Aerosols for Insects

by RANDALL LATTA and L. D. GOODHUE

INSECTICIDES in aerosol form have become, since 1940, an important means of controlling insects. Aerosols had just emerged from the laboratory and were undergoing practical testing when the United States entered the Second World War. They were immediately adopted by the military forces to combat disease-carrying insects, such as the malaria and yellow-fever mosquitoes. Because of accelerated research and widespread use during the war period, the aerosol today is a household word and item.

The modern insecticidal aerosol is simply a very fine spray, so fine that the individual particles will stay suspended in air for some time. By staying suspended, the minute particles of insecticide have greater opportunity to touch an insect than larger particles, such as those in an ordinary fly spray, which rapidly fall to the floor or ground. Likewise, the ability of an aerosol to remain airborne makes it possible to drift an aerosol cloud for long distances under the proper meteorological conditions. When the particles of an aerosol are liquid, a fog is formed, whereas solid particles form a smoke. At present the most efficient aerosols are composed of liquid particles and are true fogs, not smokes.

Aerosols are efficient when properly used because of the minimum of wastage. For example, enough aerosol to contain only 5 milligrams (one small drop) of pyrethrins will kill all yellow-fever mosquitoes in a thousand cubic feet of space.

The particles in an aerosol range anywhere from 0.5 to 35 or 40 microns in diameter. (One micron is 1/25,000 of an inch.) Above this size, particles tend to be airborne for shorter and shorter periods as their weight increases.

Particles of an aerosol come in contact with an insect by settling on it through gravitational fall or by striking it through motion of the particles or the insect. When aerosols are used in confined spaces, such as a room, the contact is partly by the first method, and the time necessary for enough particles to accumulate on a resting insect to cause its death is related to the rate at which the particles settle.

It would be necessary, for instance, to expose an insect 85 times as long to an aerosol composed of particles 1 micron in diameter as to an aerosol composed of particles 10 microns in diameter. On the other hand, too large particles fall too rapidly, are not diffused as well by convection currents, and reduce the number of chances of coming in contact with an insect. For example, one 40-micron particle will make 64 10-micron particles. By biological testing, an average size of 10 to 20 microns was found most effective for aerosols under confined conditions.

Outdoors, aerosols drifting parallel to the ground strike objects in their paths according to the weight and velocity of the particles and the shape of the object. Biological tests have shown that below a certain range of size the ability to strike decreases rapidly, so there would have to be a corresponding increase in the amount of insecticide. Above that range practically all particles are deposited on insects in their paths; therefore greater size would be of no benefit. The range was determined to be in the neighborhood of a diameter of 10 microns.

Because of the small dosages necessary in confined spaces, and the airborne characteristics in outdoor applications, aerosols generally leave minute deposits and are considered an unsatisfactory means of applying insecticides where a residual effect is desired, although overdosing or repeated applications may leave an effective insecticidal deposit.

Aerosols are made by several methods. It is believed that the method by which they are generated has little effect on their action upon insects, provided that they are composed of the same elements and are of the same particle size. They can be generated (1) by incomplete combustion of materials containing insecticides; (2) by spraying solutions of insecticides in oil on a hot surface, thus vaporizing the liquid which immediately condenses into a fog when the vapor is cooled by contact with air; (3) by dissolving insecticides in a liquefied gas, such as dichlorodifluoromethane, and forcing the solution through a small orifice by the pressure of the gas, where it is broken into a fine spray, which is further reduced in particle size by the immediate evaporation of the liquefied gas; (4) by heating a mixture of water and an oil solution of the insecticide until the water is converted into superheated steam, and passing this mixture of oil and steam through nozzles where it is broken up into aerosol-sized droplets; and (5) by mechanical means, such as atomizing nozzles.

The original experiments with foglike aerosols were made by spraying solutions of insecticides in oil onto a hot plate. This new method was found to be highly effective in comparison with other methods of dispersing insecticides known at that time. It was soon supplanted by the liquefied-gas method. Later the method was reconsidered in attempts to create large aerosol clouds for outdoor applications. It was determined that the particle size produced was too small for high efficiency against insects under such conditions.

Liquefied-gas aerosols are composed of a liquefied gas, such as dichlorodifluoromethane; from 7 to 20 percent of nonvolatile materials, such as sesame oil, lubricating oil, and solvents; and an insecticide, which may be pyrethrum, DDT, thiocyanate, nicotine, rotenone and derris resin, phenothiazine, and so on. The aerosol solution is held under pressure (approximately 80 pounds per square inch for dichlorodifluoromethane) in a metal cylinder. When released by a simple valve, the gas pressure forces the clear solution through the nozzle orifice to create an aerosol. The particle size is regulated by varying the content of nonvolatile material in the formula, and the size of aperture in the nozzle.

Hand dispensers vary in size. The widely used military and civilian model contains 1 pound of aerosol and is popularly called the aerosol bomb because it resembles a small bomb. Others hold from ½ ounce to 5 pounds. Industrial dispenser systems that are supplied from a large cylinder of aerosol solution have also been developed, as well as agricultural equipment with multiple outlets fed by a single supply cylinder.

Liquefied-gas aerosols are best adapted to controlling insects in confined or restricted spaces. The military forces used a pyrethrum-sesame oil aerosol, and later a pyrethrum-DDT aerosol, to destroy disease-carrying mosquitoes in airplanes to prevent their dissemination from one area to another along air routes. The same aerosols were used to control insects in foxholes, tents, barracks, rooms, mess halls, and such. More than 40 million 1-pound dispensers or "bombs" were supplied to the military forces. The British Army used several million one-shot ½-ounce dispensers. A large war plant with 27,000,000 cubic feet under one roof, located in a mosquito-breeding zone, increased worker efficiency enormously by frequent application of aerosols from a portable dispensing apparatus.

