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8/4/77

MORTALITY PATTERNS AMONG HARD ROCK GOLD MINERS EXPOSED TO AN ASBESTIFORM MINERAL - A CRITIQUE [a]

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Introduction

A paper entitled "Morbidity And Mortality Among Hard Rock Miners Exposed To An Asbestiform Mineral" by J. Dean Gillam, M.A., John Dement, M.S., Richard A. Lemen M.S., Joseph K. Wagoner, S.D. Hyg., and Victor E. Archer, M.D., all of the National Institute for Occupational Safety and Health (NIOSH) was read to a conference entitled "Occupation Carcinogenesis" sponsored by the New York Academy of Sciences in New York in March 1975 by J. Dean Gillam, one of the authors.

In June 1976, the New York Academy of Sciences published the papers given at this conference in Volume 271 in its series entitled "Annals of the New York Academy of Sciences", which volume is entitled "Occupational Carcinogenesis". In this volume the text and tables of the paper read by Gillam the year before were greatly changed; the title was revised to "Mortality Patterns Among Hard Rock Gold Miners Exposed To An Asbestiform Mineral", and an additional author, Hector P. Blejer, was listed. (1)

(a) A condensed version was read at the American Industrial Hygiene Conference, in New Orleans, La. on May 26, 1977 at the General Industrial Hygiene Non-Monitoring Programs session.

This critique is of the paper (hereinafter referred to as "the NIOSH study") as finally published in the Occupational Carcinogenesis volume, although the NIOSH authors should also be criticized for the many substantial changes made in the text, tables and conclusions during the 15 months between first presentation and final publication.

The Homestake mine is an underground gold mine located in Lead, South Dakota in the northern Black Hills. The mine was discovered in 1876 and began operation with a small surface working. Homestake Mining Company was incorporated in 1877. By the end of 1878 the first underground levels were being opened. The mine at the present time produces about 6,600 tons of ore per operating mine day. Ore production started on the surface at an elevation of about 5,300 feet above sea level. Workings now extend down to the 8,000 f level below surface or to about 2,700 feet below sea level.

The gold ore occurs in a number of different ore bodies in what is called the Homestake formation. This was originally a sedimentary formation containing the iron-magnesium carbonate mineral sideroplesite. Regional metamorphism converted this in parts of the formation to the iron-magnesium silicate mineral cummingtonite. The formation is highly folded and crossfolded. Gold ore in the formation has been associated with both the cummingtonite and sideroplesite.(2) Cummingtonite is an amphibole mineral. It is the low iron, high magnesium end of an isomorphous series of iron-magnesium silicates. If the iron silicate content exceeds 70% the mineral is called grunerite.(3)

The NIOSH Study

The study was made of 440 Homestake mine underground employees who volunteer for the U.S. Bureau of Mines - Public Health Service 1958-61 silicosis study. A total of 848 Homestake employees volunteered to take physical examinations under the 1958-1961 silicosi study.(4),(5) The USPHS did this work at the Homestake mine in Lead, South Dakota, in April and May, 1960. The 440 employees studied in the NIOSH study were selected from the 848.(1) The basis for selection is stated in the NIOSH study to have been as follows:

"Selected for study were all male caucasians who in 1960 had been examined by the U.S. Public Health Service during a silicosis survey of a hard rock gold mine in Lead, South Dakota, and on whom social, demographic and occupational data had been obtained in sufficient detail to permit following of their health status. The study cohort was further restricted to those 440 individuals who in 1960 had achieved at least 60 months of underground mining at that facility and who had never mined underground elsewhere." (1)

In connection with the 1958-61 silicosis study, the U.S. Bureau of Mines did an extensive dust survey, taking eight settled dust samples for free silica determination and 592 midget impinger air samples in the mine which were counted for dust.(6) The NIOSH study reports:

"These samples showed an airborne dust concentration of 1.7×10^6 particles per cubic foot in miners' breathing zones, whereas airborne and settled dust samples showed an average free silica content of 39%. Given a 39% free silica content, the Occupational Safety and Health Administration (OSHA) 8-hr. time-weighted average standard for occupational exposure to free silica would be approximately 5×10^6 particles/ft^3. Thus, free silica exposures were well below the present applicable OSHA standard." (1)

In 1973, the U.S. Bureau of Mines performed another environmental survey of the mine.(7) The NIOSH study reports:

"With personal samplers, a total of seven working shifts were sampled for respirable and total dust concentrations. X-ray diffraction analysis of the respirable dust showed an average free silica content of 13.1%. All samples of mining personnel exposures showed average breathing zone dust concentrations below the OSHA standard for free silica. In addition to air samples, material samples of the ore were analyzed by scanning microscopy using energy-dispersive x-ray techniques. Numerous fibrous particles were observed. Their identification was not determined, however." (1)

In 1974 the Mining Enforcement and Safety Administration (MESA) did a more detailed fiber survey. [8] The NIOSH study reports:

> "During that study, approximately 200 personal membrane filter samples were collected over full working shifts. Fiber concentrations were determined with the NIOSH phase-contrast optical microscopic analytic method for asbestos fibers. The average fiber concentration was found to be 0.25 fibers greater than 5 μm in length/cm^3, the highest single concentration found was 2.8 fibers/cm^3." [1]

The results of the NIOSH mortality study of the 440 employees showed an excess of deaths actually observed over those expected in the respiratory system category of deaths. [1] The NIOSH study states:

