ORGANOPHOSPHATE RESISTANCE OF *CULEX PIPIENS* IN TWO URBAN MOSQUITO ABATEMENT DISTRICTS' – A CASE HISTORY

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The house mosquito, *Culex pipiens*, is one of the most important of nineteen species of mosquitoes found in each of these highly urbanized Districts. Their importance stems partially from the potential abundance of these mosquitoes capable of being produced in catch basins, storm drains, septic tanks and sumps, as well as other breeding sources. Another contributing factor is the low tolerance exhibited by the public to this species of mosquito which exhibits a propensity for the indoors, a trait making even low numbers of these mosquitoes obvious.

CHEMICAL HISTORY

The types of sources producing the house mosquito in the Districts have dictated a chemical approach to control. The most important sources are catch basin and storm drain systems found throughout the residential areas. These types of sources are not readily amenable to source reduction methods because of cost factors. The solution to the problem has been achieved through the use of chemicals.

ALAMEDA COUNTY MAD.–In 1973, 92% of the total control effort directed at *Culex pipiens* was chemical in nature. The records suggest that heavy reliance upon chemicals to control this species began early in the District's history.

In 1934, four years after formation of the District, a chemical program was initiated to control the production of the house mosquito in underground drain systems. The program consisted of applying oil to drains and catch basins in the vicinity of complaints but due to the lack of adequate equipment too few were treated and the results were judged to be poor. In 1935 routine oiling of catch basins was carried out in the District with a three-wheeled motorcycle. Approximately 10,000 basins needed treatment, the most productive requiring 8-12 applications per year. The oiling program provided good control of the mosquito population but was suspended with the advent of World War II. The greatest number of catch basins ever treated with oil in one season (46,271) occurred in 1937.

In 1945 DDT was tested in catch basins and found to be highly effective and by 1947 the catch basin/storm drain treatment program was established using DDT rather than oil. The residual effect of DDT was immediately apparent in the operational data. Only 4,072 basins were treated in 1947 compared to an average of more than 30,000 when oil was used. Instead of the 8 or more retreatments that were necessary in the catch basins using oil, only one in 40 catch basins required an additional treatment with DDT. The number of DDT treated basins peaked at 39,546 during 1961. The tremendous increase in DDT treatments since 1947 cannot be attributed only to the addition of new catch basins. Many basins were being treated three or more times per year in order to provide effective control.

In 1964, field tests were made to compare DDT with fenthion. The effectiveness was assessed by the time interval between required treatments. The results of the tests showed fenthion to be more effective.

The District began using fenthion in the basins in 1964. The number of treatments remained approximately the same as with DDT. The total number of catch basins treated per year with fenthion has remained essentially the same to date. This year some of the most productive basins were treated seven times. During the peak breeding season some were treated as frequently as every two weeks. After 1970, Dursban® was used selectively in specified catch basins.

SAN MATEO COUNTY MAD.–There are few historical records available concerning catch basins. It has only been since 1954 that the number of basins treated yearly was published in the annual report, and only since 1968 that records were kept that delineated types and amounts of chemicals used in catch basin work. Fenthion came into general use in 1970, being preceded by diazinon, with an average of three to four applications per season. Diazinon was not used after 1971. In 1973, some areas which were considered to be hot spots, that is, areas where breeding frequently will generate service requests, were treated 5 or 6 times. In 1974, a different approach to catch basin work was initiated. Basins were treated regularly only when they were considered hot spots or they were treated as a result of service requests. This approach resulted in a saving of 1.4 man months (248 hours) to the District and a considerable reduction in the number of basins treated. No appreciable increase in service requests was noted that could be attributed to this change in operational procedure.

DETECTION OF RESISTANCE

Monitoring of susceptibility levels of local mosquito populations was initiated, in cooperation with the Vector Control Section of the State Department of Health, in 1972.

ALAMEDA COUNTY MAD.–The results of some tests on *Culex pipiens* suggested resistance during the first test year (1972). Testing in 1973 was less frequent, but samples containing *C. pipiens* continued to suggest possible resistance. By 1974 full blown fenthion resistance in *C. pipiens* was documented when numerous tests showed high LC_{50} values. When the locations of the samples were plotted on a District map, a distribution pattern emerged indicating a large area of resistance from Oakland south to Fremont. This area of high resistance was bordered on the north and east by more susceptible populations of the same species.

