

WORLD HEALTH ORGANIZATION

TECHNICAL REPORT SERIES

No. 443

INSECTICIDE RESISTANCE AND VECTOR CONTROL

**Seventeenth Report
of the WHO Expert Committee
on Insecticides**

This report contains the collective views of an international group of experts and does not necessarily represent the decisions or the stated policy of the World Health Organization.

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GENEVA

1970

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Geneva, 19-25 November 1968

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INSECTICIDE RESISTANCE AND VECTOR CONTROL

Seventeenth Report of the WHO Expert Committee on Insecticides

The WHO Expert Committee on Insecticides met in Geneva from 19 to 25 November 1968. Dr P. Dorolle, Deputy Director-General, opened the meeting on behalf of the Director-General.

1. PRESENT STATUS OF RESISTANCE

1.1 Resistance of arthropods to insecticides

In 1962, the WHO Expert Committee on Insecticides reported that there was clear evidence of developed resistance in 81 arthropod species of medical or veterinary importance, and indications of resistance in about 10 more. In 1968, the number of species which had developed resistance was 102, with isolated indications in 4 more. Many of them have developed 2 or even 3 types of resistance, the comparison over the 6-year period being as follows :

	<i>DDT</i> <i>resistance</i>	<i>Dieldrin</i> <i>resistance</i>	<i>Organophosphorus</i> <i>resistance</i>
1962	47	65	8
1968	56	84	17

Among the anopheline mosquitos, 38 species have developed resistance to 1 or more insecticide, 36 having developed resistance to dieldrin, 15 to DDT (Table 1), and increased tolerance to malathion developed in 1 species. Among the culicine mosquitos 19 have developed resistance, 16 to DDT, 12 to dieldrin, and 9 to organophosphorus compounds (Table 2), with 4 additional isolated cases which will be mentioned later.

In the housefly, resistance to malathion or to diazinon is now becoming quite widespread in Western Europe, North America and Japan, and diazinon resistance has appeared in Australia (Table 3). Resistance to ronnel is now common in California, with cross-tolerance to fenthion; cross-resistance to dimethoate has been low, but control failures with

TABLE 1.
RESISTANCE OF ANOPHELINE MOSQUITOS TO DDT AND DIELDRIN ^a

Insecticide	Mosquito	Year	Area
DDT	<i>A. sacharovi</i>	1951	Greece ; Iran ; Turkey
	<i>A. sundalcus</i>	1954	Java ; Sumatra
	<i>A. stephensi</i>	1955	Saudi Arabia ; Iraq ; Iran ; S. India
	<i>A. subpictus</i>	1956	N. India ; W. Pakistan ; Nepal ; Java
	<i>A. albimanus</i>	1958	El Salvador ; Nicaragua ; Guatemala ; Honduras ; Mexico ; Cuba
	<i>A. pharoensis</i>	1959	Egypt ; Sudan
	<i>A. quadrimaculatus</i>	1959	Georgia, USA ; Maryland, USA ; Mexico
	<i>A. annularis</i>	1959	India
	<i>A. culicifacies</i>	1960	W. & S. India ; W. Pakistan ; Nepal
	<i>A. albitarsis</i>	1961	Colombia
	<i>A. nuneztovari</i>	1961	Venezuela
	<i>A. aconitus</i>	1962	Java
	<i>A. fluviatilis</i>	1963	W. India
	<i>A. hyrcanus sinensis</i>	1964	Ryukyus
	<i>A. gambiae</i>	1967	Upper Volta ; Senegal
Dieldrin	<i>A. sacharovi</i>	1952	Greece
	<i>A. quadrimaculatus</i>	1953	Mississippi, USA ; Georgia, USA ; Mexico
	<i>A. gambiae</i>	1955	Nigeria ; Liberia ; Ivory Coast ; Dahomey ; Upper Volta ; Cameroon ; Sierra Leone ; Togo ; Ghana ; Mali ; Congo (Brazzaville) ; Sudan ; Mauritania ; Madagascar
	<i>A. subpictus</i>	1957	Java ; Ceylon ; N. India ; W. Pakistan
	<i>A. coustani</i> and <i>A. pulcherrimus</i>	1957	Saudi Arabia
	<i>A. albimanus</i>	1958	El Salvador ; Guatemala ; Nicaragua ; Honduras ; Jamaica ; Ecuador ; Mexico ; British Honduras ; Cuba ; Dominican Republic ; Haiti ; Colombia
	<i>A. pseudopunctipennis</i>	1958	Mexico ; Nicaragua ; Peru ; Venezuela ; Ecuador
	<i>A. aquasalis</i>	1958	Trinidad ; Venezuela ; Brazil
	<i>A. culicifacies</i>	1958	W. India ; Nepal
	<i>A. vagus</i>	1958	Java, Philippines
	<i>A. barbirostris</i> and <i>A. annularis</i>	1958	Java
	<i>A. sergenti</i>	1958	Jordan
	<i>A. fluviatilis</i>	1958	Saudi Arabia
	<i>A. splendidus</i>	1958	N. India
	<i>A. stephensi</i>	1959	Iran ; Iraq
	<i>A. minimus flavirostris</i>	1959	Philippines ; Java
	<i>A. pharoensis</i>	1959	Egypt ; Sudan ; Israel
	<i>A. albitarsis</i>	1959	Colombia ; Venezuela
	<i>A. labbranchiae</i>	1959	Morocco ; Algeria
	<i>A. strodei</i>	1959	Venezuela
	<i>A. triannulatus</i>	1959	Venezuela ; Colombia
	<i>A. sundalcus</i>	1960	Java ; Sumatra ; Sabah
	<i>A. aconitus</i>	1960	Java ; India
	<i>A. neomaculipalpus</i>	1960	Trinidad ; Colombia
	<i>A. crucians</i>	1960	S. Carolina, USA ; Dominican Republic
	<i>A. filipinae</i>	1960	Philippines
	<i>A. maculipennis</i>	1961	Romania
	<i>A. rangeli</i>	1961	Venezuela
	<i>A. maculipennis messeae</i>	1961	Romania
	<i>A. labbranchiae atroparvus</i>	1961	Romania ; Bulgaria
	<i>A. philippinensis</i>	1962	Sabah
	<i>A. funestus</i>	1962	Nigeria ; Ghana ; Kenya
	<i>A. nill</i>	1966	Ghana
	<i>A. rufipes</i>	1968	Mali

