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MALARIA CONTROL BY APPLICATION OF INDOOR SPRAYING
OF RESIDUAL INSECTICIDES IN TROPICAL AFRICA AND
ITS IMPACT ON POPULATION HEALTH

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The "WHO Inter-regional Conference on Malaria Control in countries where time-limited eradication is impractical at present", Brazzaville, 1972, reached the conclusion that insecticides remain "the most effective weapon in the hands of malariologists for controlling rural malaria" and it has been recommended that intradomiciliary insecticide spraying "should be promoted in situations where this measure is considered by experts to be the method of choice" (WHO, 1974a).

In using this method, considerable experience has been accumulated in tropical Africa during the last 30 years, especially at the time when numerous malaria eradication pilot projects were operating in different parts of Africa with the assistance of WHO and UNICEF, aiming at the interruption of malaria transmission. Most of these projects have failed to achieve the primary objective, although a considerable degree of malaria control was attained by some of them; however, very little information on the results of these studies has been published.

On the other hand, there were only few systematic attempts of investigating the impact of different degrees of malaria control on population health.

This review aims at assessing the past experience in the use of residual insecticides for malaria control in tropical Africa in the light of the revised strategy and at providing the Public Health Officers responsible for antimalaria operations with information regarding (a) the degree of malaria control to be expected from the use of indoor spraying with different insecticides in the main epidemiological zones, and (b) the benefit to be expected from these control measures in terms of improvement of health of the population.

1. Use of house-spraying with residual insecticides in the control of malaria in rural
    areas of tropical Africa

Between the two World Wars, antilarval operations were the traditional, and almost the only malaria control measures applied on a relatively large scale in Africa. In general, these operations were restricted to urban areas of political, strategic and economic importance. During this period there were, however, some successful attempts to control malaria by house-spraying with pyrethrum. The work was pioneered by Giemsa in 1911 at the military barracks of Dar es Salaam (Clyde, 1967) and during the two following years these measures were successfully applied by Balfour (1913) in cabins and holds of steamers on the Nile River. The high cost of the material hampered this approach until the beginning of the 1930s when severe malaria epidemics became a threat to some recently established agricultural and economic enterprises. Systematic application of this method brought down the epidemics of malaria in South Africa (Booker, 1935; de Meillon, 1936; Ross, 1936) and reduced malaria incidence in other parts of Africa (Eddey, 1944; Garnham & Harper, 1944). The method

greatly contributed to the control of malaria epidemics caused by the introduction of
Anopheles gambiae to Brazil and Egypt and to the eradication of this species from these two
countries (Soper, 1949).

The strategy of malaria control in Africa south of the Sahara did not change much in the
1940s, although the potentialities of chlorinated hydrocarbon insecticides for malaria control
in rural Africa were realized quite early in Natal and Transvaal (Annecke, 1950), Mauritius
(Dowling, 1951), and West Africa (Davidson, 1947; Thomson, 1947a, b).

Large-scale malaria control programmes using house-spraying with DDT and BHC were
initiated in 1948-1949 in South Africa, Swaziland, Southern Rhodesia, Madagascar and Mauritius.
However, by the end of 1949, no more than 500 000 persons were living in areas protected by
this measure (Pampana, 1950). In order to promote the expansion of malaria control activi-
ties in rural areas of tropical Africa, the First African Malaria Conference (also known as
"Malaria Conference in Equatorial Africa, 1950") was organized in 1950 in Kampala by WHO and
the Commission for Technical Cooperation in Africa south of the Sahara. This Conference
recommended that "whatever the original degree of endemicity, malaria should be controlled by
modern methods as soon as feasible and without awaiting the outcome of further experiments"
(WHO, 1955).

As a result, operating control programmes were extended in 1952-1953 and eight projects
were newly established with the assistance of UNICEF and WHO in order to demonstrate the
effectiveness of malaria control by house-spraying with residual insecticides in different
epidemiological conditions of tropical Africa (in tropical forest areas - South Cameroon and
Liberia; in lowland savanna - North Cameroon, Nigeria, Senegal, Upper Volta; in degraded
forest - Benin, Togo). By 1955, some 166 million people were living in malarious areas in
Africa south of the Sahara; of these, 14 million were protected by some type of measure and
nine million by house-spraying with DDT, BHC or dieldrin.

The control operations yielded excellent results at the limits of tropical Africa where
malaria is seasonal and of the unstable type (South Africa, Swaziland, Southern Rhodesia,
high plateau and south coast of Madagascar), and in the islands (Mauritius, La Réunion); in
these areas, malaria transmission was interrupted in large territories and malaria incidence
and prevalence were drastically reduced. A considerable degree of malaria control was
obtained in Rwanda and Burundi, the eastern coast of Madagascar and in some schemes in West
Africa, but nowhere was malaria transmission interrupted at the beginning of 1955. The
failure to interrupt malaria in tropical Africa led to a temporary exclusion of Africa from
the Global Malaria Eradication programme which started in 1955. The results of the first
few years of malaria control operations in Africa south of the Sahara were discussed at length
by the Second African Malaria Conference held in Lagos at the end of 1955. It was recognized
that in large areas of tropical Africa, malaria was little or not at all responsive to the
measures applied. This lack of success was ascribed to the high intensity of transmission,
the behaviour of A. gambiae, the development of resistance in A. gambiae to dieldrin, the
characteristics of residual insecticides, the effect of sorption on mud surfaces, the mobility
of the population and the limited size of the trial areas allowing reintroduction of vectors.
The Conference therefore recommended that insecticidal attack be supplemented by chemotherapy.
While agreeing with this, the WHO Expert Committee on Malaria in its Sixth Report (WHO,
1957) recommended at the same time "further studies on eradicating malaria by residual
spraying". During the subsequent five years, practically all efforts in the fields of
malaria control in tropical Africa were directed towards this goal and Malaria Eradication
Pilot Projects (MEPP) were implemented.

