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NEW DATA ON THE PROBLEM OF AEROSOL RETENTION DURING RESPIRATION

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This article presents the results of some ~~xxxxxx~~ research :1-th study the amount of aerosol condensate retained, 2- to study the amount of aerosol particles(disintegrated) retained and 3-to explain the relationship of the retention of aerosol during respiration and the electric charge of the particles.

Retention of Aerosol Condensate during Respiration

Studies to determine aerosol condensate retention were conducted on smokes containing zinc oxide and cadmium oxide.

A crucible electric furnace was utilized to create the smokes at a temperature of 900°. Measured amounts of metal were placed directly into the furnace.

Experiments were conducted with the following smoke concentrations: cadmium oxide smoke - 65,000 to 400,000 particles per cubic centimeter, and zinc oxide smoke- 40,000 to 360,000 particles per cubic centimeter. Five (humans) were subjected to these smokes and a total of 139 experiments were carried out: 59 with cadmium oxide and 80 with zinc oxide.

Test
1 Results ~~of the experiments~~ are shown on Fig 1.

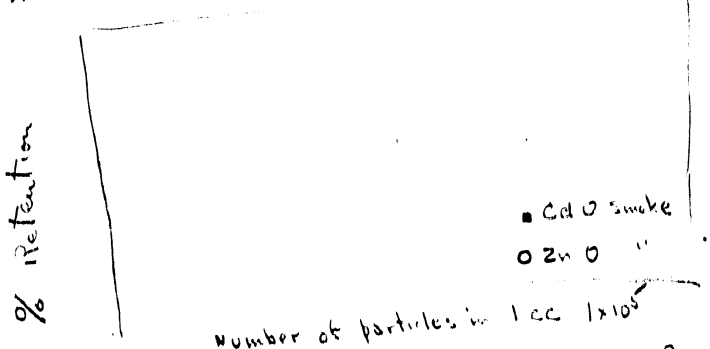


Fig. 1. Retention of Cd O and Zn O Particles during Respiration.

In the greater part of the tests the degree of retention varied from 45 to 70%. In general there was a higher degree of retention of zinc oxide particles. Table 1 shows the maximum, minimum and average retention in the five humans [redacted], for the two types of smoke.

Table 1 - Degree of Retention after inhaling Cd O and Zn O Smoke

Experiment Volunteers	Cd O			Zn O		
	Maximum	Minimum	Average	Maximum	Minimum	Average
A						
B						
C						
D						
E						

From Table 1 it is evident that in 4 of the 5 cases, the average amount of retention for both smokes was more than 60% and in only one case (cadmium oxide), the amount was ~~it~~ below 60; in this case it was 49%. The degree of retention varied greatly

in the five cases. The relatively greater retention of zinc oxide can be attributed to the different degrees of dispersion and the greater particle content of zinc oxide in smoke, ~~containing the zinc oxide.~~ To date there are no data which show the relative degree of dispersion of cadmium oxide and zinc oxide. Microphotographs, obtained with the aid of an electron microscope (shown in Fig 2 and 3 which are available in the original document) do not aid in determining the relative dispersion of these two substances. ~~However, it was shown~~ according to the data ~~which was~~ obtained from our studies, ~~that~~ the charge of particles has much to do with their degree of retention after inhalation. ~~as a result of respiration.~~ However, even in this respect there is insufficient data on the percent of charged particles in smoke.

Test results ~~of experiments which were~~ described above, confirmed the fact that there is a considerable amount of retention after inhaling ~~breathing~~ smokes containing aerosol condensate, and that the retention of zinc oxide was higher than cadmium oxide. Results were compared to those obtained from experiments conducted with tobacco, coal and magnesium oxide smokes. The action of the aerosols which are retained in the respiratory passages, depends not only on the amount of aerosol which is actually ~~re~~ retained, but also on the degree and depth of penetration into the respiratory tract. Other studies were conducted to determine the role of the nasal passages on the retention of aerosols. Two of those tested, ~~breathed~~ inhaled through their nasal

passages ~~for~~ 40 ~~breaths~~ times and then ~~breathed~~ inhaled through their mouths ~~2~~ 40 times. Thus two tests were conducted. Concentrations used were: cadmium oxide - 130,000 to 495,000 particles per cubic centimeter and zinc oxide - 145,000 to 300,000 particles per cubic centimeters. A total of ~~xxx~~ 08 tests were conducted. The results are shown ~~on~~ in table 2.