> "This excess was not specific to any response. Rather it showed up for both respiratory malignancies (10 observed vs. 2.7 expected, $p<0.01$) and for respiratory nonmalignancies (8 observed vs. 3.2 expected, $p<0.05$)." [1]

The authors of the NIOSH study state that methods of engineering control at the gold mine have been quite good for many years, [1] and then state (underlining ours):

> "These methods would have been equally effective in controlling exposures to all dusts, including asbestos fibers, compounds of arsenic, and trace metals. Based on observations of present and past use of engineering controls and their effectiveness, as demonstrated by the Bureau of Mines 1960 and 1973 dust surveys, <u>it may be adjudged that past exposures to asbestos fibers were not significantly different from those found by the 1974 MESA survey.</u>" [1]

With regard to the effects of smoking habits of the employees studied, the NIOSH study states that cigarette smoking could not account per se for the observed increased respiratory cancer risk among these gold miners, and that exposure to fibrous grunerite (amosite stands out as the prime etiological agent for the increased respiratory cancer among the study cohort. [1]

The NIOSH study concludes:

"A study among a group of miners exposed to amphibole fibers (amosite) in the cummintonite - grunerite series, airborne concentrations less than 2.0 fibers/cm$^{(3)}$ as determined by the NIOSH phase-contrast counting technique, and fibers shorter than 5μm in length has demonstrated significant risks of mortality from both malignant and nonmalignant respiratory disease. Exposures to known carcinogens in the mine, other than asbestos, did not exceed normal ambient residential levels for radon daughters or were adjudged to be negligible for arsenic, chromium and nickel. The observed excess of malignant respiratory disease can, therefore, be attributed to asbestos, singly or in combination with cigarette smoke and that of nonmalignant respiratory disease can, therefore, be ascribed to asbestos, with a possible additive role from low exposures to free silica dust." (1)

A Limited Amount of Basic Data Was Obtained From USPHS

After becoming aware of the existence of the NIOSH study shortly before the presentation by Gillam in New York in March 1975, various members of the Homestake Mining Company staff have attempted to obtain information from the USPHS about the study. Much of the information requested has been denied to Homestake, including a listing of the names of the 440 employees included in the study.

The USPHS did, however, furnish, under the provision of a federal district court order, to Reserve Mining Company, and Reserve in turn furnished the Homestake Medical Director with a copy of the following material related to the ten cases of "observed" respiratory cancer and the eight cases of "observed" nonmalignant respiratory diseases:

1. Death certificates.
2. 1960 silicosis study interview sheets, including smoking histories, medical histories and occupational histories as reported by the employees in 1960, pulmonary function tests and reports on chest x-rays.

3. Correspondence between USPHS and hospitals and doctors who treated the employees in their terminal illnesses.

The occupational history of one of the ten cases of "observed" respiratory cancer was missing from the papers delivered to the Homestake Medical Director, thus only 17 USPHS 1960 occupational histories were available for review.

Apart from the above, the USPHS furnished Homestake with a computer printout of the smoking histories of the 440 employees (without their names), and an explanation of the coding used in the computer listing.

The comments made herein are based on the information furnished Homestake Mining Company as listed above, plus information in Homestake Mining Company's own records. Our comments would be more complete and our task considerably easier if all the information requested had been furnished.

The incorrect assumption that past exposures to asbestos fibers were not significantly different from those found by the 1974 MESA survey.

The authors have made the assumption that the exposure of the 440 workers during the period when they worked in the mine is not significantly different from the exposures found by the 1974 MESA survey. This assumption is totally unwarranted and is a gross error which effectively invalidates the entire study.

The NIOSH study does not mention the following statement in the conclusions of the 1974 MESA fiber survey report (underlining ours):

"The survey data are inconsistent when coupled to current epidemiological studies. One must recognize that the fiber dust survey recorded conditions as they existed at the time of the survey and that these conditions do not necessarily represent the conditions that existed in the past. "(8)

Table 1 shows the year of first underground employment in the Homestake mine

and the total length of employment with Homestake Mining Company for the 18 employees who were classified in the NIOSH study as having died of respiratory system malignancies or of respiratory system nonmalignant disease.

TABLE 1

Analysis of 18 employees classified in NIOSH study as having died of respiratory malignancies and nonmalignant respiratory disease showing year of first employment underground in Homestake mine and total length of employment with Homestake Mining Company.

Employee number	Calendar year began underground work in Homestake mine	Total length of employment
1.	1916	38 yrs. 7 mos.
2.	1919	30 yrs. 7 mos.
3.	1922	37 yrs. 11 mos.
4.	1924	19 yrs. 5 mos.
5.	1924	39 yrs. 4 mos.
6.	1925	39 yrs. 10 mos.
7.	1925	36 yrs. 5 mos.
8.	1930	30 yrs. 4 mos.
9.	1935	27 yrs. 11 mos.
10.	1936	22 yrs. 11 mos.
11.	1936	31 yrs. 6 mos.
12.	1947	18 yrs. 1 mo.
13.	1947	26 yrs. 1 mo.
14.	1949	18 yrs. 1 mo.
15.	1950	11 yrs. 5 mos.
16.	1952	13 yrs. 10 mos.
17.	1952	17 yrs. 11 mos.
18.	1952	20 yrs. 0 mos.

Over the 59 years beginning with 1916, when the first of these 18 men began underground work, through 1974 when the MESA fiber survey was made, many major improvements were made in underground ventilation and in mining practices in the Homestake gold mine which have had a very significant effect on the dust (and consequently on any fiber) exposure of workers. The following is a tabulation of the major changes made.

