FILE NAME: Owens Corning (OC)

DATE: 1935

DOC#: OC294

DOCUMENT DESCRIPTION: Journal Article - Ruck Wool in Relation to Health

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Reprinted from The Journal of Industrial Hygiene
Vol 17, No 6, November, 1935

ROCK WOOL IN RELATION TO HEALTH*

Lawrence T. Fairhall, Ph.D., Stewart H. Webster, Ph.D., and Granville A. Bennett, M.D.

From the Laboratory of Physiology, Harvard School of Public Health, and the Department of Pathology, Harvard Medical School, Boston, Mass.

THE utilization of furnace slags in the form of wool for insulation purposes has become so extensive that the former metallurgical by-product is now manufactured direct and marketed under various names such as "rock wool," "mineral wool," etc. In insulating houses this material is blown into all spaces in the outer walls and a covering laid down in the attic so that the house is completely insulated. Since individuals living within the houses are surrounded by such material it has been questioned whether the use of rock wool could be a problem of hygienic importance. Inasmuch as this material enters into construction in such a manner that the occupants are separated from it by plastered walls which act as very efficient filters, the only conceivable way in which it could cause injury (assuming harmful ingredients) would be by means of vapor, either direct or as a result of slow decomposition. The following experiments were devised to test this effect.

In this investigation all the raw materials entering into the manufacture were examined as well as the finished product.† Although the latter is a relatively low silica glass, stable, insoluble and chemically inert, a searching investigation was made of its chemical composition and of the possibility of any vaporization of injurious substances. The presence or absence of any poisonous element would to a large extent establish the material as either dangerous or innocuous—not completely, it is true, for, assuming a very toxic combination of certain elements, this combination might escape detection in the search for the individual elements. The practical test therefore was to determine the effect of the material upon animal life. To this end the following experimental procedure was adopted.

Experimental Procedure

Cats were selected as experimental animals since they are sufficiently sensitive to poisons, can be housed conveniently, and have tissues sufficiently large for extended chemical investiga-

* Received for publication October 15, 1935.

† Our thanks are due the Johns-Manville Company for the materials provided for this investigation. In addition to the raw materials entering into the manufacture of the rock wool, the finished products of three plants geographically distributed as follows were investigated: Manville, N. J., Alexandria, Ind., and Waukegan, Ill.

tion. Three types of procedure were followed with these animals: One group (1) was exposed to any fume or vapor that could be evolved by passing air over the rock wool at room temperature. Another group (2) was exposed to air passed through the rock wool so heated that the air current acquired a temperature varying between 67°C. and 82°C. The third group (3) in addition to the same exposure given to (1) were further exposed for 1 hour daily to a dusty atmosphere of very finely ground rock wool. All these groups received the exposure indicated for 2 months continuously. At the end of this time the cats were chloroformed and their tissues removed for pathological investigation and chemical and spectrographic analysis.

Preliminary analysis of the raw materials and of the rock wool from the various sources showed the following elements to be present and readily detectable chemically: silicon, calcium, magnesium, sodium, iron, aluminum, sulfur, titanium, manganese and zinc.

When large enough samples were used (10 gm. or more) an extremely minute amount of lead could be detected (of that order of magnitude one would expect to find in a natural rock) and traces of arsenic—often considered questionable—could barely be detected by the most refined chemical means.

TABLE I

CHEMICAL COMPOSITION OF VARIOUS ROCK WOOLS

	A	B_1	B_2	C
SiO_2	43.11	45.20	42.11	42.69
CaO	28.37	21.96	23.93	21.26
MgO	10.33	11.18	13.67	13.88
R_2O_3	9.98	11.83	11.11	14.56
Na_2O	7.26	9.19	9.52	7.65
MnO	0.28	0.37	0.19	0.30
S	0.13	0.023	0.028	0.16
Cl	0.039	0.016	0.054	0.025
H_2O	0.11	0.155	0.17	0.125
Total	99.969	99.921	100.812	100.650

R_2O_3 includes Fe_2O_3, Al_2O_3 and TiO_2.
B_2 manufactured oil-free.

Oil content

A	B_1	B_2	C
per cent	*per cent*		*per cent*
1.18	1.08	Oil-free	0.06

In order to minimize dust production in the process of manufacture the material is treated with mineral oil, a small amount of which remains in the finished product. The chemical composition of the various types of rock wool was determined and also the oil content. These values are given in Table I.

