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(54) FOG ABATEMENT AND CLOUD MODIFICATION

(71) We, THE DOW CHEMICAL COMPANY, a corporation organised and existing under the laws of the State of Delaware, United States of America, of Midland, County of Midland, State of Michigan, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method for the control of atmospheric moisture and more particularly relates to a method for fog abatement and the modification of clouds, and includes a method for producing coalescence and precipitation of particles suspended in the atmosphere in the form of a smoke.

In the past, many methods have been proposed to modify clouds to produce rain or snow, to dissipate haze or fog, to modify and decrease the intensity of tropical storms or hurricanes, or to remove smoke or smog from the air. Most of the reported work deals with cloud modification and many materials have been employed with varying degrees of success. In general, to produce rain from a cloud by seeding, it is necessary to employ an ice-former such as silver iodide or dry ice or a hygroscopic material such as $NaCl_2$, $CaCl_2$ or $Mg\ Cl_2$. Usually such seeding materials depend on a temperature within the cloud of less than 0° C. so that ice crystals form and grow. Many low clouds or fogs are too warm, however, and such seeding materials are not effective. Attempts have been made to produce rain from low warm clouds and fog by employing hygroscopic materials or sprays of water thereto to effect coalescence and precipitation of the particles within the cloud. Whilst rain has at times been produced by this method, such rainfall will not propagate itself unless the cloud was already in a metastable condition. Another problem presented by present systems is that very thick layers of cloud or fog, e.g. 5000 ft. are normally required to achieve good nucleation, coagulation and precipitation. Therefore, while a process to reliably control the agglomeration of atmospheric particles is greatly desired, no method has been heretofore provided which is effective in producing the agglomeration and subsequent precipitation of particles suspended in the air, particularly when such particles are above their freezing point.

The present invention, in its broadest aspect, provides a method for producing coalescence and precipitation of particles suspended in the atmosphere which method comprises contacting a mass of suspended atmospheric particles with a polymer in particulate form, the polymer having a molecular weight of at least 30,000 and at least a portion of the polymer particles having a charge which is opposite or different in magnitude from that of the suspended particles which are to be precipitated. More particularly the present invention provides a method for dissipating fog or modifying clouds whose temperature is above 0° C., which method comprises contacting a finely dispersed water-soluble or water-swellable polymer in particlate form with the fog or cloud, the polymer having a molecular weight of at least 30,000.

The polymer may readily be brought into contact with the fog cloud or smoke in the form of a dust or as an aqueous mist; preferably the dust or mist has an average particle diameter of 10 to 300 microns.

The more preferred polymers for use in the process of the invention are alkylenimine polymers, partially hydrolyzed acrylamide polymers, styrene sulfonate polymers and polyalkylenepolyamines. Thus the preferred polymers of the invention are polyelectrolytes which may be cationic, anionic or both. The polymers may also be nonionic. However, they are usually hydrophilic and include polyalkylenimines such as ethylenimine or polypropylenimine, polyalkylenepolyamines such as the condensation polymers of diethylenetriamine and dihaloalkanes, sodium polystyrene sulfonate, copolymers of sodium acrylate and acrylamide, partially hydrolyzed, cross-linked, acrylamide polymers, ion exchange resins such

[*Price 5s. 0d. (25p)*]

as a condensation product of epichlorohydrin and ammonia, polyalkylene oxides and copolymers of alkylene oxides with other organic electrolytes.

In order to possess the necessary properties for use in the process of this invention, the polymers, preferably organic polyelectrolytes, must have a molecular weight of at least 30,000 and preferably of at least 50,000. Such polymers may be employed either in aqueous solution, spray or mist form or in the form of a finely-divided particulate solid. In general, the most effective size of the particles of polymer e.g. the polyelectrolyte or the particles of the polyelectrolyte solution is from 10 to 297 microns. Particles smaller than 10 microns lose effectiveness in producing coalescence of the atmospheric particles and particles larger than 297 microns, while effective, begin to significantly reduce the number of particles produced from a given volume of polymer and therefore become inefficient.

