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ARMY MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

REPORT NO. 1

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SILICA CONTENT OF DUST FROM TANK RANGES[1]

[1]Sub-project under Studies of Physiological and Psychological Problems of Military Personnel in Relation to Equipment, Environment and Military Tasks (AMRL-57). Approved by CG, ASF, 31 May 1946.

MEDICAL RESEARCH AND DEVELOPMENT BOARD
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DEPARTMENT OF THE ARMY

REPORT NO. 1

SILICA CONTENT OF DUST FROM TANK RANGES[1]

by

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from

Armored Medical Research Laboratory
Fort Knox, Kentucky, January 14, 1947

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ABSTRACT

SILICA CONTENT OF DUST FROM TANK RANGES

OBJECT

Men engaged in tank operations are exposed to many potential hazards. Among these is the problem of dust. In a previous report the dust concentration to which armored personnel is exposed on maneuvers in the Fort Knox area was found to be quite high (187 to 700 million particles per cubic foot). The type of dust was not determined and, hence, the amount of free silica of a damaging character, especially those particles 10 to 3 microns or less in diameter, is not known.

Dust was collected from surface soil on dry tank ranges and from within tanks on maneuvers in the Fort Knox area. The surface soil was analyzed for free and total silica, the air-borne dust for particle size distribution and content of free silica.

RESULTS

The results to date are listed below:

1. Surface soil samples from two tank ranges have a high concentration of silica with an average of 74.3% total silica and 63.9% free silica.

2. The tank dust averages 21.5% by weight of particles below an equivalent diameter of three (3) microns, of which 10% is free silica.

3. These particles of free silica less than three (3) microns in diameter average 2.2% by weight of the total dust.

CONCLUSIONS

This content of silica of a damaging character in air-borne dust is regarded as high but the data do not permit conclusions as to whether inhalation of silica particles of such concentration and particle size distribution constitutes a medical menace to operating armored personnel.

RECOMMENDATIONS

None.

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SILICA CONTENT OF DUST FROM TANK RANGES

I. INTRODUCTION

A. Object and Background.

Men engaged in tank operations are exposed to many potential hazards. Among these is the problem of dust. In a previous report (1) from this laboratory it was established that, in the Fort Knox tank training areas which contain the highest concentration of dust, the count within and without tanks moving on a dry range at about ten miles per hour varied from 187 to 700 million particles per cubic foot.

This concentration is extremely high, but the type of dust was not determined. Accordingly, the investigation was extended to include analyses of surface soil from tank ranges and the air-borne dust in tanks on maneuvers for (1) particle size distribution, and (2) content of free and total silica.

II. EXPERIMENTAL

A. Materials, Collection.

1. Surface soil from dry tank ranges in recent use was collected at 150 to 200 yard intervals.

2. Air-borne soil was collected from the interior and, usually, in the front of tanks driven in the dust cloud of a preceding tank. Usually, an 8 to 9 gram sample was obtained. The dust laden air was drawn through a reduced pressure filter box* (filtering area about 300 square inches) consisting of two filter beds of salicylic acid crystals supported by two 120-mesh copper screens. The filter was activated by the exhaust blower of an M4A3 tank and mounted within a tank. Only particles less than about 150microns in diameter were trapped by this method.

B. Procedures, Methods.

The surface soil was analyzed for free and total silica, the air-borne dust for particle size distribution and the percentage of free silica in each particle size range and in the total sample.

1. The alpha quartz (free silica) content of surface soil was determined spectrographically by the Bureau of Mines Laboratory, Pittsburgh, Pennsylvania.

*Box design obtained from Committee of Industrial Hygiene, Mellon Institute, Pittsburgh, Pennsylvania

2. The alpha quartz of air-borne soil was determined as follows: First, the dust collected in the filter box was removed by dissolving the salicylic acid in anhydrous methanol and suction filtering the suspension through a No. 50 Whatman filter paper. The filtrate gave no evidence of sedimentation over a period of 72 hours, but did appear a reddish-brown in color. The filter cake and paper were oven-dried at 110° C. for 4 hours and the cake then removed from the paper and dried further for 20 hours. The filter cake was analyzed for free silica by the Bureau of Mines Laboratory, Pittsburgh, Pennsylvania.

