The American Journal of Medicine

VOL. VII SEPTEMBER, 1949 NO. 3

Editorial

Disinfection of the Air with Triethylene Glycol Vapor

THE present premature large-scale commercialization of glycol vapors for prevention of acute respiratory disease, together with the accompanying propagation of much misinformation concerning the use and effects of this form of aerial disinfection, make it seem particularly appropriate to review our knowledge of the field. Furthermore, in the two and one-half years intervening since a previous summary of this subject,[1] considerable new information has been acquired.

Among the many chemical compounds which have been tested as vapors or mists for their lethal action on air-borne infectious particles triethylene glycol still remains the agent of choice for use in environments occupied by human beings. Germicidal concentrations of this vapor are odorless, tasteless, non-irritating, non-toxic, invisible and have no deleterious effect on walls, fabrics, books or other objects in the treated space. The presence of as little as 1 cc. of vaporized triethylene glycol in several hundred million cc. of air is, under laboratory conditions, highly lethal for the common respiratory bacteria, pathogenic and non-pathogenic, as well as for the viruses of influenza,[1] psittacosis and meningopneumonitis.[2] Other bacteria including Bacillus coli and subtilis (vegetative form), a number of common non-pathogens of the air and certain molds appear to be susceptible to the action of the vapor.[3] No reports have been made of such studies on air-borne tubercle bacilli. Naturally occurring dust-borne bacteria have been found to be much more resistant to the killing action of the vapor than are those experimentally dispersed into the air.

The recent development of certain quantitative technics for study of this subject has made possible much more precise experimentation, the results of which amplify previous knowledge of the activity of triethylene glycol vapor and provide new interpretations. First, fundamental to a more exact understanding of its germicidal effects was determination of the amounts of glycol vapor which could exist in the air at varying humidities and temperatures. By means of a suitable method devised for this particular purpose[4] curves were constructed indicating the saturation concentrations of triethylene glycol under conditions of relative humidity from 0 to 90 per cent and at temperatures from 20°C. to 29°C. It was found that increasing humidity resulted in

[1] ROBERTSON, O. H. New methods for the control of air-borne infection with especial reference to the use of triethylene glycol vapor. *Wisconsin M. J.*, 46: 311–317, 1947.

[2] ROSEBURY, T., MEIKLEJOHN, G., KINGSLAND, L. C. and BOLDT, M. H. Disinfection of clouds of meningopneumonitis and psittacosis viruses with triethylene glycol vapor. *J. Exper. Med.*, 85: 65–76, 1947.

[3] BIGG, E. and MELLODY, M. Fungicidal action of triethylene glycol. *J. Infect. Dis.*, 79: 45–56, 1946.

[4] PUCK, T. T. and WISE, H. Studies on vapor liquid equilibria. I. A new dynamic method for the determination of vapor pressure of liquids. *J. Phys. Chem.*, 50: 329–339, 1946.

a progressive although not straightline diminution in quantity of glycol vapor required to saturate the air. Raising the temperature was found to increase the capacity of the air to hold glycol.[5] With these data available chemical analyses of glycol-containing air could then be interpreted in relation to per cent saturation—a figure which has been found to be much more significant in respect to bactericidal effect than was the absolute quantity of glycol in the atmosphere.

Another important advance was the further development of the glycostat, or glycometer, an instrument for measuring and controlling the concentration of triethylene glycol vapor in the air.[6] This instrument is extremely sensitive, being capable of detecting as little as 1 microgram of glycol /L. of air under ordinary conditions of humidity and temperature and responds rapidly to changes in concentration of vapor. By means of attachment to a recording device the glycometer provides a continuous record of the concentration of glycol in the atmosphere in terms of per cent saturation. It can be used also to control the output of the glycol vaporizer. Unfortunately this apparatus is not yet commercially available.

Employing the glycostat in specially constructed experimental rooms in which atmospheres could be maintained at any desired temperature and relative humidity, a large series of observations has been made on the bactericidal and virucidal action of varying concentrations of glycol vapor under a wide range of environmental conditions. Optimum conditions for the rapid action of the glycol vapor at ordinary room temperatures were found to be relative humidities of 15 to 40 per cent and vapor saturations of 40 to 100 per cent. In such atmospheres freshly atomized bacteria were killed in two to three minutes; 80 per cent or more of them were destroyed in the first minute. At high relative humidities (60 to 80 per cent) the rate of action was much reduced but still appreciable. Likewise, at very low humidities (5 to 10 per cent) killing was somewhat retarded. The more nearly the concentration of the glycol vapor in the air approached the saturation value the more rapid the kill. However, the increase in effectiveness at levels about 70 per cent was slight.[7]