Since the coagulation and precipitation of, for example, water particles by the present method is electrostatically produced, it is necessary that at least a portion of the polymer (preferably the polyelectrolyte) employed contains an opposite charge from that of the fog or cloud to be treated. Therefore, since clouds and fogs usually have an electronegative charge, it is often desirable to employ at cationic polymer, e.g. a polyelectrolyte, or where the fog, cloud, or other particulate mass to be coagulated, and dispersed contains a positive charge, an anionic polymer, e.g. a polyelectrolyte, may be employed. However, aggregation and precipitation of particles may also be accomplished by the addition of polymer polyelectrolyte having like charge but of different magnitude and which therefore disrupts the electrostatic equilibrium.

The amount of polymer, e.g. polyelectrolyte or polyelectrolyte solution, required for a given atmospheric condition will vary depending upon the density of the atmospheric particles, e.g. the density of the cloud or fog and the depth of the mass of atmospheric particles through which it is to pass. As each polymer particle passes through the mass of atmospheric particles, oppositely charged particles combine to form a particle of altered electrical charge which falls through the atmospheric mass, collides with other particles to produce a large particle and continues to increase in acceleration and speed until the surface tension is overcome and the particle redivides. Each of the divided particles then continues to fall and grow to produce a "chain-reaction" of acceleration and division of particles.

Any suitable means may be employed to distribute the polymer, e.g. polyelectrolyte, within the fog, smoke, cloud, or other particle-containing atmospheric mass and thereby produce contact between the dissimilar particles, i.e. the atmospheric particles and the polymer particles. For example, spraying a solution of a polyelectrolyte above or within the fog or cloud from an airplane or helicopter, explosively disseminating a polyelectrolyte within the cloud by means of a bomb or exploding rocket or spraying or blowing a polyelectrolyte from ground vehicles produces sufficient dispersion to cause coalescence and precipitation of the particles and thereby produce dissipation of fog or smoke and rain, snow or other precipitation from the clouds.

Example 1

Steam was injected into a room 20 ft.×12 ft.×8 ft. (6.1×3.66×2.43 m) until a dense fog was produced. The degree of fog density was measured by shining a light a distance of 16 feet (4.88 m) through the fog and into a light intensity meter such that higher readings are produced on the light intensity with less dense fog and lower readings with more dense fog. A reading of 120 units is achieved when no fog is present.

When the light intensity meter reading stabilized at 18 units, a 10 weight percent aqueous solution of an ethylenimine polymer having a molecular weight of 100,000 was sprayed as a fine mist 4 feet (1.22 m) above the beam of light for 10 seconds at the rate of 1 gm. of spray per second. The spray was produced from a spray bomb powered by CO_2 cartridges which was moved back and forth between the light source and the light meter. Within 30 seconds after spraying was started, the light intensity meter showed a reading of 21 units for a total of two minutes. a reading of 21 minutes and continued to show After a total of five minutes, the fog had returned to the equilibrium value of 18 units. It should be noted that the substantial reduction in fog is produced with an effective particle fall distance of only four feet (1.22 m).

In a control run, a spray of water was employed in place of the spray of polyethylenimine solution. During the ten second period of spraying, the light intensity meter reading decreased to 16 units and remained at this level for 45 seconds. After a total time of about five minutes from the beginning of the water spraying, the light intensity meter reading returned to the equilibrium value of 18 units.

Example 2

In the same manner as Example 1, a 5 weight percent solution of polyethylenpolyamine having a molecular weight of 100,000 was sprayed four feet (1.22 m) above the beam of light for a period of five seconds at a rate of one gram of spray per second. After 30 seconds from the beginning of application of the spray, the light intensity meter reading had increased to 20 units and remained at this value for a period of one minute. After a total of three minutes, the intensity meter reading had returned to the equilibrium value of 18 units.

EXAMPLE 3

In the manner of Example 1, a 10 weight percent aqueous solution of ethylenimine polymer having a molecular weight of 100,000 was sprayed for two minutes along a line four feet above the light beam. During this period the light intensity meter reading rose to a value of 24 units and an additional three minutes was required for the reading to return to the equilibrium value of 18.

When a five weight percent solution of polyethylenepolyamine having a molecular weight of above 100,000 was employed in the same manner, the light intensity meter reading increased to a value of 22 units and an additional two and one-half minutes was required for the reading to return to an equilibrium value of 18 units.

