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# Mortality Study of Talc Miners and Millers

**Giovanni F. Rubino, M.D.; Giovanni Scansetti, M.D.; Giorgio Piolatto, M.D.; and Canzio A. Romano, M.D.**

The purpose of this research is to ascertain the causes of death in talc miners and millers. Special attention is paid to the incidence of pulmonary, mesothelial and gastrointestinal tumors.

Our study was conducted on a talc which is mineralogically very pure in its natural state. This is the type of material used in the pharmaceutical and cosmetic industries. All the subjects of our study have worked in the mines and the mills of the talc operation in the Germanasca and Chisone Valley (Piedmont). This particular talc has been mined for many decades and has continued to be recognized to be of the highest standard of purity (see Appendix).

An epidemiological study which can be taken as reference for our investigation was conducted by Kleinfeld et al., and recently reviewed with additional informations (1974), on talc miners and millers in the State of New York.[1] [2] The incidence of carcinoma of the lung and pleura in those workers was found to be about four times that which is observed in the general population.

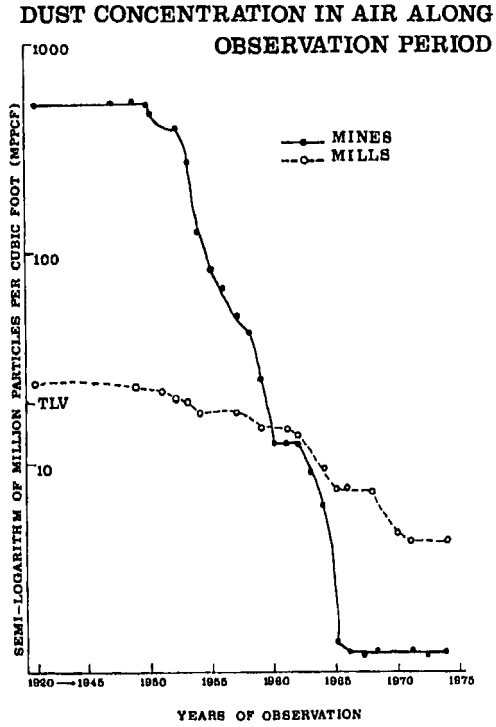
This New York Study was on workers exposed to an industrial talc which is a mixture of talc and other materials. Kleinfeld points out that the talc to which his workers were exposed "contained not only mineral talc but also other silicates such as serpentine, tremolite, anthophyllite, and other ingredients predominately carbonates. Moreover free silica was present in the dust in variable amounts, usually averaging not more than three percent".

Therefore, our present epidemiological study provides a basis for comparing subjects exposed to an impure industrial type of talc (e.g. Kleinfeld Study) to subjects exposed to a very pure type of talc.

## Type of Study and Data Collection

An historic prospective study has been employed consisting in the follow-up of a cohort of male subjects who began work at a definite time and including retired as well as active workers. We have been able to do so because we had at our disposal a group of subjects fit for this type of investigation.

Data were collected for each worker who began work in the years between 1921 and 1950 and who has been employed for at least one year in a job involving exposure to talc in the mines or in the mills. Necessary informations such as birth date, place of birth, last known address, type and duration of all works performed, were abstracted from pay rolls and




**Decreasing trend of total dust in respirable range, following the adoption of technical preventive means from 1950.**

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Dr. Rubino is Professor of Occupational Medicine and Director, Institute of Occupational Medicine, Turin University. Drs. Scansetti, Piolatto and Romano are assistants, Institute of Occupational Medicine, Turin University.

Reprint requests to Dept. of Occupational Medicine, University of Torino, C.T.O. — Via Zuretti 29, 10126 Torino, Italy.

records of a mining company of Pinerolo (Piedmont).

Cumulative exposure for each worker was estimated from the results of successive determinations of air dust content from 1948 till today (see Figure) and quantified by calculating an approximative value of the total amount of inhaled particles during the employement period. This one was considered to be finished at the retirement time for retired workers and on June 30, 1974 for active workers.

To compute cumulative dust exposure for each man, periods of job along which the dust level was uniform were selected, then the number of particles per cubic foot was multiplied by the number of years within each period and the resulting values for each period were summed.

The cumulative exposure is then expressed as mppcf/years. Thus, if a worker has been employed for 12 years at the following exposure to dust: 10 years at 566 mppcf, 1 year at 440 mppcf, 1 year at 360 mppcf, his cumulative exposure would be (10 x 566) + (1 x 440) + (1 x 360) = 6460 mppcf/years.

All workers were then classified on the basis of three exposure levels for miners and millers as follows: (see also Table 2)

**Miners**

| | |
|---|---|
| Exposure Level 1 mppcf/years | 566 - 1699 |
| Exposure Level 2 mppcf/years | 1700 - 5665 |
| Exposure Level 3 mppcf/years | 5666 - 12750 |

**Millers**

| | |
|---|---|
| Exposure Level 1 mppcf/years | 25 - 141 |
| Exposure Level 2 mppcf/years | 142 - 424 |
| Exposure Level 3 mppcf/years | 425 - 906 |

However we should remember that miners and millers exposures are not comparable because air dust in the mines includes a certain amount of inhalable silica particles (see Appendix). Therefore we have separately studied miners and millers obviously excluding from the cohort of millers all subjects who have worked in the mines even for a very short period of time. We gathered a total of 1514 miners and 478 millers qualified by our definition of the sample.