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Upon first glance at District operational data the high levels of resistance might appear to be a laboratory phenomenon, since no increase in service requests and no appreciable increase in control effort of *C. pipiens* is evident. Approximately the same number of catch basins are being treated per year and, most important, only one documented field failure has occurred. Close scrutiny of the recent catch basin treatment program, however, reveals information which supports the laboratory findings. The certified technicians, over the last few years, have become more selective in their treatments of catch basins. Selected catch basins are now treated much more frequently than in the past.

Even more dramatic evidence was provided by interpretation of the results of field tests conducted to establish retreatment schedules for catch basins. On the basis of these tests, operational personnel established retreatment cycles exceeding a month for catch basins in 1964. After 10 years of fenthion usage, treatment cycles on some catch basins were at intervals of less than two weeks.

A review of the District's chemical history strongly suggests the same kind of scenario occurred with DDT. In 1947, the newly acquired DDT was used once a year in most basins. By 1961, records indicate three or more treatments were required. It appears that an impending control breakdown was averted by shifting to fenthion in 1964.

SAN MATEO COUNTY MAD.–Resistance tests began in 1973. Most of the tests run that year in the laboratory were intended to perfect techniques as well as provide susceptibility levels of local mosquito populations. The high levels found during the two year testing period have been confirmed by the Vector Control Section of the State Department of Health, and also this year by Dr. Georghiou of the University of California at Riverside. The field data (catch basin schedules), as in Alameda, gave no suggestion of the developing resistance. The number of treatments per season remained relatively stable as did the number of basins. Resistance levels were fairly uniform throughout the District.

SOLUTIONS

Before solutions could be properly formulated, a thorough analysis of the available data was necessary to provide a clear statement of the problem. Hopefully, one pitfall was averted very early in the process when both Districts avoided defining resistance as the ultimate problem. Resistance, after all, is a well documented, predictable, biological phenomenon. Its appearance simply indicated the existence of inadequacies in the control programs of both Districts. Therefore, the problem in need of solution is to be found in the character of the programs.

Intensive program review sessions were conducted by both Districts during the winter months to establish a basis for the formulation of future control strategies. These independent sessions uncovered a number of common characteristics that appeared central to the problem:

1. Chemicals were by far the most heavily relied upon technique used to control the house mosquito.
2. As long as inexpensive replacement chemicals were available, the chemical in use was changed before resistance induced field failures became apparent.
3. The existing methods used to collect and interpret operational data, and the field inspection procedures, were insufficient to detect control failures.
4. Both Districts lacked clear objectives defining the level of control to be provided. Control operations had evolved over a long period of time to the point that the treatment of many catch basin and storm drain systems occurred whether or not it could be reasonably inferred that they would cause complaints.

The following program was planned for the control of the house mosquito in both Districts for 1975:

1. Efforts will be made to gain the cooperation of public works departments of the various cities in attempt to coordinate their storm drain clean-out programs to supplement our control programs.
2. Treatment of catch basins and storm drains will be accomplished with a larvicidal oil. Abate or Dursban® may be used when *Culex pipiens* is found in sources that cannot be treated with oils, or when adequate control cannot be obtained with a larvicidal oil.
3. Where possible, selected catch basins that had been treated routinely in the past have been designated to be treated on the basis of service requests only.
4. Only those catch basins that, when breeding, and are known to cause service requests will be treated on a routine basis. (The approach outlined in steps 3 and 4 was used successfully by San Mateo County in 1974.)
5. Efforts are currently underway to determine the feasibility of controlling adult mosquitoes at their resting sites.
6. The susceptibility of the house mosquito to various insecticides will continue to be monitored.
7. More emphasis will be given to post-treatment inspections.

SUMMARY AND CONCLUSIONS

The history of chemicals applied to the house mosquito (*Culex pipiens*) in the Alameda and San Mateo County Mosquito Abatement Districts leaves little doubt that we are dealing with insecticide-induced resistance. Both Districts have made significant changes in their control strategies to adapt to the new limitations created by resistance. The new control programs reduce reliance upon chemicals through more selective treatment procedures and more emphasis on alternative approaches. Early indications from the 1974 control program of San Mateo County Mosquito Abatement District suggests this approach may provide significant savings of man-hours.

Other benefits should be derived by a reduction in handling hazards and lowering environmental contamination risks usually associated with the excessive use of chemicals.

These new programs are certainly not without risk. The programs assume that citizens will tolerate a somewhat higher level of the house mosquito than has prevailed in the past, at least during that period when the approved chemicals were highly effective. One should not conclude here that we are lowering standards of mosquito control. We are simply recognizing that in the past an unnecessarily high level of control was established through the use of effective and inexpensive chemicals.

The future of these programs may very well be determined by the effectiveness of public education within the Districts.