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THE PROBLEM OF THE APPLICATION OF TOXIC CHEMICALS IN THE FORM OF AEROSOLS

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/Figures referred to are appended./

Spraying and dusting with toxic chemicals of large areas of agricultural fields and forest plantings to combat pests is expensive because the rate of utilization of the chemicals is low. Furthermore, such methods have the following disadvantages.

Relatively large drops are formed in spraying, so that the toxic chemical is not distributed uniformly over the surface. In dusting, solid particles of the dust do not adhere to the surface of the plants and are blown off by the wind. Addition of substances which improve adhesion complicates the technology of the production of materials for dusting and promotes their caking.

Treatment of crops is made considerably cheaper and, at the same time, is simplified by the use of liquid-in-air aerosols. Dispersion of a liquid is easier to accomplish than that of a solid material, so that a liquid toxic chemical can be dispersed immediately before its application. The droplets of liquid, after reaching the surface of the plant, stick to it and thereupon spread and penetrate into the surface. In this manner, the uniformity of coverage of the surface with the toxic agent is improved, and penetration of the toxic agent into the organism of insects is assured when the insects feed on the poisoned plant or come in contact with its surface.

To obtain the most uniform coverage of the surface, it is desirable to use an aerosol cloud consisting of the smallest possible drops. However, in some cases, we are compelled to increase the dimensions of the drops to improve their deposition on the surface being treated.

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Enclosed spaces, open air spaces, or field and forest sections may be treated. Depending on which of these objectives is involved, the degree of dispersion of the aerosol cloud must be varied, and this determines the method of obtaining the liquid-in-air aerosol as well as the way in which it is applied.

The application of liquid-in-air aerosols is particularly effective for the treatment of large areas and results in the highest efficiency under these circumstances. However, one cannot bring about a directed movement of drops under such conditions because covering of the surface with the toxic agent takes place as a result of precipitation of drops of the liquid from a moving cloud. Hence, precipitation of the drops depends on their size, velocity of the wind, velocity of rising currents of air, etc.

The rate of precipitation of drops in the layer of air next to the ground consists of two components which are added together: (1) Stokes' velocity of precipitation, which is brought about by the force of gravity; and (2) the turbulent velocity of precipitation, which results from turbulent expansion of the air stream [1]. Furthermore,

$$W = S' = \frac{v \alpha}{4}, \qquad (1)$$

where S' is Stokes' velocity of precipitation; v, velocity of the wind; and α, a coefficient which characterizes the irregularity of the wind.

In Figure 1, both components are plotted as functions of the velocity of the wind. The data of Figure 1 applies to drops with a density up to 1 g/cm^3. Precipitation of suspended particles under the action of the force of gravity takes place only when the atmosphere is in a state of viscous calm. Periods during which the atmosphere is in this state are the less prolonged, the higher the velocity of the wind. Therefore, the Stokes velocity of precipitation drops when the velocity of the wind increases.

It can be seen from Figure 1 that when the velocity of the wind is higher than 2 m/sec and the drops have a diameter smaller than 120 micron (this is the size usually applied under practical conditions), the turbulent velocity of precipitation greatly exceeds the Stokes velocity. Under these conditions, the Stokes velocity does not have to be considered at all.

This means that in a strong wind, all drops, independently of their dimensions, precipitate with the same velocity. One might think that this circumstance would facilitate designing of equipment for the production of liquid-in-air aerosols, but this is not the case at all.

In a strong wind the quantity of matter deposited per unit of area under the action of the turbulent velocity of precipitation drops logarithmically with the distance from the aerosol generator, i.e., a very large quantity of matter precipitates in the vicinity of the generator, and this quantity drops sharply as the distance from the generator increases.

The quantity of matter that precipitates on a surface is given by the equation

$$A = CW \qquad (2)$$

where C is the concentration of the matter in air and W, the velocity of precipitation of the particles suspended in air.

In a strong wind, and for small drops in any wind, the concentration of matter in an aerosol cloud is given by the following equation [2]:

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$$C = \frac{Q}{\pi^{\frac{1}{2}} s v l^{1-\frac{1}{2}m}} e^{-\frac{h^2}{s^2 l^{2-m}}}, \qquad (3)$$

where Q is the quantity of matter dispersed per unit of time; v, the velocity of the wind; l, the distance from the generator; h, the height from the ground at which the aerosol is released; and s and m are constants.

Using this equation, we carried out sample calculations, the results of which are shown in Figure 2. These results show that the quantity of precipitated matter drops rapidly with increased distance from the generator. Furthermore, the smaller the height from which the aerosol is released, the more sharply the quantity of precipitated matter diminishes.

The curves shown on Figure 3 represent the quantity of matter precipitated on the total surface between the generator and some distance l from it, if this quantity is expressed in percent of the total quantity of matter which has been dispersed. The values used have been computed from Shleykhovskiy's equations [1].

As can be seen from Figure 3, the total quantity of matter which precipitates on the surface is small. With a wind velocity equal to 2 m/sec and height of aerosol release equal to 3m, only 40% of the dispersed matter precipitates up to a distance of 200 m from the generator. When the height of aerosol release is reduced, the completeness of precipitation is somewhat increased. Thus, when the aerosol is released at a height of 1 m, the degree of precipitation reaches 55%, but the main quantity of liquid precipitates near the generator, i.e., the uniformity of coverage diminishes.

In the calculations cited, it has been assumed that a drop which reaches the surface precipitates on it. Actually, a part of the drops rebounds from the surface and is carried away by the air current. The coefficient of reflection which characterizes the proportion of drops that rebound increases when the velocity of the wind becomes greater and the diameter of the drops smaller. For that reason, the degree of precipitation under field conditions will be lower than that shown in Figure 3, and its reduction will depend on the wind velocity and the drop size.