After some unsuccessful attempts of interrupting the transmission of malaria by a
combination of residual house-spraying and chemotherapy in the African savanna and in savanna
areas with relict forest, the Malaria Eradication Pilot Projects were reviewed by joint WHO,
UNICEF and government teams. It was established that in all instances the quality of
spraying operations was below the required level. WHO continued to stimulate further efforts
and new large MEPPs were set up in Sudan, Ethiopia, Somalia and Uganda, in addition to the

existing projects. At the same time, malaria eradication programmes were implemented on the islands of Pemba and Zanzibar, while the malaria control programmes in South Africa, Swaziland, Mauritius and La Réunion were converted into countrywide malaria eradication programmes.

By the end of 1960, more than 4.4 million people (in the Republic of South Africa, Swaziland, Rhodesia and Mauritius) were living in areas where the malaria eradication programmes had reached consolidation or maintenance phase and some 6.6 million people were protected by spraying operations aimed at the interruption of malaria transmission. The increase of technical, administrative and operational efficiency in the application of residual insecticides resulted in the near interruption of malaria transmission in forest areas of South Cameroon and Liberia (Choumara, 1962; Guttuso, 1962) as well as in highland savanna areas with an altitude above 1000 metres in Madagascar and Uganda (WHO/AFRO, 1960; de Zulueta, 1962). Good results (reduction to one-fifth to one-eighth of the original parasite rates) were observed in the degraded forest areas of Togo and Benin. In the fringe areas of savanna and semi-desert zones, very good results were obtained in the Sudan and in Somalia where malaria was hypo- to meso-endemic. In all these areas, A. funestus almost disappeared and A. gambiae densities showed a spectacular decrease. The other local vector populations followed this trend. In the lowland savanna areas of western Africa, where malaria was hyper- and holo-endemic, the reduction of parasite rates was less impressive and, as a rule, short-lived. In many instances, dieldrin proved to be more effective than DDT, but its higher cost, its toxicity to mammalians and the fast-spreading resistance of A. gambiae to this insecticide limited its further use in tropical Africa.

Assessment of the progress of these trials was based on the results of parasitological and entomological surveys, but the opportunity of studying the effect of their reduction on community health has been missed. An exception was the Pare Taveta control scheme in the highland savanna area of Tanzania where some of these aspects were closely examined (Draper & Smith, 1960; Draper & Draper, 1960; Pringle & Matola, 1967).

By this time, experience gathered by Malaria Eradication Programmes throughout the world indicated that the feasibility of malaria eradication depends not only on the possibility of interrupting malaria transmission but also on factors associated with the level of socio-economic development of the countries concerned.

As a result, the Expert Committee on Malaria in its Eighth Report (WHO, 1961) warned the developing countries against launching malaria eradication programmes before ensuring that certain minimum requirements had been fulfilled.

The postponement of malaria eradication programmes in Africa led to the termination of most of the Malaria Eradication Pilot Projects with the exception of those in Nigeria, Senegal, Sudan, Togo and Uganda, which were converted into malaria demonstration areas for Malaria Pre-eradication Programmes. Between 1961 and 1965, no new Malaria Eradication Programmes were launched in the region, but the existing ones still continued their activities. By the end of 1965, approximately 500 000 people were living in areas protected by house-spraying with residual insecticides (WHO, 1966). In the formerly hyper- and holo-endemic malarious areas, malaria epidemics did rarely occur after cessation of spraying operations, probably due to the fact that the persistence of a low level of malaria transmission has maintained some degree of protective immunity in the population.

During the next 10 years, malaria was eradicated in the islands of Mauritius and La Réunion. Two more countries are gradually approaching this goal (South African Republic and Cape Verde Islands). The Malaria Eradication Programme launched in Ethiopia in 1966 is making little progress towards its ultimate goal, but a certain degree of malaria control has been achieved in the mountainous areas where malaria was previously of the meso-endemic or epidemic type. During this period, spraying operations were discontinued in Southern Rhodesia Zanzibar and Pemba and in many areas of Swaziland, but the initially achieved high degree of malaria control has nevertheless been maintained.

Various reasons were given for the cessation of large-scale insecticide spraying operations in tropical Africa in the early 1960s, and for failing to resume such operations after the WHO revision of the Global Strategy of Malaria Eradication in 1969. Today, some of these reasons are no longer valid, but others continue to hold true. The former category of reasons pertains to:

(a)   the unwillingness of some agencies, international and bilateral, to assist malaria control programmes;

(b)   the fear of promoting vector resistance to insecticides by the continuation of spraying operations until malaria eradication might become feasible;

(c)   fears created by supporters of the DDT-prohibition movement in the United States of America and in Europe.