Table 2 - Percentage Retention of Various Smokes

Test Cases

Experimental volunteers	Cadmium oxide % retention		Zinc oxide	
	nasal	oral	nasal	oral
A				
B				

There was no appreciable difference between the ~~with respect to the~~ two ~~types~~ methods of ~~breathing~~ inhalation ~~where~~ of cadmium oxide. In the case of zinc oxide, the retention ~~as a result of~~ for the nasal ~~breathing~~ inhalation was from 5.5 to 5.5% greater than ~~as a result of~~ the ~~mouth breathing.~~ oral inhalation.

These tests confirmed the statements made earlier that the nasal passages are actually very poor filters, and that in all ~~xxxxxx~~ experiments with smokes, it was determined that the greatest ~~xxxxx~~ amount of retention occurred in the deeper regions of the respiratory tract.

Aerosols made up of
Retention of/Disintegrated Particles ~~xxxxxx~~

Studies were conducted with quartz dust and aluminium powder. The former plays a very important role in the etiology of silicosis, while the latter is an important substance in the therapy of silicosis.

~~So as~~ to permit observations, about 3,500 particles per cubic centimeter were placed in the observation chamber. It appeared that ~~on the~~ average of about 47 to 48% of microscopic particles were retained during respiration. Results are tabulated in Fig 4.

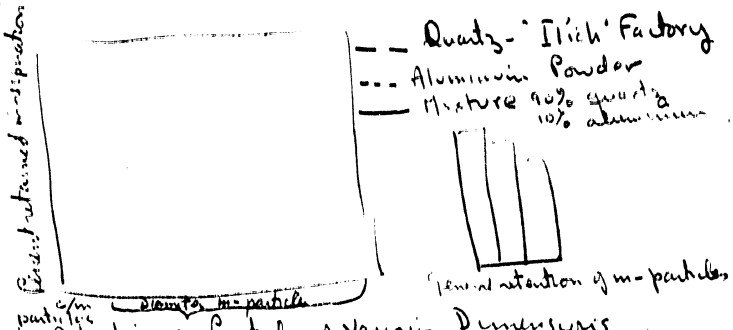


Fig 4 - Comparative Retention of Particles of Various Dimensions

Significant differences in degrees of retention were observed according to the various sizes of particles in the aerosols. The lowest degree of retention was with particles which measured 0.3 to 1 micron, and it was observed that with an increase in the size of the particles the degree of retention also increased. However, it was shown that ~~more~~ aluminium powder was retained more than the quartz dust (0.3 to 1 micron) while the larger aluminum particles were retained to a less degree than the quartz particles (1 to 3 microns). In any case the ~~small~~ more minute aluminium powder was retained to a greater degree than the larger particles.

Experiments were also conducted with submicroscopic particles in the forms of smokes having 45,000 to 50,000 particles per cubic centimeter. The average retention of these submicroscopic particles was 53% for the ~~quartz~~ aluminium, and 46% for the quartz.

Comparison of the degrees of retention of submicroscopic and microscopic particles of both materials showed that:

1- submicroscopic particles of quartz are retained about 13% more than its ~~xxx~~ smallest ~~fractions~~ microscopic particles (0.3 to 1 micron)

2-submicroscopic particles of aluminium powder were retained 9% more than the larger ~~xxx~~ particles (0.3 to 1 micron) and 16% more than submicroscopic quartz particles. ~~of quartz.~~

~~The~~ Large amounts of microscopic (0.3 to 1 micron) and ~~xxxxxxxxxx~~ submicroscopic particles are frequently observed in all types of factories. It is therefore very important to determine some method for decreasing the degree of retention, which ~~xxxxxxxx~~ apparently is very high (as can be seen from the data).

Studies were also conducted to determine the retention of a mixture of quartz dust (90%) and aluminium powder(10%).The concentration of the test smoke was 3,500 particles per cubic ~~xxxxxxx~~ centimeter. On the whole the retention was similar ~~in~~ for the amount ~~of the~~ retention of ~~the separate~~ other substances, while the ~~general~~ overall retention of microscopic particles of the mixture was slightly less than the retention of aluminium and quartz, when tested separately. From this it can be seen that the addition of 10% of aluminium powder to quartz greatly changed the nature of the retention. This is of interest as it opens up the possibility of lowering the retention of quartz by judicious additions of some ~~xxxxxx~~ other ~~substances.~~ powders.

