

OPERATIONAL EXPERIENCES WITH PARIS GREEN PELLETS IN MOSQUITO CONTROL

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INTRODUCTION. Mosquito control workers have long wished for a cheap, lightweight, effective larvicidal material which could be applied on a routine basis against mosquito larvae without danger of their developing resistance and which would not be harmful to people, domestic animals, fish, or wildlife. The recent development of paris green (copper acetoarsenite) vermiculite pellets by the Entomological Research Center of the Florida State Board of Health (Rogers and Rathburn, 1958a) promised to provide a material having many of these desirable qualities. One year's successful experience in routine ground application of paris green pellets has been acquired by the Chatham County Mosquito Control Commission. Their results fully justify the belief that a new, valuable, inorganic chemical tool is available to mosquito control workers.

The use of pellets (granulated carriers) in the control of mosquito larvae offers several advantages, outstanding of which is their great superiority over sprays and dusts in penetrating vegetative cover. In addition, pellets are less affected by thermal air currents and changing wind conditions than sprays and dusts; thus they may be more evenly distributed in larval breeding places. Pellets may be dispensed by airplane during any daylight hour when normally good weather conditions prevail, whereas sprays and dusts usually may be dispensed only during early morning and late evening hours. Finally, it is believed that there are generally fewer toxicity hazards associated with pellets than with sprays or dusts.

In a comparison of pellets with sprays and dusts, however, it must be noted that the secondary effect on adult mosquitoes often achieved with the latter formulations is seldom secured with pellets.

Dr. Griffiths (1927) of the U. S. Public Health Service made studies of mosquito problems in salt marshes along the Atlantic Seaboard and Gulf of Mexico during the years 1926 through 1929. During these studies, he found that paris green mixed with wet sand was a very effective larvicide for *Aedes sollicitans*, *A. taeniorhynchus*, *A. aegypti*, *Culex quinquefasciatus*, and *C. salinarius*. The formulation used consisted of one part of paris green to 99 parts of wet sand by volume. It was applied at the rate of one pound of toxicant per acre. The paris green apparently became coated on the sand during the mixing process. On application by hand to breeding plots, some of the paris green was carried to the bottom by the sand and some remained floating on the water surface.

Paris green mixed with pyrophyllite and other diluents was used extensively for more than 25 years as a larvicide for anopheline control operations. It was usually applied by hand-operated blowers and small power blowers at the rate of one pound of toxicant and 10 pounds of mix per acre. In 1945 the approximate cost of hand application was as follows: (T.V.A. and P.H.S., 1947)

15% paris green, 10 pounds mix/acre:	29¢ per acre
Labor @ 60¢/hour:	48¢ per acre
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	77¢ total/acre

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No indication of resistance ever developed. Toxicity problems, such as skin rash or effect on fish, wildlife, or domestic animals, were few. Although no indication of resistance developed, resistance to sodium

arsenite has been reported in cattle ticks when this compound was applied in dips for from 12 years to several decades (Brown, 1958). This experience raises the possibility that mosquito resistance to paris green might develop.

Two general methods were used to check pellet application rates and distribution patterns in the operations described in this paper. One method involved the use of 3" x 12" glass slides coated with car grease (Stains, 1958). The slides were placed on wood floats located on or near the water line. Falling pellets were trapped and held on the car grease. The number of pellets per unit area was determined later using a laboratory bacteria colony counter. The dosage of four pounds of No. 3 vermiculite-paris green pellets per acre represents about 4.2 pellets per square inch or about 0.65 pellet per square centimeter. The other method of dosage measurement used was to catch pellets in 20-inch square wooden pans with 2" high sides. The pellets caught in each pan were run through a small hole in one corner into a stoppered glass vial. Later, the contents of each vial were weighed on an analytical balance.

OPERATIONAL EXPERIENCE WITH PARIS GREEN PELLETS. One year's ground application experience with 15 percent paris green on No. 3 vermiculite has been acquired by the Chatham County Mosquito Control Commission. Field tests indicated that the recommended application rate of four pounds of 15 percent pellet mix per acre (0.6 pound of toxicant per acre) is ample for 100 percent larval kills. Excellent larval kills of *Aedes taeniorhynchus*, *A. sollicitans*, *Psorophora confinnis*, and *Culex quinquefasciatus* have been obtained. Most of the experience acquired has been on the control of salt-marsh mosquitoes, as they are the most important mosquitoes from the standpoint of biting annoyance in Chatham County. The vegetation penetration of these pellets in the many different types of mosquito habitats found in the Savannah area has been remarkable and excellent. Application crews consistently obtained complete

kills in treated breeding places. There was only one incomplete kill during the summer; it occurred when larvae were present in a large expanse (about one acre) of vegetation-free water and a high wind was blowing. The crew re-treated this area successfully on a day when there was less wind. In late fall, a drought occurred resulting in prodigious production of *C. quinquefasciatus* in open drainage ditches heavily polluted with sewage and containing some aquatic vegetation and floating organic material. Excellent kills on these larvae were obtained with the paris green pellets applied by hand-casting from a small boat.

