A. Burkett, Michael J. Perich, Robert A. Wirtz and Russell E. Coleman. Journal of Medical Entomology, volume 41, Issue 2, March 2004.
4. Oviposition deterrent and skin repellent activities of Solanum trilobatum leaf extract against the malarial vector Anopheles stephensi, by S. Rajkumar and A. Jebanesan. Journal of Insect Science, 10th May 2005.
5. Field evaluation of deet, Repel Care, and three plant based essential oil repellents against mosquitoes, black flies (Diptera:Simuliidae) and land leeches in Thailand. B Tawatsin A, Thavaru U, Chansang U, Boonruad T, Wongsinkongman P, Bansidhi J, Mulla MS and Chavalittumrong P., Journal of American Mosquito Control Association, 2006 June.
6. Malaria control using indoor residual spraying and larvivorous fish: a case study in Betul, central India. By Singh N, Shukla MM, Mishra AK, Singh MP, Paliwal JC, Dash AP. Tropical Medicine and International Health Oct 11, 2006.
7. Effect of irrigated rice agriculture on Japanese encephalitis, including challenges and opportunities for integrated vector management. By Jennifer Keiser, Michael F. Maltese, Tobias Erlanger, Robert Bos, Marcel Tanner, Burton H. Singer and Jurg Utzinger. Acta Tropica vol. 95, issue 1.
8. Acceptability and use of insecticide impregnated bednets in northern Ghana by F. N. Binka and P. Adongo. Tropical Medicine and International Health May 1997, volume 2 page 499.
9. Implementing a malaria curtains project in rural Malawi. By Marcia Rubardt, Augustin Chikoko, Deborah Glik, Stan Jere, Okey Nwanyanwu, Weiying Zhang, Wilfred Nkhoma and Charles Ziba. Health Policy and Planning, 1999. 14(4): 313-321
10. Socio-cultural determinants of treatment delay for childhood malaria in southern Ghana. Collins K. Ahorlu, Kwadwo Koram, Cynthia Ahorlu, Don de Savigny and Mitchell Weiss. Tropical Medicine and International Health. Volume 11 no7 pp1 022-1031. July 2006.
11. WHO- Global Malaria Programme 2006
12. Environmental Study Group Website
13. Impact of DDT spraying on malaria transmission in Bareilly District, Uttar Pradesh, India. SN Sharma, RP Shukla, K Raghavendra and Sarala K. Subbarao. Journal of Vector Borne Diseases 42, June 2005, pp54-60
14. Effect of Artemether-Lumefantrine Policy and Improved Vector control on Malaria Burden in KwaZulu-Natal, South Africa. Karen Barnes, David Durrheim, Francesca Little, Amanda Jackson, Ushma Mehta, Elizabeth Allen, Sicelo Dlamini, Joyce Tsoka,

Barry Bredenkamp, Jotham Mthembu, Nicholas White, Brian Sharp. Public Library of Science Medicine. Published October 4th 2005.

15. DDT indoor residual spray, still an effective tool to control Anopheles fluviatilis-transmitted Plasmodium falciparum malaria in India. By Gunasekaran K, Sahu SS, Jambulingam P and Das PK. Tropical Medicine and International Health, Feb 2005.
16. Impregnated nets or DDT residual spraying? Field effectiveness of malaria prevention techniques in Solomon Islands, 1993-1999. Mead Over, Bernard Bakote'e, Raman Velayudhan, Peter Wilikai and Patricia Graves. American Journal of Tropical Medicine and Hygiene. 2004
17. Behavioral responses to DDT and pyrethroids between Anopheles minimus species A and C, malaria vectors in Thailand. Potikasikorn J, Chareonviriyaphap T, Bangs MJ, Prabaripai A. American Journal of Tropical Medicine and Hygiene August 2005
18. Impact of different strategies to control Plasmodium infection and anaemia on the island of Bioko (Equatorial Guinea) by Gema Pardo, Miguel Angel Descalzo, Laura Molina, Estefanía Custodio, Magdalena Lwanga, Catalina Mangue, Jaquelina Obono, Araceli Nchama, Jesús Roche, Agustín Benito and Jorge Cano Malaria. Journal 2006 volume 5.
19. Combination of a non-pyrethroid insecticide and a repellent: a new approach for controlling knockdown-resistant mosquitoes. By Pennetier C, Corbel V. and Hougard JM. American Journal of Tropical Medicine and Hygiene. April 2006
20. Control of aedes vectors of dengue in three provinces of Vietnam by use of Mesocyclops (Copepoda) and community-based methods validated by entomologic, clinical, and serological surveillance. By Kay BH, Nam VS, Tien TV, Yen NT, Phong TV, Diep VT, Ninh TU, Bektas A, Aaskov JG. America Journal of Tropical Medicine and Hygiene. January 2002.
21. Malaria prevention practices in Mopti region, Mali. By Rhee M, Sissoko M, Perry S, Dicko A, McFarland W, Doumbo O. East African Medical Journal Aug. 2005
22. A steep decline of malaria morbidity and mortality trends in Eritrea between 2000 and 2004: the effect of combination of control methods. By Nyarango PM, Gebremeskel T, Mebrahtu G, Mufunda J, Abdulmumini U, Ogbamariam A, Kosia A, Gebremichael A, Gunawardena D, Ghebrat Y, Okbaldet Y. Malaria Journal April 2006.
23. Impact of the malaria control campaign (1993-1998) in the highlands of Madagascar: parasitological and entomological data. By Romi R, Razaiarimanga MC, Raharimanga R, Rakotondraibe EM, Ranaivo LH, Pietra V, Raveloson A, Majori G. American Journal of Tropical Medicine and Health Jan 2002.