NOTES ON THE DEVELOPMENT OF MALARIA CONTROL IN OKLAHOMA

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INTRODUCTION

Malaria came to Oklahoma long before statehood, judging from records and reminiscences of chills and fever, and the known circumstances inviting the disease. The lengthy history of Oklahoma is remarkable for its shifting and varied populations. Spanish and French explorers, traders and pioneers, Gulf States tribes removed to Indian Territory, African slaves, travellers on the early trails, boomers and homesteaders—any and all of these may have con-

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tributed to the introduction of malaria. The natural agents of transmission were already present in the native anopheline mosquitoes along the valleys of the Red River and the Arkansas and their tributaries.

Malaria deaths have been reported throughout most of Oklahoma, but the contrasting topography and climate within State boundaries—southeastern Gulf coastal plain to northwestern prairie uplands—largely restrain endemic malaria to the eastern river valleys. These are the areas of greatest rainfall and concentrated rural populations. The fertile valleys are also productive of the malaria mosquito, *Anopheles quadrimaculatus* Say, and local economic conditions usually do not encourage adequate screening or medical attention. The eastern malarious areas include fewer than one-third of the 77 counties in the State and the problem is especially serious in 10 or 12 counties (Table I).

The principal lines of field attack in malaria control are medical, engineering, entomological, and educational. The medical contribution, in the field operation plan, is usually through epidemiological surveys, guiding the program into those areas which most require an extended malaria-control effort. Coordinated engineering and entomological operations are directed toward reduction of malaria mosquitoes, through surveys of anopheline breeding sources to establish the problem in area and in season, and the elimination or control of important sources by drainage, filling, and application of insecticides. The educational program is designed to facilitate field operations by distributing information on malaria and securing public cooperation and participation in malaria control. While all of these field operations are recognizably overlapping and intersupporting, each has had its period of emphasis in Oklahoma. Considered from this point of view, malaria control in this State has attained its present effectiveness through progressive development and coordination of several distinct phases in field effort—in some ways representative of antimalarial developments elsewhere, in other ways unique.

PREWAR MALARIA CONTROL

The program was initiated in 1928 by the Bureau of Sanitary Engineering, as outlined in the Ninth Annual Report of the State Department of Health (Beson and Hassler 1931), with the objective of bringing direct aid, as far as possible, to all of the most-malarious areas in the State. The first comprehensive aim has been the keynote in subsequent field development of the malaria-control program.

In 1926 splenic examination of 1352 school children had indicated malaria histories among 14.1 to 34.5 percent in river areas of eight eastern counties (Beson and Hassler 1931). School malaria census (made by sending malaria cards from the schools to the homes, to be filled out and returned by the parents), 1929-31, reached 56,295 persons, showing 8.4 to 49.0 percent with malaria histories in 17 counties (Canavan 1935). Blood smears taken in schools during 1934 yielded 4112 slides, showing 0.9 to 7.3 percent positive in the eight counties surveyed in 1926 by splenic examination, and 7448 slides, showing 0.6 to 11.9 percent positive in 16 of the counties surveyed in 1929-31 by school census (records of the State Department of Health). The results of such different survey techniques are scarcely comparable, but do indicate the established endemicity of malaria in Oklahoma and the types of epidemiological studies which have laid the foundations for field attack on the control problem. The most recent national survey (1938-42), on which the present State malaria-control program is based (Fig. 1), placed one southeastern county as 50th in rank among the 911 malarious counties surveyed in the United States, and also placed seven other eastern Oklahoma counties in the upper third of the national list.

In the first field operations the two greatest needs were concluded to be

malaria educational work and treatment of malaria cases. School and community meetings were organized, with informative talks, picture shows, and printed matter, supplemented by newspaper articles and mail circulars. The educational activities were accompanied by the unique experiment of quininization through "pill drills" in the schools of the most-malarious counties (Beson and Hassler 1931, Bilby and Hassler 1932). From 1929 to 1931 approximately 3,000,000 five-grain capsules (4.5 grains quinine bisulphate, 0.5 grain powdered ginger) were distributed in the standard eight-weeks treatment for participating school children and adults. Reduction of malaria and increased school attendance were noted, but much of the ground gained was lost when the work could no longer be supported (Canavan 1935).

