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DETERMINATION OF PHYSICAL PARAMETERS OF VIRAL AEROSOLS

- USSR -

[Following is a translation of an article by A. I. Gromyko, A. I. Danilov and G. Ya. Vlasenko, Institute of Virology imeni Ivanovskiy, Academy of Medical Sciences USSR, in the Russian-language periodical Zhurnal Mikrobiologii, Epidemiologii i Immunobiologii (Journal of Microbiology, Epidemiology and Immunobiology), Moscow, No 7, 1966, pages 94-97.]

Communication II: Investigation of the Condition of the Aerosol Cloud in an IVK-2 Chamber and the Significance of Changes Observed for the Dosimetry of Aerosol Infection

In Communication I* we discussed the desirability of using the method of continuous ultramicroscopy for the purpose of studying viral aerosols and developing the conditions of reproduction of infections in an aerosol chamber. It was demonstrated that by means of type VDK continuous ultramicroscopy it is possible to determine the degree of saturation of the chamber with viral aerosol and the time of clearance [removal] of infectious aerosol after termination of the experiment. A correlation was made between the data of theoretical calculations and visual observation.

The purpose of the present investigation was to determine the concentration of dispersed substance in an aerosol state, determination of the correlation between the

* Zh. Mikrobiologii (Journal of Microbiology), No 6, 1966.

changes in this concentration and time of animals' contact with the viral aerosol, determination of the fractional composition of aerosols, calculation of gravimetric (by weight) concentration and determination of quantity of aerosol that has passed through an animal's respiratory system. The methods of obtaining and measuring aerosols were described in Communication 1.

Processes occur in an aerosol cloud that lead to a decrease in number of aerosol particles. There is the most significant decrease in concentration of the substance during the first few minutes in the aerosol's "life," thereafter the concentration remains relatively constant.

Table 1

Changes in aerosol concentration after discontinuing dispersion

a Интервал времени (в мин.)	b Количество аэрозольных частиц (×10⁵) в 1 см³				
	[illegible]	[illegible]	[illegible]	[illegible]	d [illegible]
c Фон	0,01	0,07	—	—	0,04
1	7,75	8,22	7,2	—	7,7
5	7	6,2	8,8	—	7,3
10	6,8	7	5,6	6,2	6,4
15	5,2	5,2	5,6	5,2	5,3
20	6,2	5,6	6,9	5,2	6,1
25	4,4	5,2	3,4	3,8	4,2
30	5,2	4,8	5,2	5,2	5,1
35	3,6	3,8	3,8	4,1	3,8
40	3,8	4,1	4,1	4,4	4,1
45	3,8	3,6	3,8	—	3,7
60	3,3	3,2	3,6	3,6	3,4
75	3,4	3,6	3,3	3,4	3,4
90	3,4	3,3	3,4	3,6	3,4
105	2,9	3,2	3,4	2,8	3,1
120	2,6	2,3	3,4	3,2	2,9
Через 24 часа e)	0,03	0,03	0,06	—	0,04

Legend:

a) time interval (minutes)

b) quantity of aerosol particles (X 10^5) per cubic centimeter

c) background

d) mean

e) after 24 hours

Starting at the 30th minute and up to two hours the number of particles in the aerosol cloud decreases negligibly (Table 1).

Previously (Bolotovskiy, 1959) it had been established that with this method of spraying, a 60 minute contact of the animal with the viral aerosol suffices for it to be infected. However, in order to determine the quantity of substance aspirated by the animal during contact, it is important to know the quantity of particles and weight concentration of the aerosol in the chamber for the duration of the contact period.

The methods used previously (Bolotovskiy 1959) for calculation of substances that settled in the animals' respiratory tract did not take into consideration the changes in concentration related to different forces acting upon the aerosol particles (precipitation, Brownian movement, coagulation, etc.). It seemed of interest to check these calculations by visual methods.

For this purpose we made a study of the fractional composition of the aerosol and changes in it in the course of contact. Determination of the dispersive composition is also important in order to evaluate the site of application of the viral aerosol in the animal's respiratory organs. Thus, in experiments on rabbits (Buckland et al, 1950) it was established that upon inhalation of the aerosol the particles of which had a radius measuring 0.5 μ [microns], 29% of these particles settled in the nasopharynx, 13 to 19% in the trachea, and 51 to 58% in the alveoli; with a radius of 2 μ, 65% of the particles settled in the nasopharynx, and up to 98% with a radius measuring 4 μ.

Experiments on mice (Shoshkes, 1950) revealed that settling of the aerosol in the bronchi, bronchioles and alveoli was related to particle size in the following manner: at a radius of 0.2 to 0.62 μ 26 and 42%, respectively, settled in these areas, at a radius of 1.05 to 1.46 μ, 35 and 38%, and at a radius of 1.46 to 1.88 μ -- 48 and 15%. Thus, the smaller the particles of the inhaled aerosol, the deeper and more extensive the injuries to the lungs.

Previously (Bolotovskiy, 1959) the concentration of aerosol in the chamber was calculated on the basis of data about the dispersion composition and the output of the atomizer and quantity of viral substance sprayed in a certain quantity. However, a comparison of the fractional composition of the aerosol at the output of the atomizer (Table 2) and in the chamber (Table 3) revealed significant differences. There were also differences in the absolute number of particles of different sizes (Table 4).