1. In 1917 the first fans to mechanically ventilate the underground workings were installed. These were two 35 horsepower fans and one 15 horsepower fan, located at two shafts and rated at a total volume of about 77,000 cubic feet per minute at 4" water pressure, but it is not known what the operating pressures were.

2. The early drilling in the Homestake mine was by dry hand drilling. In 1883 the first dry power drills were in service. Before World War I wet pneumatic drills began to replace dry drills. By 1919 most drilling was being done with wet drills and by 1926 all drilling was being done with wet drills - i.e., drills designed to force water into the holes being drilled in order to make a slurry out of the dusty cuttings.

3. In 1923 the first large main fan for mine ventilation was installed and the use of underground secondary air distribution fans was begun. The main fan was rated and operated at 225,000 cfm with a 300 horsepo motor and 4" of water pressure.

4. Up until the late 1930's it was the practice in many ore breaking areas of the mine for the miners to blast the boulders that were too big to handle by drilling short holes into them and charging these with dynamite, which was detonated by blasting caps and fuse after the miners temporarily left the working place. A few minutes after the blast, the miners would return to the area through the smoke, fumes and dust and then charge and blast the primary breakage holes which they had drilled during their shift. This was normally done at the end of the work shift and the miners then left the mine, which was allowed to ventilate for several hours between shifts for the air to clear. This boulder blasting procedure was a very dusty practice which was discontinued by 1939.

5. Prior to 1950 blasting was permitted at any time throughout the mine. As a result of this practice large amounts of dust, fumes and smoke drifted through working places that were down wind in the flow of ventilation from the places where blasting was performed, so that employees breathed

concentrations of dust fumes and smoke which were not directly related to the work they were performing. In 1950 the company blasting regulations were changed to permit blasting only at lunch time and quitting time in square set (timbered) stopes and only at quitting time in open (untimbered) stopes, and in drifts and raises. This change greatly reduced the amounts of smoke, fumes and dust in the mine during working hours.

6. Until 1951 the holes drilled to advance a "drift" (a horizontal tunnel-like excavation) were blasted in a 2-step sequence. The first holes to be blasted were the "cut holes" (the holes which determine how far from the face the rock will be broken by the blast). A few minutes after blasting these (with dynamite, blasting caps and fuse), the miners re-entered the working place in the smoke, fumes and dust and then inspected the results of the blast. If the cut holes had not broken to the desired depth, they were cleaned out, recharged and reblasted until they had broken as deep as possible. Then the rest of the holes were charged and blasted and the miners left the area until their next work shift. This was another very dusty practice which was changed in 1951 to blasting all the holes at one time using electric delay blasting caps and dynamite.

7. Until 1952 the holes drilled to advance a "raise" (a vertical tunnel-like excavation) were blasted in the same 2-step sequence. This probably caused even greater dust exposure to the men involved than did the drift practice because the miners had to climb ladders back up to their working place which might be up to 150 feet above their entry point. This very dusty practice was discontinued in 1952 and the holes in raise rounds since then have all been blasted at once.

8. In 1950 conversion of the mine to drills equipped with automatic water valves was begun. These valves turn on the water for dust suppression when the compressed air is turned on. Older drills had separate air and water valves, and miners normally began most of the holes they drilled by using only the compressed air without using any water for dust suppression. This conversion of drills was completed in 1953.

9. In 1954 a change in the method of extraction of ore was made which greatly reduced the amount of secondary blasting which had to be done in the extraction chutes.

10. In 1963 wheeled carriage mounts for drills in ore breaking areas were designed and built. These resulted in a much longer drilling cycle so that all holes in an area could be drilled at once and then all holes blasted by means of large blasts. Previously the miners on each shift blasted the holes they drilled that shift. Under the new cycle they might drill for a week and blast all the holes at once. This reduced the times that smoke, blasting fumes and dust were generated.

11. In 1964 chutes for drawing the broken ore from breakage areas were redesigned and enlarged to reduce the physical exertion required from a miner and to reduce the amount of blasting of rocks too big to flow through the chutes. This also reduced the amount of smoke, blasting fumes and dust generated.

12. In 1963 a program of improving secondary distribution of air to individual working places was begun. Prior to that time, secondary distribution fans were primarily 5-horsepower in size and used 12" diameter ventilation bag or tubing. In 1955, there were 97 5-h.p. fans on hand. Between 1955 and 1963, 40 more were purchased. None have been purchased since 1963. In 1955 there were no 10 h.p. fans on hand. Between 1965 and 1969, 42 were purchased. In 1955, there were twelve 15 h.p. fans on hand. Eighty-four were purchased between 1955 and 1974. The larger fans required the use of 16" and 20" diameter ventilation bag or tubing. The higher horsepower fans with the 16" ventilation bag or tubing deliver more than twice as much air over the same distance as do the older 5 h.p. fans with 12" ventilation bag or tubing, and about 2-1/2 times as much air with the 20" ventilation bag or tubing.