If the rock wool is capable of giving off vapor or fume at room temperature it would be expected that this would be more abundantly evident by direct distillation. Accordingly an all-glass apparatus was constructed consisting of a large distillation bulb joined to small glass receivers capable of being closed by means of stop cocks. A manometer was connected in series in order to read the degree of vacuum attained. Except where glass-sealed, all connections were made by means of ground glass joints. A Hyvac pump could reduce the pressure to at least 1 mm. of mercury. The material tested was the commercial oiled product powdered to facilitate loading into the apparatus. The distillation bulb containing 10–12 gm. of rock wool was heated by a bath of boiling water. The receiver was cooled to a low temperature by means of a mixture of alcohol and carbon dioxide snow. After one-half hour of distillation a very small amount of distillate (0.02–0.05 cc.) was collected and found to be simply water. No oil distilled over. Since under these extreme conditions no vapor other than a trace of water could be evolved, there is no probability that anything is likely to be evolved under ordinary conditions of commercial or domestic use.

1. THE COLD VAPOR EXPERIMENTS

In order to determine further whether any vapor inimical to animal life could be evolved from rock wool at room temperature, animals were made to depend solely upon air that had been in contact with rock wool. To this end an apparatus was constructed which is shown in section in Fig. 1. The metal cylinder was 4 ft. high and 1 ft. in diameter with spun ends and locked seams. The orifices at top and bottom measured 1½ inches in diameter. A screen separated the rock wool from the bottom so as to insure an even distribution of the air blown through the lower opening. The cylinder held 20–25 pounds of rock wool depending upon the degree to which it was packed. Air was blown through at a velocity of 3.3 to 4.5 cu. ft. per minute. The animals simply lived in this atmosphere and were watched

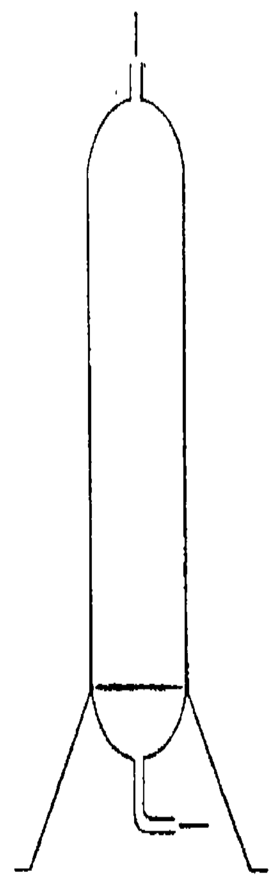

FIG. 1.—Cold vapor cylinder

for weight changes or other effects of their environment. At intervals of 3 weeks the rock wool was changed so that the animals were exposed to all three types. The eight cats receiving this exposure were chloroformed at the end of the 2 months and their tissues removed for chemical and pathological examination.