3. The total silica content of surface soil was determined chemically by a standard method (2) with some modifications. The collected samples were air-dried in the laboratory for 24 hours. The sample was then ground in a mullite mortar and 1.5 to 2.0 grams were used for the analysis. The sample was placed in a 20 ml. platinum crucible and 10 grams of anhydrous sodium carbonate (Na_2CO_3) was mixed with the sample. The mixture was fused over a Meker burner. After CO_2 elimination had ceased, the crucible was cooled to room temperature and placed in a 600 ml. beaker. 120 ml. of 1-1 hydrochloric acid was used to dissolve the melt. The solution was evaporated to dryness over a hot plate. To the residue was added freshly mixed acetic anhydrate (65 ml.), water (55 ml.). The suspension was heated on the hot plate until it foamed strongly; it was removed and cooled slightly; then 1-1 HCl was added until the solution was canary yellow in color (5-15 ml.). The solution was warmed and 120 ml. of distilled water added. The suspension was filtered on fine ashless paper and washed with cold water. After impurities were removed the paper and precipitate were ignited and heated to constant weight. To the silicon dioxide residue was added 4 ml. water, 5-6 drops of concentrated sulfuric acid, and then slowly 6 ml. of 48% hydrofluoric acid. The solution was evaporated to dryness on a hot plate and the crucible heated to constant weight. The loss in weight was silicon dioxide.

4. Particle size distribution in air-borne dust samples on a weight basis was determined by the pipette sedimentation separation method (3). The oven-dried sample of air-borne dust (1 1/2 to 2% of the fluid by weight) was dispersed in a solution containing 40 cc. sodium metasilicate stock solution (10 gm. per liter of water) and approximately 400 cc. distilled water. The dispersion was carried out in a Waring mixer for a period of 20 minutes. The dispersion was then cooled under tap water to room temperature and distilled water added to make a volume of 500 cc. This suspension was then added to a pipette apparatus which consisted of a chamber (1000 ml. hex base graduate cut off 28 cm. from the base), three stationary calibrated pipette tubes 0.15 cm. I.D.,

whose depths from the starting level of the liquid are 4 cm., 10 cm., and 19 cm., and joined by a suitable stopcock to a calibrated pipette of 10 ml. volume. The apparatus was inverted several times and then clamped in a water bath. At suitable time intervals samples were removed by means of the pipettes and discharged into weighed porcelain crucibles. These samples were evaporated on a hot plate to dryness and then heated in an oven at 140° C. for 2 hours before re-weighing.

a. The maximum size of the particles remaining in suspension at the time each sample was withdrawn was calculated from the following equation derived from Stokes' Law:

$$d = \sqrt{\frac{307\,(u)\,(h)}{(ps - p)\,(t)}} \quad \text{where}$$

d	= diameter particle--micron	
u	= fluid viscosity--cps	(0.8983)
h	= height of fall-cm	(19.09)
ps	= density of solid--gm/cc	(2.651)
p	= density of fluid--gm/cc	(0.9952)
t	= time of fall--minutes	(1.5)

For example, when the test is conducted with the values indicated above,

$$d = \frac{(307)\,(0.8983)\,(19.09)}{(2.651 - 0.9952)\,(1.5)} = 46 \text{ microns}$$

b. The concentration of the particles remaining in suspension at the time each sample was withdrawn was computed:

$$Gc = \frac{(100)\,(Vc)\,(w)}{(Vp)\,(W)} \quad \text{where}$$

Gc	= percentage of particles under d-microns remaining in suspension	
Vc	= starting volume of suspension--cc	(587.5)
Vp	= volume of sample withdrawn--cc	(11.56)
w	= weight of solids in Vp (corrected for dispersing agent)--gm	(0.1415)
W	= dry weight of sample in Vc--gm	(7.1095)

Again, when computation is made using the data inserted above,

$$Gc = \frac{(100)\,(587.5)\,(0.1415)}{(11.56)\,(7.1095)} = 97.8\%$$

A plot of cumulative percentage under size d-micron versus diameter allows interpolation of the amount below any particle size.