13. Over the years there have been many changes in working hours and average number of shifts worked per year. The daily shift was 10 hours until 1906 when a gradual change to 8 hours was made. In those days there were no regular days off, holidays or vacations. The men worked every day and looked on a day off as a loss in wages. No detailed records

of average shifts worked are available until 1920. At that time, underground employees worked an average of 52 hours per week. (They actually worked 13 successive days, then had one day off). In 1920, the average underground employee worked 333 shifts in the year or 2664 hours. On September 1, 1933 the work week was changed to 48 hours. This resulted in a reduction in average shifts worked per year from 328 in 1933, to 304 in 1934 and to 298 in 1935. On October 20, 1940 the work week was changed to 42 hours and the daily shift was reduced to 7 hours, but average total work shifts remained about the same as in 1935. The work week and work shift were increased to 48 hours and 8 hours, respectively, on March 2, 1952. Average shifts worked per year ranged from 294 to 288 in the period 1952-1967. Since then, this figure has declined to 249 in 1974. On August 28, 1972 the work week was reduced to alternating 48 and 40 hour weeks. On April 20, 1973 the work week was reduced to 40 hours which it was at the time of the 1974 MESA survey. Thus, the average underground employee worked 1992 hours in 1974, when the MESA fiber survey was made, as contrasted with 2664 hours in 1920.

14. Great changes have been made in the overall ventilation provided to the mine. In 1933 a second fan was installed on surface to supplement the air provided by the 1923 installation. Total air volume circulated in the mine was then raised from 225,000 cubic feet per minute (CFM) to 475,000 CFM. In 1941, another surface fan was installed, and the oldest one shut down, resulting in an increase to 547,000 CFM. In 1960, another fan was installed which increased the volume to 600,000 CFM. Over the next few years various improvements gradually raised the volume to 650,000 in 1963. In 1964, another major fan was installed increasing the capacity to 800,000 CFM. Since then, volume has ranged from 775,000 CFM in 1974, when the MESA fiber survey was made, to 867,000 CFM in 1966. Table 2 shows ventilation volumes and other pertinent figures on a yearly basis from 1916 through 1974.

TABLE 2
Homestake Mine Employment and Ventilation Data by Years

Year	Average No. Employees Underground	Average No. Shifts Worked per/Employee	Hours in Shift	Average No. Hours in Workweek	CFM Air Circulated through Mine	CFM Air Circulated per/Employee
1916	?	?	8	52(a)	?	?
1917	?	?	"	"	77,000(?)	?
1918	837(b)	333(c)	"	"	"	92 (?)
1919	640(b)	333(c)	"	"	"	120 (?)
1920	641	333	"	"	"	120 (?)
1921	852	326	"	"	"	90 (?)
1922	842	327	"	"	"	91 (?)
1923	781	326	"	"	"	99 (?)
1924	790	318(d)	"	"	225,000	285
1925	723	336	"	"	"	311
1926	695	330	"	"	"	323
1927	665	333	"	"	"	338
1928	642	327	"	"	"	350
1929	723	320	"	"	"	311
1930	810	306(e)	"	"	"	278
1931	780	322	"	"	"	288
1932	783	335	"	"	"	287
1933	830	328(f)	"	52 and 48(f)	475,000	572
1934	957	304	"	48	"	496
1935	965	298	"	"	"	492
1936	1,037	299	"	"	"	458
1937	988	299	"	"	"	481
1938	1,044	299	"	"	"	455
1939	1,103	296	"	"	"	431
1940	1,085	297	7 & 8(g)	48 and 42(g)	"	438
1941	1,138	293	7.0	42	547,000	481
1942	850(h)	306(h)	"	"	"	644(h)
1943	162(h)	289(h)	"	"	"	3,377(h)
1944	151(h)	280(h)	"	"	"	3,623(h)
1945	267(h)	263(h)	"	"	"	2,048(h)
1946	614	276	"	"	"	891
1947	676	279	"	"	"	809
1948	684	273	"	"	"	800
1949	948	274	"	"	"	577
1950	993	286	"	"	"	551
1951	726	314	"	"	"	753
1952	739	290(i)	"	42 and 48(i)	"	740
1953	803	291	8	48	"	681
1954	887	291	"	"	"	617
1955	889	290	"	"	"	615
1956	914	292	"	"	"	598
1957	943	293	"	"	"	580
1958	925	294	"	"	"	591
1959	880	294	"	"	600,000	694
1960	870	292	"	"	"	690
1961	892	294	"	"	"	673
1962	939	288	"	"	619,000	639
1963	1,036	289	"	"	650,000	627
1964	1,046	290	"	"	800,000	765
1965	1,022	290	"	"	829,000	811
1966	983	288	"	"	867,000	882
1967	1,006	280	"	"	864,000	859
1968	1,002	272	"	"	830,000	828
1969	990	280	"	"	802,000	810
1970	933	282	"	"	800,000	857
1971	954	294	"	"	815,000	854
1972	900	264	"	48 and 44(j)	780,000	867
1973	960	249	"	44 and 40(k)	780,000	813
1974	963	249	"	40	775,000	805

Notes: See next page

Notes to Table 2:

(a) Alternating 56 and 48 hour workweeks.

(b) Calculated from record of total shifts worked and assuming 333 shifts per employee from the 1920 figures.

(c) Assumed from 1920 figure.

(d) Assumed figure. Data available for year are unreliable.

(e) Fire in Ellison shaft headframe caused a short shutdown of underground mine operations.

(f) Workweek changed from alternating 56 and 48 hour weeks to 48 hour weeks on September 1, 1933.

(g) Workweek and workday changed to 42 hours and 7 hours respectively on October 20, 1940.

(h) Production operations shut down during World War II from October 8, 1942 to July 1, 1945 with War Production Board order L-208.

(i) Workweek and workday changed to 48 and 8 hours respectively on March 2, 1952.