For purpose of comparison with a non-exposed group we thought it advisable to use an "ad hoc" control sample matched by age to the exposed workers sample, rather than a comparison with national death rates which could introduce some confounding variables (such as feeding habits, ethnic characteristics differences etc . . .).[3 4]

Control subjects were taken from the population of the town of Alba which presents similar ethnic characteristics and comparable social and economic conditions. Alba is a Piedmontese center, about 38 miles from the Pinerolo Valleys, with a dominant traditional agricultural activity and very little industrial development not involving any obvious hazard of occupational diseases or carcinogenesis to its workers.

Every subject in the exposed groups was individually matched to a control subject by the following procedure. From the City Hall records all subjects born in the same year as a given exposed worker and still alive at the time of his first employement were ordered and listed according to their month and date of birth. Among these the first available (i.e. not already used for matching) subject was selected as the matched control subject. As it turned out, by this procedure almost the full list of subjects potentially suitable for matching was in the end included in the control sample.

**Table 1. — Follow-up Status of Talc Miners and Millers (1921-1974).**

| | Total | Found | Unknown |
|---|---|---|---|
| Miners | | | |
| No. | 1514 | 1346 | 168 |
| % | 100 | 88.9 | 11.1 |
| Millers | | | |
| No. | 478 | 438 | 40 |
| % | 100 | 91.6 | 8.4 |

**Table 2. — Distribution of Total Number of Inhaled Particles in Miners and Millers With Completed Follow-up.**

| | Exp. Level 1 | Exp. Level 2 | Exp. Level 3 | Total |
|---|---|---|---|---|
| Miners mppcf/years | 566 - 1699 M 849 | 1700 - 5665 M 3798 | 5666 - 12750 M 8470 | |
| No. | 405 | 423 | 518 | 1346 |
| % | 30.1 | 31.4 | 38.5 | 100 |
| Millers mppcf/years | 25 - 141 M 76 | 142 - 424 M 297 | 425 - 906 M 651 | |
| No. | 163 | 144 | 131 | 438 |
| % | 37.2 | 32.9 | 29.9 | 100 |

**Table 3. — Vital Status of 1346 Miners and 438 Millers With Completed Follow-up and Respective Controls (on June 1974).**

| | | Dead | Alive | Known Causes of Death |
|---|---|---|---|---|
| Miners | No. | 704 | 642 | 667 |
| | % | 52.3 | 47.7 | 94.7 |
| Controls | No. | 651 | 695 | 813 |
| | % | 63.2 | 36.8 | 95.5 |
| Millers | No. | 227 | 211 | 218 |
| | % | 51.8 | 48.2 | 96 |
| Controls | No. | 275 | 163 | 254 |
| | % | 62.8 | 37.2 | 92.4 |

**Table 4. — Groups to be Compared: Distribution of Subjects by Age, Latency and Vital Status.**

| | | Group With Risk Under Examination | | | | Group Used as Control | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Age Groups yrs. | | | | Age Groups yrs. | | | |
| Latency | | <30 | 30-50 | 51-70 | >70 | <30 | 30-50 | 51-70 | >70 |
| 1 - 10 | Obs. Dead | $^{X}$E1 | $^{X}$E2 | $^{X}$E3 | $^{X}$E4 | $^{X}$C1 | $^{X}$C2 | $^{X}$C3 | $^{X}$C4 |
| | Alive | $^{Y}$E1 | $^{Y}$E2 | $^{Y}$E3 | $^{Y}$E4 | $^{Y}$C1 | $^{Y}$C2 | $^{Y}$C3 | $^{Y}$C4 |
| | Total | $^{Z}$E1 | $^{Z}$E2 | $^{Z}$E3 | $^{Z}$E4 | $^{Z}$C1 | $^{Z}$C2 | $^{Z}$C3 | $^{Z}$C4 |
| 11 - 20 etc. | | id. | | | | id. | | | |

## Follow-up of Study Population

A follow-up procedure was instituted for every exposed subject who had left employment and whose vital status could not be determined at the plant as well as for the whole control group. The City Hall registries of birth place and/or death place provided information on vital status. Follow-up is 88.9% complete on miners and 91.6% complete on millers. Table 1 shows the follow-up and vital status of the exposed population and their controls, as of June 30, 1974.

The distribution of all workers on whom follow-up was complete according to the Exposure Level is shown in Table 2.

Table 5. — Overall Mortality — Observed/Expected Deaths by Interval Between First Exposure and Death (by Exposed vs. Controls Comparison).

| | Miners | | Millers | |
|---|---|---|---|---|
| Latency yrs. | Obs./Exp. | Ratio | Obs./Exp. | Ratio |
| 1 - 10 | 68/84.2 | 0.81† | 16/29.6 | 0.54† |
| 11 - 20 | 110/119.6 | 0.92 | 46/41.7 | 1.10 |
| 21 - 30 | 203/208.8 | 0.97 | 65/67.9 | 0.97 |
| 31 - 40 | 188/207.0 | 0.91 | 57/72.5 | 0.79† |
| 41 - 50 | 126/157.5 | 0.80† | 38/42.2 | 0.90 |
| 50+ | 9/14.1 | 0.64* | 4/4.5 | 0.89 |
| Total | 704/791.2 | 0.89† | 227/258.4 | 0.88† |

*Statistically significant at 5% level
†Statistically significant at 1% level

The information relating to cause of death was obtained from death certificates for both exposed and controls and was coded according to the International Intermediate Classification of 150 causes of death[5] with additional items (mesothelioma, silico-tuberculosis) related to the possible effect of occupational exposure. Death certificates are the source of information used by the Italian Central Institute of Statistics (ISTAT) to compute national mortality rates. Although they may not always be completely accurate, they are available in a high percentage of cases and are suitable for epidemiological purposes and widely used, by many authors,[6-10] allowing to compare two populations with homogeneous diagnostic criteria. A total of 1840 death certificates were collected.

