INSECTICIDE USE FOR MALARIA CONTROL IN CENTRAL JAVA, INDONESIA: A REVIEW

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SUMMARY

DDT indoor residual sprayings in the Province of Central Java, Indonesia, for the past 28 years are reviewed in terms of ***Anopheles aconitus*** *resistance to DDT and incidences of malaria. DDT resistance by* ***An. aconitus*** *has continued to increase and spread since its first detection in Central Java in 1962. In most areas malaria transmission is perennial, which appears to be not interrupted by DDT residual spraying of inner walls because of DDT resistance. In searching for alternatives to DDT, fenitrothion was the most effective residual compound among five insecticides tested in village-scale trials, giving control for about 13 weeks at 2 g/m^2. Because the target species rests largely on the lower portions of walls, when applied at 2 g/m^2 to only one horizontal swath between 10 and 85 cm from the ground, this compound was effective for over two months, about one-third less than that found in full coverage applications. For a single application this selective method reduced the amount of insecticide by 65 percent and manpower by 43 percent, and three applications, to compensate for less residual effectiveness, will reduce insecticide use by about 50 percent and manpower by 15 percent, compared to two applications with full coverage. Further field investigations on application of insecticides and the ecology of the DDT-resistant vector continue to be needed in Central Java to reduce further the cost of residual sprayings in malaria control programmes. This review also suggests the possibility of other selective spraying methods and anti-vector methods applicable at the village level by the community.*

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INTRODUCTION

In Indonesia, of all vector-borne diseases, malaria is still the one which causes most concern in public health. The national anti-malaria programme for the past five years took about 10 percent of total health budget. [1] The province of Central Java is one of the most malarious areas in the country, and *Anopheles aconitus* is the major vector, known to be primarily zoophilic, exophagic and exophilic. [2] DDT has been the main residual insecticide used in the malaria control programme since 1953. [3] In many parts of Central Java, indoor spraying with DDT appears to have reduced malaria transmission in spite of vector resistance, [4] but not in other areas. [5]

In the past, malaria transmission by *An. sundaicus* was prevalent in coastal areas, and a small part of the insecticide consumption reported here was used in these foci, some of which overlapped areas of *An. aconitus* transmission. [6] However, since about 1965 *An. sundaicus* has disappeared from the entire north coast of Java, is now responsible for only limited transmission in a few foci in the south coast of Central Java. Therefore, this paper will be restricted to *An.*

aconitus and its areas of transmission.

In view of the complexity and difficulties of malaria control in Java due to the double resistance of *An. aconitus* to DDT and dieldrin, [5,7] the WHO Vector Biology and Control Research Unit (VBCRU), in collaboration with the Ministry of Health and with financial support from USAID, has carried out field trials to test alternate residual insecticides and to develop new application methods. [8] During the period from 1976 to 1980, 12 village trials of five residual insecticides in different formulation and dosage were tested in a group of villages near Semarang, Central Java.

The objectives of this paper are to 1) review problems implicated in the use of DDT in malaria control programmes in the Province of Central Java: 2) summarize field trials for alternative insecticides carried out for the past five years; and 3) suggest field research on development of malaria vector control methods which can be applicable at community level.

DDT CONSUMPTION AND MALARIA

A large scale malaria control programme (MCP) commenced in the province in 1952 with indoor residual spraying of DDT water dispersible powder (wdp) in areas of important malaria foci, supplemented with dieldrin from 1956. [9] During the first 8 years of the MCP, from 1952 to 1959, when malaria eradication programmes (MEP) were organized, the total use of DDT (75%) and dieldrin (75%) amounted to 645 and 293 tons respectively, with over 7.7 million people protected. The MCP reduced the slide positive rate of malaria parasites (SPR) from 23.7% in 1953 to 5.0% in 1958 (Fig. 1). The SPR was further decreased during the MEP to 0.06% in 1964. During the MEP period of 5 years (1960-1964), a population of over 117 million people were protected with 12,341 tons of DDT and 88 tons of dieldrin. During the first 10 years of the MEP, about 75% of the USAID input for malaria control programmes were for DDT. [10] However, the MEP had to be discontinued in 1965, and in 1969 the programme was reorganized as malaria control programmes (IMCP) with decentralized responsibility for implementation at the Regency level under central direction of the General Directorate of Communicable Disease Control (CDC) of the Ministry of Health. [9]