(j) Workweek changed from 48 hour week to alternating 48 and 40 hour weeks on August 28, 1972.

(k) Workweek changed from alternating 48 and 40 hour weeks to 40 hour week on April 20, 1973.

Another major reason for the NIOSH assumption of unchanged exposure being totally incorrect is found in the silicosis incidence. The 1960 and 1974 Bureau of Mines and MESA surveys found relatively low silica concentrations, well below the applicable OSHA standards to prevent the occurrence of silicosis. Yet among the 18 employees who died after 1960 of respiratory system malignancies and nonmalignant respiratory disease, 7 had mention of silicosis as a cause of death in the death certificates and 15 had been diagnosed as having some stage of silicosis by the Homestake medical staff when they were still working. Why then, if silica exposure by the NIOSH assumption was as low from 1916 to 1960 as it was in 1960 and 1974, have there been so many silicosis cases? The answer is that the exposure must have been higher in the past. The falsity of the NIOSH assumption is thus readily revealed by data which NIOSH had but did not include in the NIOSH study.

Further evidence that the NIOSH assumption is incorrect is found in the Homestake Mining Company records of dust counts found in air samples and presented in Table 3. Unfortunately, no dust counts can be found prior to 1937, and it may well be that prior to then no regular air sampling was done. Dust exposures in the 1937-1951 period average about 8 times as high as those in 1974 when the MESA fiber survey was made. From the 1933 change in ventilation it can be calculated that dust exposures in the 1924-32 period were at least as great as those in the 1937-1951 period, or about 16 times as great as in 1974, and those in the 1916-23 period were about 20 times as great as in 1974. If the changes in dust control practices and hours worked are taken into account, the differences are even greater.

TABLE 3

Approximate exposures to silica dust of employees working underground in the Homestake gold mine by years from 1937 through 1974 based on occupational exposure midget impinger air samples.(a)

Year	Number of Samples Averaged	Average Silica Dust Count in Millions of Particles per Cubic Foot
1937	107	11.0
1938	216	25.5
1939	748	15.3
1940	1,056	11.1
1941	498	13.3
1942	184	24.6
1943-1946	0	-
1947	255	24.3
1948	178	12.0
1949	183	15.5
1950	297	12.6
1951	198	18.4
1952	247	9.7
1953	140	6.7
1954	22	5.9
1955	249	5.1
1956	104	5.2
1957	290	4.1
1958	121	4.3
1959	74	4.0
1960	24	4.4
1961-1963	0	-
1964	247	3.3
1965	86	4.2
1966	311	3.5
1967	261	3.1
1968	290	5.0
1969	228	4.0
1970	146	4.4
1971	195	2.4
1972	200	2.8
1973	180	2.5
1974	124	2.0

NOTE:

(a) Much of the air sampling at the Homestake mine is done for control purposes and is in areas expected to have high dust counts. If all samples taken in a given year were averaged, the results would be biased on the high side. Only samples which represent exposures of employees have been used in obtaining the averages in this table. Repetitive samplings in high dust concentration areas were not used in obtaining the averages.

The U. S. Bureau of Mines 1960 report[6] does not give a single figure for average airborne dust concentrations in the mine such as the 1.7×10^6 particles per cubic foot as reported by the NIOSH study authors. Instead, the 1960 report shows low, high and weighted average dust concentrations by occupation in the mine, as follows:

TABLE 4

Low, high and weighted average dust concentration by occupation in Homestake mine in 1960 as given in U. S. Bureau of Mines Report[5]

Occupation	No. of samples	No. of crews or employees sampled	Dust concentrations in MPPCF[a]		
			Low	High	Weighted average
Timbered cut and fill stopes	146	9 crews[b]	0.3	76.3	3.8
Open cut and fill stopes	129	8 crews[b]	0.3	24.7	3.0
Stope fill preparation	66	4 crews[b]	0.3	25.1	2.2
Drifts	32	2 crews[b]	0.3	3.5	0.9
Raises	30	2 crews[b]	0.4	117.0	6.5
Motormen	44	5 employees	0.4	15.2	3.0
Chute puller	27	2 employees	0.3	3.7	1.3
Sand crew	16	1 crew[b]	0.6	5.2	2.4
Gunnite crew	15	1 crew[b]	0.5	672.0	99.8
Hoistmen	9	3 employees	0.3	6.3	1.7
Cagers and skipper	9	5 employees	0.8	2.3	1.3
Timber repair	23	3 employees	0.5	13.0	1.7
Trackman	6	1 employee	0.5	1.3	1.0
Diamond drillers	12	3 employees	0.3	2.2	0.9

(a) Million particles per cubic foot.
(b) Regular crews consist of two employees except for sand crew and gunnite crew which vary from 5 to 2.

The Homestake authors have been unable to determine how the NIOSH study authors were able to derive as low an overall average dust concentration as 1.7×10^6 particles per cubic foot from the data in the 1960 Bureau of Mines report, even if the high average of the gunnite crew is excluded. The 1.7×10^6 figure used in the NIOSH study for 1960 is obviously low and improperly derived.

Review of Occupational Histories

For the NIOSH study, occupational history information was obtained by the USPHS from their 1960 interviews with the employees, and was not verified by Homestake or other employers. To date, the USPHS has refused to furnish Homestake a list of the names of the 440 employees, so that no check has been made by Homestake of the correctness of the employment histories of all 440 persons. As mentioned above, however, the Homestake medical director did receive the USPHS 1960 occupational histories on 17 men and the names and death certificates and other information on 18 men. The work histories of these 17 employees have been checked against the Homestake records and other sources of information.