When the cause of death was not found by death certificates or if there were not enough indications for diagnosis (e.g. cardiac failure reported as death cause) a further enquiry was started with relatives of deceased, attending physicians or examining hospital records for hospital deaths.

A further number of 112 causes of death (59 for miners, 39 for miners controls, 5 for millers, 9 for millers controls) were so obtained to give the total number of known causes of death reported in Table 3.

The subsequent statistical analysis was conducted on 1346 miners and 438 millers on whom follow-up was complete. Workers reported dead but for whom neither death certificates nor the above sources of information were available were considered as deaths due to unknown cause.

No smoking data were available for dead people in exposed and control groups. However, as the two populations (exposed and controls) come from areas previously studied from ethnic, social and economic point of view, we have no grounds for assuming that there are differences in smoking as well as in feeding habits.

## Methods of Analysis

Statistical analysis was conducted by a comparison between exposed groups (miners and millers) and their matched controls and, within exposed samples, by an internal comparison among the three above mentioned groups with different cumulative dose of inhaled particles.

For both exposed versus controls comparison and internal comparison a modified life table technique, adjusting for age by indirect standardization method[11] was used to compute expected number of deaths.

Age intervals were: < 30, 30 - 50, 51 - 70, > 70.

Latency periods (interval between first exposure and death) were: 1 - 10, 11 - 20, 21 - 30, 31 - 40, 41 - 50, > 50.

General outline is shown in Table 4.

Number of deaths to be expected on null hypothesis for each age-latency period sub-group at risk under examination ($Z_{Ei}$) was computed as:

$$\text{EXPECTED DEATHS} = \frac{X_{Ei} + X_{Ci}}{Z_{Ei} + Z_{Ci}} \times Z_{Ei}$$

While for the comparison between exposed workers and controls the "combined group" (exposed + controls) was taken as the reference group ($Z_{Ei} + Z_{Ci}$), the comparison among classes of differently exposed workers the whole exposed group was taken as reference.

Deaths to be expected were computed for overall mortality and for 22 major causes of death.

Expected and observed values of deaths were added up for different ages within each latency period cell in order to examine the total impact of mortality along the observation period (see Tables 5, 6, 7).

Pooling for age and latency was performed for comparison according to specific causes of death (see Tables 8, 9, 10, 11, 12). The ratio of the number of observed deaths to the number to be expected provides an indication of the excess of mortality in the group with risk under examination in respect of the standard population (reference group).

One degree of freedom "chi square" tests were used to assess statistical significance of individual comparisons (exposed vs. controls, exposed at Level 1 vs. exposed at Level 2

Table 6. — Miners: Overall Mortality — Observed and Expected Deaths by Interval Between First Exposure and Death (by Internal Comparison).

| | Exp. Level 1 | | Exp. Level 2 | | Exp. Level 3 | |
|---|---|---|---|---|---|---|
| Latency yrs. | Obs./Exp. | Ratio | Obs./Exp. | Ratio | Obs./Exp. | Ratio |
| 1 - 10 | 36/24.5 | 1.47† | 32/23.4 | 1.37* | -/18.7 | — |
| 11 - 20 | 60/33.7 | 1.19 | 42/35.4 | 1.19 | 28/39.7 | 0.71* |
| 21 - 30 | 62/59.5 | 1.04 | 60/55.1 | 1.09 | 81/87.2 | 0.93 |
| 31 - 40 | 50/53.7 | 0.93 | 41/41.4 | 0.99 | 97/93.1 | 1.04 |
| 41 - 50 | 41/40.6 | 1.01 | 32/29.8 | 1.07 | 53/55.2 | 0.96 |
| 50+ | 2/2.6 | 0.77 | 2/2.1 | 0.93 | 5/4.4 | 1.14 |
| Total | 231/214.6 | 1.08 | 209/187.2 | 1.12* | 264/298.3 | 0.89* |

*Statistically significant at 5% level
†Statistically significant at 1% level

Table 7. — Millers: Overall Mortality — Observed/Expected Deaths by Interval Between First Exposure and Death (by Internal Comparison).

| | Exp. Level 1 | | Exp. Level 2 | | Exp. Level 3 | |
|---|---|---|---|---|---|---|
| Latency yrs. | Obs./Exp. | Ratio | Obs./Exp. | Ratio | Obs./Exp. | Ratio |
| 1 - 10 | 14/7.6 | 1.84† | 2/5.2 | 0.38 | -/2.9 | — |
| 11 - 20 | 20/16.7 | 1.20 | 23/18.5 | 1.24 | 3/11.0 | 0.27 |
| 21 - 30 | 32/27.3 | 1.17 | 20/14.5 | 1.38 | 14/22.7 | 0.62* |
| 31 - 40 | 23/21.2 | 1.08 | 15/10.3 | 1.46 | 19/24.4 | 0.78 |
| 41 - 50 | 10/12.9 | 0.78 | 4/8.7 | 1.08 | 24/21.6 | 1.11 |
| 50+ | 3/2.6 | 1.15 | -/0.15 | — | 1/1.4 | 0.71 |
| Total | 102/88.3 | 1.15 | 64/52.4 | 1.22* | 61/84 | 0.73† |

*Statistically significant at 5% level
†Statistically significant at 1% level

and 3, etc . . .) standardized as previously described for age or for age and latency.