The use of paris green pellet larvicides greatly reduced the expected adult *Culex* and salt-marsh mosquito annoyance in portions of the county. Airplane treatment of large breeding sources inaccessible to ground application crews will be required to obtain a more adequate control of salt-marsh mosquitoes on a county-wide basis.

No. 3 vermiculite has been used for hand application in preference to No. 4 vermiculite because No. 3 is larger and heavier and fewer pellets land on the operator. In addition, No. 3 gives better distribution patterns. No. 3 displays a tendency to spread in all directions after landing in the water whereas No. 4 is more apt to spread only in a downwind direction. These factors, in ground application, outweigh the advantages of more pellets per unit volume obtained with No. 4.

Paris green pellets float for several hours on the water surface after application, thus making it easy to check applications after they are made. It appears that a floating pellet is necessary for this technique. The paris green particles come off the pellet rapidly and most drift slowly down through the water. Some of the particles remain floating on the water surface. Particles of paris green in the water are swallowed by mosquito larvae and act as a stomach poison. Particles are drawn into the esophagus by the current created by the rapidly moving mouth brushes. Paris green pellets must be applied during the 2nd, 3rd, or 4th larval instars since there is little, if any, pre-flood

or residual effect. Applications on larvae broods in the 1st stage were not effective. There is no toxic effect on pupae.

One advantage of pellets is that every control operator can carry a supply and immediately treat breeding sources as great as one acre in size. Pellets weigh only about 16 pounds per cubic foot and only four pounds are required to treat one acre. One-man, hand application crews are possible, economical, and appropriate in many situations. In Chatham County's larvicidal work, it was found desirable and efficient at times to use two-man crews, each crew equipped with a vehicle. Usually pellets were carried in a pail in one hand, leaving the other arm free for hand casting (Figure 1). Employees of the



FIG. 1.—Hand-casting 15% paris green on #3 vermiculite pellets in Savannah, Ga., *Distichlis* salt-marsh.

commission were most pleased with the ease and convenience of applying pellets and with their effectiveness in killing larvae. They considered fuel oil much more difficult to apply.

At the beginning of control operations, rotary grass seed distributors operated by a hand crank were used for dispensing paris green pellets. They were soon discarded because distribution patterns in the

water were too uneven, and too much of the material was thrown on the operator.

Later, hand crank rotary dusters with a three-foot long discharge tube were tried in the field. This type of dispersal equipment produced good pellet distribution patterns in the water, but proved too slow in comparison with hand casting. Other difficulties noted were clogging of the equipment and separation of paris green particles from the pellets in the duster impellers.

Thus, the hand casting method, using a pail, proved to be the best technique of application and was most used. In a time-motion test in shallow water, it was found that one man could treat one acre in 30 minutes using this technique. There is a need for light hand-dispersal equipment which will increase swath width and rate of application and propel the pellets away from the operator.

As in all hand-larviciding operations, there is a strong tendency to use more material than necessary. An early check of the hand-casting technique showed that the field application rate was about 57 pounds of paris green pellets per acre. In order to train operators in the correct rate of application, a one-quart capacity hand shaker applicator was devised. Such a shaker can be made from mailing tubes commonly used by entomologists. Eighteen $\frac{1}{4}$ -inch holes were drilled in the metal cap. An area on the ground measuring 75 x 75 feet was marked off. Each crew member then regulated the application so that one quart evenly treated the 75 x 75 foot area. This gave good reference experience to the operators in the amount of pellets required and greatly reduced over-treatment. The shaker was very useful for treating small breeding places during regular operations. In a time-motion test in shallow water, one man could treat a 75 x 75 foot area in 3 minutes and one acre in 30 minutes using the hand shaker.

It was noted that field men tended to increase the dosage when treating heavy concentrations of larvae. One check in a heavily breeding and heavily vegetated area 80 by 2,000 feet showed an application rate of 24.5 pounds of mix per acre.

A study of all the field checks indicated the actual average field application rate was about 10 pounds of mix per acre.