Observations of an analogous nature on influenza virus in which white mice were exposed to atmospheres containing freshly atomized virus and glycol vapors showed that the presence of the glycol in the air at saturations of 70 to 90 per cent afforded the mice complete protection against lethal concentrations of the virus. Protection was optimum at relative humidities of 15 to 40 or 50 per cent, as was the case with bactericidal activity of the glycol. However, at high humidities, 70 to 80 per cent, the glycol had relatively little effect as most of the test mice died even when the air was saturated or supersaturated with triethylene glycol. Under optimum conditions of humidity and glycol saturation the virucidal action of the vapor was found to be very rapid.[8]

Studies with dried bacteria in the form of droplet nuclei or as a fine dust made from desiccated saliva suspensions have shown them to be about as susceptible to the lethal action of triethylene glycol vapor as are freshly atomized suspensions. The importance of this finding lies in the fact that most pathogenic bacteria present in an infected atmosphere are probably in the dried state.[8]

These more recent observations bring out the fact that, in adequate concentrations, triethylene glycol vapor is effective over a wider range of relative humidities

[5] Wise, H. and Puck, T. T. The saturation concentrations of triethylene glycol vapor at various relative humidities and temperatures. *Science*, 105: 556–557, 1947.

[6] Puck, T. T. An automatic dewpoint meter for the determination of condensible vapors. *Rev. Scient. Instruments*, 19: 16–23, 1948.

[7] Lester, W., Robertson, O. H., Puck, T. T., Wise, H. and Smith, M. The rate of bactericidal action of triethylene glycol vapor on microorganisms dispersed into the air in small droplets. *Am. J. Hyg.*, to be published.

[8] Robertson, O. H., Lester, W. and Dunklin, E. Unpublished experiments.

than was formerly thought to be the case.* It has not been found possible, however, to sterilize the air of inhabited rooms. Numerous tests under a variety of conditions have shown that the air-borne bacterial population can be reduced by not more than 70 to 75 per cent and the rate of killing is much slower than in the case of atomized bacterial suspensions. Investigation of dust-borne bacteria (non-pathogens with rare exceptions) indicates that the reason for their relative insensitivity to the lethal effect of triethylene glycol vapor lies in the physical state of the bacterial particle which obviously differs from that of the glycol-sensitive micro-organisms desiccated under laboratory conditions.

The utilization of glycol vapor for purposes of aerial disinfection involves a number of considerations which may be outlined briefly as follows: since triethylene glycol has a very low vapor pressure (boiling point is 550°F.) heat is essential for vaporization. However, the temperature which can be employed for this purpose is limited by the fact that this glycol begins to decompose at temperatures far below its boiling point. These properties of triethylene glycol introduce very definite requirements for the design of vaporizers. In order to disperse sufficient glycol into the air extended evaporating surfaces must be employed. Heating of the pool or reservoir of glycol should be avoided. Certain glycol vaporizers commercially available embody these principles, others do not.

Continuous dispersion of the glycol vapor into the treated space is essential because of the constant loss of vapor from the air, due to invisible condensation on all surfaces (including dust in the air) and the exchange of air which goes on to some degree even when windows and doors are closed. This loss amounts to 70 to 90 per cent of the glycol vaporized.[8] Hence in order to secure and maintain adequate concentrations of glycol in the air it is necessary to vaporize usually four to five times the amount of triethylene glycol calculated to produce the desired concentration in a given space. When air exchange in the room is increased by opening of doors and windows, the glycol requirement is even higher.

Air currents are necessary for uniform dispersion of glycol vapor throughout the treated space. In moderate-sized rooms of several thousand cu. feet the natural convection currents are usually adequate for this purpose. In larger spaces an electric fan or two depending on the size and shape of the space to be glycolized accomplishes the desired result. Air conditioning systems offer the most satisfactory means of glycol vapor distribution.

Maintenance of an adequate concentration of triethylene glycol vapor in the atmosphere offers the principal problem in the field of practical application. Until glycostats become available the only means of knowing whether sufficient glycol vapor is present, aside from chemical determination, is to produce a slight fog. The presence of a mist, best determined by the Tyndall effect (from a focused flashlight) does not necessarily indicate saturation of the air. A beam may be detectable at any concentration above 50 per cent saturation depending on the dustiness of the air. However, the occurrence of a Tyndall beam under ordinary conditions indicates the presence of a germicidal concentration. The optimum concentrations in terms of per cent saturation probably lie between 60 and 80 per cent.