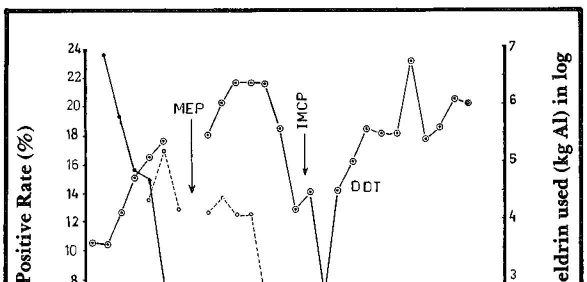

Fig. 1 Overall malaria slide positive rate and amount of insecticide sprayed in Central Java, from 1952 to 1978.

During the transition period of the IMCP (1965-68), the DDT consumption declined gradually from 3,626 tons in 1964 to 0.7 ton 1968 while the SPR increased 11 times, from 0.04% in 1965 to 0.44% in 1968. As the IMCP was better organized, the annual use of DDT increased steadily from 45 tons in 1969 to 1,390 tons in 1978, an increase of 31 times. The increase in the number of houses sprayed and population covered was about 35 times during the same period. DDT consumption appeared to be relatively constant during the period in terms of houses sprayed (0.74-1.0 kg/house) and population protected (0.15 - 0.20 kg/capita) throughout the province. However, the number of houses sprayed or population protected varied with regencies. In Banjarnegara, where the DDT consumption has been highest among the 29 regencies, the overall use of DDT was 808 g/house and 162 g/inhabitant.

Under the IMCP since 1969, the overall malaria prevalence (SPR) remained at the 2-3% level. When the mean SPR for the first 3 years (1969-71) of the IMCP were compared to that for 1976-78, there were 17 regencies and five cities where the SPR declined up to 57 times. On the other hand, there were 11 regencies and one city where the SPR was increased up to nearly 7 times, with an overall increase of 27 percent. The increase was mainly due to the higher SPR in Regency Banjarnegara and Regency Wonosobo.

During the 3-year period 1976-78 nearly 50 percent of total malaria positive slides in Central Java were from Regency Banjarnegara. When the mean SPR for each regency is plotted against the mean annual use of DDT for this 3-year period (1976-1978), it can be seen that more DDT was sprayed in regencies where there was more malaria

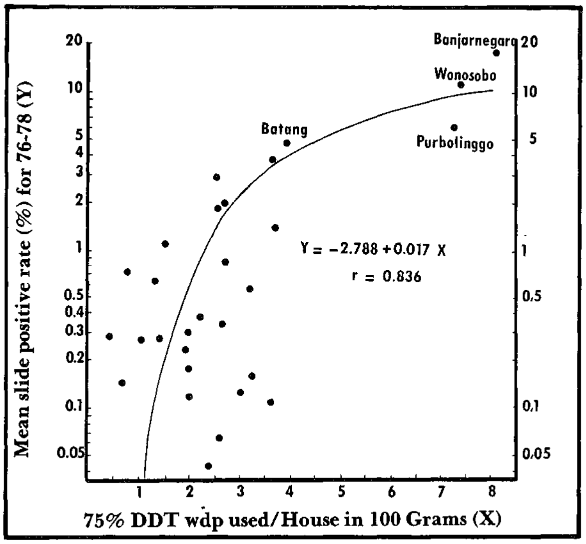

Fig. 2 Use of DDT in relation to slide positive rates in 29 regencies in Central Java, Indonesia (mean for 1976-78).

(Fig. 2). The correlation coefficient for the SPR vs DDT sprayed per house (r = 0.836) is positively significant. This implies that use of DDT during the period did not much affect malaria transmission in Central Java (Table I).