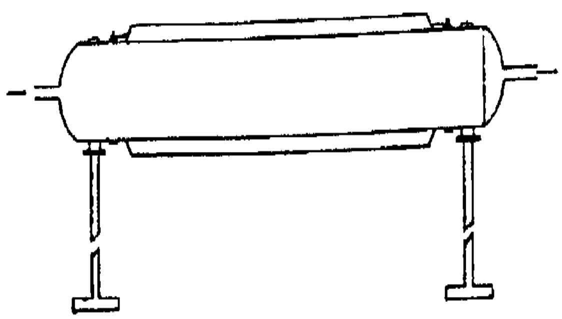

Fig. 2.—Hot vapor cylinder

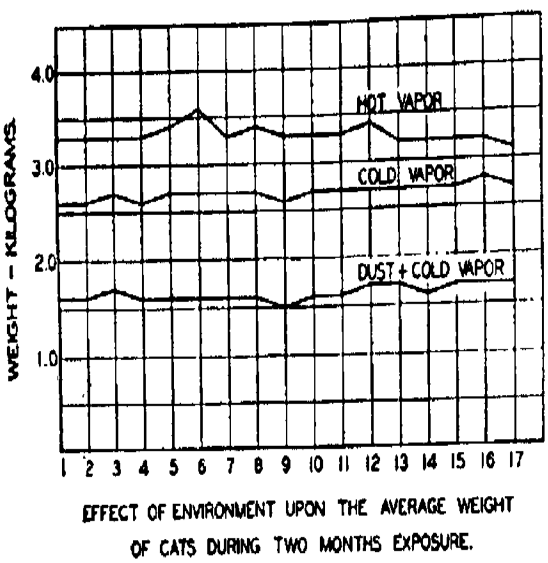

Fig. 3.—Weight changes during the experimental period

II. The Hot Vapor Experiments

The apparatus used for heating the rock wool was a metal cylinder 7½ inches in diameter and 4½ ft. in length; the air tubes at either end were 1 inch in diameter. It held 10–12 pounds of rock wool when filled. It was externally heated electrically by means of a winding of nichrome resistance wire (Fig. 2). Air was blown through at the rate of 9 cu. ft. per minute. The air leaving the apparatus at a temperature of 67–82°C. was obviously too hot to breathe and was therefore passed through a coil of 1-inch copper tubing immersed in running water and was thereby brought down to a temperature slightly below outside room temperature. The animals were confined to this atmosphere for 2 months, successive lots of rock wool (A), (B) and (C) being used. The space in

which the animals were kept was small and wholly dark, except at such times as when cleaning, feeding and weighing were carried on. Furthermore in spite of a liberal run of cooling water the room became unpleasantly warm and humid during especially warm days. These animals were therefore subjected to rather severe conditions. The slight weight loss indicated in the chart (Fig. 3) is therefore not surprising. Beyond this however no other effect was noted. The animals remained healthy and normal throughout the experiment. At the conclusion of the experiment they were chloroformed and their tissues examined as in the previous case for any significant changes.

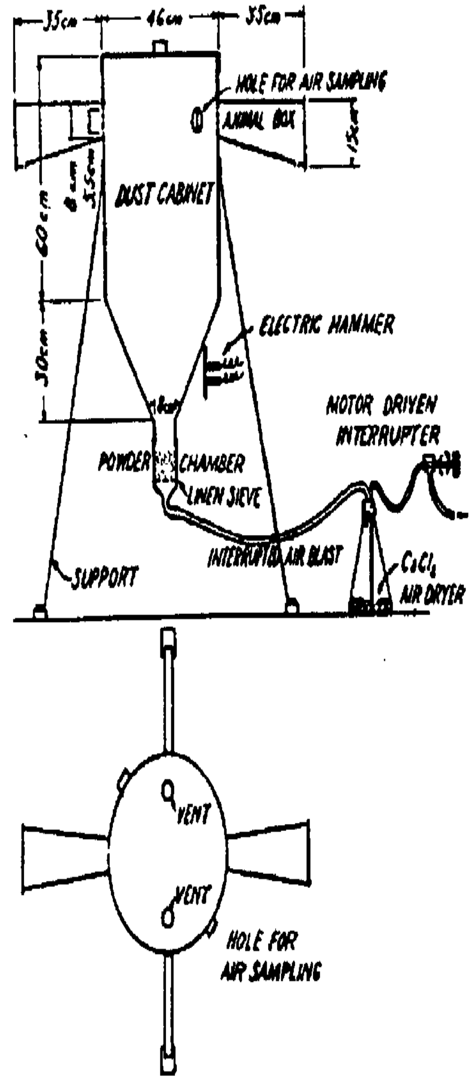

Fig. 4.—Dusting apparatus

III. The Dusting Experiments

The eight animals exposed to the rock wool dust for 1 hour each day (5–6 days per week) were incidently exposed during the remainder of the time to the conditions of group I. The cats were exposed in groups of four at a time in the apparatus shown in Fig. 4. Compressed air freed from the slight moisture usually present by passing over calcium chloride was forced through the rock wool which had been repeatedly extracted with carbon tetrachloride and then finely ground in a ball mill. It was found to be rather difficult to produce dust with the com-

course The average particle size of the floating dust after allowing the coarser material to settle for a few minutes was 2.2μ. Impinger samples of a fixed volume (5 cu. ft. of air) were taken during the actual dusting The distilled water suspensions thus obtained were evaporated to dryness in platinum dishes and weighed. The dust content in terms of milligrams per cubic meter is shown in the chart (Fig. 5). No attempt was made to