Other experiments were conducted to determine the

degree of according to
retention ~~from~~ the concentration of the air inhaled.
~~which from expiratory being breathed.~~ It was found that with concentrations of 50,000 submicroscopic particles of aluminium powder per cubic centimeter, about 57% was retained, but ~~if the~~ when this concentration was increased three times (150,000 particles per cubic centimeter) the retention increased to

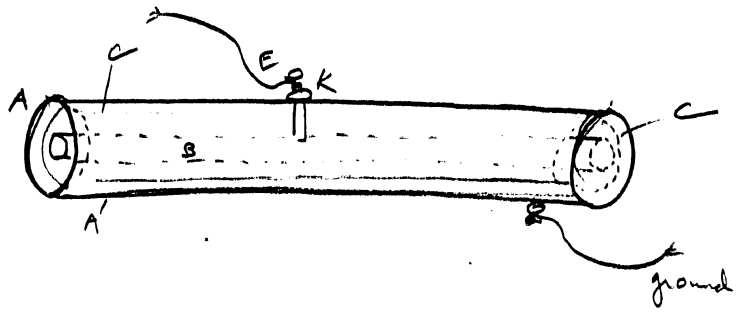
Table 3 - Retention of Microscopic Particles of Aluminum Powder of various concentrations (average).

Experimental rabbits —	Number of Particles per cubic centimeter: Entered lungs during respiration	Retention in lungs: absolute	Retention in lungs: %
A			
B			
C			

precipitation [illegible]
in a cylindrical condenser. The uncharged particles, which ~~are~~ are not affected by the field, ~~are~~ do not precipitate and emerge from the condenser without any change. Particles of given specific dimensions have corresponding saturation potentials, at which ~~all charged particles~~ they are precipitated in the condenser. The apparatus incorporates a simple

Owen's ~~oniountator~~ counter I, which is coupled ~~up~~ with a pipe.
This pipe is converted into a condenser by the simple

Fig 7 - Diagram of Condenser for determining the amount of charged particles of aerosols -
A - outer covering of condenser, B - inside pipe -
C - humidifying paper, E - post, K - condenser -



factories Imeni Lomonosov and "Proletariy" and the turning shop of ~~the~~ Abrasive the factory "Il'ich" were selected as the experimental ~~locales.~~ sites. The dusts found at these places can be classed as the disintegrated type of aerosols, and many tribo-electric particles are present in the air. The amount of these charged particles varied with the type of machining process in the immediate vicinity. Table 4 shows the relatively large amounts of charged particles which were found in some of the ~~work~~ shops.

Owen's counter I, which is coupled with a pipe. This pipe is converted into a condenser by the simple expediency of inserting a metallic core through which electrical currents are passed. The outside pipe is grounded. With this apparatus (fig 7) it is possible to determine the degree of charge on the particles of the aerosol.

The air which is being examined passes in view of the lense of an ultra microscope, thus permitting a count of the submicroscopic particles. The Owen's counter was used to determine the number of microscopic particles. The particles were strongly illuminated and magnified 1,000 times, and so as to permit a general count of all the particles. The amount of particles in the inhaled air was compared with the number of particles in the air prior to inhalation thus establishing a ratio, as well as fixing the degree of retention.

An attempt was made to determine the amount of charged particles which could be detected in the air of a factory. The lathe shop of the porcelain factories imeni Lomonosov and "Proletariy" and the turning shop of the abrasive factory "Il'ich" were selected as the experimental sites. The dusts found at these places can be classed as the disintegrated type of aerosols, and many tribo-electric particles are present in the air. The amount of these charged particles varied with the type of machining process in the immediate vicinity. Table 4 shows the relatively large amounts of charged particles which were found in some of the shops.