In each table a single asterisk indicates the ratios which had a probability of 0.05 of occurring by change and a dagger indicates those which had a probability of 0.01 or less. Statistical significance of comparison between cells containing less than five cases was not tested.

## Results

By exposed versus controls comparison the observed overall mortality of talc miners and millers is significantly lower than expected. There are 704 observed deaths compared with 791.2 expected among miners and 227 observed compared with 258.4 expected among millers.

Table 5 shows that no relationship exists between the ratio of observed to expected deaths and interval between first exposure and death. Among miners a number of individuals, who died more than 41 years after their initial exposure, has been found significantly below its expected values.

By the comparison among different exposure classes the ratio does not increase with increasing exposure. As shown in Tables 6 and 7 in both miners and millers an excess of observed to expected deaths occurs at Exposure Level 2 for the total sample. In the "high" exposure groups the excess does not persist and on the contrary statistically lower than expected number of deaths is detectable. Neither in this last group nor in the others are there increases in ratio with increasing interval between first exposure and death for miners and millers.

When the overall mortality of study populations is subdivided according to cause of death some major patterns emerge for miners. Table 8 shows that by exposed versus controls comparison death from all respiratory diseases is significantly higher than expected as opposed to malignant neoplasms as a whole, cardiovascular diseases, gastrointestinal diseases and "all other causes" which show a number of observed cases significantly lower than expected.

Splitting respiratory diseases by kind provides evidence that the excess of mortality in exposed miners is due to the high incidence of pneumoconiosis with or without tuberculosis. Among all malignant neoplasms, lung cancer shows an incidence significantly below its expected values.

By comparison among different exposure classes as shown in Table 9, the ratio of observed to expected deaths from respiratory cause constantly increases with increasing exposure because of the excess of pneumoconiosis in people with greatest exposure. An increasing trend is also shown by larynx cancer but the number of cases is too small to assess significance of comparison. For all malignant neoplasms, oesophagic and gastric cancer as well as for tuberculosis and senility the ratio decreases with increasing exposure but no significant values are obtained in any cell to refuse the hypothesis of no difference among the three groups.

No clear decreasing or increasing trends are detectable for all other causes of death in miners.

Millers show an observed number of deaths below its expected values for cardiovascular diseases (Table 8).

As shown in Table 10, for all causes of death there are no consistent relationships between the ratio and the exposure level. Considering the trend of mortality by cause and by interval between first exposure and death all malignant neoplasms and lung cancer decrease in miners with increasing latency (see Table 11) as opposed to respiratory diseases as a

**Table 8. — Miners and Millers — Observed/Expected Deaths and Ratios by Cause (by Exposed vs. Controls Comparison).**

| Cause of Death | Miners | | Millers | |
|---|---|---|---|---|
| | Obs./Exp. | Ratio | Obs./Exp. | Ratio |
| Tuberculosis (all sites except cases associated with silicosis) | 45/40.4 | 0.91 | 12/14.0 | 0.86 |
| Respiratory diseases (all except pulmonary tuberculosis) | 140/101.8 | 1.38† | 25/21.4 | 1.17 |
| Respiratory diseases, acute | 45/44.7 | 1.01 | 10/11.6 | 0.86 |
| Silicosis | 62/30.9 | 2.01† | 3/2.1 | 1.43 |
| Silico-tuberculosis | 18/9.1 | 1.98† | 2/1.0 | 2.00 |
| Respiratory diseases, chronic | 15/17.1 | 0.88 | 10/6.7 | 1.49 |
| Other infectious diseases | 13/17.5 | 0.74 | 2/3.5 | 0.57 |
| Malignant neoplasms | 100/129.5 | 0.77† | 42/45.8 | 0.92 |
| Malignant neoplasms, larynx | 6/5.3 | 1.09 | 0/1.1 | — |
| Malignant neoplasms, lung, bronchus and trachea | 9/19.7 | 0.46† | 4/6.5 | 0.62 |
| Malignant neoplasms, pleura (mesothelioma) | 0/0.5 | — | 0/0.5 | — |
| Malignant neoplasms, oesophagus | 15/11.9 | 1.25 | 7/5.2 | 1.35 |
| Malignant neoplasms, stomach | 28/28.3 | 0.99 | 7/10.8 | 0.65 |
| Malignant neoplasms, intestine | 13/16.4 | 0.79 | 5/6.1 | 0.78 |
| Malignant neoplasms, liver (primary site or metastases) | 6/7.5 | 0.80 | 9/7.2 | 1.25 |
| Malignant neoplasms, other sites | 23/39.9 | 0.58† | 10/9.4 | 1.06 |
| Nervous system diseases | 9/9.9 | 0.91 | 4/2.5 | 1.60 |
| Cardiovascular diseases | 208/276.1 | 0.75† | 72/92.0 | 0.78† |
| Digestive organs diseases | 49/59.1 | 0.83* | 20/21.8 | 0.92 |
| Senility | 12/11 | 1.09 | 4/4.6 | 0.87 |
| Accidents | 68/64.7 | 1.05 | 28/26.7 | 1.05 |
| All other causes | 23/33.5 | 0.69† | 9/9.8 | 0.92 |
| Unknown | 37 | | 9 | |

*Statistically significant at 5% level
†Statistically significant at 1% level

whole which significantly increase with increasing latency. We should underline that for silicosis with or without tuberculosis, the ratio shows unchanged values over time because of the absence of pneumoconiosis in control sample (see computation of expected deaths), but the number of observed cases shows a constant increase with increasing latency, which explains the excess in ratio for all respiratory diseases.