For drops which have an electric charge, the coefficient of reflection must be lower, so that the completeness of precipitation will be greater in this case.

The most favorable conditions exist in the case of a cloud consisting of drops with a diameter of about 100 microns. In a weak wind (up to 1 m/sec), such drops precipitate mainly under the effect of the force of gravity. Theoretically, one may create an aerosol cloud having such a dispersion of drop sizes that a uniform quantity of matter per unit of area will be precipitated throughout the whole extent of the surface being treated. Under such conditions, one may achieve a practically complete precipitation of the dispersed liquid on the surface that has been treated.

The advantages presented by large drops give reason to assume that clouds consisting of large drops will be widely used whenever the surface under treatment must be covered by a large quantity of the toxic agent per unit of area.

The velocity of precipitation of drops under the effect of the force of gravity is given by the following equation [1]:

$$W = \frac{P \rho g D^2}{18 \mu}, \qquad (4)$$

where W is the velocity of precipitation of the drops; P, a coefficient the value of which depends on the velocity of the wind; ρ , the specific gravity of the liquid; g, acceleration of the force cf gravity; μ , viscosity of the air; and D, diameter of the drops.

Knowing the velocity of precipitation of the drops, it is easy to calculate the distance from the fog or aerosol generator to the spot where the drops precipitate by using the expression

$$l = \frac{hv}{W}, \tag{5}$$

where l is the distance from the aerosol generator; h, the height from the ground at which the aerosol cloud is released; and v, the velocity of the wind.

Substituting W from equation (4) into equation (5), we obtain

$$l = \frac{18\, h\mu}{P\rho\, gD^2}. \tag{6}$$

The quantity of liquid which precipitates per unit of time on the area dl, is given by the expression

$$dQ = qudl, \tag{7}$$

where Q is the expenditure of liquid per unit of time, i.e., the output of the generator; q, the degree of coverage, the quantity of liquid per unit of area; and u, the velocity of displacement of the generator along the section being treated. If the number of drops precipitated on the section between the distances 0 and l is designated by n, the quantity of liquid precipitated on the section dl will amount to

$$dQ = \frac{\pi D^3}{6} \rho\, dn. \tag{8}$$

Equating the right sides of equations (7) and (8), and substituting the value of dl obtained from equation (6), we get, after differentiation,

$$\frac{dn}{dD} = \frac{216\, quhv\mu}{P\rho^2 \pi g}\, D^{-6} = AD^{-5}. \tag{9}$$

It follows from this that

$$lg \frac{dn}{dD} = lgA - 6\, lgD. \tag{10}$$

Equation (10) is the equation of a straight light for which $tg\alpha = -6$, which corresponds to a slope angle $\alpha = 99^{\circ}28'$. Under the assumed conditions, the magnitude of this angle does not depend on the velocity of the wind, the nature of the substance being dispersed, the height at which the aerosol cloud has been released, etc.

Equation (6) permits determination of the dimensions of drops of which the aerosol cloud should consist, while equation (10) indicates the number of drops which is necessary so that the total volume of drops per unit of area be uniform throughout the extent of the area being treated within a given distance from the generator. Sample calculations show that to treat a section extending over 100 m at a wind velocity of 1 m/sec and at a height of release of the aerosol cloud equal to 4 m, the average surface diameter of the drops should comprise 114 microns.

Conclusions

1. Whenever an adequate quantity of a toxic chemical is to be precipitated per unit area of the surface being treated, the use of an aerosol cloud consisting of drops having a diameter smaller than 30 microns is inadvisable; such drops will be carried away too far from the generator, so that the chemical of which they consist will be lost.

2. The treatment of large areas with aerosol clouds should be carried out in a wind which is not particularly strong, i.e., one that has a velocity up to 1 m/sec. A wind of this strength usually occurs at night and in the morning; consequently, this is the most favorable time for releasing the aerosol cloud.

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/Appended figures follow./

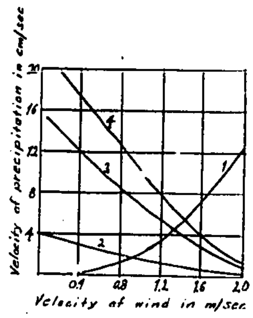

Figure 1. Velocity of Precipitation of Drops, Depending on the Velocity of the Wind. 1 - Turbulent velocity of precipitation. 2,3, and 4 - Stokes velocity of precipitation for drops having diameter of 50, 100, and 150 μ , respectively.

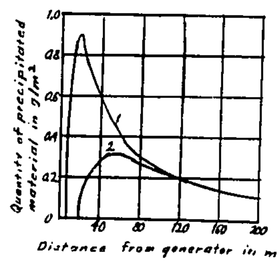

Figure 2. Quantity of Substance Precipitating per Unit of Area Being Treated at Wind Velocity of 2 m/sec. 1 - Aerosol released at height of 1 m. 2 - Aerosol released at height of 3 m.

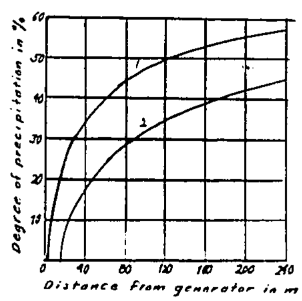

Figure 3. Degree of Precipitation at Wind Velocity of 2 m/sec. 1 - Aerosol released at height of 1 m. 2 - Aerosol released at height of 3 m.

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