DDT SUSCEPTIBILITY

An. aconitus was first found to be resistant to DDT in Central Java in 1962 after six cycles of DDT spraying or three years after dieldrin resistance was detected in 1959. [4] The species is now resistant to DDT over large areas in Java, including the Province of East Java. [11] Susceptibility tests show a steady increase in the level of DDT-resistance in Central Java for the past 20 years (Table II). Before 1965, about 36 percent of the 39 localities tested in Central Java showed over 91 percent mortality when exposed to 4% DDT paper for one hour. This percentage of localities declined gradually to 6.7 percent for the last five years. On the other hand, areas showing less than 20 percent mortality increased from 2.6 percent during 1961-65 to 26.0 percent during 1976-80.

TABLE II
CHANGES IN LEVEL OF DDT RESISTANCE OF *ANOPHELES ACONITUS* IN DIFFERENT AREAS OF CENTRAL JAVA, INDONESIA, FROM 1961 to 1980 *

Years tested	Number areas tested	% of total areas showing % mortality of			
		< 20	21-50	51-90	> 91
1961-65	39	2.6	28.2	33.3	35.9
1966-70	25	4.0	44.0	24.0	28.0
1971-75	145	7.6	38.6	37.9	15.9
1976-80	15	26.0	33.3	33.3	6.7

* Exposed to 4% DDT for one hour.

TIMING OF SPRAYING OPERATIONS

The malaria seasons are less clearly defined in most of malaria-prevalent areas of Central Java and transmission continues to occur without seasonal interruption during months of lower rainfall (Fig.

TABLE I
REGENCIES WITH DIFFERENT MALARIA SLIDE POSITIVE RATE (SPR), RAINFALL, DDT USAGE AND SUSCEPTIBILITY OF *ANOPHELES ACONITUS* TO DDT

SPR (%)	Number Regency	Mean SPR (%)*	Annual Rainfall (x 10 mm)	DDT/House (gr)**	Mortality (%)***
< 0.1	7	0.05	221	200	46.8
0.1-0.5	13	0.26	221	201	59.9
0.5-1.0	4	0.70	254	197	59.7
1.0-5.0	7	2.55	315	294	50.4
5.0-10.0	1	6.02	357	726	49.2
> 10	2	14.51	404	773	26.9
Mean (Total)	(34)	1.37	259	239	48.8

* Mean for 1976-1978.
** Based on the total use of DDT divided by number of houses in the regencies.
*** Susceptibility tests with 4% DDT impregnated paper exposed for one hour.

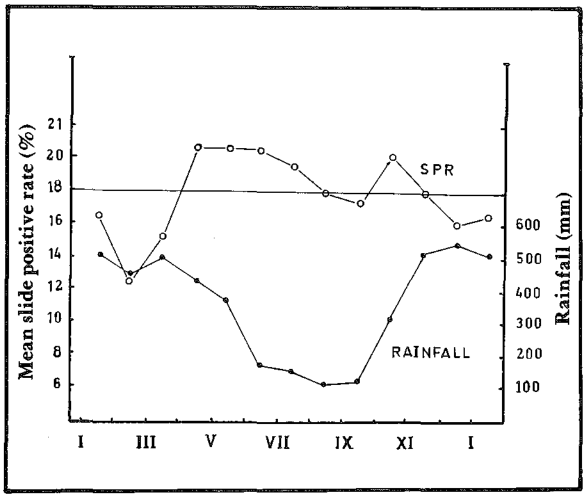

Fig. 3 Mean monthly rainfall (1931-1960) and malaria slide positive rate (1976-1978) in Regency Banjarnegara, Central Java.

3). In the Banjarnegara area the monthly SPR fluctuated within the range of less than twofold, while changes in monthly rainfall were fivefold. However, geographical prevalence of malaria appears to be related to annual rainfall (Fig. 4). When mean annual rainfall (1931-1960) for each regency was plotted against malaria rates (SPR), there was a positive correlationship between the SPR and mean rainfall (r = 0.815). A high positive correlation was also observed between the SPR and mean number of rainy days (r = 0.780).