To avoid any misunderstanding, WHO clearly stated that "malaria control is a necessary and valid step towards the ultimate goal of eradication", and as such is eligible for the same amount of assistance as malaria eradication (WHO, 1971). The Organization also took a strong stand against attempts to ban the use of DDT for public health programmes and submitted sufficient evidence that indoor spraying with DDT adds little, if anything, to the pollution of the environment (WHO, 1974b). At the same time, WHO collected and presented convincing evidence idicating that house-spraying with residual insecticides, especially with DDT, contributes little to the development of resistance in vectors as compared with the massive amounts used in agriculture (WHO, 1974a).

Other obstacles to the expansion of spraying operations with residual insecticides include:

(a)   High cost of residual insecticides. Even in the early 1960s when DDT was comparatively cheap, the annual per capita cost of malaria eradication activities in tropical Africa (US$ 0.80) was hardly less than the annual per capita health expenditure. It is certainly much higher now, after the price of DDT has risen by nearly 300%. All alternative insecticides are considerably more expensive, and since most of them require more frequent application than DDT, the overall operational cost is many times higher than with the use of DDT.

(b)   Vector resistance to insecticides. During the last 15 years, considerable changes have occurred in the susceptibility of A. gambiae and A. funestus to chlorinated hydrocarbons as a result of extensive use of insecticide in agriculture. In the early 1960s, dieldrin resistance had only developed in A. gambiae and was restricted to the western part of the African continent; today it is widespread throughout Africa and also recorded in the A. funestus populations of Cameroon, Central African Republic, Ghana, Nigeria and Upper Volta. During the past eight years, A. gambiae has developed DDT resistance in some areas of Benin, Cameroon, Central African Republic, Congo, Ethiopia, Gambia, Guinea, Mauritius, Nigeria, Senegal, South African Republic, Sudan, Togo and Upper Volta. No reports of DDT resistance in A. funestus have appeared up till now.

In the search for suitable substitutes for DDT in areas where vectors have developed resistance to this insecticide, WHO has implemented field trials of candidate insecticides in Africa; such compounds include dichlorvos (Foll et al., 1965), malathion (Najera et al., 1965), propoxur (Molineaux, 1976, personal communication), and fenitrothion (Pull, 1976, personal communication).

The first three of these insecticides have not shown definite advantages over DDT when used alone in savanna areas, but a considerable degree of malaria control was obtained by the combined use of propoxur and mass drug administration in Northern Nigeria. In Kenya, where field trials with fenitrothion were carried out, a very good degree of malaria control has been obtained by applying 2 g of fenitrothion/m^2, four times a year.

So far, no case of malaria vector resistance to dichlorvos, malathion, propoxur and fenitrothion has been reported from Africa. However, the assessment of the susceptibility status of vectors to insecticides prior to its continuous monitoring during insecticide use for malaria control is necessary in Africa nowadays when many chemically related compounds are widely used in agriculture.

The cost of insecticides, their use in agricultural practice, the susceptibility status of vectors and many other related elements will have to be taken into consideration by the malariologist in planning malaria control operations.

(c)   Lack of evidence that antimalaria schemes falling short of eradication are contributing to the improvement of population health in highly endemic areas of tropical Africa.

Although more than 25 years have passed since the necessity for such investigations has been emphasized by the First African Malaria Conference, few systematic attempts were made to collect such evidence and to relate it to particular levels of control achieved (Draper & Draper, 1960; Pringle & Matola, 1967; Molineaux, 1976, personal communication; Pull, 1976, personal communication).

The need for such data is felt especially now, when the responsible Public Health Officer is held to be very careful in establishing priorities and to be cost/benefit-minded. This particularly applies to the planning and execution of expensive malaria control measures such as intradomiciliary house-spraying, since the efficacy of these measures is related to specific epidemiological conditions and may vary from an insignificant reduction of parasite rates to the eradication of malaria, or even of the vector.

2.   Effect of insecticide house-spraying on malaria and on population health in different epidemiological zones of tropical Africa

The impact of insecticide house-spraying on malaria in the five main epidemiological zones in tropical Africa - lowland savanna, tropical forest, highland savanna, African islands and semi-desert areas - was discussed in the previous chapter. Therefore the present chapter reviews only the results of those projects in which observations were carried out on the effect of malaria reduction on population health. In order to give an indication of the level of control achievable by well-organized projects using DDT or newer insecticides, the results of pre- and post-operational parasitological observations are presented as well.

2.1   Lowland savanna zone

The data for three projects presented in Table 1 indicate the different degree of control which could be achieved in this zone by house-spraying with the existing insecticides alone or in combination with regular mass drug administration.

Although A. funestus has become scarce in all areas and the indoor density of A. gambiae was considerably reduced, the extradomiciliary transmission caused by the latter vector was in general sufficient to maintain a considerable level of endemicity.

The importance of reducing malaria from holo- to meso-endemicity might be disputed, but a considerable reduction of malaria indices in infants and young children should not be over-looked. The postponement of malaria primo-infection until late childhood is expected to lower the mortality rate due to malaria in infants and young children. Unfortunately, observations on outpatient clinic attendance and hospital admissions have only been carried out in two projects - and not in the most successful ones.

The results indicate an important reduction in the number of attendances and admissions for malaria and a decline in hospital morbidity and mortality due to malaria. In the Kano project, spot temperature checks were carried out in the two to five years age-group at the

height of the transmission season.   The fever rate was statistically significantly lower in the protected group than in the unprotected group.