In the prewar decade, through federal relief agencies, an enormous program of ditching and filling was undertaken to remove breeding sources of anopheline mosquitoes in rural areas and communities of malarious counties. The program began in 1933, sponsored by the State Department of Health, Bureau of Sanitary Engineering, and by 1935 had already accomplished the elimination of many acres of undesirable water through large earth ditches. There followed an intensive construction period in 26 eastern counties, involving numerous projects and several thousand workers. Summarized from 1935 to 1941, main-channel ditching exceeded 269 miles —over 60 miles having been made permanent with stone and concrete linings. The ditches removed more than 7150 acres of mosquito breeding waters, and approximately 165 additional acres were eliminated by filling. Wages and rental costs totalled $2,563,535; actual labor, 6,241,366 manhours expended. At least 275,000 people were shown to benefit directly from this huge effort toward elimination of mosquito breeding sources, and the permanent construction is continuing to serve many communities long after the intensive work program closed in the early years of the War.

The Oklahoma malaria-control program was reorganized in 1937 when a physician and an engineer, both specially trained in malariology, were added to the staff of the State Department of Health. These workers included entomological surveys and educational activities among their duties, forming the technical nucleus for the developing malaria-control division. Their efforts were directed through county health units toward increasing facilities and progress in survey, education and control, better case reporting, and local participation in malaria control. Case studies made by the physician also contributed to an understanding of the epidemiological basis for control operations. The work was continued through several years until the physician and the engineer were called to other duties.

WAR MALARIA CONTROL

World War II made necessary the rapid expansion of malaria-control activities in areas of war concentrations, such as military bases, ordnance works, and congested war-housing areas. In the spring of 1942 the emergency program of Malaria Control in War Areas was initiated by the State Department of Health in cooperation with the United States Public Health Service. The program was designed as an extrareservational activity, complementing the malaria-control programs of military authorities by extending zones of survey and control beyond government property and jurisdictional limits.

War areas and *endemic areas* of malaria control usually coincided, but not necessarily. This was due primarily to important differences in the localization of the disease and the wide range of its potential vectors. While endemic malaria is plainly restricted under normal circumstances to the eastern counties in Oklahoma, anopheline mosquitoes may be found in significant numbers throughout the State, given favorable local and seasonal conditions. War-related populations not only brought new haz-

ards of malaria transmission through the unusual concentrations in malarious areas, but also threatened the introduction of malaria into areas then free from the disease. War construction distributed potential areas of malaria control throughout Oklahoma, many of these areas being several miles in circumference and involving personnel numbering in the thousands (Table II and Fig. 1). These growing problems demanded an effective answer as the primary and immediate obligation of war malaria control.

The State Department of Health set up and directed its program in the Malaria Control Division, Bureau of Sanitary Engineering, under the guidance of the Chief Engineer of the Bureau. The national-headquarters office of Malaria Control in War Areas (United States Public Health Service, Atlanta, Georgia) provided assistance in survey, training, personnel, materials, equipment, and administration, through the district office (then District 7, Kansas City, Missouri; tranferred to District 9, Dallas, Texas, with the close of the fiscal year 1946). An engineer, an entomologist, and the clerk-stenographer composed the initial State malaria-control-office staff. Field educators were employed only in the summer months. Area supervisors, assisted by area entomological inspectors, were directly responsible to the State malaria-control office, though in close cooperation with county health offices. Foremen and laborers were recruited locally.

Control operations were directed against malaria mosquitoes at the breeding sources, through drainage, clearing and cleaning, and larviciding (oiling and dusting) in routine weekly treatments. These operations were initiated, evaluated, and discontinued each season (May-October), according to the findings of routine weekly entomological inspections coordinated with the treatments. Control limits were established in one-mile zones (approximate flight range of the malaria mosquito) surrounding war concentrations. In some cases several war establishments might fall within the radius of one control zone—the field unit of operations—and several adjacent zones might be grouped as one war area.

The mosquito breeding sources in all zones were mapped and provisionally studied for control; but initiation of control operations depended upon thorough reconnaissance surveys showing (1) significant malaria-mosquito production demonstrated through entomological collections, (2) war concentrations within flight range of the breeding sources, and (3) malaria occurrence sufficient for possible transmission. The usual location of war establishments near centers of population incidentally brought the experience and benefits of the malaria-control program to several hundred thousand State residents.