5. The per cent of free silica of the various samples withdrawn for determination of particle size and weight distribution was determined at the Bureau of Mines, Pittsburgh, Pa. (and corrected locally for the dispersing agent).

C. Results.

Table I shows the concentrations of total and free silica in the surface soil of two tank ranges. The soil averaged 74.3% total silicon dioxide and 63.9% free silica, or the free silica averages approximately 86% of the total silica.

TABLE I

Amount of Total and Free Silica in Surface Soil of Fort Knox, Kentucky

Sample Number	Date Obtained	Total Silica--Per Cent Air Dry Basis	Total Silica--Per Cent Mineral Basis	Free SiO_2--Per Cent
4	May 1946	69.5	--	58
5	"	70.0	--	56
6	"	71.6	--	53
7	"	68.0	--	62
8	"	71.2	--	61
9	"	73.8	--	63
10	"	73.4	--	66
11	"	71.8	--	58
12	June 1946	74.5	80.0	67
13	"	77.0	82.1	69
14	"	78.8	84.0	72
15	"	77.0	82.0	70
16	"	78.4	82.7	65
17	"	78.0	82.7	66

In Fig. 1 are plotted the data for air-borne soil particle size and distribution according to weight as calculated under methods. The distribution for the two tank ranges is almost identical and the graph indicates that the dust contains approximately 22% by weight of particles below an equivalent diameter of three (3) microns, and 33% by weight of particles less than 10 microns.