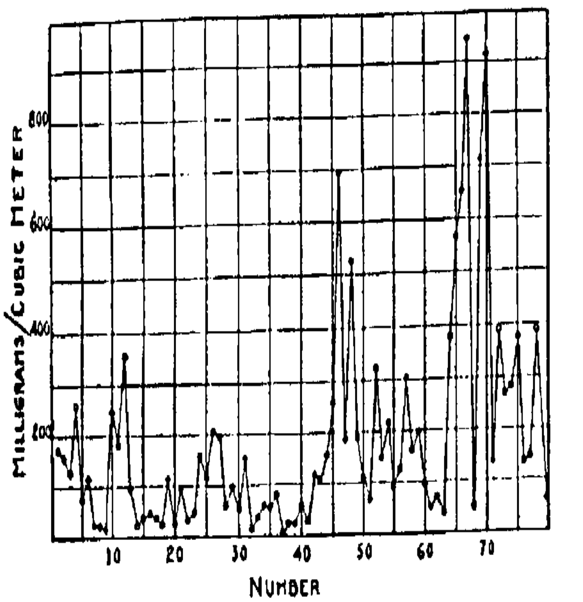

Fig 5.—Dust concentrations during the experimental period

mercial type of oiled rock wool no matter how finely ground. Furthermore what dust was carried into the air remained in suspension a very short time only, and quickly settled out. The oil very effectively prevents dust formation. When repeatedly extracted with carbon tetrachloride and thoroughly dried, however, a very satisfactory dust was produced which remained in suspension reasonably well. Although finely ground, the particle size varied considerably of

keep the dust at a constant level; on the contrary every effort was made to make the conditions extreme by running the dust content to high levels. The animals were exposed to the various types of rock wool in turn at intervals of 3 weeks. The sole purpose of the dusting experiment was to determine whether the rock wool contained any poisonous substance that had escaped detection by other means. Since, as noted later, the only evidence obtained was of a negative character,

and because of the difficulty we experienced in raising dust from it, one may fairly assume that dustiness in the commercial utilization of rock wool is distinctly a factor of no hygienic importance. Throughout the experiment the animals remained in excellent condition. At the conclusion of the experiment their tissues were removed as in the other cases for further examination.

Discussion

Chemical investigation failed to disclose any single factor of toxic importance. From the raw materials including slag, limestone, sandstone and oil to the finished products including both un-oiled and oil-treated rock wool, nothing but spectrographic traces of any elements of toxic significance could be found and these traces obviously are fixed in the form of silicates and are therefore most inert. The small amount of oil left in the rock wool is also inert, except that it has the valuable property of increasing the filtering action of the rock wool with respect to dust Not only is it difficult to make a cloud of dust by blowing air through the ground up commercial rock wool, but the rock wool of itself constitutes a filtering medium.

In order to test this, runs were made both with the normal rock wool and with rock wool that had been heated for a month and largely dried out.* The velocity of the air flow through the latter was three times that through the rock wool at room temperature. The heated cylinder (No 1) was operated 18 hours before testing, the room temperature cylinder (No. 2) was operated for 1 hour before testing. The air flow through cylinder No. 1 was 9.9 cu. ft. per minute; that through cylinder No. 2 was 3 cu. ft. per minute. The temperatures were as follows:

	°C.
Compressed air	35
Corridor air	32.5
Air leaving Cyl. 1	71
Air leaving Cyl 2	27.5
Experimental Room	33

Two samples of the compressed air, one of the corridor air and one each of the air leaving the cylinders, were collected. The dust concentration measurements were made by the dark field method. The results of the counts and the calculation of the concentrations are as follows:

Sample	Description	Dust concentration (dark field) particles per cubic foot
1	Cylinder No 1	58,300,000
2	Compressed air	41,600,000
3	Cylinder No. 2	18,300,000
4	Compressed air	45,000,000
5	Corridor air	28,000,000

That there is a slight increase in dustiness of air going through the heated cylinder is probably owing not only to the high velocity of the air, but also to the fact that the filtering action was probably reduced by the oil having been largely dried out by the continuous heating during the preceding month.

There is a definite filtering action apparent in passing the air through the cylinder at room temperature at the lower velocity of 3.3 cu. ft. per minute. That is, there is a drop in number of dust particles from the mean value of 43,300,000 particles per cu. ft. in the compressed air to 18,300,000 particles per cu. ft. on leaving the cylinder.

With respect to the effect of the rock

* We are indebted to Mr Richard Page for the dust concentration measurements.