A total of 6,990 pounds of paris green pellet mix was used in Chatham County in 1958. Assuming 10 pounds per acre, a total of 700 acres were treated using 915 man hours for inspection and treatment. Cost figures per acre were:

Materials	\$1.20 per acre
Labor, formulation	.25 per acre
Inspection and treatment	1.60 per acre
Vehicle	.15 per acre
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	\$3.20 per acre

The total cost per acre could be reduced to about \$2.50 per acre by taking measures to achieve the recommended dosage of 0.6 pound of actual paris green per acre. One such measure would be to reduce the paris green formulation strength to $7\frac{1}{2}$ or 10 percent.

Component costs of the pellets were: paris green \$0.43 per pound, Triton N-101³ \$0.27 per pound, and No. 3 vermiculite \$1.10 per 4 cubic foot bag (weight about 32 pounds).

The batch formula used in Chatham County in 1958 was as follows:

1. No. 3 vermiculite = 2 four cu. ft. bags.
2. 90% paris green = 20 pounds.
3. Sticker = 5 gallons.

The sticker contained 10 percent Triton N-101, 30 percent water, and 60 percent 40W motor oil by volume and was mixed in a 55-gallon drum. It is important to follow the sticker formula closely. The Triton should be added to warm water and mixed thoroughly before slowly adding the motor oil. A motor driven pump was used to provide agitation by recirculation and to power the spray application of the sticker onto the pellets.

The vermiculite should be free of fine dust particles when purchased. If not, dust should be removed by using a 30-mesh screen. Some differences have been noted in the size and shape of vermiculite processed in different plants. The follow-

ing mesh analysis was made on paris green pellets made up with No. 3 vermiculite obtained in 1959 from a Savannah, Georgia source:

Held on screen number	Percent of total by weight
10	4.4
16	36.5
20	32.8
25	14.2
30	4.2
Pan (less than 30)	7.9

The 1959 vermiculite product was somewhat superior to that obtained in 1958 because, as a result of a visit to the plant, more of the finer sized particles were eliminated by the manufacturer through rearrangement of the shaker screens.

In formulating the larvicide, the vermiculite is placed in a concrete mixer and rotation started. The sticker is then applied through an 8006 spray nozzle. Finally, the paris green is added slowly. The mix is then spread in a thin layer 2-3" thick for 24-48 hours of air drying.

Mixing of paris green pellets is a good wintertime or rainy day job for mosquito control organizations.

The only difficulty experienced in pellet application during the summer of 1958 was several light and one severe case of rash. The mild cases involved skin folds: neck, eyelids, scrotum, inside portion of elbows, and armpits. There is an apparent association between the rash and sweating and/or rubbing. The worker with the severe rash was very careless in handling the pellets and may have had a special sensitivity to the material. An injection of sodium thiosulfate by his physician relieved the symptoms overnight. It was concluded that this severe rash was probably caused by the paris green in the formulation since similar and highly characteristic poisoning has occurred in other workers (Von Oettingen, 1958). The light cases of rash may have been caused by the paris green or possibly by the vermiculite, which is an exploded hydrated variety of biotite, one of the groups of materials found in mica. Most of the difficulty was associated with the use of hand operated rotary grass seed distributors, which threw a considerable

³ Use of trade names in this paper is for identification purposes only and does not constitute endorsement by the Public Health Service.

amount of the pellets on the operators. Skin rashes resulting from the hand casting method have been less frequent. Pellets should be applied in a downwind direction as much as possible. Frequent washing and the use of drying powders are helpful in preventing rash. Operators may protect their casting hand with a loose fitting rubber chemical glove.

No special precautions were taken with regard to domestic animals, fish, or wildlife. Paris green does not persist in water (Brown, 1951). The only evidence of possible harm was a few dead tadpoles which were observed one day only. Repeated applications have been made in pastures containing feeding livestock with no known deleterious effect; however, it seems prudent to exercise caution in this type of application. The observation of depression and skin lesions in livestock would call for studies to determine whether arsenic poisoning was responsible (Brown, 1951).

OPERATIONAL TESTS WITH POWER DUSTERS AND AIRPLANES. Limited tests, with greased glass slides, show that a power dust machine such as the Buffalo Turbine can successfully apply No. 3 paris green pellets to a swath as wide as 100 feet. Only the middle hopper in the Buffalo Turbine was used when dispensing pellets. DDT on No. 4 vermiculite pellets is being successfully applied in Illinois mosquito control districts (Buchanan, 1958) by Buffalo Turbines and helicopter, both as a pre-flood application for the control of *Aedes vexans* as well as post-flood treatment for the control of many mosquito species.