Although highest larval densities of *An. aconitus* are known to be a few weeks before the harvest time of rice, [12] the species occurs throughout the year in most areas in Java. [5,13] This is probably due to the irregularity of the rice transplanting season under improved irrigation facilities. Seasonal abundance of the malaria vector varied from locality to locality, but there is a main peak usually occurring in the early months of the year. [3,5] In most of the terraced rice growing areas there are two seasonal peaks, the first in February - March and the second in August - September. [13] Considering the main peak of *An. aconitus* in the early months of the year, the perennial malaria transmission, the first round of spraying usually begins in the latter part of January or early February, followed by the second in July-August. The duration of the spraying cycles are usually longer than the 2-month period recommended by WHO. [14] In many cases, spraying schedule is further delayed due to the refusal of spraying. [15]

ALTERNATIVE INSECTICIDES

In view of increased resistance of *An. aconitus* to DDT in many parts of Indonesia, five selected residual insecticides in different formulations at different dosages were tested for their efficacy in controlling vector populations in villages near Semarang, Central Java (Table III). In addition, a village-scale trial of outdoor ultra low volume (ULV) application of fenitrothion with backpack machines was carried out. [16] None of the compounds had been tested before in this area for the control of DDT-resistant *An. aconitus*. While fenitrothion [17] and pirimiphos-methyl [18] gave good control of both nocturnal landing and diurnal resting population, malathion [19] and chlorphoxim [20] had a little impact on man-vector contact. Fenitrothion and pirimiphos-methyl [21] gave high contact and air-borne bioassays mortalities for prolonged periods, while malathion and chlorphoxim were effective only in contact exposure.

Fenitrothion

This compound at 2 g/m^2 in a 40% wdp formulation was the most effective residual insecticide tested, with effective control up to about 13 weeks after spraying. [17] However, its high cost may prevent large scale operational use of this insecticide at the standard dosage of 2 g/m^2. Because of cost, as well as mammalian toxicity and possible resistance considerations, two additional trials were carried out using reduced amounts. In the second trial, [22] with normal total coverage at 1 g/m^2, manpower requirements were the same as at 2 g/m^2, but insecticide usage was reduced by one-

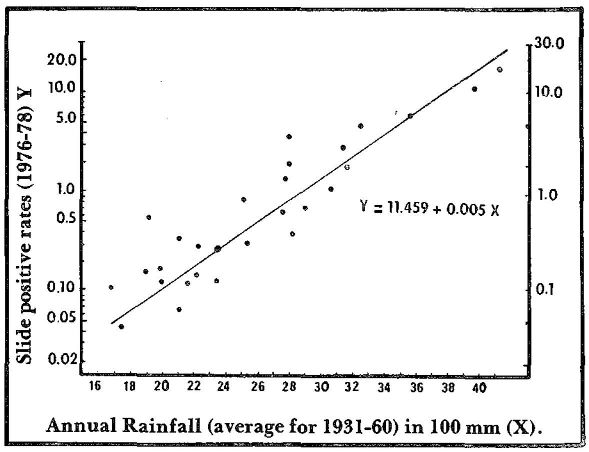

Fig. 4 Mean malaria slide positive rates in relation to annual rainfall in 29 Kabupaten, Central Java, Indonesia.

TABLE III
RESIDUAL EFFECTIVENESS OF FIVE DIFFERENT INSECTICIDES AS DETERMINED WITH NATURAL DENSITIES OF *ANOPHELES ACONITUS* AND BIOASSAY TESTS. 1/

Insecticides	Year tested	Dosage g/m^2 a.i.	No. weeks efective control	Bioassay-houses			References
				wood 2/	bamboo 2/	airborne 3/	
Fenitrothion	1976	2	13	25	23	16	14
	1979	1	11	17	11	8	19
	1979 4/	2	9	14	14	4	7
	1980 4/	2	9	18	14	6	
Malathion	1976	2	> 4	11	9	< 1	16
	1977	2	4	4	8	1	
	1977	2	8	7	7	< 1	
	1980	2	8	6	8	<1	
Pirimiphos-methyl	1978	2	12	9	9	9	15
	1979	1	6	4	6	<1	18
Chlorphoxim	1978	2	< 8	1	1	<1	17
Decamethrin 5/	1980	0.025	< 5	< 1	< 2	<1	