FIG I

AIRBORNE SOIL PARTICLE SIZE ANALYSIS

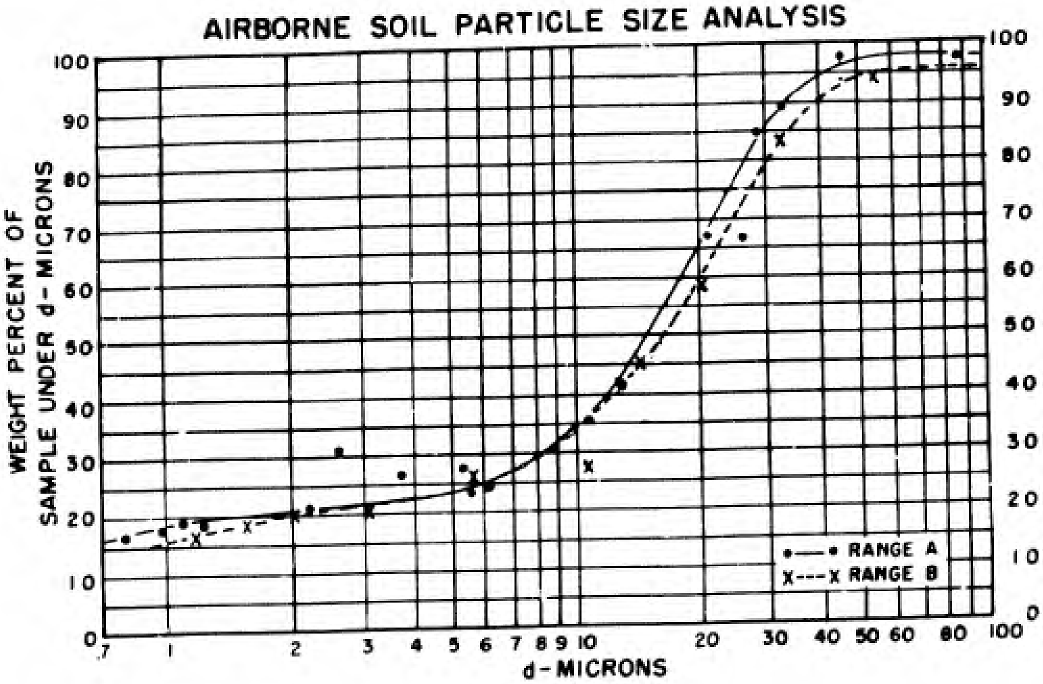


Fig. 2 represents the percentage of alpha quartz in each particle size range of air-borne dust. This graph was constructed by plotting the percentage of free silica of the various samples in Methods 5 against the equivalent diameter of each size fraction as obtained in Methods 4a. It is apparent that particle sizes three microns or less in diameter contain 10% of alpha quartz by weight, despite the fact that as particle size decreases the percentage of alpha quartz also decreases.