Observations on the influence of malaria on general health indices have been carried out by a well-organized malaria research project, where malaria was reduced to the hypo-endemic level.   A more than twofold decline in infant mortality rates was observed there.   In the Thies project, however, where the results of attack measures were less impressive, a more than threefold decline was observed.   In Nigeria (Kano state), where observations were limited to the age group of one to four years, the annual death rate remained unchanged;   it was noticed, however, that before spraying most deaths occurred during the malaria transmission season, but during the operational stage just the inverse picture was observed.   In the same project, an increase in birth rates was seen, but it was considered statistically insignificant. Investigations carried out by the Kano project also indicated that weight, arm circumference and triceps skinfold were greater in the group of maximum protected children than in unprotected children.

The data from the lowland savanna zone indicate considerable benefit in terms of improvement of population health which may be derived even from partially successful antimalaria schemes.

2.2   Tropical forest zone

The results presented in Table 2 include data from two Malaria Eradication Pilot Projects which suggest that malaria transmission in this zone may be drastically reduced by DDT intra-domiciliary spraying.   Unfortunately, as in all malaria eradication pilot projects, the observations were limited to parasitological and entomological indices while missing the opportunity of assessing the net impact of the disappearance of hyper-endemic malaria on population health.   In two small-scale malaria control schemes, the densities of A. funestus were reduced to an undetectable level during the first year of control, but A. gambiae continued to appear in numbers sufficient to maintain malaria transmission, although at a reduced level.   This reduction was accompanied by an appreciable decline in parasite rates which was most pronounced in infants and young children.

In both areas, the number of malaria cases attending outpatient clinics was considerably reduced;   in the case of the Klouto area, though, the reduction of malaria cases was nearly proportional to a reduction of the general attendance rate.   This fact was explained by a lesser number of fever cases of unknown etiology and of patients with diseases of the respiratory tract.   A marked reduction in crude death rate and infant mortality rate, similar to that observed in the partially successful project in the savanna areas, was noted in the least successful malaria control project in Ilaro Town, Nigeria.

2.3   Highland savanna areas

The entomological and parasitological results presented in Table 3 suggest that malaria could be well controlled in this zone by house-spraying with the residual insecticides.   The achievement of similar results in tropical conditions require much more intensive and better organized efforts than in areas of Africa with subtropical and temperate climates.

In all three areas, A. funestus was practically eliminated and densities of A. gambiae were greatly reduced.   The small-scale transmission which continued in these areas was attributed to outdoor resting A. gambiae populations.   Unfortunately, there are no data of hospital and outpatient admissions and attendances, except general data for all areas of Madagascar where success of malaria control was heterogenous.

The pre-operational data on outpatient attendance due to malaria are not available, but even seven years after the beginning of operations the malaria incidence continues to decrease under the impact of antimalaria measures.   This impact was much more pronounced in the high plateau area with approximately 40% of the protected population and which yielded about 2% of

all malaria cases reported in 1959. The same applies to the number of deaths from malaria. The proportion of malaria cases seen per consultant among patients attending health clinics on the plateau decreased from 37.7% in 1948 to 0.002% in 1971.

There was a marked reduction in infant mortality rates, from 165‰ to 78‰ in Pare Taveta and from 135‰ to 55‰ in Kisumu. In all three areas under operations the crude death rate dropped to nearly half within a few years. All areas recorded an increased birth rate. In the Pare Taveta scheme, the annual ratio of live births to women aged between 15 and 49 increased from 100 to 150 per thousand and the same proportionate increase in number of births was observed in the Malagasy Republic. Investigations carried out in two well-organized research projects in Tanzania and Kenya have demonstrated that children in treated areas had less anaemia (an increase of almost 2 gm% in haemoglobin level was observed in Pare Taveta) and less clinical signs than children born and living in unprotected areas. The children in the protected areas also appeared to be taller and less undernourished. The results presented in Table 3 are as yet the most convincing evidence of what might be expected from the reduction of malaria from the hyper/holo-endemic level to the state of hypo-endemicity.

2.4   African islands

The results of four control schemes which were carried out in two distinct groups of African islands are presented in Table 4.

The first group is represented by Mauritius and La Réunion. Both islands are small in size and remote, and have a nearly subtropical climate. Prior to the initiation of extensive malaria control measures, malaria was mainly of an unstable type with periodical epidemic outbreaks. Spraying operations carried out on the islands have drastically reduced the densities of A. gambiae and quickly brought A. funestus below detectable levels. This was accompanied by a considerable reduction of malaria. Implementation of surveillance operations, detection of residual foci and application of remedial measures quickly led to the eradication of malaria from the islands.

The second group is represented by Zanzibar. The island is located near the equator and close to the mainland. Prior to the initiation of the malaria eradication programme, malaria was hyper- to holo-endemic.

Although malaria was not eradicated from the island, the spraying operations produced a considerable reduction of malaria prevalence and helped to keep it at a low level for at least 10 years.

In the first group of islands (Mauritius), following the dramatic reduction of malaria incidence and mortality, the crude death rate declined from 23.8 to 14.8 and infant mortality from 186 to 83 per thousand.

Unfortunately, the impact of a more than tenfold reduction of malaria prevalence registered in Zanzibar has not been measured in terms of other health indices except the reduction in the percentage of malaria cases attending outpatient clinics prior to and after the initiation of spraying operations.

One might expect, however, that the reduction of infant mortality rate and crude death rate would be of the same magnitude as in neighbouring Tanzania (Pare Taveta), where a similar degree of control was achieved and sustained for a number of years.