In the first years of operation (1942-43) there was apparent emphasis on drainage, reducing the problem of larviciding to which emphasis was duly transferred in succeeding years. Two major projects of particular interest in this early period were the clearing of 48,443 cubic yards of tornado drift from 9.8 miles of Pryor Creek, and the construction of 22,576 linear feet of ditch with dynamite, permanently eliminating 61 acres of swamp water near Miami, Oklahoma. Following the initial work in removing undesirable water, the first consideration in ditching, clearing, and cleaning was to improve the attack on larval mosquitoes with fuel oil and paris-green dust.

The total problem was emphasized and clarified in the fall of 1944 by a "watered area census" in 20 control zones, showing approximately 2062 acres of ponded water and 447 miles of streams and ditches, of which 369 acres and 218 miles, respectively, were shown to breed *Anopheles quadrimaculatus* Say. This survey was completed after approximately 244 acres and 3 miles of undesirable water had been eliminated by drainage, and the figures given represent less than one-half of the total breeding sources then under surveillance in zones where control did not become necessary. In this

representative season (May-October 1944) 43,647 manhours were used in larviciding 5577 acres (accumulated total) with 69,359 gallons of oil and 1396 pounds of paris-green dust; while 13,953 manhours were used in clearing and cleaning 109 acres (accumulated total) and in the incidental ditching of 44,863 linear feet to drain 110 acres. In spite of the increased breeding problem evident in this season when compared with 1942 and 1943, the extent of satisfactory control (zones with no more than 10 adult *Anopheles quadrimaculatus* Say in the highest collection within one-fourth mile of the protected war concentration) dropped to 75-80 percent in only three weeks and exceeded 90 percent most of the season. Through the peak seasons of operations in 1943, 1944, and 1945, some 104,505 manhours were expended in larviciding and 51,451 manhours in minor drainage work (ditching, cleaning, and clearing).

Entomological inspection contributed primarily to economy and effectiveness through direction of control operations to those areas and seasonal periods where most needed, and evaluation of control results with reference to the malaria mosquito, *Anopheles quadrimaculatus* Say. This was *species control* in the fullest application. There are 42 species of mosquitoes in Oklahoma, six being anopheline, though only the one is considered significant in malaria transmission. However, other serious diseases are mosquito borne, and by other mosquitoes. The entomological inspection service came logically into the responsibility of obtaining as much information as possible on the distribution of all mosquitoes throughout the State, and their potential relation to public health. Reconnaissance surveys and the operation of mosquito light traps have greatly extended this information (Fig. 1). The work is being continued in cooperation with the University of Oklahoma, and is planned to obtain full seasonal mosquito-production records for every county in the State. Significant results are already at hand. Of particular interest is the abundant and widely distributed production of malaria mosquitoes throughout Oklahoma, though particularly in the southeastern portion of the State, with local problems possible in almost any county under conditions favorable for mosquitoes. When such problems are augmented by unusually favorable anopheline breeding places adjacent to especially attractive recreational and summer residential areas, men and mosquitoes meet together with recognizable invitation for malaria to join the association.

The problem of the United States Engineers reservoirs and other impoundments (mentioned as early as 1926 in reports of the State Department of Health) met with significant advances toward solution in the cooperative survey organized in September 1944 by the State Department of Health and the United States Engineer Office at Lake Texoma on the Red River. The plain demonstration of the malaria-mosquito breeding potential of that reservoir led to an extensive cooperative seasonal survey by the Impounded Water Section (Malaria Control in War Areas, United States Public Health Service) on Lake Texoma through 1945. The State Malaria Control Division also cooperated with the Impounded Water Section and the United States Engineers in surveys at reservoir sites on the Poteau River (Wister), the Illinois River (Tenkiller Ferry), the Grand River (Fort Gibson and Markham Ferry), the Arkansas River (Mannford), the Verdigris River (Oolagah), the Caney River (Hulah), and the Canadian River (Canton and Optima), and the completed Fort Supply and Great Salt Plains reservoirs. The reports were used in recommendations to the United States Engineers for control operations or precautionary measures where needed to reduce malaria-transmission hazards.

An interesting series of changes in the emphasis of the State malaria-control program began with the reconnaissance surveys surrounding prisoner-of-war camps, branch camps for contract-labor purposes, and military hospitals. This work began in 1943 and reached its peak in 1944, with an assistant entomologist assigned to special duty in 1944-45. Prior to this new responsibility the main hope of war malaria control was to prevent the rise of endemic malaria to epidemic proportions in the unusual concentrations incident to war

—that is, to protect the introduced populations from native malaria. The first few inspections of concentrations of prisoners of war and hospitalised American soldiers and sailors from malarious war fronts heralded the coming necessity of protecting native populations from introduced malaria—an exact reversal of the previous aim. Protection of the home front was, and is, particularly necessary in areas where the history of endemic malaria indicates conditions inviting reintroduction or increase of the disease.