^a This table covers only the first reported instance of resistance in any area.

TABLE 2. RESISTANCE OF CULICINE MOSQUITOS TO THREE INSECTICIDE GROUPS ^a

Mosquito	DDT group		HCH-dieldrin group		Organophosphorus group ^b	
	Year	Area	Year	Area	Year	Area
<i>Culex fatigans</i> (<i>quinquefasciatus</i>)	1952 1953 1956 1957 1958 1959 1961 1964 1966	India Reunion Venezuela; Taiwan Puerto Rico W. Africa; S. Australia; Panama Tanganyika; Hawaii; Congo Madagascar; Cuba; Georgia, USA China (mainland) Ryukyus; Queensland, Australia	1951 1953 1954 1956 1957 1958 1959 1960 1961 1964 1966	California, USA Malaya; India E. Asia S. America W. Africa Panama Zanzibar; Congo Texas, USA Mali; Madagascar; Brazil Tanganyika; China (mainland) Togo; Ivory Coast; Queensland, Australia	1959 1960 1963 1967	Cameroon (O) California, USA (M) Sierra Leone (O) Ryukyus (M)
<i>C. pipiens</i>	1947 1955 1959 1961 1965	Italy Massachusetts, USA; New Jersey, USA Israel; Japan; California, USA New York, USA; Maryland, USA; Illinois, USA; Utah, USA France; Korea; Turkey	1950 1955 1959 1965 1966	Italy Israel France; Japan Korea Morocco		
<i>C. tarsalis</i>	1951 1956 1961	California, USA Oregon, USA Washington, USA; Utah, USA	1951 1961	California, USA Oregon, USA	1956 1961	California, USA (M) Oregon, USA (M)
<i>C. coronator</i>	1958	Panama				
<i>C. tritaeniorhynchus</i>	1958	Ryukyus	1959 1965	Dahomey; Ryukyus Korea	1967	Ryukyus (M)
<i>C. peus</i>	1961	Oregon, USA				California, USA (M)
<i>Aedes aegypti</i>	1954 1955 1956 1957 1958 1959	Trinidad; Dominican Republic Venezuela Haiti Antigua, Colombia S. Viet-Nam Puerto Rico; Jamaica; Guadeloupe; French Guinea	1959 1962 1963 1964 1965 1966	Puerto Rico Jamaica; Haiti; Curaçao Virgin Islands Surinam; Guyana; Cambodia; S. Viet-Nam Texas, USA Cameroon; Tahiti; Thailand; Congo; Senegal; Ivory Coast	1965 1966	Jamaica, Venezuela (M) Thailand; S. Viet-Nam Congo (Brazzaville)

TABLE 2. RESISTANCE OF CULICINE MOSQUITOS TO THREE INSECTICIDE GROUPS ^a (concluded)