1/ As determined and reported by the referred authors.
2/ Produced over 70% mortality in contact bioassay (*An. aconitus* females exposed for 30 min.).
3/ Produced over 70% mortality in airborne bioassay (*Ae. aegypti* females exposed for four hours).
4/ One horizontal swath treatment.
5/ WHO/VBCRU Progress Report, 1980.

half and the residual effectiveness only by about 1/3, i.e. to 2 months from 3 months at 2 g/m^2.

The third trial with reduced amounts of insecticide was made by spraying at 2 g/m^2 only horizontal swath between 10 and 85 cm from the ground. [8] This "selective spraying" reduced insecticide use by about 50 percent and manpower by 25 percent (Table IV). The results indicate that the vector populations were effectively suppressed for 2 months, about 3 weeks less than that of total coverage at 2 g/m^2 and about the same as total coverage at 1 g/m^2. In view of the significant reduction in the amount of insecticide (65 percent) and manpower used (43 percent), less potential to induce resistance, and less exposure of spraymen during operations, the Government of Indonesia (GOI) began an operational-scale malaria control trial of this selective method in Regency Banjarnegara in 1981. The rationale of this selective spraying was based on observations on the resting behaviour of *An. aconitus,* which showed that about 78 percent rest below 85 cm from the ground. [23]

Malathion

This insecticide has been the most common replacement for DDT elsewhere since the early 1960's because of its safety, relatively low cost and effectiveness. [24] As DDT-resistant populations of *An. aconitus* increasingly appeared in Java, the MOH became extremely interested in the replacement of DDT with malathion. Accordingly, this insecticide was tested in three village-scale trials in 1976, 1977 (2 cycles), and again in 1980. [17] Man-vector contact indices (indoor and outdoor landing rates) and associated parous rates were not reduced, and other population density indices and parous rates were only moderately reduced for short periods, generally less than 8 weeks. The reason for this is yet to be established, but results of these village trials enabled the Government to avoid planned large expenditure for malathion to replace DDT in Java.

Pirimiphos-methyl

Two trials of this compound were carried out,

TABLE IV
COMPARISON OF ANNUAL OPERATIONAL COSTS REQUIRED FOR 1000 HOUSES IN FOUR METHODS OF FENITROTHION APPLICATIONS

Type of application	Insecticide		Spraymen	
	Kg, a.i.	% reduction	mandays	% reduction
Total coverage at 2 g/m^2 (2 cycles/year)	1219	0	408	0
Total coverage at 1 g/m^2 (2 cycles/year)	613	50	408	0
One swath spraying 2 g/m^2 * (2 cycles/year)	411	66	232	43
Cattle shelter spraying 2 g/m^2 (7 cycles/year)	124	90	118	71

* 113 cattle shelter/1000 houses.

one [18] with a 25% wdp formulation at 2 g/m^2 and the other [21] with 50% emulsifiable concentrate (EC) at 1 g/m^2. The 2 g/m^2 wdp treatment was effective for about 12 weeks, but the formulation was shown to be unsuitable because of heavy, unsightly brown deposits left on surfaces and high erosion of nozzle tips. The reduced dosage treatment (1 g/m^2) with EC was effective for about 8 weeks and the formulation was found to be very suitable. This compound is being presently tested for control of malaria in Regency Ngetos by the Province Health Authorities of East Java in collaboration with CDC/HQ in Jakarta and WHO/VBCRU.

Fenitrothion ULV

A village-scale trial of ground ULV treatments was carried out using backpack machines (Fontan R12) annd 95% fenitrothion to apply 5 weekly cycles of about 40 ml per house per cycle. [16] Vector populations were effectively suppressed during the treatment and for about 2 weeks after the last cycle. However, considering the amount of insecticide used (about the same as selective spraying), short residual effect, equipment costs and intensive supervision required it was concluded this type of ULV application would only be useful for epidemic situations of limited area.