As shown in Table 12 for millers only one pattern emerges: the ratio for all tumors increases with increasing latency, but the number of observed deaths remains less than expected in any cell.

Two cases of pleural mesothelioma were found in controls death certificates, confirmed by hospital records, but no autopsy data were available to the investigators. The occupational anamnesis carried out with relatives has not revealed any exposure to asbestos dust.

We should also underline that in both miners and millers a number of oesophagic cancer cases higher than expected was found, even if the small number cannot provide statistical significance to the comparison.

## Discussion

On general grounds, differences between exposed and controls mortality as we observed could be due to several factors: (a) a biased selection of the exposed groups; (b) a difference in recording mortality in the exposed and in the control groups; (c) the well known effect whereby occupational groups experience a lower mortality than controls taken from the general population because of a selection upon starting work; and (d) a lack of comparability of the two groups.

Cause (a) can be excluded because all the workers who have been enrolled between 1921 and 1950 and who have worked at least one year (therefore including a substantial number with a very long period of observation) were included in the study.

Cause (b) seems very unlikely: methods of data collection on mortality were the same for the two groups (exposed and controls respectively) and in both groups a similar number of cases were lost to follow-up for reasons unrelated to mortality (as accidental destruction of record files at the local City Hall registries, carelessness of clerical workers, etc . . .).

Cause (c) is less easy to discard, although a definite indication that it cannot provide the entire explanation for the higher mortality in control group comes from the uniformity of the mortality ratio during the observation period. Assuming that lower mortality of the exposed group is due to selection of more healthy individuals, the effect would have vanished after one or two decades: on the contrary it remains practically unchanged for the whole period of observation (see latency tables).

Cause (d) could be the main contributor to the observed differences. As already mentioned (section Data Collection) male controls were matched by age to exposed individuals and drawn from a population similar in economic and social structure and general habits. However, it could be possible that the matched population exhibits (for not easily understandable reasons) a constantly higher death rate in respect to the whole population of the Piedmont Region. But this is not easy to verify because of the lack (so far back in the past) of regional statistical data fit for this comparison.

It may be concluded that exposed vs. controls comparison has to be taken with caution and not generalized as confidently as if no doubt would exist on control group adequacy.

However further insight, in accordance with exposed versus

Table 9. — Miners — Observed/Expected Deaths and Ratios by Cause (by Internal Comparison).

| Cause of Death | Exp. Level 1 | | Exp. Level 2 | | Exp. Level 3 | |
|---|---|---|---|---|---|---|
| | Obs./Exp. | Ratio | Obs./Exp. | Ratio | Obs./Exp. | Ratio |
| Tuberculosis (all sites except cases associated with silicosis) | 17/14.4 | 1.18 | 13/12.2 | 1.07 | 15/13.6 | 0.81 |
| Respiratory diseases (all except pulmonary tuberculosis) | 26/36.9 | 0.70* | 38/36.3 | 1.05 | 76/67.1 | 1.13* |
| Respiratory diseases, acute | 9/12.6 | 0.71 | 16/11.9 | 1.34 | 20/20.8 | 0.96 |
| Silicosis | 8/14.9 | 0.54* | 14/15.3 | 0.89 | 40/31.6 | 1.27* |
| Silico-tuberculosis | 1/4.3 | 0.23 | 6/5.1 | 1.18 | 11/8.6 | 1.28 |
| Respiratory diseases, chronic | 8/5.1 | 1.57 | 2/3.5 | 0.57 | 5/6.1 | 0.82 |
| Other infectious diseases | 4/3.8 | 1.05 | 2/3.1 | 0.65 | 7/6.2 | 1.13 |
| Malignant neoplasms | 38/31.9 | 1.19 | 28/28.3 | 0.99 | 34/39.5 | 0.86 |
| Malignant neoplasms, larynx | 1/1.5 | 0.67 | 1/1.4 | 0.71 | 4/3.1 | 1.29 |
| Malignant neoplasms, lung, bronchus and trachea | 3/2.7 | 1.11 | 1/1.9 | 0.53 | 5/4.4 | 1.14 |
| Malignant neoplasms, pleura (mesothelioma) | — | | — | | — | |
| Malignant neoplasms, oesophagus | 6/4.8 | 1.25 | 4/4.5 | 0.98 | 5/5.9 | 0.85 |
| Malignant neoplasms, stomach | 12/9.2 | 1.30 | 7/7.6 | 0.92 | 9/11.7 | 0.77 |
| Malignant neoplasms, intestine | 4/3.9 | 1.03 | 4/3.4 | 1.18 | 5/5.5 | 0.91 |
| Malignant neoplasms, liver (primary site or metastases) | 1/1.6 | 0.63 | 4/2.1 | 1.90 | 1/2.1 | 0.48 |
| Malignant neoplasms, other sites | 11/8.2 | 1.34 | 7/7.8 | 0.90 | 5/6.8 | 0.74 |
| Nervous system diseases | 3/2.8 | 1.07 | 2/2.3 | 0.87 | 4/3.9 | 1.03 |
| Cardiovascular diseases | 66/63.7 | 1.04 | 71/57.9 | 1.23+ | 71/86.2 | 0.82* |
| Digestive organs diseases | 16/14.8 | 1.08 | 12/12.7 | 0.94 | 21/21.5 | 0.98 |
| Senility | 5/4 | 1.25 | 3/2.8 | 1.07 | 4/4.9 | 0.81 |
| Accidents | 23/20.8 | 1.11 | 27/21.4 | 1.26 | 18/25.4 | 0.70 |
| All other causes | 11/7.7 | 1.43 | 4/5.2 | 0.77 | 8/9.8 | 0.82 |
| Unknown | 22 | — | 9 | — | 6 | — |

*Statistically significant at 5% level
+Statistically significant at 1% level

controls comparison, may be gained by the internal comparisons of groups of workers exposed to different cumulative dose of inhaled particles and splitting total mortality by cause.