Mosquito	DDT group		HCH-dieldrin group		Organophosphorus group ^b	
	Year	Area	Year	Area	Year	Area
<i>Aedes aegypti</i> (cont.)	1961 1963 1965 1966 1968	Florida, USA Guyana ; Thailand E. India ; Japan ; Texas, USA W. India ; St Vincent Liberia ; Ivory Coast ; Dahomey ; Cameroon	1968	Liberia ; Togo ; Nigeria ; Upper Volta		
<i>A. sollicitans</i>	1947 1951	Florida, USA Delaware, USA	1951 1958	Florida, USA Delaware, USA		
<i>A. taeniorhynchus</i>	1949 1959	Florida, USA Georgia, USA	1951 1959	Florida, USA Georgia, USA		
<i>A. nigromaculis</i>	1949	California, USA	1951	California, USA		
<i>A. melanimon</i> ^c	1951	California, USA	1951	California, USA	1958 1960	California, USA (P) California, USA (M)
<i>A. dorsalis</i>					1962	California, USA (P)
<i>A. cantator</i>	1960	New Brunswick, Canada	1960	New Brunswick, Canada	1966	New Mexico, USA (O)
<i>A. cantans</i>	1958	Germany				
<i>A. detritus</i>	1959	France				
<i>A. albopictus</i>	1964	S. Viet-Nam, S. India				
<i>A. vittatus</i>	1964	W. India				
<i>Psorophora</i> <i>confinis</i>			1954	Mississippi, USA		
<i>P. discolor</i>			1954	Mississippi, USA		

^a This table covers only the first reported instance of resistance in any area.^b M = malathion resistance ; P = parathion resistance ; O = general organophosphorus resistance.^c Formerly called *A. dorsalis*.

TABLE 3. RESISTANCE TO THREE INSECTICIDE GROUPS BY NOXIOUS DIPTERA ^a

Species	DDT_group		HCH-dieldrin group		Organophosphorus group	
	Year	Area	Year	Area	Year	Area
<i>Musca domestica</i>	1946 1947 1948 1949	Sweden ; Denmark USA ; Mediterranean New Zealand ; S. America W. Europe ; Canada	1949 1950 1951 1952	California, USA ; Sardinia ; Egypt USA ; Scandinavia S. America Africa	1955 1956 1957 1958	Denmark ; Florida, USA Switzerland ; Italy ; Georgia, USA New Jersey, USA California, USA ; Arizona, USA ; Louisiana, USA
	1950 1953 1956 1958 1960	USSR ; Africa Japan China Czechoslovakia ; Poland India	1953 1954 1957 1961 1962	USSR Japan India Caribbean Romania	1960 1961 1962 1967	Japan Germany ; France Australia USSR
<i>Stomoxys calcitrans</i>	1948 1958 1966	Sweden Norway Germany ; Italy	1958 1965 1966	Norway Florida, USA Germany		
<i>Phaenicia cuprina</i>			1957	Australia	1966	Australia
<i>Phaenicia sericata</i>			1959	New Zealand ; S. Africa		
<i>Chrysomya putoria</i>			1949 1960 1961	Congo (Kinshasa) Madagascar Zanzibar	1954	Congo (Kinshasa)
<i>Protophormia terraenovae</i>	1964	European Russia				
<i>Haematobia irritans</i>			1959	Texas, USA	1962	Louisiana, USA
<i>Fannia canicularis</i>	1953 1962 1967	Spain Japan England ; California, USA	1967	California, USA		

TABLE 3. RESISTANCE TO THREE INSECTICIDE GROUPS BY NOXIOUS DIPTERA ^a (concluded)

Species	DDT group		HCH-dieldrin group		Organophosphorus group	
	Year	Area	Year	Area	Year	Area
<i>F. femoralis</i>	1967	California, USA	1967	California, USA		
<i>Simulium aokii</i>	1963	Japan				
<i>S. ornatum</i>	1966	Japan				
<i>S. venustum</i>	1967	Quebec, Canada				
<i>Chironomus zealandicus</i>			1966	New Zealand		
<i>Glyptotendipes paripes</i>			1953	Florida, USA	1955	Florida, USA
<i>Chaoborus astictopus</i>	1961	California, USA				
<i>Psychoda alternata</i>	1949	Illinois, USA	1953	England		
<i>Leptoconops kerteszi</i>	1961	California, USA				
<i>Culicoides furens</i>			1958 1959	Florida, USA Panama		
<i>Hippelates collusor</i>			1957	California, USA		
<i>Leptocera hirtula</i>	1955	Malaya	1955	Malaya		
<i>Drosophila virilis</i> ^b	1952	Japan				

^a This table covers only the first reported instance of resistance in any area.^b Also *D. melanogaster*, both field strains.

dimethoate started to appear in Denmark and New Jersey in 1966. Resistance to trichlorfon in baits and sprays has been encountered first in Florida, then in Denmark, and very recently in the USSR. The use of dichlorvos vapour can induce resistance, but very slowly. Resistance to coumethioate has developed in Italy; fenitrothion and Gardona¹ have not yet been used long enough for their liability to resistance to be determined.