TABLE II

CAT NUMBER	CAT WEIGHT	WEIGHT OF TISSUES: Lung	Liver	Kidney	ANALYSES OF TISSUES: Weight used	Arsenic	Mercury	Lead
					Cold vapor cats			
	kgm	grams	grams	grams	grams			
23	2.9	23.15	100.80	42.00	Lung 22.1[illegible]	Nil	Nil	Nil
					Liver 98.10	Questionable	Nil	Nil
					Kidney 41.15	Nil	Nil	Nil
11	1.9	11.55	71.10	17.65	Lung 10.60	Nil	Nil	Nil
					Liver 69.1[illegible]	Questionable	Nil	Nil
					Kidney 17.00	Nil	Nil	Nil
2	2.9	21.00	91.00	27.20	Lung 20.00	Nil	Nil	Nil
					Liver 89.10	Questionable	Nil	Nil
					Kidney 26.10	Nil	Nil	Nil
6	3.1	19.10	109.95	32.30	Lung 18.10	Nil	Nil	Nil
					Liver 106.90	Questionable	Nil	Nil
					Kidney 31.25	Nil	Nil	Nil
9	2.2	16.25	73.85	20.70	Lung 15.65	Nil	Nil	Nil
					Liver 72.00	Questionable	Nil	Nil
					Kidney 19.60	Nil	Nil	Nil
15	3.0	25.15	93.05	21.10	Lung 23.20	Nil	Nil	Nil
					Liver 90.00	Questionable	Nil	Nil
					Kidney 23.00	Nil	Nil	Nil
16	2.1	24.55	86.65	21.75	Lung 22.15	Nil	Nil	Nil
					Liver 83.60	Questionable	Nil	Nil
					Kidney 23.10	Nil	Nil	Nil
14	3.2	21.75	101.55	37.00	Lung 21.10	Nil	Nil	Nil
					Liver 98.70	Questionable	Nil	Nil
					Kidney 35.60	Nil	Nil	Nil
					Hot vapor cats			
19	3.5	26.25	89.30	15.20	Lung 21.25	Nil	Nil	Nil
					Liver 86.10	Nil	Nil	Nil
					Kidney 42.95	Nil	Nil	Nil
20	2.5	26.85	84.85	29.10	Lung 23.85	Nil	Nil	Nil
					Liver 83.15	Nil	Nil	Nil
					Kidney 27.00	Nil	Nil	Nil
21	3.0	35.10	81.70	23.10	Lung 33.05	Nil	Nil	Nil
					Liver 81.10	Nil	Nil	Nil
					Kidney 22.00	Nil	Nil	Nil

TABLE II—*Continued*

CAT NUMBER	CAT WEIGHT	WEIGHT OF TISSUES: Lung	Liver	Kidney	ANALYSES OF TISSUES: Weight used	Arsenic	Mercury	Lead
					Hot vapor cats—*Concluded*			
	kgm	grams	grams	grams	grams			
10	4.5	30.05	134.20	54.15	Lung 28.15	Nil	Nil	Nil
					Liver 130.90	Nil	Nil	Nil
					Kidney 52.05	Nil	Nil	Nil
5	2.9	21.30	88.40	29.75	Lung 22.70	Nil	Nil	Nil
					Liver 85.55	Nil	Nil	Nil
					Kidney 28.00	Nil	Nil	Nil
22	2.0	21.70	88.95	22.25	Lung 20.20	Nil	Nil	Nil
					Liver 85.80	Nil	Nil	Nil
					Kidney 21.00	Nil	Nil	Nil
17	2.2	25.00	70.55	22.60	Lung 23.50	Nil	Nil	Nil
					Liver 68.60	Nil	Nil	Nil
					Kidney 21.25	Nil	Nil	Nil
18	3.4	27.50	103.70	31.80	Lung 25.75	Nil	Nil	Nil
					Liver 101.60	Nil	Nil	Nil
					Kidney 30.55	Nil	Nil	Nil
					Dusting experiment			
24	2.0	18.35	67.35	22.45	Lung 16.25	Nil	Nil	Nil
					Liver 64.30	Nil	Nil	Nil
					Kidney 20.40	Nil	Nil	Nil
12	1.7	22.05	64.70	15.65	Lung 20.25	Nil	Nil	Nil
					Liver 61.60	Nil	Nil	Nil
					Kidney 14.45	Nil	Nil	Nil
4	2.0	17.55	80.30	23.25	Lung 15.65	Nil	Nil	Nil
					Liver 76.70	Nil	Nil	Nil
					Kidney 21.20	Nil	Nil	Nil
8	1.1	22.30	60.45	16.70	Lung 20.00	Nil	Nil	Nil
					Liver 57.35	Nil	Nil	Nil
					Kidney 15.15	Nil	Nil	Nil
13	1.1	12.50	46.05	13.25	Lung 11.50	Nil	Nil	Nil
					Liver 44.40	Nil	Nil	Nil
					Kidney 11.65	Nil	Nil	Nil
1	1.5	13.35	68.35	23.05	Lung 11.90	Nil	Nil	Nil
					Liver 64.95	Nil	Nil	Nil
					Kidney 21.10	Nil	Nil	Nil