2.5   Semi-desert

There have been very few antimalaria schemes carried out in this sparsely populated area with predominantly nomadic or semi-nomadic people.

However, settled populations could be found where water sources of a more permanent nature are available such as rivers, artesian wells, irrigation channels, etc. Malaria is in general hypo- to meso-endemic with periodical outbreaks during the years of abundant rainfall. Malaria control activities carried out in towns located in this zone proved to be very successful (Khartoum, Wadi-Halfa, Atbara, Mogadishu). Larviciding operations, later supplemented by insecticide house-spraying, along the Nile River south of the border of Sudan and Egypt led to the eradication of A. gambiae from a considerable stretch of the Nile valley. Spraying operations with DDT twice a year, plus single-dose treatment with chloroquine at the time of spraying, carried out in the area of the irrigation development scheme at Kashm el Girba (Sudan) have nearly achieved the interruption of malaria transmission in the villages with settled populations (Wernsdorfer, unpublished WHO documents, 1965). In this area, two rounds per year of spraying with DDT, and then with dieldrin, prevented epidemics of malaria among the non-immune resettlers for nearly 12 years in spite of a continuous influx of malaria reservoir into the area in the form of seasonal labourers and nomads. There was a definite reduction in the number of malaria cases attending outpatient clinics, but, as in many previous instances, the impact of malaria operations on population health was not assessed since no such investigations were planned.

CONCLUSIONS

Almost 30 years have elapsed since the control of malaria with residual insecticides has first been attempted in Africa south of the Sahara. During these years, several malaria control and eradication schemes have been carried out employing different types and formulations of residual insecticides in the five main eco-epidemiological zones of this area, namely: lowland savanna, tropical rain forest, highland savanna, African islands and semi-desert.

The experience acquired during the implementation of these projects, although limited, indicates that:

(a) Malaria could be brought to a very low level of endemicity or even be eradicated in semi-desert areas, remote African islands and in highland savanna areas with sub-tropical and temperate climate.

(b) Malaria could be reduced from high endemicity to hypo-endemicity in tropical areas in the forest zone, in the islands located near the mainland and in parts of the highland savanna zone.

(c) Malaria could be reduced from high endemicity to low meso-endemicity in the lowland savanna zone.

The achievement of such degrees of control is largely related to the quality of the spraying operations, the size of the area, and population ecology (i.e. migration and living habits). The effect of insecticidal attack was enhanced by the use of non-irritant insecticides and the results improved by supplementing the insecticidal attack with mass drug administration.

In spite of the experience that a good measure of malaria control could be achieved by house-spraying with residual insecticides in areas of tropical Africa with more than 60% of the total exposed population, no serious attempt was made to extend these operations and even the inverse trend was observed during the last 15 years. Various reasons were given to explain or justify this fact at a time when residual insecticides were extensively used in malaria eradication programmes. Nowadays, malaria control is regarded as an essential step towards eradication; therefore only a few of these former reasons remain valid.

The technical and operational problems encountered during the implementation of large-scale malaria control programmes in tropical Africa using intradomiciliary residual spraying as the main intervention measure are well known (Hamon, 1967; Bruce-Chwatt, 1972); practical

suggestions for their solution were discussed during the "WHO Interregional Conference on Malaria Control where Malaria Eradication is impractical at present" (WHO, 1974a). The recent findings of A. gambiae resistance to DDT in several areas of Africa deserve special attention. DDT remains the insecticide of choice for the major part of tropical Africa; the periodic monitoring of susceptibility of the main vectors to DDT and other insecticides is essential; in addition, a more precise delineation is required of areas in which resistance is reported. Because of their high cost and considerable operational requirements, the use of newer residual insecticides may only be justified for areas of great socioeconomic importance, in lowland savanna zones and in areas where A. gambiae is resistant to DDT. Another factor preventing the extension of spraying operations to further areas was the lack of evidence that a mere reduction of malaria prevalence will result in a significant improvement of the population health and justify the necessary expenses and efforts. The data analysed in this review permit the following conclusions:

(a)   A reduction of malaria from holo- and hyper-endemicity to hypo-endemicity results in a reduction of 50-75% of the infant mortality rate and of at least 50% of the crude death rate. An increase of the birth rate was often observed, but its statistical significance needs to be verified. In two well-organized research projects, haemoglobin levels, body weight, arm circumference and triceps skinfold were significantly greater in operational than in unprotected areas. No correlations were attempted regarding reductions in malaria prevalence and outpatient clinic admissions and hospital attendance. Furthermore, in many developing countries the majority of the fever cases are considered to be malarious and hence the outpatient clinic reports do not accurately represent the trend. Nevertheless, information from the Malagasy Republic and Zanzibar indicates a considerable reduction (tenfold and fourfold respectively) in outpatient clinic attendance and in the case of the Malagasy Republic almost a fiftyfold reduction in hospital admissions. In both countries, the number of hospital deaths due to malaria dropped practically to zero.

(b)   In two projects, reduction of malaria from holo- and hyper-endemicity to low meso-endemicity resulted in reductions of 30% and 50% respectively of the infant mortality rate and of 30% and 40% of the crude death rates. A more than threefold reduction of the infant mortality rate was registered in one project. There are also some indications that children born in the operational area of one research project showed less anaemia, less clinical signs and appeared taller and better nourished than children living in the unprotected comparison area. A marked reduction of outpatient attendance and hospital admissions due to malaria was noted as well as a reduction of hospital mortality.