Of the ten respiratory system malignancy cases, three were found who do not meet the NIOSH study requirement of never having mined underground elsewhere. They, therefore, should have been excluded from the study. These three individuals had mined underground elsewhere before 1960, (one as long as 3-1/2 years) and the information on two of them was available in the NIOSH records. Another worked 3 years in a Connecticut chemical plant with exposure to toxic fumes and logically should have been excluded from the study also. This information was also in the NIOSH records. A fifth employee worked for 5 years at a dusty bentonite surface mine and processing facility where he probably had high silica dust exposure. Again, this information was contained in the NIOSH records.

Of the eight nonmalignant respiratory disease cases, one had worked at least 3 times in other underground mines, and should, therefore have been excluded from the study. Again the information was in the NIOSH records.

The employment underground in the Homestake mine for 60 months or more by 1960 was easily verified for all 18 persons.

The NIOSH screening of the group to be certain they all met the criteria of never having worked underground elsewhere can only be classified as slipshod. Of the 4 persons found not to meet this criteria, two had clearly shown it in their work histories and the information on the third one was in NIOSH correspondence attached to the 1960 interview forms. The information on the 4th case was not in the NIOSH papers, but was information developed by Homestake Mining Company.

Review of Smoking Histories

The USPHS furnished Homestake Mining Company with a computer listing of the individual smoking histories of the 440 employees as given by the men at the time they were examined in 1960. These smoking histories were tablulated by Homestake Mining Company and the results are shown in Table 5, along with similar figures for U. S. underground uranium miners and U. S. males (adjusted to the age of uranium miners).

TABLE 5

Smoking Histories of Homestake Underground Miners, U.S. Underground Uranium Miners and U.S. Males

Smoking Status	Homestake Underground Miners (a)	U.S. Underground Uranium Miners (b)	U.S. Males[b]
Non-cigarette smokers	28.3%[c]	28.8	45.4
Cigarette smokers:			
1 pack/day or less	59.5%	54.2	39.8
More than 1 pack/day	12.2%	16.9	14.8
	100.0%	99.9	100.0

NOTES:

(a) From smoking history computer print-out furnished by USPHS.

(b) From Lundin, F. E., J. K. Wagoner and V. E. Archer, "Radon Daughter Exposure and Respiratory Cancer - Quantitative and Temporal Aspects", National Institute for Occupational Safety and Health - National Institute for Environmental Health Sciences Joint Monograph No. 1, Page 26. Figures for U.S. Males were adjusted to age of uranium miners by the authors of the Joint Monograph.[9]

(c) Includes 2.8% who were pipe and/or cigar smokers, and 10.6% former smokers who had quit for one year or more at time of interview. This follows NIOSH practice used for U.S. Underground Uranium Miners and U.S. Males.

The NIOSH study states in its discussion of smoking (underlining ours):

> "The role of cigarette smoking also must be taken into account. Smoking histories obtained during the 1960 silicosis study of this hard rock gold mine indicate that these miners smoked <u>far less</u> than did underground uranium miners. Although a known factor in the causation of lung cancer, it has been estimated in studies of underground uranium miners that such smoking by itself would increase the expected lung cancer death risk by no more than 49%. Cigarette smoking, therefore, could not account per se for the observed increased respiratory cancer risks among these gold miners."[1]

The figures in Table 5 clearly show that the miners studied at the gold mine smoked somewhat more than average U.S. males, especially in the 1 pack/day or less class. They smoked slightly less than both U.S. males and uranium miners in the 1 pack/day or more class. Some elevation of the "expected" rates would result from this but it would be something less than the 49% estimated for the uranium miners. The NIOSH study makes no attempt to estimate this factor, but we believe that such a correction should be made in the "expected" respiratory malignancy cases. We do not have all the statistical data required to do a refined estimate of this correction, but a figure of 40% seems reasonable. This correction would raise the "expected" respiratory system cancers from 2.7 to 3.8.

The experience of the Homestake staff has been that employees tend to understate their smoking habits when being questioned about possible occupational disease. The USPHS 1960 smoking histories that were compared with Homestake records bore this out, although it is possible that the individuals involved may have become heavier smokers after 1960. For example, one of the 10 respiratory malignancy cases gave his smoking history in 1960 as "1/2 pack daily for 40 years," but the Homestake medical chart says "heavy smoker all of his life."

In another of these 10 cases, the USPHS 1960 forms show he smoked 1/2 pack daily for 20 years plus 6 oz. of pipe tobacco per week. The Homestake records state, "Heavy smoker, both cigarettes and pipe. Two packs daily. Smoked all his life from a young man."

In one of the 8 cases of nonmalignant respiratory disease, the USPHS 1960 forms show one pack daily for 40 years and occasional pipe. He was classified as a 1/2 to 1 pack

per day cigarette smoker. The Homestake record says, "Smoked heavily of cigarettes and pipe. At least 1 to 2 packages daily since age 16-17 and until his death."

Medical Review

After reading one of the early drafts of the NIOSH study, the Homestake Medical Director and consultants began to search for cases of asbestosis among the Homestake workers. It was reasoned that due to the medical staff's pre-occupation with silicosis for many years, that asbestosis might incorrectly have been called silicosis or overlooked. X-rays of long term employees and of other present employees taken during their pre-employment and bi-annual physical examinations were examined to see if any of them were typical of asbestosis. In addition, all x-rays were read by a firm of consulting radiologists in Rapid City, South Dakota, and by Robert F. Bell, M. D., a consultant of Denver, Colorado, specializing in occupational medicine and a certified reader in the ILO-UC classification of pneumonoconiosis in radiographs under the Federal Coal Mine Health & Safety Act.