The stable fly, *Stomoxys*, has developed DDT resistance in Western Europe and dieldrin resistance in Florida. The latrine fly, *Fannia canicularis*, has become resistant to DDT in England and Japan, and in addition is resistant to dieldrin in California where *F. femoralis* has also developed resistance to both insecticides. The blowfly, *Protophormia terraenovae*, has developed DDT resistance in European Russia. The horn fly, *Haematobia*, first developed resistance to toxaphene in Texas, and then to ronnel in Louisiana. The sheep blowfly, *Phaenicia cuprina*, is gradually developing resistance to diazinon in New South Wales, Australia. Whether the same change has occurred in the dieldrin-resistant species *P. sericata* in South Africa (wrongly listed as *P. cuprina* in the Committee's thirteenth report) has yet to be established. Increased tolerance to DDT and dieldrin in *Leucophya leucostoma* in California is not yet high enough to be listed. Resistance has not yet been recorded in *Phlebotomus*, or in *Glossina*.

One of the most serious developments has been the recent appearance of populations of *Simulium* blackflies resistant to the larvicides which have been used against them, DDT resistance and some HCH tolerance has been reported in a population of *S. aokii* near Tokyo, and DDT resistance coupled with tolerance to fenthion in *S. ornatum* at Chino, Japan. A third species, *S. venustum*, has developed a population 10 times as resistant to DDT as normal in an area of Quebec Province, Canada, which had been treated with this insecticide for the preceding 10 years. A recent control failure with DDT against *S. damnosum* on the lower Volta River in Ghana may have been caused by an increased tolerance to DDT in this important vector of onchocerciasis. Among the midges, the only addition since 1962 is *Chironomus zealandicus*, which has developed resistance to HCH and cyclodiene insecticides in New Zealand.

Among body lice, new records of DDT-resistant populations have come from Hungary and Romania, and strong HCH resistance has recently been found in Turkey (Table 4). There have been a number of new reports of resistance among lice of veterinary importance and these are listed in Table 4.

New records of chlordane resistance in the German cockroach, *Blattella*, have come from Germany, Denmark, Hawaii, New South Wales (Australia) and New Guinea. Diazinon resistance has been found in Texas as well as in Kentucky and Indiana, and malathion resistance in Louisiana, Texas

¹ Dimethyl 2,4,5-trichloro- α -(chloromethylene)benzyl phosphate.

TABLE 4. RESISTANCE OF CERTAIN ARTHROPODS OF PUBLIC HEALTH AND VETERINARY IMPORTANCE ^a

Species	DDT group		HCH-dieldrin group		Organophosphorus group	
	Year	Area	Year	Area	Year	Area
<i>Pediculus corporis</i>	1951 1952 1955 1956 1958 1959 1961 1964	Korea ; Japan Egypt ; E. Mediterranean (UNRWA camps) Iran ; Turkey ; Ethiopia ; W. Africa ; Peru ; Chile France Yugoslavia ; Libya ; Afghanistan ; India Mexico ; Uganda Sudan Romania	1955 1956 1957 1958 1959 1961	France ; Japan W. Africa ; S. Africa Iran India ; Korea Tanganyika Sudan		
<i>Linognathus vituli</i>	1957 1966	Virginia, USA Alberta, Canada				
<i>L. africanus</i> and <i>L. stenopsis</i>			1967	S. Africa		
<i>Haematopinus eurysternus</i>	1964	Alberta, Canada	1964	Alberta, Canada	1966	Alberta, Canada
<i>Boophilus limbata</i> and <i>B. caprae</i>			1957	Texas, USA		
<i>Blatta orientalis</i>	1964	Czechoslovakia	1958 1964	Germany Czechoslovakia		
<i>Blattella germanica</i>	1958 1959 1961	France ; Germany ; Cuba ; Bahamas ; Puerto Rico Trinidad ; Poland England	1951 1955 1956 1958 1959 1961 1963	Texas, USA S. E. USA N. E. USA California, USA ; Panama ; Cuba ; Puerto Rico Canada ; Trinidad ; Japan ; Poland England ; Germany Denmark ; Hawaii ; New Guinea	1960 1964 1966	Kentucky, USA ; Indiana, USA Texas, USA Louisiana, USA