TABLE II—Concluded

Cat number	Weight	Weight of tissues: Lung	Liver	Kidney	Analyses of tissues: Weight used		Arsenic	Mercury	Lead
Dusting experiment—Concluded									
	kg	grams	grams	grams	grams				
7	1.5	19.35	67.25	11.30	Lung	17.20	Nil	Nil	Nil
					Liver	63.75	Nil	Nil	Nil
					Kidney	13.05	Nil	Nil	Nil
3	2.7	20.95	83.05	27.10	Lung	19.05	Nil	Nil	Nil
					Liver	79.85	Nil	Nil	Nil
					Kidney	25.20	Nil	Nil	Nil

wool on animal life nothing whatever was evident that could be construed as injurious. The animals either retained their weight, or showed an increase in weight with the exception of those subjected to air passed through heated rock wool and, as has been noted above, the slight average decrease in weight particularly during the last 3 weeks is probably largely owing to the trying living conditions of temperature and humidity to which they were subjected. At the time they were chloroformed the animals looked healthy and macroscopic inspection of their tissues on removal showed nothing unusual.

After chloroforming the cats, their tissues were weighed at once before and after removal of pieces for microscopic examination and the remainder analyzed chemically for arsenic, mercury and lead. For this purpose the tissues were wet ashed by means of nitric acid in order to prevent any possible loss by volatilization of arsenic and mercury. The data thus secured are given in Table 2. It will be noted that the results are wholly negative. No foreign metals of chemical significance were present in the tissues. The very slight traces of arsenic found were balanced by the trace of arsenic in the nitric acid used in ashing.

Microscopic Examination of Tissues

Microscopic sections were prepared from the lungs, kidneys and liver of each cat used in these experiments and from four normal control cats. In the experimental animals the tissues were all fixed in Zenker's fluid, embedded in paraffin and the sections were stained with eosin and methylene blue. Tissues from the control cats were fixed in Zenker's fluid and also in 10 per cent formaldehyde and paraffin sections were stained with eosin-methylene blue and hematoxylin and eosin.

Cold Vapor Experiment

Microscopic examination of the lungs, liver and kidneys showed no constant changes from the normal. The lungs from 5 of the 8 cats used in this experiment showed varying degrees of congestion. In the three animals (Nos. 23, 16 and 11) in which congestion was most marked there were also slight to moderate amounts of hemorrhage in the pulmonary alveoli. The bronchi and bronchioles of all animals contained small amounts of a blue-staining coagulum that had the histological appearance of mucus. In three cats the larger bronchi contained considerably larger amounts of this material than was observed in sections from the control animals. Slightly excessive amounts of desquamated epithelium and cellular débris were also present in both large and small bronchi in a few specimens. Occasional groups of mononuclear phagocytes were observed in the smaller bronchi and bronchioles of all animals. Although many of these cells contained very fine dark brown or black dust particles, it was only in two animals that rare refractile particles of silicate could be detected. Slight emphysema was observed in most animals and in three of the eight cats there were small amounts of peribronchial inflammatory cell infiltration. These abnormalities were also observed in the control animals.

Sections of the kidneys and livers showed no abnormalities that were not observed in the control cats.