For millers no clear dose-effect relationship shows up either for total mortality considered over time of latency, or for cause of death.

For miners the only one clear pattern emerges for respiratory causes of death: here, in spite of the lower overall mortality in the exposed group, an excess of mortality is present in the exposed versus controls comparison and as an increasing mortality with increasing dose and latency period. The trend of mortality from respiratory diseases in relation with dose and latency and the different incidence of silicosis respectively in miners and in millers, allow us to assume that inducing factor is silica rather than talc.

The deficit of tumors in the exposed in respect of controls is supported by the absence of any dose-effect pattern and is more easily interpreted as just one aspect of the lower mortality of the exposed group. The lack of lung cancer in miners is similar to that observed by several authors: Kennaway and Kennaway,[12] and more recently Goldman,[13] Ashley,[14] Enterline[15] and Liddell[16] have found a strikingly low rate of lung cancer in coal miners. Gooding[17] has found an incidence of lung cancer of 0.5% in the autopsied cases among 592 coal

**Table 10. — Millers — Observed/Expected Deaths and Ratios by Cause (by Internal Comparison).**

| Cause of Death | Exp. Level 1 | | Exp. Level 2 | | Exp. Level 3 | |
|---|---|---|---|---|---|---|
| | Obs./Exp. | Ratio | Obs./Exp. | Ratio | Obs./Exp. | Ratio |
| Tuberculosis (all sites except cases associated with silicosis) | 5/4.2 | 1.19 | 6/4.5 | 1.33 | 1/3.3 | 0.30 |
| Respiratory diseases (all except pulmonary tuberculosis) | 11/9.9 | 1.11 | 9/6.9 | 1.30 | 5/8.1 | 0.62 |
| Respiratory diseases, acute | 4/3.7 | 1.08 | 5/3.7 | 1.35 | 1/3.1 | 0.32 |
| Silicosis | 1/1.1 | 0.91 | 2/0.6 | 3.33 | -/0.9 | — |
| Silico-tuberculosis | -/0.4 | — | 1/0.9 | 1.11 | 1/0.3 | 3.33 |
| Respiratory diseases, chronic | 6/4.7 | 1.28 | 1/1.7 | 0.59 | 3/3.8 | 0.79 |
| Other infectious diseases | 2/1.1 | 1.82 | -/0.4 | — | -/0.5 | — |
| Malignant neoplasms | 18/16.5 | 1.09 | 13/9.7 | 1.34 | 11/15.6 | 0.71 |
| Malignant neoplasms, larynx | — | | — | | — | |
| Malignant neoplasms, lung, bronchus and trachea | 3/1.8 | 1.67 | 1/0.8 | 1.25 | -/1.3 | — |
| Malignant neoplasms, pleura (mesotheliona) | — | | — | | — | |
| Malignant neoplasms, oesophagus | 4/3.4 | 1.18 | 2/1 | 2.00 | 1/2.4 | 0.42 |
| Malignant neoplasms, stomach | 3/2.7 | 1.11 | 2/1.7 | 1.18 | 2/2.6 | 0.77 |
| Malignant neoplasms, intestine | 2/1.8 | 1.11 | 1/1.2 | 0.83 | 2/1.9 | 1.05 |
| Malignant neoplasms, liver (primary site or metastases) | -/2.4 | — | 3/1.9 | 1.58 | 6/4.5 | 1.33 |
| Malignant neoplasms, other sites | 6/4.4 | 1.36 | 4/3.1 | 1.29 | -/2.9 | — |
| Nervous system diseases | 2/1.5 | 1.33 | -/0.7 | — | 2/1.8 | 1.11 |
| Cardiovascular diseases | 28/26.6 | 1.05 | 20/15.2 | 1.32 | 24/30.2 | 0.79 |
| Digestive organs diseases | 7/7.3 | 0.96 | 4/4.3 | 0.93 | 9/8.7 | 1.03 |
| Senility | 2/1.8 | 1.11 | 2/1.6 | 1.25 | -/0.6 | — |
| Accidents | 15/11 | 1.36 | 7/8.3 | 0.84 | 6/8.8 | 0.68 |
| All other causes | 3/3.5 | 0.86 | 3/2.7 | 1.11 | 3/2.7 | 1.11 |
| Unknown | 9 | | — | | — | |

