Aerosols and Insects

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An aerosol, like fog or mist, is an assemblage of particles suspended in air. An insecticidal aerosol has particles whose diameters range from 1 to 50 microns—from 1/25,400 to 50/25,400 inch.

Insecticidal aerosols are dispersed in air by burning organic material, atomizing mechanically, vaporizing with heat, or liberating through a small opening an insecticide that has been dissolved in a liquefied gas. In the last the liquefied gas evaporates and leaves small particles suspended in air.

Many householders have become acquainted with aerosols in small containers—so-called bombs, although of course they are not explosive. A more general application has been in use a long time. The Mono Indians of California knew the value of smoke in stupefying insects so that they could be easily collected for food. They prepared a smooth floor under trees containing the full-grown larvae of the pandora moth and built a smudge fire. The smoke caused the caterpillars to drop to the ground in countless numbers. They were then raked into the fire, partly cooked, dried, and later eaten as a stew.

Another example of an aerosol was seen in the Northeastern States one day in September 1950, when the sun turned an eerie purple and darkness came at 2 p. m. A mass of cold air had drifted down from northwestern Canada and brought along the smoke from forest fires in the Alberta and Mackenzie district—an illustration of how aerosols can be dispersed in air currents from one point through large areas.

Aerosol bombs were developed in 1941, when L. D. Goodhue and W. N. Sullivan of the Bureau of Entomology and Plant Quarantine discovered that aerosols produced by spraying a solution of liquefied gas and insecticide through a small hole into the air were highly toxic to mosquitos and flies. The aerosol solution was made by dissolving pyrethrum and sesame oil insecticides in a liquefied gas commonly used in household refrigerators and called dichlorodifluoromethane. The liquid has a vapor pressure of approximately 75 pounds per square inch at room temperature.

The aerosol solution is held in a strong steel container with an outlet tube to the bottom. In operation, the vapor pressure of the liquefied gas is sufficient to force the solution out of the tube and into the air through an orifice that may vary from 0.013 to 0.024 inch in diameter. The gas immediately evaporates and the tiny particles of insecticide are dispersed as a fine mist.

The scientists knew the gas was nontoxic and noninflammable, and they found it to be nontoxic to man and animals when they mixed it with insecticide. The ease of application, the high concentration of insecticide, and the ability of the small aerosol particles to disperse and to stay suspended in the air for a long time fulfilled requirements for a good household insecticide. A public service patent was issued on the invention and assigned to the Secretary of Agriculture for the free use of the people of the United States. Licenses are issued, royalty free, for the manufacture, use, and sale of products produced under the patent.

So urgent was the need for a better way to kill mosquitoes and flies in war zones and so good was cooperation of the Department of Agriculture, the military, and industry that our troops used aerosol bombs within a year after they were discovered. Throughout the war the bombs were highly efficient against disease-carrying insects in barracks, mess halls, tents, and foxholes. They became standard equipment in long-distance airplanes, in which they were used to prevent the spread of hitchhiking insects. Occasionally one was used to cool the beer of a jungle fighter. In all, more than 40 million aerosol bombs were made for the Armed Forces.

At the end of the war aerosol bombs were made for civilian use. Strong, inexpensive containers and suitable push-button valves were developed. New low-pressure propellants and solvents were perfected. The earlier formulations were modified to include combinations of pyrethrum, a pyrethrum synergist, and DDT or methoxychlor.

Making low-pressure aerosol containers is a growing business. It has expanded to include deodorants, disinfectants, and other products, besides insecticides. It amounted to 33 million dollars in 1949, with prospects of going above 100 million dollars in later years.

The aerosol bomb is a good servant in kitchen, pantry, living room, bedroom, and cellar. Before it is used, the windows and doors of a room should be closed. Pets, birds, fish bowls, and food should be removed or covered. The container should be held upright with the opening away from the face, so the aerosol will go toward the ceiling. The operator walks around the room to give a good initial distribution. The bomb should not be held closer than 3 feet to any object, or the aerosol may stain furniture, wallpaper, curtains, or draperies. It can be held 6 to 12 inches from baseboards and cracks where insects like roaches and ants crawl or hide.

In treating the average room (1,000 cubic feet) to control such fliers as the mosquitoes, house flies, sand flies, black flies, gnats, and moths, the bomb valve should be opened to release the aerosol for about 6 seconds. This dosage will also kill some types of ants, but is not effective against the larvae of clothes moths. A 15-second release will kill fleas, wasps, and hornets. Roaches can be decimated but it takes at least 2 minutes of spraying per room and a whole bomb (12 ounces) for good results in the cellar. Spiders are hard to kill with aerosols.

The room should be kept closed for 10 or 15 minutes after treatment for flying insects and ants, 30 minutes for fleas, and 1 hour or more for roaches. Then the room may be aired out, but that is not necessary.

Gas-propelled aerosols are widely used to control insects in greenhouses. They cut the usual time for treating greenhouses from 48 man-hours to 10 minutes, eliminate black spot on roses, and can increase production 25 to 50 percent, depending on the degree of infestation.