(c)   In hypo-endemic areas situated at the fringe of the malarious areas, the impact of house-spraying on malaria was most obvious, often leading to the interruption of malaria transmission and to the eradication of the disease. In these areas, the danger of dramatic malaria epidemics was eliminated. Malaria morbidity and mortality were drastically reduced, taking a considerable workload from the outpatient clinics and hospitals.

The only available information on the effect of the disappearance of malaria from formerly meso/hypo-endemic areas of Africa on the crude and infant mortality rates originates from Mauritius. Within a few years the infant mortality rate declined by more than 50% and the crude death rate by nearly 40%. Since other improvement of general health services and population health was rather limited during this period, the reduction of the death rate was solely attributed to malaria control. It should be pointed out, however, that antibiotics became widely available at that time.

This review reveals a number of lacunae in our knowledge regarding the effect of house-spraying on population health and shows the need for more comprehensive and well-organized studies. However, the available information is sufficient to support the views of many prominent malariologists, expressed by L. J. Bruce-Chwatt (1972) and A. Gabaldon (1972), that

house-spraying in highly malarious endemic rural areas of tropical Africa, even if it does not lead to malaria eradication, makes a considerable contribution to the general improvement of health and the socioeconomic well-being of the population.

ACKNOWLEDGEMENT

SUMMARY

During the last 30 years, considerable experience has been gathered in the use of indoor spraying with residual insecticides for malaria control in different epidemiological conditions of tropical Africa. The experience suggests that the use of this method would greatly reduce the level of malaria endemicity in all eco-epidemiological zones of tropical Africa, and even permit malaria eradication in some of them. However, no serious attempt was made to extend these operations to new areas and even the inverse trend was observed during the last 15 years. Among other reasons, it was attempted to explain this stagnation by a lack of evidence that a mere reduction of malaria prevalence would result in a significant improvement in the population's health. The data collected and analysed in this review suggest that population health in all malarious zones of tropical Africa will greatly benefit from the extensive use of this method. It is concluded that indoor spraying with residual insecticides is at present certainly the most effective method of malaria control in the rural areas of tropical Africa. It could be extensively used wherever economic conditions permit or demand these measures, and where the malaria vector population is susceptible to insecticides.

RESUME

Durant les dernières trente années, il a été possible d'acquérir une connaissance pratique fort étendue sur l'emploi intradomiciliaire d'insecticides à effet rémanent dans différentes situations épidémiologiques d'Afrique.

Il apparaît que l'emploi de cette méthode abaisserait considérablement le niveau d'endémicité paludéenne dans toutes les zones éco-épidémiologiques d'Afrique tropicale et, même, permettrait d'obtenir l'éradication du paludisme dans certaines d'entre elles. Toutefois, il n'a été fait aucune tentative sérieuse pour étendre ces opérations sur de nouveaux territoires et, au contraire, une tendance inverse a été constatée ces dernières quinze années.

De plus, on peut expliquer ce statu quo par le manque de preuves qu'une simple réduction de la prévalence puisse sensiblement améliorer la santé des populations.

Les renseignements recueillis et analysés indiquent que la santé des populations vivant dans les zones impaludées d'Afrique tropicale tirerait grand bénéfice de cette méthode. L'auteur en conclut que la méthode la plus efficace de lutte antipaludique dans les zones rurales d'Afrique tropicale demeure l'application intradomiciliaire d'insecticides à effet rémanent. Cette mesure antipaludique pourrait être largement appliquée lorsque justifiée ou requise par une situation économique et là où le vecteur du paludisme est sensible aux insecticides.

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TABLE 1.   LOWLAND SAVANNA

EFFECT OF HOUSE-SPRAYING WITH RESIDUAL INSECTICIDES ON ENTOMOLOGICAL,
MALARIOMETRIC AND HEALTH INDICES

Brief description of operational area	Malaria situation prior to intervention	History of insecticide house-spraying	Parasite rates (%)		Entomological observations	Hospital and outpatient admittance and attendance	Observations on general health indices
			Pre-operational	Post-operational			
WESTERN SOKOTO (Nigeria) Pop.: 500 000 Climate: tropical, dry Bruce-Chwatt et al. (1957)	Holo-endemic, P. falciparum predominant. Transmission perennial. Vectors: A. gambiae, A. funestus.	Dieldrin 0.6 g/m² once a year from 1953 to 1956, then DDT 2 g/m², two cycles a year until 1959.	Years (-1) 79.5 (1-2) 97.5 (3-4) 98.8 (5-7) 86.2	Years (-1) 1.0 (1-2) 21.0 (3-4) 17.0 (5-7) 46.0	Considerable decrease in indoor vector densities observed in sprayed areas, but both species found in a number of temporary shelters.	Reductions in dispensary attendance from 170 000 to average 120 000; in number of cases from 6.4% to 1.6%; in hospital attendance from 11.7% to 4.3%.*	
KANO STATE (Nigeria) Pop.: 16 000 Climate: tropical, dry Molineaux (pers.comm., 1976)	Hyper-endemic, P. falciparum predominant. Transmission almost perennial. Vectors: A. gambiae, A. funestus.	Propoxur in 1972 and 1973, three cycles a year (I) and mass treatment with sulfalene + pyrimethamine combination at intervals of 70 days (II) and two weeks (III).	All ages I 46-64 II 42-63 III 42-66	All ages I 27-44 II 2-28 III 1-5	Man-biting rate of A. gambiae declined ten-fold. A. funestus practically disappeared.		Infant mortality rate in 1973 was 135‰ in unsprayed villages and 55‰ in protected villages. In area III, weight, arm circumference and triceps skinfold were significantly greater than in the control area.
THIES REGION (Senegal) Pop.: 50 000 Climate: tropical, dry WHO/AFRO (1959)	Meso-endemic, P. falciparum predominant. Transmission almost perennial. Vectors: A. gambiae, A. funestus.	DDT 2 g/m², one cycle a year from 1952 to 1957.	Years (-1) 25.6 (1-2) 36.8 (3-4) 38.5 (5-9) 34.2 (19+) 22.7	Years (-1) 8.5 (1-2) 6.6 (3-4) 17.8 (5-9) 28.0 (19+) 22.8	Density of A. gambiae diminished to less than 1%. A. funestus disappeared in 1957.	From 1952 to 1955, the morbidity and mortality rates in Thies hospital fell from 12.65% to 2.24% and 13.43% to 4.96% respectively.	Infant mortality rate during first three years of operations fell from 177 to 50.