**Table 11. — Miners — Observed/Expected Deaths by Interval Between First Exposure and Death and by Selected Causes (by Exposed vs. Controls Comparison).**

| Cause of Death | Latency yrs. | | | | | |
|---|---|---|---|---|---|---|
| | < 20 | | 20 - 40 | | > 40 | |
| | Obs./Exp. | Ratio | Obs./Exp. | Ratio | Obs./Exp. | Ratio |
| Malignant neoplasms | 19/20.1 | 0.95 | 55/73.8 | 0.75† | 26/35.6 | 0.73* |
| Malignant neoplasms, larynx | 2/1.9 | 1.05 | 3/2.2 | 1.35 | 1/1.2 | 0.83 |
| Malignant neoplasms, lung, bronchus and trachea | 1/1.4 | 0.71 | 6/14.2 | 0.42† | 2/4.1 | 0.49 |
| Malignant neoplasms, oesophagus | 2/2.4 | 0.83 | 10/7.0 | 1.43 | 3/2.5 | 1.20 |
| Malignant neoplasms, stomach | 2/2.9 | 0.69 | 18/15.8 | 1.14 | 8/9.6 | 0.83 |
| Malignant neoplasms, intestine | 3/2.9 | 1.03 | 6/9.6 | 0.63 | 4/3.9 | 1.03 |
| Malignant neoplasms, liver (primary site or metastases) | 4/1.9 | 2.11 | 1/2.9 | 0.34 | 1/2.7 | 0.37 |
| Tuberculosis (all sites except cases associated with silicosis) | 23/28.6 | 0.71 | 20/18.8 | 1.35 | 2/2.0 | 1.00 |
| Respiratory diseases (all except pulmonary tuberculosis) | 28/23.5 | 1.19 | 76/54.4 | 1.40† | 36/23.9 | 1.51† |
| Respiratory diseases, acute | 9/11.2 | 0.80 | 34/30.8 | 1.10 | 2/2.7 | 0.74 |
| Silicosis | 11/5.4 | 2.04† | 24/12.1 | 1.98† | 27/13.4 | 2.01† |
| Silico-tuberculosis | 3/1.4 | 2.14 | 10/5.1 | 1.96† | 5/2.6 | 1.92 |
| Respiratory diseases, chronic | 5/5.5 | 0.91 | 8/6.4 | 1.25 | 2/5.2 | 0.38 |

*Statistically significant at 5% level
†Statistically significant at 1% level

miners in South Wales, while Doll,[18] in reviewing all the autopsies of male subjects in general hospitals in England, has found an autopsy lung cancer incidence of 6.2%. No risk of excess of lung cancer was detected by Waxweiler[9] examining death certificates of potash workers.

Therefore our findings are in accordance with the hypothesis that lung cancer is unrelated with underground mining, in absence of specific cancerogenic agents (radon daughters, asbestos, haematite).

Oesophagic cancer has shown an incidence in exposed groups higher than expected, although not statistically significant. This needs further studies at a more advanced status of the follow-up.

In conclusion exposure to silica in talc mines increases the risk of death from respiratory causes. No increase of risk is detectable for other causes of death in miners nor for any cause of death in talc exposed millers.

While Kleinfeld's Study provides evidence of cancerogenicity risk when talc mining or milling is a source of asbestos exposure caused by fibrous contamination, our conclusions support the thesis of no cancerogenic effect attributable to pure talc. From these considerations emerges the definite indication that adequate environmental analyses must be performed in case of exposure to talc[19] to assess the possible presence of fibrous materials contamination and to provide in this last case to an adequate prevention.

## Appendix

Results of mineral samples examinations and of environmental determinations are reported in this Appendix.

### Mineralogical Examinations

A greatly detailed report on minerals coming from the mines and the mills of Val Chisone was carried out by Dr. Pooley* in 1972. The examined samples included footwall contact rocks, rock type inclusions, carbonate, calcite and magnesite inclusions and talc specimens from mines as well as talc powders from mills. Specimens were examined by optical and electron microscopy and by x-rays diffraction.

For specific results of each examination we should refer to complete text. However, patterns emerging from the conclusions of the authors are the following:

Footwall contact rocks are mainly composed of mineral quartz, muscovite, chlorite, garnet, some carbonate material both calcite and magnesite and other materials in minor amount. Rock type inclusions in talc have similar composition to footwall rocks.

In few specimens of footwall rocks as well as in inclusions

Table 12. — Millers — Observed/Expected Deaths by Interval Between First Exposure and Death and by Selected Causes (by Exposed vs. Controls Comparison).

| Cause of Death | Latency yrs. | | | | | |
|---|---|---|---|---|---|---|
| | < 20 | | 20 - 40 | | > 40 | |
| | Obs./Exp. | Ratio | Obs./Exp. | Ratio | Obs./Exp. | Ratio |
| Malignant neoplasms | 8/9.4 | 0.85 | 24/26.1 | 0.92 | 10/10.3 | 0.97 |
| Malignant neoplasms, larynx | -/- | — | -/1.1 | — | -/- | — |
| Malignant neoplasms, lung, bronchus and trachea | -/0.5 | — | 1/1.5 | 0.67 | 3/4.5 | 0.67 |
| Malignant neoplasms, oesophagus | -/- | — | 5/4.1 | 1.22 | 2/1.1 | 1.82 |
| Malignant neoplasms, stomach | 2/2.5 | 0.80 | 2/6.0 | 0.33 | 3/2.3 | 1.30 |
| Malignant neoplasms, intestine | 3/2.5 | 1.15 | 2/2.0 | 1.00 | -/0.5 | — |
| Malignant neoplasms, liver (primary site or metastases) | 1/0.5 | 2.00 | 6/5.1 | 1.18 | 2/1.6 | 1.25 |
| Tuberculosis (all sites except cases associated with silicosis) | 6/8.9 | 0.67 | 6/4.0 | 1.50 | -/1.1 | — |
| Respiratory diseases (all except pulmonary tuberculosis) | 7/8.1 | 0.86 | 17/11.7 | 1.45* | 1/1.6 | 0.63 |
| Respiratory diseases, acute | 4/6.1 | 0.66 | 6/5.0 | 1.20 | -/0.5 | — |
| Silicosis | -/- | — | 2/1.6 | 1.25 | 1/0.5 | 2.00 |
| Silicotuberculosis | 1/0.5 | 2.00 | 1/0.5 | 2.00 | -/- | — |
| Respiratory diseases, chronic | 2/1.5 | 1.33 | 8/4.6 | 1.74 | -/0.6 | — |