Liquefied-gas aerosols can control a variety of household insects, such as mosquitoes, flies, sand flies, fleas, and adult moths. An aerosol can kill only the insects that it touches and consequently it is relatively ineffective against those that are protected, such as clothes moth larvae, carpet beetles, and bedbugs.

Aerosols have been widely used by international air lines since 1941 to destroy disease-carrying insects accidentally introduced into plane cabins. They have also been used during the war and since to prevent the spread of agricultural insects of importance.

Aerosols have been used to control a number of insects in greenhouses. Nicotine in an aerosol is twice as effective as when applied as a

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burning mixture. Lorol thiocyanate aerosols controlled cyclamen mite on snapdragons. DDT aerosols were effective on thrips, whiteflies, aphids, sowbugs, ants, and crickets. Pyrethrum aerosols gave good control of flies in mushroom houses.

Liquefied-gas aerosols were found to be of practical use for control of some pests of agricultural crops. When retained briefly over pea vines by means of a small canopy, small dosages gave good control of the pea aphid. The aerosols were applied by a multiple dispenser composed of a supply tank of the aerosol mixture with several outlets, mounted on a light, hand-drawn or jeep-drawn carriage. Various insects on truck crops were controlled by aerosols applied in the same way. These aerosols contained a larger proportion of nonvolatile material than those usually prepared for indoor use, in order to increase particle size.

Numerous other uses have been found for liquefied-gas aerosols. Seedless tomatoes have been produced by applying plant hormones as aerosols. Germicides can be applied by this method. A patent has been issued to Department workers for a combined germicidal-insecticidal aerosol. Certain soluble fungicides also work well in aerosol form.

Thermal-generated aerosols are very efficiently formed by heating a mixture of water and oil-insecticide solution. A 50–50 mixture of water and the oil solution is pumped through a coil suspended in a furnace, where enough heat is applied to convert the water to superheated steam. The pressure generated by the steam forces the mixture of steam and oil through a nozzle where it is broken up into aerosol-sized particles. The range of particle size can be regulated by varying the viscosity of the oil used, or the temperature to which it is subjected. Generators are now available which have capacities as high as 40 gallons of oil an hour, which may contain 30 percent or more of DDT. A relatively nonvolatile oil should be used or the aerosol particles will shrink by evaporation during application.

Thermal-generated aerosols are strictly for large-scale use. They are applied to outdoor areas by drifting the aerosol cloud across a desired area. Usually the generator is mounted in a truck and moved back and forth across a front at right angles to the direction of air movement. The cloud must be applied under meteorological conditions which will hold it close to the ground. Inversion conditions (a layer of colder air next to the ground) are the most favorable and usually occur during the periods near dawn and dusk. A wind movement of from 1 to 3 or 4 miles an hour is desirable.

The concentration of aerosols, and therefore their effectiveness, is greatest nearest the generator and diminishes with the distance. In order to obtain a high degree of control at a given distance, it is necessary to overdose the intervening area. For this reason it is more economical to treat in narrow strips than in deep areas. Mosquito adults and larvae were controlled downwind from the point of generation for distances ranging from 1,200 feet in heavily wooded areas to nearly a mile in open terrain. Gypsy moth larvae in naturally infested forests were apparently completely wiped out for distances up to 900 feet. Furthermore, enough residue remained to be repellent to migrating larvae, which prevented reinfestation in all except the marginal areas.

In recent tests by H. A. Jaynes and his associates, adult onion thrips on young cabbage plants were effectively reduced for a distance of 200 feet but the nymphs were not controlled; cabbageworms on cauliflower were reduced 85 percent at this distance; species of *Empoasca* were controlled for 150 feet in parsnips, in a weed field for 600 feet, and on alfalfa for 250 feet; beet armyworms were reduced over 90 percent in a weed field for 500 feet, completely killed for 100 feet in broccoli, and over 70 percent for 200 feet in tomatoes; *Lygus* bugs were reduced 90 percent for 250 feet in alfalfa. Unsatisfactory results were obtained against insects on very low growing plants or with low dense foliage, such as red spiders on celery or aphids on potatoes.

Thermal-generated aerosols were found to be very toxic to adult horn flies on cattle. Herds can be quickly treated and enough residue remains to prevent reinfestation for several days.

Aerosols have been created by various types of mechanical dispersion, particularly by various methods of atomization. In one method, an oil solution of insecticide is sprayed into a stream of high-velocity exhaust gases, where it is broken up into aerosol-sized particles. A simple venturi arrangement is attached to the exhaust pipe of an airplane or vehicular motor for this purpose. One type of a proprietary generator utilizes this principle also by burning gasoline or fuel oil in a forced draft of air, thus producing a high velocity-gas stream which is used in the same manner to break up an oil solution into an aerosol. Other kinds of atomizing nozzles and also whirling disks are being investigated.

THE AUTHORS

Randall Latta is an entomologist in the Bureau of Entomology and Plant Quarantine. Since 1942, in addition to other duties, he has been in charge of the development of new methods and equipment for applying insecticides. He made the initial tests with army screening smoke equipment in an attempt to convert it to make insecticidal aerosols, and later supervised a study of the use of heat-generated aerosols for outdoor control of insects. As a part of these studies, the Department carried on cooperative work with the National Defense Research Committee on the fundamental characteristics of aerosols in relation to particle size and speed of motion.

L. D. Goodhue was a chemist in the same Bureau until he resigned December 28, 1945. He also is a native of Iowa. Dr. Goodhue was a cooperator in the original studies on insecticidal aerosols; he was a coinventor of the liquefied-gas aerosol and has been a leader in the development of these aerosols since their origination. He played an important part in the military adaptation of aerosols, through his chemical studies on formulations.