Hot Vapor Experiment

Sections of the lungs of these animals were practically identical in histological appearance to those in Group I. Excessive mucus, desquamated epithelium and cellular débris were observed in the large and small bronchi of two cats. The lungs of two animals showed recent hemorrhage into pulmonary alveoli. In sections from one of these animals and in sections from two other cats, there was also fresh blood within large and small bronchi, indicating that a terminal aspiration of blood was the probable method of spread to the alveolar spaces. The lungs from two cats showed slight traces of connective tissue increase in scattered areas. The most extensive of these lesions was located in the periphery of the lung beneath a moderately thickened pleura. The entire area was infiltrated with moderate numbers of lymphocytes, mononuclear leucocytes and occasional polymorphonuclear leucocytes. In the remaining areas there were no signs of active inflammation. No particles of silicate were detected in any of these areas, or in the surrounding lung tissue and there was no evidence of associated foreign body reaction. These areas were interpreted as healed, or healing inflammatory lesions probably initiated by pulmonary infection. Occasional bronchioles contained small groups of mononuclear phagocytes which contained small amounts of dark brown or black pigment. Silicate particles, however, were observed in only one animal. In this instance a rare particle was found after prolonged search.

Sections from the kidneys showed no significant abnormality.

Sections from the livers revealed no lesions except in Cat 5. In this animal there was a moderate amount of chronic periportal inflammation throughout the organ. The liver cells, however, were well preserved and there was no evidence of bile stasis.

Dusting Experiment

The most significant difference in the lungs of this group of cats, as compared with those already described, was the presence of large numbers of refractile particles of silicate in the small bronchi, bronchioles and alveolar ducts of all animals.

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Smaller amounts of this particulate matter were observed in the alveolar spaces and interstitial tissues. Regardless of its location, much of this foreign material was contained in phagocytic cells. Many of the small bronchial passages were filled with clumps of macrophages, each containing large numbers of varying sized particles of silicate in addition to the fine, dark pigment observed in cats from the other experimental groups.

With the exception of the presence of numerous particles of silicate, the lungs of five of the eight cats showed no abnormalities not present in the previous groups of animals. In the three remaining cats there were varying numbers of small circumscribed lesions that consisted for the most part of dense accumulations of large, oval and elongated mononuclear cells, lymphocytes, eosinophiles and scattered polymorphonuclear leucocytes. The alveolar walls at the periphery of some of these lesions were moderately thickened and infiltrated with mononuclear and polynuclear inflammatory cells. Silicate particles could be found readily in the majority of these lesions. Four of the cats showed a recent and probably terminal extravasation of blood into the bronchi and pulmonary alveoli. Excessive mucous secretion and an increased desquamation of bronchial epithelium were observed in two cats. These abnormalities, however, did not differ from those observed in the other experimental groups.

Histological examination of the kidneys and livers showed no noteworthy abnormality.

Summary of Microscopical Examination

No pathological change that could be attributed to the experimental environment was observed in the liver and kidneys of any animal. The renal epithelium of the proximal convoluted tubules of 11 cats (five from Group I, four from Group II and two from Group III) showed slight to moderate degrees of vacuolization. Because 2 of the 4 control cats showed equal or greater amounts of vacuolization and because there were no accompanying signs of retrograde changes in the tubules and no glomerular lesions, this finding was not considered important.

Examination of the lungs from cats in Groups I and II revealed no constant changes that were considered significant. The slight to moderate excess secretion of mucus in the bronchi and bronchioles and the increased epithelial desquamation which were observed in a few cats were not accompanied by any evidence of inflammation of the bronchial walls or peribronchial tissue.

Hemorrhage into the lungs was observed in a few cats from all experimental groups and in one of the four normal control cats. The microscopic appearances clearly indicated that this extravasation of blood had occurred as a terminal event—probably during chloroformization.

Examination of the lungs of cats which had been subjected to the excessive dusting (described earlier in the paper) revealed that large amounts of silicate particles had been inhaled and retained in the smaller air passages and lung tissues. In 3 of the 8 cats from this group there were varying numbers of small cellular lesions in which silicate particles could be detected. Except for the presence of silicate particles, the remaining 5 cats revealed no abnormalities that were not present in animals from the other experimental groups. The absence of wide-spread inflammatory changes in the lungs of all of these animals where silicate particles were in intimate contact with the tissues suggests that no highly irritating substance was present.

Spectrographic Examination

In addition to the chemical analyses, an aliquot portion of the ash of each tissue was examined spectrographically by means of a Hilger quartz spectrograph with the following results:

Arsenic.—The most sensitive line for arsenic is 2319.8. It can be seen only very faintly if at all in any of the tissues. *Mercury* apparently is not present in any tissue. *Lead.* The typical lead line is extremely faint in all cases with the exception of cat kidney No. 5. In this case other lead lines can be found readily to confirm the first line. The other tissues of this cat show a very faint or no lead line. The lead in the kidney of this cat is doubtless due to some previous exposure, otherwise some other of the 23 cats subjected to similar conditions would have exhibited similar effects. *Thallium* is absent. *Cadmium* is very faintly present in most cases. No certain indication of *Antimony* is given owing to the presence of iron and traces of silicon.