* Observations limited to the first two years of operations.

TABLE 2.   TROPICAL FOREST

EFFECT OF HOUSE-SPRAYING WITH RESIDUAL INSECTICIDES ON ENTOMOLOGICAL, MALARIOMETRIC AND HEALTH INDICES

Brief description of operational area	Malaria situation prior to intervention	History of insecticide house-spraying	Parasite rates (%)		Entomological observations	Hospital and outpatient admittance and attendance	Observations on general health indices
			Pre-operational	Post-operational			
ILARO TOWN, SOUTH-WEST (Nigeria) Pop.: 12 500 Climate: equatorial Semi-rural area Bruce-Chwatt et al. (1955)	Holo-endemic, P. falciparum predominant. Transmission perennial. Main vectors: A. gambiae, A. funestus.	HCH 0.2 g/m², four cycles p.a. from 1949 to 1953.	a. 33.3 b. 78.0 c. 13.0	10.2 51.8 17.7	A. funestus practically eliminated at end of first year. Densities of A. gambiae decreased by 90%. A. funestus reappeared one year after cessation of spraying.	Number of cases attending outpatient clinic declined from 6.2% to 0.8%. Clinical attendance declined slightly.	Crude death rate fell from 15.6‰ to 10.7‰ and infant mortality rate from 137‰ to 70.1‰.
YAOUNDE PILOT ZONE, SOUTH (Cameroon) Pop.: approx. 130 000 Climate: equatorial Choumara (1962)	Hyper-endemic, P. falciparum predominant. Transmission perennial. Vectors: A. gambiae, A. funestus, A. moucheti, A. nili.	DDT 2 g/m², two cycles half zone and other half with dieldrin 0.6 g/m² over nine months (1953-1960).	a. 38.0 b. 59.0 c. 7.5	0.0 0.4 0.2	A. gambiae and A. funestus could not be found. A. moucheti and A. nili became very rare.		
KPAIN AREA (Liberia) Pop.: 300 000 Climate: equatorial Guttuso (1962)	Holo-endemic, P. falciparum predominant. Transmission perennial. Main vectors: A. gambiae, A. funestus.	Dieldrin from 1953 and DDT 2.65 g/m², one cycle p.a. from 1957 to 1961.	a. 67.5 b. 73.3 c. 35.7	0.0 30.0	A. gambiae and A. funestus have virtually disappeared from the area.		
KLOUTO AREA (Togo) Pop.: 86 000 Climate: equatorial Noguer et al. (1972)	Meso- to hyper-endemic, P. falciparum predominant. Transmission perennial. Main vectors: A. gambiae, A. funestus.	DDT 2 g/m², only one cycle in 1974.	a. 32.8 b. 50.7 c. 24.8	15.5* 31.6 12.9	Densities of A. gambiae considerably reduced. A. funestus could not be found two years after cessation of spraying.	Outpatient attendance reduced from 138 000 to 114 000. Number of cases fell from 10.3% to 6.9%.	

* Data for 1975.