The x-rays reviewed were of 100 randomly selected from among underground employees who have had 20 years or more of underground mining at the Homestake gold mine and of 789 current underground employees regardless of length of service.

No evidence of asbestosis was found. Furthermore, the Homestake hospital has had no cases of mesothelioma, and Mr. Gillam advised in a telephone conversation that USPHS had not found any asbestosis or mesothelioma in the 440 employees in the NIOSH study group, nor any excess of gastro-intestinal cancer.

Thus, it is clear that the incidence of respiratory cancer which the NIOSH stud claims is due to low asbestos fiber exposure is not accompanied by either asbestosis, mesothelioma, or excess gastro-intestinal cancer, all of which generally occur in populations exposed to asbestos fibers.

Three of the cases of respiratory system malignancies in the NIOSH study require a special comment.

The underlying cause of death in one case is shown on the death certificate to be a "Mediastinal tumor, highly undifferentiated with metastasis to supraclavicular nodes," and is coded as ICD 164. This individual is one of those who worked in other underground mines.

Another cause of death in another case is shown on the death certificate to be "Adenocystic Carcinoma, lt. maxillary antrum with mestasis," and is coded as ICD 160.2.

In the third case, the death certificate says "Bronchogenic Carcinoma" due to "Silicosis-Lungs", and indicates that an autopsy was performed. The Homestake records show that the pathologist who performed the autopsy changed the cause of death from bronchogenic carcinoma to malignant lymphoma.

It does not seem reasonable to include cancer of the nasal sinuses or mediastinum in the respiratory system analysis of the effects of asbestos fibers in the respiratory system. These parts of the body have virtually no contact with the dust or fibers contained in the air breathed. The coding should be refined to place these causes of death in a different grouping.

Current literature does not implicate asbestos fibers as an etiological agent in any of these three types of tumors, and these types should not be included in either the "observed" or "expected" cases of respiratory system cancer.

Epidemiological Aspects

Possible causes for respiratory system cancer other than asbestos fibers are not given dignified discussion. For instance, the limited number of determinations of radon daughter concentrations made subsequent to 1960 average about 0.006 Working Levels (WL). Occasional readings of 0.015 WL and 0.02 WL have been obtained. Unfortunately no record can be found of the individual, five 1960 samples which averaged under 0.01 WL.

In the 1916-23 period when ventilation volume through the mine was about one-tenth what it is now, the concentration would have been about 0.06 WL. In the 1924-32 period when ventilation volume was one-third what it is now, the concentration would have been 0.018 WL. In the period 1933-41, the concentration would have been 0.01 WL. Given the longer working hours per year in those days, an employee would have accumulated 0.916 Working Level Months (WLM) per year in the first period, 0.267 WLM per year in the second period, and 0.139 WLM per year in the third period.

In their NIOSH-NIEHS Joint Monograph No. 1, entitled "Radon Daughter Exposure and Respiratory Cancer Qualitative and Temporal Aspects," [9] Frank E. Lundin, Jr., Joseph K. Wagoner, and Victor E. Archer, predict that exposure of a population of 10,000 at 4 WLM per year for 30 years will produce 159.59 excess lung cancers within 50 years of first exposure. This is 30 x 4 x 10,000 or 1,200,000 Working Level Man Months (WLMM). The number divided by 159.59 excess lung cancers = 7519.3 WLMM to cause one excess lung cancer. (10)

If the number of underground employees in each year beginning with 1916 and ending with 1923 is multiplied by 0.916 WLM per year and those in the period 1924-32 by 0.267 WLM per year, and those in the 1933-41 period by 0.139 WLM per year, the results shows that the 7,519.3 WLMM of exposure to produce one excess lung cancer would have been reached in 1935, some 20 years after first exposure. This committed lung cancer would have as long as 30 years in which to appear and thus could have occurred after 1960.

The authors of this critique do not subscribe completely to the Lundin, Wagoner, Archer predictions and calculations, but it is clear that the NIOSH study authors Wagoner and Archer have not applied their own previously published radon daughter exposure theory to the Homestake mine.[4] Under that theory, radon daughter exposure in the early years of the working period covered by the NIOSH study cannot be eliminated as a cause for some of the incidence of lung cancer.

The NIOSH study in attempting to draw the far-reaching conclusions that it does from the small number of cases presented in it is engaging in a questionable practice. There are recognized dangers to drawing conclusions from such small numbers. A small change in the number of observed or expected cases can make a drastic difference in the statistical significance of the results. The numbers in Table 6 are not represented to be precise. The Homestake authors lack much of the data necessary (such as the 1960 occupational histories of 423 study group employees or the necessary statistical data to accurately correct for smoking histories) to generate precise numbers. The exercise presente in Table 6 does show, however, how easily statistical significance can vanish when small numbers are involved.

TABLE 6

Adjustments to "Observed" and "Expected" cases of respiratory system malignancies based on Homestake Mining Company comments

	Observed Cases	Expected Cases
Respiratory system malignancies per NIOSH study	10	2.7
Adjustment of 40% due to smoking histories	-	1.1
Adjustment for 5 persons included in study who worked in other underground mines or in chemical plant with toxic fumes	(4)	0.015[a]
Adjustment for 3 persons whose malignancy was outside direct stream of breathed air	(2)[b]	(0.01)[c]
Adjusted respiratory system malignancies	4	3.8

Notes to Table 6:

(a) Roughly estimated from the person years represented by the 5 persons eliminated from the study and the total person years used in the study.