The formula originally developed for greenhouses contained 10 percent of hexaethyl tetraphosphate and 90 percent of methyl chloride. Parathion partly has replaced hexaethyl tetraphosphate because it has lasting effect. Because parathion gives unsatisfactory control of resistant spider mites and aphids, new materials and formulas had to be found. Tetraethyl dithiopyrophosphate came into use in localities where resistant insects have been found. A newer material, octamethyl pyrophosphoramide, applied as an aerosol, has appeared promising against resistant greenhouse insects.

Liquefied gas aerosols have been used also against such insects as pea aphids on peas in the field. The liquefied gas is released close to the peas through nozzles on a boom that has a shield above it. The aerosol thus is distributed so that much of it is held near the plants for a long enough time.

The work that led to the development of the aerosol bomb started with a study of insecticidal smokes. Insects were subjected to a burning mixture of derris or pyrethrum, cornstalks, and sodium nitrate. The mixture burned like Fourth-of-July fireworks, and the smoke did kill insects, but such dispersal of nonvolatile or slightly volatile insecticides was wasteful.

The next step was to spray oil solutions of rotenone and pyrethrum on a hot plate. On contact with the heated surface (about 375° C.), the droplets were partly vaporized and formed particles of aerosol size. Aerosols so produced are called heat-generated. It is an efficient way to produce insecticidal aerosols.

Aerosols were then produced in the same way by spraying them onto the inner walls of a tube heated with electricity. After that, the hot exhaust of a small gasoline engine was used as the source of heat energy. From that came the suggestion that an Army smoke-screen generator be used to produce insecticidal aerosols to treat large areas for mosquitoes and flies.

Smoke was formed in the generators by running a mixture containing a little water in oil through coils passing through a combustion chamber, which was heated by an oil or gasoline burner. The oil-water mixture was completely volatilized by the heat and condensed into a smoke on contact with the outer air. The aerosol particle thus created was ideal for an Army screening smoke because it gave a good scattering of transmitted light and remained suspended in the air for a long time. It turned out, however, that the particle size was too small for efficient insect kill. A larger particle size and better insect kill was obtained by using a 50–50 mixture of water and oil and operating the machine at a lower temperature.

Another Army smoke generator used incomplete combustion to produce smoke. It was later modified to an insecticide aerosol generator by using a gasoline motor to drive a rotary air pump. The pumped air passes through and is heated in a gasoline-burning combustion chamber regulated at 482° C. The hot air then passes through special nozzles into which the insecticide is injected. The particle size is regulated by the flow of insecticidal solution through the nozzle.

Several methods have been used since the war to generate aerosols on a large scale. One machine uses a number of spinning disks to break up the solution. One uses the exhaust gases from a small pulse-jet engine. Another employs steam to atomize the solution as it issues from a nozzle.

Many small indoor types of aerosol generators have been placed on the market. They use electrically driven spinning disks, rotors, and pressure pumps, electrically generated vaporizers, and steam atomizers. One of the machines uses extremely high pressure generated by hand-pumping the liquid solution against a fixed charge of nitrogen. There are also convenient packages of mixtures for partly burning and releasing the insecticide as a fine aerosol smoke.

For best results, the farmer or health official must study his problem in detail before applying an insecticide with an aerosol generator. The machines can be set to produce different particle sizes. The choice of machine depends on the use to which it is to be put, whether for insects in confined spaces, flying insects, or those that attack his field crops. These principles may guide the prospective purchaser:

Aerosols are used indoors effectively as a way to control flying insects and to apply a light deposit on the top of exposed horizontal surfaces.

The particle size has a bearing on the effectiveness of the aerosol. The particle size is critical for the amount that collects on an insect as it flies through the aerosol. Particles that are too small are deflected from the flying insect as smoke is from a moving automobile. Particles that are too large settle rapidly, and their dispersion is poor; therefore their chance of touching the insect is also poor. When an insect does collide with an oversized droplet, the excess insecticide is wasted. Our research has shown that the best particle size to use for flying insects is between 10 and 20 microns mass median diameter.

Aerosols are dispersed by air currents. The particles will not be conveyed into dead-end cracks or into material through which air does not circulate. The distance to which particles will be carried depends generally on their settling rate.

An oil particle 1 micron in diameter will settle 10 feet in 26.5 hours. A particle of 15 microns will settle 10 feet in 15 minutes. In unheated buildings air currents are at a minimum, but heating sets up air convection currents that are a great aid to dispersion. Sometimes large-volume air blowers are used to aid dispersion. In an unheated room with a ceiling height of 8 feet, aerosols with a mass median diameter of 5 microns disperse fairly uniformly over an area 30 feet from the source, those of 15 microns over an area of 15 feet, and those of 25 microns less than 10 feet.

The deposit as a result of an aerosol settling is about 95 percent on the top of horizontal surfaces and the rest on walls and ceiling. The amount of deposit on a horizontal surface depends on the concentration of the aerosol above the surface so that if the aerosol is evenly dispersed throughout a room the resulting deposit will be proportional to the height above the surface.