Prior to its use in environments inhabited by human beings, prolonged tests (twelve to eighteen months) for chronic toxicity were carried out on monkeys and rats exposed continuously to atmospheres saturated with triethylene glycol vapor. In none of this large group of animals nor in

* Certain earlier studies,[9] which indicated that dried bacteria were relatively unsusceptible to glycol vapor action at humidities below 30 per cent, were carried out before any means was available for measuring concentrations of triethylene glycol in the air. Subsequent developments have shown that the amounts of glycol used in those experiments which were calculated to saturate the air actually produced concentrations so low as to be almost negligible.

[9] Robertson, O. H. Sterilization of air with glycol vapors. Harvey Lecture Series, 38: 227–234, 1942–43.

others receiving oral doses many hundreds of times the amount they could absorb from inhalation were any deleterious effects observed either during life or in histologic sections of the organs following sacrifice at termination of the experiments.[10] Subsequent to these tests thousands of individuals have resided in glycol-containing atmospheres, many of them continuously for months, without apparent disturbance. The presence of triethylene glycol vapor in the air offers no fire or explosive hazard.

Evidence of the effect of triethylene glycol vapor derived from practical application is as yet scanty. Tests of the lethal action of glycol vapor on pathogens demonstrable in the air have thus far been confined to observations on hemolytic streptococci. In hospital wards housing patients with streptococcal respiratory tract infections the dispersion of triethylene glycol vapor resulted in reduction of air-borne streptococci of approximately 70 per cent. However, when in addition to glycol, dust control measures (oiling of bedding and floors) were instituted, the reduction was increased to 95 per cent. These findings bring out the importance of dust suppression as an adjunct to the use of triethylene glycol vapor.[11]

The few studies that have been reported on the clinical effects of employing glycol vapor for the prevention of air-borne infection are much more difficult to evaluate. The results of these experiments which were carried on in hospitals and military barracks vary from marked reduction of infections in the glycolized area[12] to inconclusive effects.[13] Environmental conditions of the several tests differed markedly and it is quite likely that opportunities for the transmission of infection by routes other than the air likewise varied. This latter unknown, namely, the percentage of cases of the various diseases of the respiratory tract that are airborne makes the evaluation of any control measure most difficult. In environments such as hospital wards adequately controlled tests of the effect of aerial disinfection on the incidence of diseases acquired by way of the respiratory tract must include rigid enforcement of ward technics intended to reduce the possibility of channels of infection other than through the air.

From the foregoing summary it is apparent that the usefulness of triethylene glycol vapor as a means of protection against respiratory infection remains to be determined. However, the fact that this vapor has been shown to be a potent aerial disinfectant, at least for freshly dispersed pathogens, indicates the worthwhileness of more clinical trials in a variety of environments. The kind of control employed in such tests will of necessity vary with the particular environment and will have to be planned for each type of population under study. It is only through an accumulation of results from controlled experiments of this kind that an evaluation of the procedure will be possible.

In conclusion, reference should be made to the nationwide sale of glycol vaporizers. Two recent editorials in medical periodicals[14,15] have dealt with this subject pointing out the unfortunate aspects of unrestrained exploitation of glycol vapors and the fact that the majority of the vaporizing devices on the market are completely unsatisfactory. A few mechanically sound and efficient vaporizers are being produced and it seems likely that some means of official certification of such apparatus will soon be available.

O. H. ROBERTSON, M.D.

[10] ROBERTSON, O. H., LOSSLI, C. G., PUCK, T. T., LEMON, H. M., WISE, H. and LESTER, W. Tests for the chronic toxicity of propylene glycol and triethylene glycol on monkeys and rats by vapor inhalation and oral administration. *J. Pharmacol. & Exper. Therap.*, 91: 52–76, 1947.

[11] PUCK, T. T., HAMBURGER, M., ROBERTSON, O. H. and HURST, V. The effect of triethylene glycol vapor on air-borne beta hemolytic streptococci in hospital wards. II. The combined action of glycol vapor and dust control measures. *J. Infect. Dis.*, 76: 216–225, 1945.

[12] ROBERTSON, O. H. Disinfection of air by germicidal vapors and mists. *Am. J. Pub. Health*, 36: 390–391, 1946.

[13] LOOSLI, C. G., SMITH, M. H. D., GAULD, R., ROBERTSON, O. H. and PUCK, T. T. Control of cross infections in infants' wards by the use of triethylene glycol vapor. *Am. J. Pub. Health*, 37: 1385–1398, 1947.

[14] Commercial exploitation of glycol vaporizers. *Am. J. Pub. Health*, 39: 222–224, 1949.

[15] The sale of glycol vaporizers. *Cincinnati J. Med.*, April, 1949.