Similar results are obtained when a fine (about 200 mesh) (U.S. Standard screen) powdered form of a water-swellable, partially hydrolyzed acrylamide polymer containing 30% by weight sodium acrylate groups and crosslinked with 1500 ppm of methylene bisacrylamide is dispersed into the steam in the place of the polyethylenimine or polyalkylene polyamine.

Likewise, similar results are obtained when a finely divided form of sodium polystyrene sulfonate is employed in the place of the polyethylenimine employed above.

In a control experiment employing water in the place of an aqueous solution of polyethylenimine or polyalkylenepolyamine, the light intensity meter reading decreased to 15 units during the spraying step then increased slowly to the equilibrium value of 18 units in three minutes.

EXAMPLE 4

In order to demonstrate the applicability of the process of this invention to disperse a warm fog from airport runways under actual field conditions, an experiment was conducted at a large air port in the southern United States. For purposes of the test both a transmissometer and ground observers were employed to determine the effect of the test on visibility. The test was begun at 7:05 A.M. with an initial visibility of 80 feet to 100 feet (24 to 30 m) with no runway lights visible to the observers. An aircraft was flown over one runway at an altitude of about 500 feet (152.2 M) and a 5% solution of polyethylenimine having a molecular weight of 100,000 was applied at the rate of 200 lbs./sq. mile (35 kg/sq km) in seven passes over the runway. Both transmissometer readings and ground visual observers recorded that visibility rapidly increased with each pass of the spraying operation and by 8:00 A.M. after six of the seven passes had been completed, visibility had increased to 3200 feet (1050 m).

EXAMPLE 5

A heavily forested area covered by a large cloud of ascending white-grey smoke from burning saw mill waste was treated with a 5 weight percent aqueous solution of polyethylenimine by spraying a mist of such solution from an airplane just above the smoke an altitude of 100 feet (32.8 m). As the polyelectrolyte solution passed into the smoke a definite color change to blue was observed, showing densification of the smoke and the color change and densification could be seen continuing down through the rising smoke. After a second application of polyelectrolyte, the forest could be seen through the treated portion of the smoke but was not visible through the untreated portions.

In a like manner, spraying from aircraft into moisture-laden cloud columns of several thousand feet (several 100 meters) in height with aqueous solutions containing 1 to 10 weight percent polyethylenimine and using a deployment rate of from 5.0 to 20.0 lbs. of solution per square mile (0.9 to 3.5 kg/km^2) near the top of the clouds results in precipitation of a substantial portion of such clouds in the form of rain. Similar results are achieved when other polyalkylenimines, polyalkylenepolyamines, copolymers of sodium acrylate and acrylamide are employed in place of the polyethylenimine.

WHAT WE CLAIM IS:—

1. A method for producing coalescence and precipitation of particles suspended in the atmosphere which method comprises contacting a mass of suspended atmospheric particles with a polymer in particulate form, the polymer having a molecular weight of at least 30,000, and at least a portion of the polymer particles having a charge which is opposite or different in magnitude from that of the suspended particles which are to be precipitated.

2. A method for dissipating fog or modifying clouds whose temperature is above 0° C. which method comprises contacting a finely dispersed water-soluble or water-swellable polymer in particulate form with the fog or cloud, the polymer having a molecular weight of at least 30,000.

3. A method as claimed in claim 2 wherein at least a portion of the polymer particles have a charge which is opposite, or different in magnitude from that of the water particles which constitute the fog or cloud.

4. A method as claimed in claim 2 wherein the polymer has a molecular weight of at least 50,000.

5. A method as claimed in any one of the

preceding claims wherein the said polymer is in the form of a dust.

6. A method as claimed in any one of claims 1 to 4 wherein the said polymer is in the form of an aqueous mist.

7. A method as claimed in any preceding claim wherein the dust or mist has an average particle diameter of from 10 to 300 microns.

8. A method as claimed in any preceding claim wherein the polymer employed is a polyelectrolyte.

9. A process as claimed in any preceding claim wherein the polymer employed is an alkylenimine polymer, a partially hydrolyzed acrylamide polymer, a styrene sulfonate polymer, a polyalkylenepolyamine, or a mixture of two or more of the aforesaid polymers.

10. A method as claimed in any preceding claim wherein the said polymer is hydrophilic.

11. A method as claimed in claim 1 or claim 2 and substantially as hereinbefore specifically described in any one of the specific Examples.

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