a = infant parasite rate

b = child parasite rate

c = adult parasite rate

TABLE 3. HIGHLAND SAVANNA

EFFECT OF HOUSE-SPRAYING WITH RESIDUAL INSECTICIDES ON ENTOMOLOGICAL,
MALARIOMETRIC AND HEALTH INDICES

Brief description of operational area	Malaria situation prior to intervention	History of insecticide house-spraying	Parasite rates (%)		Entomological observations	Hospital and outpatient admittance and attendance	Observations on general health indices
			Pre-operational	Post-operational			
PARE TAVETA (Tanzania) Pop.: 50 000 Climate: tropical Altitude: 600–800 m Draper & Smith (1960) Draper & Draper (1960) Pringle & Matola (1967)	Hyper-endemic, P. falciparum predominant. Transmission season approx. nine months. Vectors: A. gambiae, A. funestus.	Dieldrin 0.5 g/m², one cycle every eight months from 1955 to 1959.	Years (-1) 47.0 (1-4) 64.0 (5-9) 62.0 (20+) 22.0	Years (-1) 1.0 (1-4) 6.0 (5-9) 9.0 (20+) 3.0	Densities of A. gambiae were reduced to one-fifth of original. A. funestus was eliminated and appeared only in 1966.		Decrease in infant mortality rate from 165‰ to 78‰ in 1957; and in crude death rate from 24‰ to 12‰ in 1957. Increase in annual ratio of live births to women aged 15-49 from 100 to 150. Marked improvement in Hb levels of almost 2 gm%.
KISUMU (Kenya) Pop.: 50 000 Climate: tropical Altitude: 1250-1400 m Pull (pers.comm., 1976)	Hyper- to holo-endemic, P. falciparum predominant. Transmission perennial. Vectors: A. gambiae, A. funestus.	Fenitrothion 2 g/m², four cycles a year from the end of 1974 to the middle of 1975.	a. 53.5 b. 82.3 c. 37.8	0.5 29.8 9.8	A. gambiae undetectable for nine months, density very low for remaining three months. A. funestus practically disappeared.		Infant death rate fell from 153‰ to 93‰. The crude death rate fell from 27‰ to 17‰. Children born in protected areas had less anaemia and less clinical signs than children in unprotected areas. They appear to be taller and less severely undernourished.
HIGH PLATEAU (Malagasy Republic) Pop.: 744 000 Climate: subtropical/ temperate Altitude: 700-1650 m WHO/AFRO (1960)	Meso- to holo-endemic, P. falciparum predominant. Transmission season of five to six months. Vectors: A. gambiae, A. funestus.	DDT 2 g/m², one cycle p.a. 1949 to 1959. Pre-school and school-children nivaquine once a week.	All ages 25.35	a. 0.69 b. 1.95 c. 0.30	Density of A. gambiae considerably reduced. A. funestus practically disappeared.	Number of cases in country has declined from: 1955 - 143 451 1959 - 48 170 1965 - 11 291. Only 998 clinical cases compared with 47 172 in the rest of country and only one death compared with 345 in other areas.	During five years' campaign deaths decreased from 70 000 to 55 000 p.a. and births increased from 110 000 to 155 000. Crude death rate fell from 26‰ in 1945/8 to 12‰ in 1954.

a = infant parasite rate
b = child parasite rate
c = adult parasite rate

TABLE 4. AFRICAN ISLANDS

EFFECT OF HOUSE-SPRAYING WITH RESIDUAL INSECTICIDES ON ENTOMOLOGICAL,
MALARIOMETRIC AND HEALTH INDICES

Brief description of operational area	Malaria situation prior to intervention	History of insecticide house-spraying	Parasite rates (%)		Entomological observations	Hospital and outpatient admittance and attendance	Observations on general health indices
			Pre-operational	Post-operational			
MAURITIUS Remote, partially mountainous island. Climate: subtropical Dowling (1951)	Hypo- to meso-endemic with frequent epidemics. P. vivax predominant. Transmission seasonal. Main vectors: A. funestus, A. gambiae.	DDT 2 g/m², two cycles p.a. Total coverage 1949-1951. Focal spraying after 1951.	a. 0.27 b. 9.54	0.4* 0.62	A. gambiae densities decreased considerably. A. funestus has disappeared completely. Attempts to eradicate A. gambiae by house-spraying and antilarval measures have failed.	Number of cases decreased from 46 000 to 23. Mortality in hospitals fell from 1580 to 61.	Crude death rate decreased from 23.8‰ to 14.8‰. Infant mortality rate declined from 186‰ to 83‰.
LA REUNION Remote, highly mountainous island. Climate: subtropical Hamon & Dufour (1954) Oddo et al. (unpublished WHO document, 1973)	Hypo- to meso-endemic with periodical epidemics. P. vivax predominant. Transmission seasonal. Vector: A. gambiae; A. funestus absent.	Insecticide spraying from 1949. By 1952 total population protected. DDT 2 g/m², one cycle.	a. 5.9 b. 2.8 c. 2.1	0.0* 0.2 0.0	Considerable reduction of A. gambiae densities was observed.	Mortality from malaria in hospitals declined from 1354 cases to 138.	Infant mortality has not changed much.
ZANZIBAR Island in close vicinity to mainland and extensive connexions with it. Climate: tropical, humid Delfini (1969)	Meso- to hyper-endemic, P. falciparum predominant. Transmission perennial. Vectors: A. gambiae, A. funestus; A. merus relatively rare.	Countrywide spraying operations started in 1958 with one cycle dieldrin (0.8 g/m²) until 1961. From 1962 to 1968, DDT 2 g/m², two cycles per annum.	a. 47.0 b. 56.4	3.2** b+c 5.4	Densities of vectors became very low, especially A. funestus. But A. gambiae was still found in abundance.	Number of cases attending outpatient clinic decreased from 8.1% in 1957 to 2.1% in 1964 and deaths due to malaria in hospitals from 20 to 0.	

* Data for 1952.

** Data for 1962.

a = infant parasite rate

b = child parasite rate

c = adult parasite rate

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(a) to acquaint WHO staff, national institutes and individual research or public health workers with the changing trends of malaria research and the progress of malaria eradication by means of summaries of some relevant problems;

(b) to distribute to the groups mentioned above those field reports and other communications which are of particular interest but which would not normally be printed in any WHO publications;

(c) to make available to interested readers some papers which will eventually appear in print but which, on account of their immediate interest or importance, deserve to be known without undue delay.

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