Technical Papers

Houseflies Resistant to Benzene Hexachloride

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In October 1948 the junior author, a staff member of the International Health Division of The Rockefeller Foundation, working in cooperation with the Egyptian Ministry of Health, initiated a housefly control campaign in the Egyptian village of Quaranfil. One of the measures used was the application of benzene hexachloride dusts containing 2.4% of the gamma isomer to all places suspected of being breeding areas. The treatment was renewed whenever it showed signs of losing its effectiveness. During the first 10 months fresh applications were made approximately once a month. A great reduction of houseflies was maintained throughout most of this period. In August, September, and October of 1949 the intervals between dustings were gradually shortened until applications were being made weekly because an adequate control could no longer be maintained. It was suspected that a strain of houseflies had developed that was resistant to benzene hexachloride.

To find out if this suspicion was correct a series of laboratory tests was run by the senior author during November and December, 1949, against houseflies (*Musca domestica vicina* Macq) collected from nine different sources, including six villages in addition to Quaranfil, a slaughterhouse in one of the suburbs of Cairo, and a laboratory-reared colony. Quaranfil was the only place in which large scale housefly control measures were being used.

The tests were run on plywood panels (1 ft square) that had been sprayed with an acetone solution containing 1.25% benzene hexachloride. The sprays were prepared from a technical grade product having a 20% gamma isomer content. Solution was applied, 10 ml to each panel, to obtain a dosage rate of 25 mg of the gamma isomer per square foot. Within one week after treatment adult houseflies were exposed on these treated surfaces for varying periods of time, confined under half-sections of Petri dishes. A previously unused surface area was used each time. After exposure the flies were transferred to untreated screen cages, furnished honey and water, and held for 24 hr, at which time mortality counts were made. The results listed in the tables are averages of six tests; three were run on each of 2 days.

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In one series all nine colonies were exposed for 30 min. As shown in Table 1, at least 99% mortality was obtained within 24 hr against the eight colonies that had not been subjected to control measures. In contrast, less than half of the Quaranfil strain was killed, indicating that this strain actually had acquired considerable resistance to benzene hexachloride.

Another series was run with the Quaranfil, slaughterhouse, and laboratory strains, to obtain more precise information on the degree of resistance that had developed. In these tests the exposure period was varied between 5 min and 120 min to obtain a range of mortalities that would permit a comparison of the contact times required to kill similar percentages of the different colonies. In all, 1,796 male and 1,511 female flies were used in these tests.

TABLE 1

TOXICITY OF RESIDUAL DEPOSITS OF BENZENE HEXACHLORIDE TO NINE HOUSEFLY STRAINS

Colony	No. of insects used		Percent kill in 24 hr	
	Male	Female	Male	Female
Kafr Aho Gomma ..	123	51	100	100
Balaks	118	76	100	100
Dandana	64	105	100	100
Kam Asfar	93	86	100	100
Z. Naggar	133	38	100	100
Sandyong	123	81	100	100
Slaughterhouse	119	92	100	99
Laboratory	192	38	100	100
Quaranfil	58	150	48	12

The results obtained in the second series are listed in Table 2. It is readily apparent that the Quaranfil strain was much more difficult to kill than the slaughterhouse or laboratory strains. An exposure that was sufficient to cause 100% mortality of those from the two untreated sources killed only 15% of the males and 12% of the females from the resistant stock. The 5-min exposure killed 65%–67% of the slaughterhouse and laboratory females but a 2-hr exposure was required to kill a comparable percentage of those from the village where benzene hexachloride treatment had been given, indicating the Quaranfil flies were about 24 times as resistant to this insecticide as the other two strains. The degree of resistance acquired by the males appeared to be even greater.

With female flies the greatest differences were observed in the 30-min tests, where the mortality obtained in individual tests was always at least 67% lower for the resistant flies than the corresponding exposure of slaughterhouse or laboratory flies. Similarly, the kill of males from the untreated sources always exceeded that of the Quaranfil stock by at least 78% in the 5-min tests.