The above metals representing those commonly met with to which may be ascribed any toxic significance are so faintly marked in general that they may be considered of quite negligible importance. Indeed there is no reason to consider them of hygienic significance, since these metals when present in the original rock wool are present in spectrographic traces only and furthermore are in the form of silicates and are therefore inert.

Summary

The chemical data thus obtained entirely deny the existence of any hygienic hazard in connection with contact with commercial rock wool of the type investigated. The histological examination of the lungs, liver and kidneys revealed no constant or significant pathological changes. In the dusted cats there was evidence of inhalation of considerable quantities of silicate and the accompanying changes in the lungs were those which one might expect such foreign matter to produce.

[illegible] animals since they [illegible]

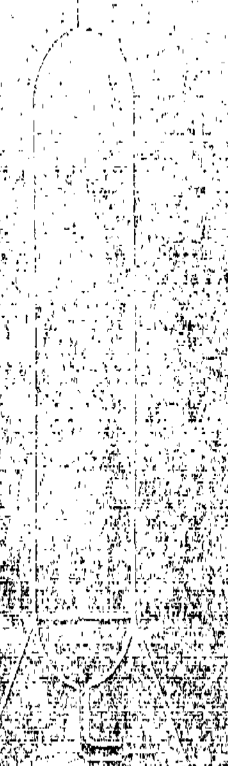
[illegible] experiments were [illegible]

[illegible]

SiO_2	[illegible]	[illegible]	[illegible]	[illegible]
CaO	[illegible]	[illegible]	[illegible]	[illegible]
MgO	[illegible]	[illegible]	[illegible]	[illegible]
B_2O_3	[illegible]	[illegible]	[illegible]	[illegible]
Na_2O	[illegible]	[illegible]	[illegible]	[illegible]
MnO	[illegible]	[illegible]	[illegible]	[illegible]
S	[illegible]	[illegible]	[illegible]	[illegible]
Cl	[illegible]	[illegible]	[illegible]	[illegible]
H_2O	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]

Oil content

13.18	7.08	Oil-free



[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

wool on [illegible] however, slight traces of arsenic found [illegible] were evident that could be considered as injurious. The animals either maintained their weight, or showed an increase in weight with the exception of those subjected to air passed through heated rock wool and, as has been noted above, the slight average decrease in weight particularly during the last 3 weeks is probably largely owing to the trying living conditions of temperature and humidity to which they were subjected. At the time they were chloroformed the animals looked healthy and macroscopic inspection of their tissues on removal showed nothing unusual.

After chloroforming the cats, their tissues were weighed at once before and after removal of pieces for microscopic examination and the remainder analyzed chemically for arsenic, mercury and lead. For this purpose the tissues were wet-ashed by means of nitric acid in order to prevent any possible loss. [illegible]

MICROSCOPIC EXAMINATION OF TISSUES

Microscopic sections were prepared from the lungs, kidneys and liver of each cat used in these experiments and from four normal control cats. In the experimental animals, the tissues were all fixed in Zenker's fluid and embedded in paraffin and the sections were stained with eosin and methylene blue. Tissues from the control cats were fixed in Zenker's fluid and also in 10 per cent formaldehyde, and paraffin sections were stained with eosin-methylene blue and hematoxylin and eosin.

Cold Vapor Experiment

Microscopic examination of the lungs, liver and kidneys showed no constant changes from the normal. The lungs from [illegible]

[illegible]

[illegible] from the other experimental groups [illegible] with the exception of the [illegible] particles [illegible] rats showed [illegible] [illegible] accumulations of [illegible] [illegible] lymphocytes, eosinophiles, and [illegible] polymorphonuclear [illegible] The alveolar walls [illegible] some of these lesions were [illegible] thickened and infiltrated [illegible] cells. Silicate particles could be [illegible] regularly in the majority of these lesions [illegible] Four of the rats showed [illegible] [illegible] blood into the bronchi [illegible] excessive mucous [illegible] increased [illegible]

[illegible] Histological examination of the kid- [illegible]

[illegible]

HAZARDS OF COMPETITIVE PRODUCTS

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