At first field operations continued along war malaria-control lines—through survey and reduction of malaria vectors, when proven necessary—employing drainage and larvicides to eliminate or control breeding sources. The development of DDT and its application as an effective residual house insecticide completely revolutionized the plan of attack. After training in Georgia early in 1945, the State malaria-control engineer and entomologist, assisted by the district and headquarters offices, organized the Extended Malaria Control Program in the two counties along the Red River selected for the first field application in this State.

POSTWAR MALARIA CONTROL

The objective of the new program was to place trained crews in the field with special equipment to spray every home in the most-malarious areas with DDT. The long-lasting quality of this insecticide, with proven residual effectiveness for several months, had been thoroughly demonstrated by the United States Army, Navy, Bureau of Entomology, and Public Health Service. DDT offered the means to prevent the transmission of malaria from house to house by direct and wide-spread attack against adult malaria mosquitoes. Since several days are required for the malaria parasite to develop an infective stage in the mosquitoes, repeated visits of the vectors to human habitation must play an important role in the normal malaria cycle. When all homes in an area have been protected with residual DDT spray the odds against survival of house-visiting malaria mosquitoes are greatly increased. Through several seasons of such protection there is even the good possibility that malaria transmission can be reduced below the level necessary to the survival of the disease.

In first organizing the DDT house-spraying program the State Department of Health met with problems such as inevitably arise in any new venture of like magnitude: Personnel had to be trained in completely new techniques; trucks, special spray equipment (hand and power-pressure sprayers), DDT and other chemicals, and public-relations materials had to be assembled; operational areas had to be mapped and field checked, and all houses numbered for control and inspection records; and it was also necessary for the work to be prosecuted without material increase in the technical staff.

Beginning in April 1945 in McCurtain and Choctaw Counties on the Red River, 14,774 house applications of 2.5-percent DDT (xylene emulsion) were made in two three-month spraying periods, requiring 15,101 manhours. From March to October 1946 in McCurtain, Choctaw, Pushmataha, Latimer, LeFlore, Haskell, Sequoyah, and Muskogee Counties on the Red River and the Arkansas, 33,608 house applications of 5-percent DDT were made in two four-month spraying periods, requiring 38,574 manhours. The areas for DDT application were selected in accordance with their rank in the total list of the most-malarious counties in Oklahoma and in the United States.

The success of the DDT house-spraying operations has been amply attested by the enthusiastic welcome accorded the program today, and the willingness of counties and communities to participate in the field costs of bringing the spray to every home. It is perhaps too soon to find indisputable evidence of malaria eradication, but it was recently pointed out by the Commissioner of Health that in 1946, for the first time in the past twelve years, fewer than 1000

malaria cases were reported in Oklahoma. Incidental benefits have included reduction of many household insect pests other than mosquitoes, and undoubtedly will eventually show reduction of the several diseases transmitted by such insects. An extensive demonstration program through county health units has clearly shown the significance of properly applied DDT in general household and community sanitation.

Public confidence in the program has been fully justified. A special inspection service was inaugurated to check houses and adjacent resting places of anopheline mosquitoes to demonstrate the effectiveness of the DDT spray. While the 1945 and 1946 seasons eclipsed any previous records of *Anopheles quadrimaculatus* Say (single resting-place collections commonly exceeding 100 and often over 1000 specimens), only 6 percent (1945) and 2 percent (1946) of the inspected sprayed houses showed a few mosquitoes during the peak season of July-September when numerous malaria mosquitoes were in more than 60 percent of the untreated collecting places.

Malaria education and public relations were necessarily expanded to satisfy the curiosity of the people regarding the program and the significance of DDT in breaking the malaria cycle, and to further the success of extended malaria control by securing admittance to homes, properly prepared for the spray crews. School and community meetings, films, newspaper articles, radio talks, and many printed leaflets and folders were used for this purpose. These served also to prepare the way for local participation which in 1946 amounted to $27,691, paid into an established malaria-control fund by house owners through the readily accepted cost-sharing plan inaugurated in participating areas. In addition several counties contributed labor.