Several test flights were made in Savannah this winter using No. 3 vermiculite (15 percent) paris green pellets dispensed by fixed wing aircraft. Two test flights were made in late 1958 with the Public Health Service AT-6 single engine airplane which was used in successful parathion-attapulgitite pellet larviciding in 1956 in Florida (Fehn, Taylor, and Rogers). The old formulation containing water was used. It was noted that the paris green pellets tended to compress in the hopper interfering with free flowing. Also, it was noted that vermiculite pellets are more affected by wind than a heavier pellet-like attapulgitite. As a result, the applications were uneven and under-dosed. Comparisons between greased slides placed above and below 18-inch-high salt grass (*Distichlis spicata*), 3-foot-high dense upright weeds, and 8-foot-high reed grass indicated that these pellets possess excellent vegetation infiltration characteristics. Pellets caught in wooden pans remained fully effective on 4th stage laboratory *A. taeniorhynchus* larvae in shallow pans, showing that loss of paris green particles during aerial dispersal was not significant. These tests indicated the necessity of modifying the dispensing equipment or improving the formulation.

In March 1959, six test flights were made with Cub airplanes using the new waterless No. 3 vermiculite formulation described below. A 150 h.p. Super Cub with the standard factory-installed dust dispensing equipment was used in three tests. A 115 h.p. Cub with specially designed light, pellet-dispensing equipment (Scott Air Service, Savannah, Georgia) was used in the other three tests. Pellets flowed evenly from both airplanes and were caught on pans and greased slides in open fields. The results indicated that a satisfactory distribution with a swath width of 50 feet can be obtained from both airplanes at a 75' altitude. Dispersions from a 50' altitude were narrowed to a 25-foot swath. Dispersions from a 100' altitude produced erratic results. Further operational tests are needed on aircraft application.

CHATHAM COUNTY OPERATIONAL PLANS FOR 1959. The newest formulation being tested in Florida (Rogers and Rathburn, 1958b) is being used because it contains no water and does not require drying after mixing:

Paris green—17 pounds
Emulsifier Triton N-101 (10%) plus Standard Oil Co. spray oil (90%) No. 345 (\$0.30 per gallon)—4 gallons (30 pounds)
Vermiculite—53 pounds

No. 3 vermiculite is being used for ground applications. Operational tests will be made to determine whether No.

3 or No. 4 vermiculite is superior for aerial application.

Results of ground application in 1958 indicate the general advisability of decreasing the strength of formulation and increasing the rate of pellet application. Accordingly, experiments in these directions will be made using 7½ and 10 percent pellets.

The Chatham County Mosquito Control Commission purchased a 150 h.p. Super Cub airplane in 1959 for application of paris green pellets. Such a light airplane will permit effective and economical treatment of salt-marsh areas as small as one acre. Assuming an 18 cubic foot hopper and a 10-pound per acre application of 15 percent paris green pellets, 28 acres could be treated per mission. Assuming a 50-foot swath width and 85 m.p.h. speed, the plane could treat 8.6 acres per minute of pellet dispersal time. Assuming one pilot and an average of 14 missions per day, one plane could treat 392 acres per day. Under the conditions described above, the cost per acre for paris green pellet application by airplane would be: \$1.20 for materials, 25 cents for formulation labor, 12 cents for aircraft operations (gas and the pilot) and 3 cents for loading (one laborer), or a total of about \$1.60 per acre. The airplane cost figure does not include other airplane costs such as depreciation, maintenance, insurance, etc. Thus aerial application will be much faster and cheaper than ground application as well as provide control in breeding places inaccessible to ground crews.

SUMMARY. Pellets are greatly superior to sprays and dusts as mosquito larvicides in penetrating vegetation, in effectiveness under adverse wind and thermal conditions, and in reduced toxicity hazards.

One year's successful experience in the ground application of 15 percent paris green on No. 3 vermiculite at the average rate of 1.5 pounds of toxicant per acre

on *Aedes*, *Psorophora*, and *Culex* mosquito larvae has been acquired by a county mosquito control district. The excellent results obtained indicate that an important light-weight larvicide has been made available. It combines the vegetation-penetrating abilities of pellets with an inorganic insecticide that can be safely, effectively, and economically used routinely on a large scale. There appears to be little possibility of resistance occurring until at least several years of extensive use. Meanwhile, the effectiveness of chlorinated hydrocarbon, and organic phosphorus insecticides will be preserved for use as adulticides.

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