ALTERNATIVE APPROACHES

In anti-malaria programmes in Java a more rational use of insecticides appears to be vital because the houses are large, having about 300 m^2 of surfaces (walls and roofs) to be sprayed for total coverage, while the cost of insecticides continues to increase. [8] To further reduce operational costs (Table IV), a village-scale trial is being carried out near Semarang by WHO/VBCRU, in collaboration with GOI, in which spraying with fenitrothion 2 g/m^2 is targeted at only those mosquitoes resting in cattle shelters (Kandang). This "kandang selective treatment" is based on the feeding preference of *An. aconitus* in Central Java where a majority (50-99 percent) feed on cattle. [25] In this trial all cattle shelters, both open and closed, are treated as in total coverage once every 1-3 months. If this method proves to be effective, it is hoped that routine sprayings can be carried out by the community with minimum technical guidance from Government health authorities.

Another possible alternative approach to control of malaria transmitted by *An. aconitus* is zooprophylaxis, i.e. diversion of the vector population to animals by increasing the number of cattle. Although there is a paucity of relevant research data, malaria prevalence seems to be correlated to the relative man vs cattle populations (Table V) expressed either as the man/cattle ratio or number of cattle per 100 inhabitants. Fig. 5 shows the SPR plotted against number of cattle per 1000 inhabitants for 16 villages *(desa)* in the Sub-district (Kecamatan) Mandiraja. If it can be proved that man-vector contact and malaria transmission can be reduced by increasing the cattle populations, this method could be implemented by giving priority to the more malarious areas in the

TABLE V
RATIO OF CATTLE TO MAN IN RELATION TO HUMAN BLOOD INDEX OF *ANOPHELES ACONITUS*, VECTOR RESISTANCE AND MALARIA INCIDENCES IN THREE PROVINCES IN JAVA

Locality	Human Blood Index 1/			Ratio	API 2/	DDT resistant 3/	
	Year tested	Number examined	% positive	Cattle : Man		Year	% mortality
Banjarnegara (Central Java)							
Kutabanjar	1978	410	19.51	1 : 60	13.37	1977	26 (125)
Pucang	1976	210	37.62	1 : 73		1976	36 (40)
Magetan (East Java)							
Negeri	72-73	1247	14.76	1 : 20	4.93	1972	21 (78)
Panekan	72-73	106	17.92	1 : 20		1972	21 (71)
Yogyakarta							
Sleman	1978	1496	0.53	1 : 8	1.08	1973	10 (115)
Bantul	1973	408	2.29	1 : 9	1.04	1973	21 (81)

1/ Identified of mosquito blood with precipitin tests.
2/ Annual malaria parasite incidences/population of 1000 for a period of seven years between 1970-1976.
3/ *An. aconitus* in DDT susceptibility, ( ) = Number of females exposed to 4.0% for one hour.

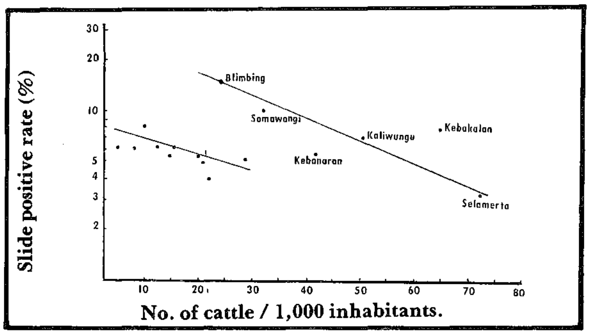

Fig. 5 Relation of malaria slide positive rates to cattle distributions in 16 desa of Kecamatan Mandiraja, Regency Banjaranegara, Central Java (based on mean for 1973-77).

Government development scheme recently undertaken which distributes cattle in rural communities for improved nutrition and paddy cultivation. Because it would be a permanent, non recurring cost and environment-enhancing method such measures could be recommended even if, as is probable, malaria was not well controlled, but merely reduced, for example, by 25-30 percent.

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