FIG. 2

ALPHA QUARTZ CONTENT OF AIRBORNE SOIL

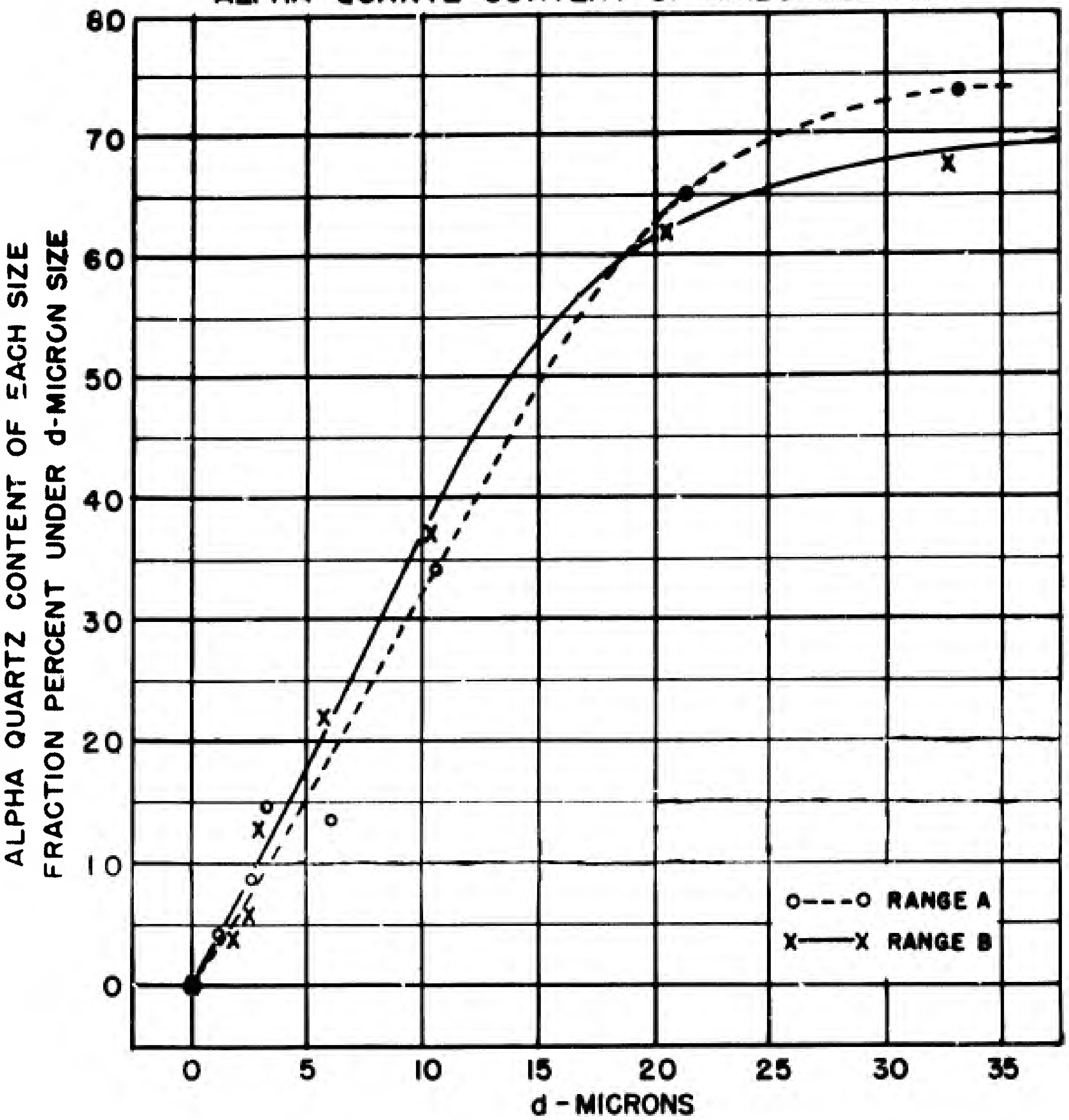
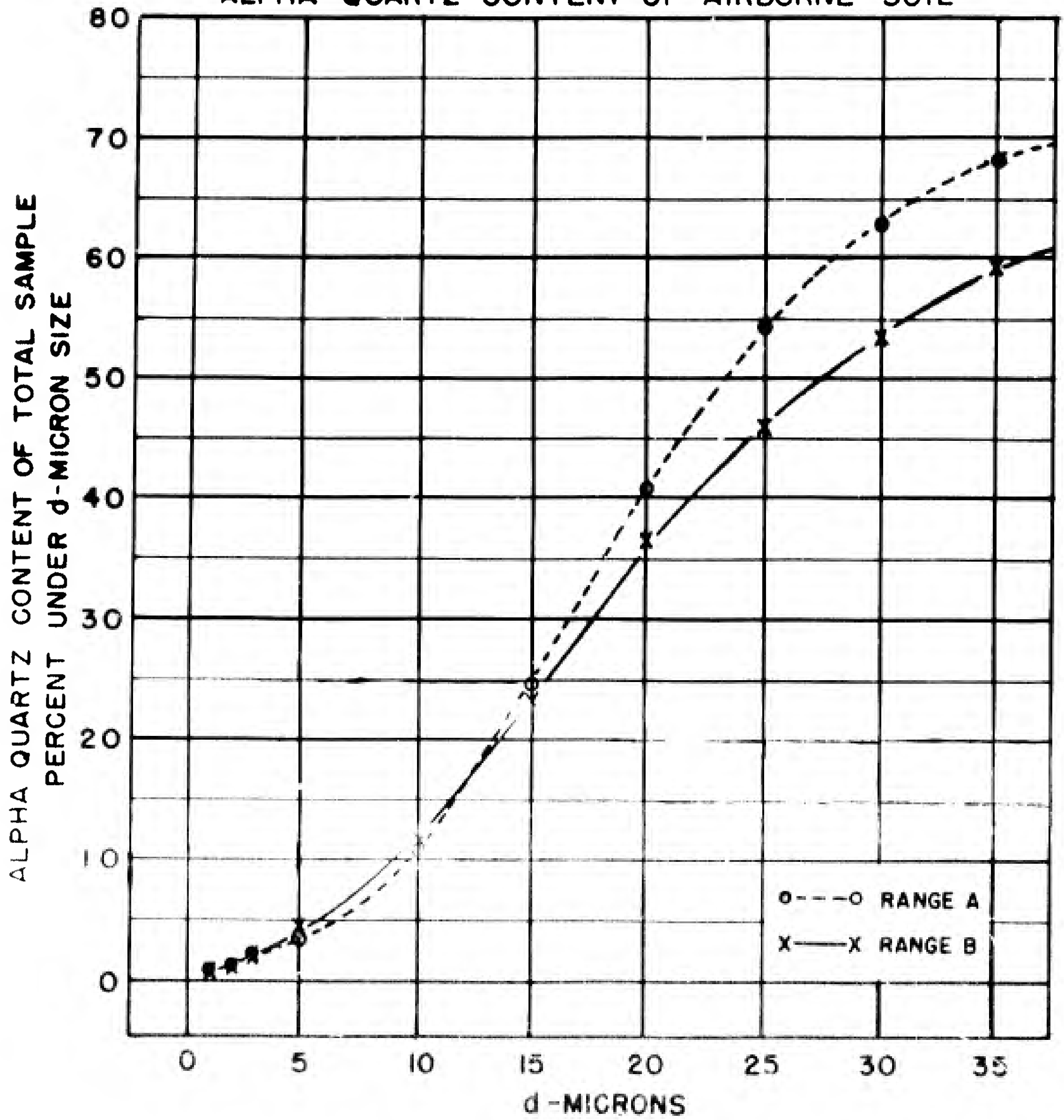