(b) One of these three persons was the same as one of the three persons eliminated due to having worked in other underground mines.

(c) Roughly estimated as in (a) above.

In the category of nonmalignant respiratory disease, the NIOSH study shows 8 observed cases versus 3.2 expected. This comparison and the conclusion linking the observed cases "to asbestos, with a possible additive role from low exposure to free silica dust" is utter nonsense. It is difficult to believe that the NIOSH study authors really believe this. Of the 8 observed cases, the death certificates show the underlying causes of death to be silicosis in 6 cases, myeloblastic leukemia in one case, and chronic obstructive lung disease in the eighth. Silicosis is an occupational disease that does not occur in the general population. Inclusion of 6 observed occupational

silicosis cases in a comparison of observed nonmalignant respiratory disease deaths to expected deaths based on general population death rates is, therefore, incorrect. The 6 silicosis cases should be removed from the observed cases, be shown separately, and compared to virtually zero expected cases in the general population. The leukemia case should also be removed. The net result then is 1 observed case versus 3.2 expected or a deficit of observed cases.

The NIOSH study data contain an inconsistency on which the NIOSH authors did not comment. The ratio of observed respiratory system cancers to the expected cases for 5 to 19 years after onset of underground employment to date of death is 5.4:1 (3 observed, 0.56 expected), which is greater than the 3.2:1 ratio (7 observed, 2.18 expected) for those cancers which caused death 20 or more years after first underground employment. The difference between these ratios would be even greater had the NIOSH authors correctly classified the 10 cancer cases. Our review of the occupational histories which the USPHS took in 1960 and checked against Homestake Mining Company employment records shows that 1 person who died 19 and a fraction years after first underground employment was classified in the NIOSH study in the 20 years or more category.

In the nonmalignant respiratory disease deaths the relationship of the ratios is reversed. In the 5-19 year period the ratio is 0:1 (0 observed, 0.59 expected) and in the 20 years or more group the ratio is 3.1:1 (8 cases observed, 2.18 expected). These results are inconsistent with each other, yet the NIOSH study authors conclude that exposure to asbestos is the basic cause of the excess in both types of deaths.

The NIOSH study is inconsistent with another epidemiological study of Homestake employees made at about the same time. J. Corbett McDonald, et al., studied a group of 1,321 Homestake employees with 21 or more years of employment at Homestake as of 1973, most of whom spent most of their working lives underground.[11] Of the 1,321 employees, 660 had died and 652 were alive in 1974. Nine were untraced. Death certific were obtained and a modified life table technique of analysis was used to compare deaths

observed by cause against deaths expected by applying death rates for South Dakota for 1937 through 1973 to the study population. There were 17 observed cases of respiratory neoplasms in the group versus 16.5 expected. Gastro-intestinal cancers observed were 39 versus 35.1 expected and other cancers were 37 observed versus 38.9 expected. Thus no significant excess of any type of cancer was found. On the other hand, 37 cases of pneumonoconiosis were observed versus zero expected, and 39 cases of respiratory tuberculosis were observed versus 3.6 expected.

Summary and Conclusions

The NIOSH study has been shown in this critique:

1. To be based on a gross error in the basic assumption made on exposure;
2. To have, through slipshod work, included a number of persons who did not meet the NIOSH criteria for inclusion in the study group;
3. To have inaccurately reflected the results of the dust concentrations found in the mine by the U.S. Bureau of Mines in 1960;
4. To have included in both the observed and expected respiratory system malignancy deaths types of malignacies in which current literature does not implicate asbestos fibers as an etiological agent;
5. To have an inaccurracy in the data presented on observed deaths due to respiratory malignancies classified by time after onset of underground mining;
6. To contain an unexplained inconsistency between respiratory malignant disease deaths and respiratory nonmalignant disease deaths in the ratios of observed to expected deaths when these were classified by time after onset of underground mini
7. To have improperly included silicosis cases in the observed cases of death from nonmalignant respiratory disease in comparison with expected deaths from general population which does not incur silicosis;
8. To have neglected completely the important role of excess smoking in the study group; and

9. To have ignored completely other possible carcinogens, such as radon daughters;

10. To be inconsistent with the McDonald et al epidemiological study of a larger group of Homestake mine employees.

Our conclusion is that the NIOSH study is neither scientific nor valid. It does not present the evidence fairly. Only items which support the authors' conclusions are presented. Factors which do not, are ignored or dismissed without discussion. At least one of the authors has been personally involved in the Reserve Mining Company litigation in the Federal District Court in the District of Minnesota since before the study was made. The tone of the text of the various drafts, the choice of references, the ignoring of factors which do not support the conclusions, the improper inclusion of certain persons in the study, etc., all leave the reader with the impression that the NIOSH authors were so intent on strengthening NIOSH's position in the Minnesota court case that it abandoned the objectivity which the taxpayers and the public have a right to expect. The entire exercise demonstrates that the USPHS and NIOSH practice of making such studies and then refusing to divulge the basic data under claims of confidentiality, is fraught with the danger of authors presenting only the information which supports their conclusions and "covering up" that which does not. The public interest requires that such studies be "audited" by knowledgeable people outside the federal government.

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