Table 4 - Percent. of Charged Particles of Dust in Shops with different machining process -

Location	Site of taking sample	General number of particles 1cc	Number of particles going through the Condenser (unchanged)	Number of charged particles.	% charged particles
Il'ich Factory	Sifting Shops				
Milling Shop Factory imeni Lomonosov.	Tin rooms —				
	Dish turning shop — vertical Flashing — tools				
Lathe Shop.	Small dish turning — shop				
	Tin rooms				
Proletariy' Factory Lathe Shop	Small dish turning shop —				

Smaus table 4

As can be seen from the above table, the largest amount of charged particles were observed in the ~~Abrasive~~ Factory "Il'ich" where carborundum was being milled. On the average there were 78.9% of the particles were charged ~~particles~~. In the "Proletariy" factory, where small porcelain articles were being ground and finished, the amount of charged particles was about 45.4%. Data obtained from the Porcelain Factory from Lomonosov showed that the type of machining process had much to do with the amount of charged particles which were observed in the air. For example, ~~in~~ in shops where large plates were being turned the amount of charged particles was about 59%, while in shops where medium sized plates were being turned on vertical machine tools the amount of charged particles was 40.4%. In shops where very small items were turned ~~by~~ manually the number of charged particles was only 32.9%.

Experiments were conducted on marshallite containing air at the "Il'ich" Factory and air filled with medical aluminium powder, produced by the VAMI Laboratories specially for the experiments, and kaolin dust.

The microphotographs (fig 5 and 6, available in the original document) obtained with the aid of an electron microscope show the relative sizes and dispersion of the aluminium and kaolin powders. The following dispersions were observed: aluminium - 69% for particles less than 1 micron, 27.3% for particles from 1 to 3 microns, 3.7% for particles of 3 to 5 microns (~~aluminium~~) and 2 - kaolin - 85.9% for particles less than 1 micron, 13.6% for particles from 1 to 3 microns and 0.5% for particles from 3 to 5 microns (~~caolin~~).

The experiment was conducted in two stages: two tests were made of the air which was ~~breathed in~~ inhaled and two tests of the air which was being ~~breathed out~~ exhaled. The first run was made without any charge on the condenser, the second run was made with a 400 volt charge on the condenser.

Microscopic examination of the samples ~~permitted~~ determined ~~of~~ the percentage content of ~~charged~~ particles in the charged particles ~~which~~ in the ~~inspired~~ inhaled and ~~the expirated~~ exhaled air. With these facts it is simple to determine the number of charged particles ~~which exist~~ present in the ~~general~~ air (of the particular shop).

A total of 350 tests were made to determine the degree of retention ~~according to the~~ average number of particles in the air as well as a study of each particle as to stability (to determine whether it was charged or not charged). It was determined that the retention of charged particles was higher than the retention of uncharged particles, for all the tested dusts. Results of tests with marshallite and aluminium powder are shown in tables 5 and 6.

Table 5 - Marshallite Powder

Experimental volunteers	General amount of Particles P_0	Number of uncharged particles P_1	Number of charged particles P_2	$\frac{P_2 \cdot 100}{P_0}$ in %
M Inhalation				
Exhalation				
Retention				
% Retention				
I Inhalation				
Exhalation				
Retention				
% Retention				

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Table 6 - Aluminum Powder Dust.

Tests in M		P_0	P_1	P_2	$\frac{P_2 \cdot 100}{P_0}$ in %
15,000 particles per cc	Inhalation Exhalation Retention % Retention				
1000 particles per cc	Inhalation Exhalation Retention % Retention				

Results obtained with marshallite powder were of ~~the~~ greatest interest (table 5). In the case of L. where the general retention was 52.9%, only 10.5% of the uncharged particles were retained while 74.6% of the charged particles were retained. ~~Actinut~~ Case I had a general retention of 41.4%, where 16% of the uncharged particles ~~were retained~~ and 70% of the charged particles were retained. The percent of charged particles in the retained dust was 80.

~~The~~ tests with aluminum dust were made only on case I and but different concentrations were used: 15,000 and 1000 particles per cubic centimeter. Where the general retention was 56.6 and 48 percent, the retention of uncharged particles was 33.9 and 22% while the retention of charged particles was 66 and 65.8%. The percent of charged particles in the retained dust was 84 and 82% respectively.

Similar data were also obtained for kaolin.

Analysis of data on the retention of charged particles on the basis of dispersion showed that the smallest particles (less than 1 micron and from 1 to 3 microns), particularly those particles which were smaller than 1 micron, comprise ~~and in~~ the greater part of ~~majority in~~ the retained dusts. Thus it can be stated that the charge of particles ~~has much to do with~~ is largely responsible for the degree of retention.

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