FIG. 3

ALPHA QUARTZ CONTENT OF AIRBORNE SOIL



III. DISCUSSION

The results indicate that at Fort Knox the dust concentration in tanks is extremely high and that the surface soil and air-borne dust have a high concentration of free silica, particularly of the clinically dangerous dust composed of small particles with equivalent diameters below ten (10) to three (3) microns.

The variation of quartz content with particle size is of particular interest. Although the quartz particles less than three (3) microns diameter constitute only 2.2% of the total particles by weight, this small percentage represents a tremendous number of particles in a small mass of material. For example, if we assume perfect spherical shape for particles, 1,000,000 quartz particles of three (3) micron diameter would weigh only 0.000013 gm., and the same number of ten (10) micron particles would weigh 0.0014 gm., so that for the same gross weight the three (3) micron particles would be 100,000,000 in number. Thus, the data in Fig. 3 indicate that there are about 25 times as many particles three (3) microns or less in diameter as compared to those ten (10) microns or less in size.

These observations raise the question whether such dust is a medical hazard. According to Lanza (3), where a highly silicious dust is involved (approximately 80% free silica), a total concentration of 5,000,000 particles per cubic foot of air is dangerous. Although the percentage of free silica found in the air within tanks is somewhat lower (64%), the total particle concentration of 187-700 million particles per cubic foot, with a relatively large complement less than three (3) microns in diameter, suggests the possibility of ultimate silicotic pathology. However, it is not to be inferred that such exposure among armored personnel will lead to silicosis unless there is demonstrated an associated adequate duration and constancy of exposure.

In this connection, mention may also be made of the fact that at Fort Knox the morbidity rate for respiratory infections is apparently much greater than at Camp Atterbury (5). For example, for the weeks ending August 24 and September 17, 1945, comparisons of the case rates per 1000 men at the two installations were 129 versus 44, and 119 versus 25. Both installations have essentially the same geological, climatic conditions and had, at the time, approximately the same mean strength of men, but differ in that Fort Knox is a tank training center while Atterbury is an infantry center. If it can be established that the much greater incidence of respiratory infections at Fort Knox is largely restricted to tank personnel participating in maneuvers, then the dust exposure considered here must be regarded as a possible contributing factor to the greater morbidity rate. However, until such time as additional data are available, this must be considered as mere speculation.

IV. CONCLUSIONS

In the Fort Knox tank training areas analyses have been made of surface soil and air-borne dust in tanks on maneuvers. The results are: (1) Surface soil samples from two distant tank ranges have a high concentration of silica with an average of 74.3% total silica and 63.9% free silica. (2) The air-borne dust within tanks from the same two tank ranges contains an average of 21.5% by weight of particles below an equivalent diameter of three (3) microns. (3) Of the particles of air-borne dust less than three (3) microns in diameter, 10% is free silica. (4) These particles of free silica less than three (3) microns in diameter constitute 2.2% by weight of the total dust.

The question is raised whether such a concentration of highly siliceous dust, especially in the dangerous sizes less than ten (10) microns or three (3) microns in diameter, constitutes a medical hazard to operating armored personnel.

V. RECOMMENDATIONS

None.

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