CONCLUSION

An opportunity is apparent for utilization of local interest and participation in bringing DDT spray to an increasing number of homes in the malarious counties of Oklahoma. At great cost in time, thought, funds, and endeavor, mechanics and methods have been well established for continuing and expanding the program. The malarious counties have been grouped into districts (Fig.1), with provision for additional areas, each district including in its personnel the supervisor, an entomological inspector, an educator, and the locally obtained labor force. A State warehouse and garage, with administrative and technical staff, is maintained for storage and repair of equipment and handling the DDT-xylene concentrate. The State office is established as the the Malaria Control Division, Bureau of Sanitary Engineering, State Department of Health, with an engineer, an entomologist (and assistant), an educator, and administrative and clerical staff.

The office of Malaria Control in War Areas was terminated with the close of the fiscal year 1946 (now Communicable Disease Center, United States Public Health Service, Atlanta, Georgia), but the coordinated national and State malaria-control programs continue in the postwar effort. The gains in control of this scourging disease deserve every possible support and advance, for and by the people of this State. The State Department of Health has been shown to have an impressive background in all phases of malaria-control effort, and the DDT house-spraying program has the confidence and appreciation of those who have experienced its benefits. The postwar program has an unusual and stimulating quality: With proper State support—not only maintaining the program at its present level, but also extending it to other malarious counties where it is in great demand—malaria *control* can become malaria *elimination*.

TABLE I

Twelve malarious counties in Oklahoma

County	Malaria mortal.[a]	U. S. rank[b]	Okla. rank	Population[c]	Square miles	Pop. per sq.mile	No. of houses	Houses per sq. mile	Persons per house
McCurtain	18.9	50	1	41,318	1,854	22.3	10,062	5.4	4.1
Pushmataha	12.3	140	2	19,466	1,423	13.7	4,798	3.4	4.1
Choctaw	9.9	190	3	28,358	784	36.2	7,275	9.3	3.9
Haskell	9.2	214	4	17,324	614	28.2	4,043	6.6	4.3
Sequoyah	7.8	265	5	23,138	703	32.9	5,358	7.6	4.3
Latimer	6.5	300	6	12,380	737	16.8	3,109	4.2	4.0
Wagoner	6.5	300	7	21,642	584	37.1	5,287	9.0	4.1
Atoka	6.4	302	8	18,702	992	18.9	4,473	4.5	4.2
Okfuskee	5.3	352	9	26,279	638	41.2	6,626	10.4	4.0
Muskogee	5.2	358	10	65,914	822	80.2	17,545	21.3	3.8
LeFlore	4.8	377	11	45,866	1,575	29.1	11,314	7.2	4.0
Coal	4.7	385	12	12,811	526	24.4	3,166	6.0	4.0

[a]Average annual malaria deaths per 100,000 estimated population, 1938-42.

[b]Based on national malaria survey of 911 counties in 16 states, 1938-42.

[c]1940 census. Information assembled by A. H. Johnson, Malaria Control Division, Bureau of Sanitary Engineering, State Department of Health.

TABLE II

*War malaria control in Oklahoma, 1942-46**

County	Location	'42	'43	'44	'45	'46
Adair	Stilwell	—	S	—	—	—
Alfalfa	Salt Plains (reservoir)	—	—	—	—	•
Atoka	Stringtown (prison)	—	S	—	—	—
Beaver	Beaver	—	—	—	—	•
Blaine	Watonga	—	—	—	—	•
Bryan	Durant	—	S	L*	I*	—
	Durant airfield	—	S	L	I	—
Canadian	El Reno	—	S	I	S	—
Carter	Ardmore	S	L*	L	L	—
	Gene Autry	S	L*	L*	L	—
Cherokee	Tahlequah	—	S	S	—	—
Choctaw	Boswell	—	—	—	L	—
	Grant	—	—	L	—	—
	Hugo	S	L	L*	L*	—
	Red River area	—	—	I	—	—
Cimarron	Boise City	—	—	—	—	•
Cleveland	Lexington (rural)	—	S	—	—	—
	Norman	—	—	L	L	—
Comanche	Lawton	—	S	S	S	—
	Medicine Park	—	—	—	—	•
Garfield	Enid	—	—	—	•	•
Garvin	Pauls Valley	—	—	S	—	—
Grady	Chickasha	—	L	L*	L*	—
Haskell	Stigler	—	S	—	—	•
Hughes	Wetumka	—	—	S	S	—
Jackson	Altus	—	—	—	•	•
Johnston	Tishomingo	—	—	S	L*	•
Kay	Blackwell	—	S	S	—	—
	Tonkawa	—	S	S	S	•
Kiowa	Hobart	—	—	S	S	—
Latimer	Talihina (sanitarium)	—	—	—	•	•
	Wilburton	—	S	—	—	•
LeFlore	Poteau	—	S	S	S	•
McCurtain	Broken Bow	—	—	—	L	•
	Idabel	—	—	S	L*	—
	Millerton (academy)	—	—	—	—	•
	Wright City	—	—	—	S	—
Marshall	Madill	—	S	S	•	—
	Powell	—	—	L	—	—
Mayes	Chouteau	L*	L	—	—	—
	Locust Grove	L*	S	—	—	—
	Plant area (near Pryor)	S	L*	L	L	—
	Pryor	LM*	LM*	L*	L	—
	Salina	L	S	—	—	—
Murray	Sulphur	—	—	—	—	S
Muskogee	Braggs	LM*	L*	L*	L	—
	Fort Gibson	—	L	L	L	—
	Haskell	—	—	I	S	—
	Muskogee	L*	L*	L	L	L