*Statistically significant at 5% level

Table 13. — Dust and Fiber Count at the Various Operations in the Mines and in the Mills.

| | pre 1948 | | 1949 - 1955 | | 1956 - 1960 | | 1961 - 1965 | | 1966 - 1974 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dust count* | | Dust count* | | Dust count* | | Dust count* | | Dust count* | | Fiber count* |
| | mppcf | free silica % | mppcf | free silica % | mppcf | free silica % | mppcf | free silica % | mppcf | free silica % | fibers/ml > 5 µm length |
| Mines | | | | | | | | | | | |
| Drilling | 798 | ‡ | 602 | 14 | 49 | 17 | 11 | 18 | 3 | 12 | 0.01 |
| Mucking | 479 | ‡ | 201 | 3 | 31 | 4 | 6 | 2 | 0.8 | 2 | 0.01 |
| Carrying | 421 | ‡ | 151 | 1 | 25 | 1 | 4 | 2 | 0.8 | 1.5 | † |
| Mills | | | | | | | | | | | |
| Milling | 19 | ‡ | 12 | 2 | 8 | <1 | 8 | 1 | 2 | <1 | 0.01 |
| Pulverizing | 21 | ‡ | 19 | 2 | 14 | 1 | 9 | <1 | 5 | <1 | † |
| Bagging | 35 | ‡ | 32 | <1 | 23 | <1 | 13 | † | 8 | † | † |

*Average of mppcf in the years within each period
†Not measurable
‡Data not available

of rock and carbonate a little amount of tremolite was detected. Neither other types of anphybolic asbestos nor chrysotile were detected in any amount in rocks and in inclusions.

Talc specimens were found very commonly contaminated by chlorite. No anphybole or chrysotile minerals were detected in any of the examined talc specimens.

Free silica content in this talc is discussed: by x-ray diffraction neither Parmeggiani in 1948,[20] nor Rubino in 1963,[21] nor Pooley in 1972 have found detectable free silica amount (quartz peaks) in mineral talc powdered specimens. By contrast an x-ray diffractogram performed by Jerry Krause (Colorado School of Mines Research Institute — Personal communication in 1974) on samples of commercial Val Chisone talc powder has shown a minor amount of chlorite and quartz plus very minor to trace amount of magnesite and dolomite in addition to talc.

This could be due to some microinclusions in talc, observed also by Pooley, which, as well known, are not even detected, and then eliminated, by means as pre-milling photoelectron screening used in Val Chisone mills.

Analytical examinations conducted by Grill[22] on mineralogical composition of rock strata in Germanasca Valley have shown that is not possible to state an average value for quartz amount in footwall rocks. This value can vary in a range which is assumed by Parmeggiani in 1948[20] to be from 10 to 25%. Rubino[21] has indicated an average amount of 45% in the strata mined in 1963.

## Environmental Determinations

Environmental data were available for mines and mills since 1948. In sampling and measuring airborne particulate contaminant, termic precipitator and optical microscopy for dust count were used until 1964: these measurements were performed by the mining company.

Since that year determinations were carried out by the Department of Occupational Medicine, Turin University, using membrane collection technique and optical microscopy. Conditions in microscopy examinations were the following: enlarging 500 x, transmitted light in phase contrast for free silica, polarized and dark field for fiber count.

The trend of workroom air total dust in respirable range (0.5 - 5 $\mu$ as defined by British Medical Research Council criteria) and expressed in mppcf is visualized in Fig 1 for the whole period of observation of the exposed workers.

The trend was obtained by linking the points corresponding to the dust level in the years in which air dust determinations were carried out. As no changes modifying the environment occurred before 1950, dust level in the years 1920 - 1950 was assumed to be uniform and equal to that of 1948. The decrease of dust content from 1950 to the actual values in mines is due to the successive applications of means of technical prevention which can be summarized as follows: Period before 1950 was characterized by dry drilling and the absence of any forced ventilation system.

Since 1950 wet drilling was introduced and more widely applied in the following years.

Forced ventilatory system was applied in the years 1958 - 1959 by air introduction and consequent dilution of dust until 1963 and by complete exhaust system after that year.

It should be noted parenthetically that adoption of prevention means was encouraged by the law n. 198 of March 4, 1958 on Rules of Policy of Mines, which establish in the mines a limit of 650 particles (in the range 0.5 - 5 $\mu$) per cubic centimeter (that is 18.41 mppcf).

Actual values of dust level in the mills were obtained by successive improvement of dust suction systems.

Table 13 shows a remarkable difference of free silica amount in air dust respectively in the mines and in the mills and within the mines jobs between drilling and other operations. This is due to the high content of quartz in footwall rocks and inclusions as opposed to the absence of free silica in talc minerals.

The small amount of free silica in mills operations is due, as above mentioned, to the actual incomplete screening of talc inclusions. The same explanation could be given for the very small number of fibers in air, caused by possible microinclusions of rock containing little amount of tremolite.

*"An examination of Italian Mine Samples and Relevant Powders", J. Lightfoot, G. A. Kingston, F. D. Pooley, Department of Mineral Exploitation, University College Cardiff, 1972.

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