TABLE 2

RELATIVE SUSCEPTIBILITY OF THREE HOUSEFLY STRAINS TO RESIDUAL DEPOSITS OF BENZENE HEXACHLORIDE

Housefly strain	No. of insects used		Percent kill in 24 hr	
	Male	Female	Male	Female
		5-min exposure		
Slaughterhouse	97	166	100	65
Laboratory	147	146	100	67
Quaranfil	71	96	6	4
		10-min exposure		
Slaughterhouse	93	133	98	90
Laboratory	207	101	99	74
Quaranfil	108	122	8	4
		30-min exposure		
Slaughterhouse	119	135	100	100
Laboratory	221	102	100	100
Quaranfil	110	105	15	12
		60-min exposure		
Slaughterhouse	136	93	100	100
Laboratory	199	88	100	100
Quaranfil	125	116	84	42
		120-min exposure		
Slaughterhouse	...	...	...	...
Laboratory	...	...	...	...
Quaranfil	163	108	86	62

There were no reversals in any of the comparisons.

Entomologists have hoped that benzene hexachloride would be one of the residual-type insecticides that could be used satisfactorily in situations where houseflies have developed resistance to DDT. The results obtained in Quaranfil indicate that any benefit derived from a change to this insecticide might be only temporary.

Acceleration of Carbon Monoxide Elimination in Man by High Pressure Oxygen[1]

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Claude Bernard (*2*) was the first to point out that carbon monoxide produces hypoxia through its reversible combination with blood to form carboxyhemoglobin, and pure oxygen at normal barometric pressures has been used as an effective therapeutic aid in the treatment of CO poisoning ever since it was first tried by Linas and Limousin (*8*). The relative affinity relationship between CO and O_2 for hemoglobin has been enunciated by Douglas, Haldane, and Haldane (*5*) in the form $\frac{[COHb]}{[HbO_2]} = K\frac{[pCO]}{[pO_2]}$ where K, the relative affinity constant, has been measured to be 210 for man (*12*). The rationale for increasing the partial pressure of inspired O_2 in the treatment of CO poisoning, therefore, seems clear on the basis of mass action consideration alone, and a direct relationship between alveolar pO_2 and the rate of CO elimination from the body might be expected. Such a relationship has been demonstrated recently for man (*10*), and will be reported in detail later. The rate of CO elimination in man is increased approximately fivefold from a half-time of over 4 hr while breathing air to a half-time of about 45 min while breathing pure oxygen, corresponding to the fivefold increase in pO_2.

The most serious effect of CO inhalation was convincingly demonstrated by Haldane (*7*) to be the combination of the gas with the blood hemoglobin and the consequent reduction in O_2-carrying capacity of the blood. In his classic experiment, a mouse was exposed in a pressure chamber to one atmosphere of CO and two atmospheres of oxygen with no loss of consciousness or obvious ill effects, the mouse apparently having met its metabolic oxygen requirement by utilizing the greatly increased oxygen in physical solution in the blood plasma. There is implicit in this experiment the use of oxygen at pressures higher than normal barometric pressure for the treatment of CO poisoning, and End and Long (*6*) have shown the worth of high pressure oxygen in treating laboratory animals after exposure to CO. Reluctance to use high pressure oxygen in the treatment of persons suffering CO poisoning stems from the toxic nature of oxygen itself at pressures of one atmosphere and higher; however, as pointed out by Bean (*1*), there is a relationship between time and concentration in the development of oxygen poisoning. This makes it possible to select an optimal combination of exposure time and ambient oxygen partial pressure such that the rate of CO elimination may be materially increased without incurring the risk of oxygen poisoning.

Following mild, acute exposure to CO, ten volunteer subjects, comprising five men and five women, were placed in a recompression chamber[2] at 22 psi gage pressure. Measurements of the rate of CO elimination were carried out while the individuals seated at rest, breathed pure oxygen for 1 hr. In this way, the subjects were exposed to an ambient pO_2 of 2.5 atmospheres. The procedure consisted in allowing the subject to rebreathe a mixture of 250 ml of CO and 2 l of air from a rubber bag for 30 sec. The individual was then seated in the recompression chamber, and the ambient pressure was raised to 2.5 atm, absolute. Oxygen breathing was begun through an A-14 mask with free flow from a tank of medical oxygen, and the first blood sample was withdrawn from the antecubital vein after a few minutes. The initial blood levels of CO ranged from 20% to 30% COHb, and blood samples were withdrawn by venepuncture every 15 min during the hour of oxygen breathing. The samples were analyzed for CO content by the method of Scholander and Roughton (*11*), and the rate of elimination was determined as the slope of the line of least squares through a plot of the logarithm of blood concentration against time. As shown elsewhere (*10*), CO elim-

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