*Work done by Malaria Control Division, Bureau of Sanitary Engineering, State Department of Health. See POSTWAR MALARIA CONTROL for summary of DDT house-spraying program. Legend: *—mosquito light trap in operation; s—Survey and occasional inspection; I—inspection scheduled, control operations occasional; L—larviciding and inspection scheduled; M—major drainage.

County	Location	'42	'43	'44	'45	'46
	Muskogee airfield	—	L	L	I	—
	Warner	—	S	—	—	—
Okfuskee	Okemah	—	—	S	S	—
Oklahoma	Oklahoma City	—	—	—	S	•
	Will Rogers Field	S*	—	—	S	—
Okmulgee	Okmulgee	—	I	LM*	L*	—
Osage	Pawhuska	—	—	—	—	•
Ottawa	Miami	LM*	LM*	L*	L	—
	Wyandotte	—	—	S	—	—
Pittsburg	McAlester	S	L*	L	L	—
	Savanna	S	L*	L*	L	—
Pontotoc	Ada	—	—	—	•	•
Pottawatomie	Shawnee	—	—	—	—	•
Pushmataha	Antlers	—	—	—	—	•
Roger Mills	Cheyenne	—	—	—	—	•
Sequoyah	Gore	S	L	L	I	—
	Moffett	—	S	—	—	—
	Muldrow	—	S	—	—	—
	Sallisaw	—	S	S	—	•
	Vian	—	S	—	—	—
Texas	Goodwell	—	—	—	—	•
Tillman	Tipton	—	—	S	S	—
Tulsa	Bixby	—	—	I	S	—
	Dawson	—	I	L*	L*	—
Wagoner	Porter	—	—	I	S	—
Washington	Bartlesville	—	—	—	•	•
Washita	Foss	—	—	—	•	•
Woods	Alva	—	S	S	S	•
	Waynoka	—	—	—	S	—
Woodward	Supply	—	—	—	—	•
	Woodward	—	—	—	•	—

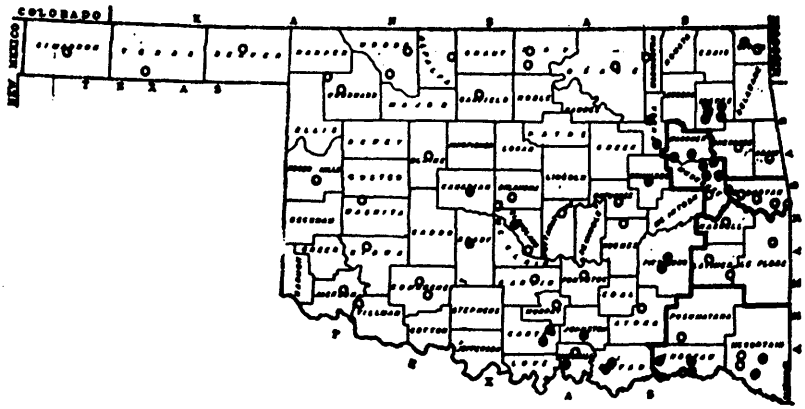

Fig. 1. Malaria control in Oklahoma, 1942-46. Work done by Malaria Control Division, Bureau of Sanitary Engineering, State Department of Health. Circles indicate locations of survey (white) and control (black) operations. Three DDT districts are shown at close of 1946 season. See Table II and POSTWAR MALARIA CONTROL for operational details.

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