In large closed warehouses that contain packaged food, the problem of flying and exposed crawling insects can be controlled by aerosol treatments. Aerosols of various particle sizes were tested; a size of about 5 microns mass median diameter was selected as most effective and easiest to apply. These small particles are produced by thermal aerosol generators that can be operated outside the warehouse; the fine particles are introduced through an open door. The aerosol is carried first to the ceiling. By the time the treatment is complete, the aerosol is well distributed throughout the interior by convection currents. The door is then closed. Overnight the particles penetrate into most of the cracks and crevices and settle on the top of exposed horizontal surfaces.

It is sometimes necessary to limit the time of application in some closed interiors. The particle size then must be large enough to settle out in the time available. A 10- to 15-minute exposure time is the minimum for satisfactory results. An aerosol having a mass median diameter of 15 to 20 microns is sufficient for the short-exposure application.

Equipment sometimes limits the particle size. When heat from thermal generators causes excess breakdown of the insecticide, equipment that produces larger particle sizes must be used. They then must be released from more than one point to cover adequately areas whose dimensions are larger than the distances of uniform deposit. Heated rooms will about double the dispersion area; rooms with high ceilings will add slightly to the dispersion.

When treating greenhouses, it should be remembered that foliage injury can be caused by a particle size larger than the foliage can tolerate with the type of formulations used.

Some formulas that we have used indoors are: (1) 1 pound of technical DDT dissolved in 7.5 pints of Sovacide 544C (Socony Vacuum) to make 1 gallon. (2) 1 pound of technical DDT dissolved in 2 quarts carbon tetrachloride; to it are added 3.5 pints of No. 3 fuel oil to make 1 gallon. This formula is relatively safe from explosion. (3) 1 quart of 10 percent pyrethrum in deobase; 1 pint of piperonyl butoxide and 1 pint No. 3 fuel oil are added.

Because of the explosion hazard when oil solutions are used indoors, not more than 1 gallon of the solutions should be used per 100,000 cubic feet. They should not be released near an open flame. Workers should wear proper respirators. The third formula, which contains pyrethrum, is recommended for use around foodstuffs.

The formulations should contain a proportion of relatively nonvolatile oil to maintain the desired particle size while it is suspended in the air. In closed warehouses, 1 pound of DDT in 1 gallon of solution per 100,000 cubic feet of space, applied about every 2 weeks in summer, will provide protection against insect infestation.

The main problem in applying the aerosols outside, other than for temporary control of flying insects, is to put down a uniform deposit. To do that the aerosols are applied as wind-borne clouds. For best results the wind should be light, steady in direction, and moving at ½ to 8 miles an hour. The air temperature at ground level should be a little cooler than at 6 feet or more. This surface inversion keeps the aerosol cloud close to the ground; it is most important when low-growing crops are treated and least important for trees having a canopy of foliage. Good inversion usually occurs from 1 hour after sunset until sunrise but may exist all day if rain has cooled the ground.

The dosage depends on how much has to be deposited on an acre to kill the insect. The deposit is heaviest nearest the point of release and decreases as the distance from the release point increases, because the larger particles settle first. Under the best conditions, only 25 to 50 percent of an aerosol containing particles less than 50 microns in average diameter is deposited over an open area in swaths up to 2,000 feet; most of it drifts beyond the area under treatment. In wooded places the deposit would be greater. When more than one swath is used, however, the dosage can be cut about 10 percent for each successive swath because of overlapping up to a total of 50 percent.

The swath width should be selected according to the location of accessible roads, to places where the wheels of the machine will do the least damage to the crop, and places where oil deposits will not injure the foliage.

Some recommended particle sizes in microns mass median diameter for various swath widths and wind velocities are as follows:

Swath width in feet	*Wind velocity in miles per hour*			
	1	*3*	*5*	*7*
100	40	70	90	100
200	30	50	65	75
300	25	40	55	65
500	20	35	40	50
1,000	15	20	30	35
1,500	10	20	25	30

At least one-fourth of the aerosol solution should be nonvolatile. Results are best with a concentrated solution. A popular formula is 5 to 7.5 pounds of DDT dissolved in 2 gallons of benzene or xylene plus 3 gallons of SAE 10 W motor oil or agricultural oil. Oil-soluble technical BHC may be used in the formula in place of DDT. The operators should wear protective masks and clothing.

Aerosol generators are useful in military and civilian situations in which mosquitoes and flies create problems of public health. They make it easy to clean up infestations in towns or camps and are particularly effective along the seashore. They are less well suited for the control of agricultural pests outdoors. Some problems require the use of fungicides and insecticides together, and the fungicides may be too bulky for efficient handling in aerosol generators. Field-model aerosol machines using concentrated DDT solutions have been employed successfully against gypsy moths, lygus bugs, tarnished plant bugs, pentatomids, potato flea beetles, and leafhoppers.

The aerosol machines are not suitable for treating individual trees or areas of less than an acre because the aerosol fog is placed entirely by wind drift and the initial thrust of about 10 feet given by the generator is sufficient only to place the aerosol in the wind.

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