In order to calculate the weight-related concentration of substance we considered the weight of one aerosol particle to equal its volume; since the density is close to one, by multiplying the volume of aerosol particles by their number per unit of volume, we obtained the concen-

tration weight (Table 5). Thus, knowing the aerosol concentration weight and its dispersive composition it is possible to evaluate the quantity of material that reached the animal's respiratory organs after a given period of exposure to the aerosol at any time after termination of spraying.

Table 2

Dispersiveness of aerosol particles at the output of the atomizer

Расстояние от сопла (в см) a)	Дисперсность (в %) при фракционном составе частиц диаметром (в мк) b)			
	1—10	11—20	21—50	51—100
10	82	5	10	3
15	85	10	5	—

Legend:
a) distance from nozzle (in centimeters)
b) dispersiveness (in %) with fractional composition of particles of the following diameters (in microns)

Table 3

Fractional composition of aerosol in the chamber upon termination of spraying

a) Диаметр аэрозольных частиц (в мк)	b) Процент частиц через c)					
	5 мин.	10 мин.	20 мин.	30 мин.	45 мин.	3
0,9—1,1	4	12	10	6	8	20
1,5—1,7	80	80	85	90	84	70
2—3	10	6	3	4	8	10
3—4	6	2	2	—	—	—

Legend:
a) diameter of aerosol particles (in microns)
b) percentage of particles after
c) ... minutes

To calculate the dose of viral aerosol inhaled by the animal we used the equation: $D = C \cdot V \cdot P \cdot t$, where C is the concentration of substance in the aerosol in grams per milliliter; V is the respiratory volume of the animal in milliliters per minute; P is the animal's weight

in grams; t is the time of contact of the animal with the aerosol.

Table 4

Quantity of particles of different size in the aerosol cloud in the chamber with different exposure times

a) Срок после прекращения распыления (в мин.)	Количество частиц (x 10⁴) в 1 см³ с радиусом (в мк) b)				Суммарное количество (x10⁴) в 1 см³ c)
	0.5	0.8	1.2	1.6	
5	2.92	58.4	7.3	4.38	73
10	7.63	51.2	3.84	1.28	64
20	6.1	[illegible]	1.83	1.22	61
30	3.0[illegible]	45.9	2.04	—	51
45	2.96	31.08	2.96	—	37
60	6.5	[illegible]	3.4	—	34

Legend:

a) time after termination of spraying (minutes)
b) quantity of particles (X 10^4) per cubic centimeter with a radius of (in microns)
c) total quantity (X 10^4) per cubic centimeter

Table 5

Gravimetric (weight) concentration of viral material in the aerosol cloud at different times after termination of spraying

a) Срок после прекращения распыления (в мин.)	Гравиметрическая концентрация (в мг/м³) при частицах радиусом (в мк) b)				c) Суммарное количество вещества (в мг/м³)
	0.5	0.8	1.2	1.6	
5	15.2	1226.4	518.3	749	2508.9
10	39.9	1075.2	272.6	218.9	1606.9
20	31.7	1088.8	129.9	208.6	1459
30	15.9	963.9	144.8	—	1124.6
45	15.4	652.7	210.2	—	878.3
60	35.4	500	241.4	—	776.8

Legend:

a) time after termination of spraying (in minutes)
b) gravimetric concentration (in milligrams per cubic meter) with particles with a radius of (in microns)
c) total quantity of substance (in milligrams per cubic meter)

Thus we obtained data on the quantity of viral aerosol inhaled by the moue following different periods of contact as well as on the total dosage for the entire contact period. Thus, with contact for one to five minutes, 0.1 mg [milligrams] of substance was absorbed, when the contact lasted 5 to 10 minutes 0.06 mg was absorbed, after 20 to 30 minutes 0.009 mg was absorbed, after 30 to 45 minutes the quantity absorbed equalled 0.1 mg, and after a 45 to 60 minute contact 0.09 mg was absorbed.

As observed by several authors (Spurnyy et al, 1964) at present there are no methods that would permit determination with absolute accuracy the concentration of substance contained in an aerosol state. Each of the methods currently in use induces more or less significant disturbances in the condition of the aerosol cloud. In the case of optical methods there is minimal disturbance of stability of the aerosol cloud. However, the possibility of error is also related to the individual ability of the eye to distinguish "bursts" from particles of small size. Therefore it is definitely of interest to explore the possibility of using automatic computers to calculate the concentration of particles (Deryagin and Vlasenko, 1959; Kiktenko et al, 1961 and 1962; Thomas and Collins, 1962). Using the system of continuous ultramicroscopy, with a photoelectronic device it is possible to automate the calculation of aerosol particles; in contrast to continuous ultramicroscopy, the recording of "bursts" of light occurring when the particles fly through a brightly lit zone is performed by means of an electron photomultiplier. Apparently this is a very promising method for dosimetry of aerosol infection and immunization, since this involves the recording of light from the bursts of particles, and not only the size but even the shape of the particles can be evaluated from the oscillogram.

Conclusions

1. By means of a type VDK continuous ultramicroscope it has been demonstrated that there was a constant change in concentration and fractional composition of aerosol in an aerosol cloud created in a static chamber following spraying of material containing virus: the calculated concentration decreased significantly during the first 15 to 20 minutes, then remained relatively stable for over two hours.

2. The measurements performed permitted assessment of the dosage of viral aerosol inhaled by the animal during various periods of contact.

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