DOSE-RESPONSE RELATIONSHIP BETWEEN ASBESTOS EXPOSURE AND INCIDENCE OF ASBESTOSIS

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INTRODUCTION

The asbestos products of a Beijing asbestos factory include textile products, brakes, rubber, asbestos-cement and thermal insulation materials. More than 80% of the raw materials was chrysotile. Both men and women were employed. The purpose of this research was as following:

1. To study the reliability of currently used hygiene criteria of asbestos in China.
2. To provide the scientific basis for the modification of these criteria in the future.

MATERIALS AND METHODS

Beijing asbestos factory was set up by combining three small factories in the 50's. No anti-dust measures were taken at that time. All procedures were operated openly with very simple equipment; the asbestos concentration reached as high as 300 mg/m^3. Since the 1960's, the working conditions have been improved and the asbestos concentration declined greatly. At the end of 1982, 90% of the dust samples had reached the recommended standard.

The asbestos concentration in the air of workplaces was collected from 1957 to 1982. The data from 1967 to 1972 was missing; it was estimated as the average of those in 1966 and 1972. The asbestos concentration level from 1951 to 1956 was calculated as 1.5 times higher than those in 1957.

There are three types of workshops: Raw material, carding and spinning, wearing. In this study, the subjects who worked for more than 1 year were selected. They should not have any exposure history in other factories and mines. According to this criterion, 532 workers who had regular X-ray photographs were selected, among which there were 46 cases with asbestosis at stage I.

At first, the data of dust concentrations were rearranged according to the type of work, and average of the annual asbestos concentrations were estimated year by year. Secondly, for each worker who was exposed to asbestos the actual exposure duration was recorded. An adjustment was given to those who only worked in the workshops part-time, such as repairmen. At last, for each worker, the cumulative dust exposure (D) was estimated according to equation (1).

$$\text{Cumulative dust exposure (mg/year)} \approx CiTi \qquad (1)$$

where, Ci is the asbestos concentration (mg) at the working time interval, Ti is the length of the i working interval in year.

Both life table and linear regression models were used to analyze the relationship between the incidence of asbestosis and the asbestos exposure.

RESULTS

Life Table Model[3]

Table I was constructed according to the principles of life table model. Let Lx be the total number of observed workers entering the x cumulative exposure interval, Lx+a=Lx-Wx-dx; dx the number of workers who got asbestosis in this interval; Wx the number of censored; Nx the corrected number (Nx=Lx-Wx/2). Other columns in Table I are calculated by using equations (2) to (5):

$$px = dx/Nx \qquad (2)$$

$$qx = 1-px \qquad (3)$$

$$x+aQo = qoqaq2a\ldots\ldots qx \qquad (4)$$

$$x+aPo = 1-x+aQo \qquad (5)$$

where px is the probability of asbestosis in x interval

qx is the probability of not suffering from asbestosis

x+aPo is the cumulative probability

x+aQo is the cumulative probability of not suffering from asbestosis

It is shown from Table I that the probability of cumulative incidence could be 2.54% when the cumulative exposure from 0 to 199 mg/yr. It is clear that the cumulative incidence rate increases as the cumulative exposure increases. The incidence rate might rise up to 56.3% if the cumulative exposure reaches 800 mg/yr. It means that more than half of the employees will suffer from asbestosis if their cumulative exposure reached 800 mg/yr.

In order to search if there is any linear correlation between the asbestos exposure and the asbestosis incidence rate, logarithmic transformation and logit transformation were made to the columns 1 and 9 in Table I respectively (Table II). It is shown that there exists a linear correlation between the logarithm of asbestos exposures and the logit value of cumulative asbestosis incidence rate (Figure 1).

The regression line is obtained from Table II:

$$\text{Logit} = 5.08\text{LgD}-15.23 \quad (r=0.99\ P<0.05) \qquad (6)$$

Table I

Probability of Cumulative Incidence under Different Cumulative

Cumulative exposures (mg.yr) (1)	Lx (2)	Wx (3)	dx (4)	lx (5)	px (6)	qx (7)	x+aQo (8)	x+aPo (9)
0-	532	356	9	354	0.0254	0.9746	0.9746	0.0254
200-	167	62	15	136	0.1103	0.8897	0.8671	0.1329
400-	90	38	11	71	0.1549	0.8451	0.7328	0.2672
600-	41	12	3	35	0.0857	0.9143	0.6700	0.3300
800-	26	6	8	23	0.3478	0.6522	0.4370	0.5630
1000-	12	9	0	7.5	0	1.0000	0.4370	0.5630

Table II

Conversion Value from Table I

Logarithmic dose (upper limit)	* logit
2.30	-3.65
2.60	-1.87
2.78	-1.01
2.90	-0.71
3.00	0.25
3.08	0.25

*logit =Ln[P/(1-P)], P is the cumulative asbestosis rate

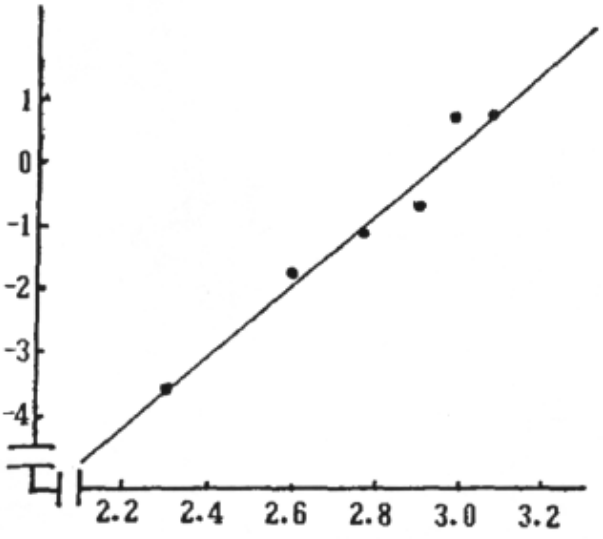

Figure 1. The correlation between logarithmic doses and logit.

Where, D is the cumulative asbestos exposure (mg/yr)

From equation (6), the conclusion could be made that the cumulative asbestosis rate will not be greater than 1% if a person worked for 40 years under the condition that the average asbestos concentration was not higher than 3.09 mg/m^3.

Regression Model[4]

This model was introduced by Dr. Tian in 1980. The principle is to translate the worker's rank into probits then by using regression model to find the relationship between the asbestosis rate and asbestos exposure. The procedure is as follows:

First to build Table III. The purpose is to illustrate the relationship between working duration (in year) and the asbestosis incidence rate among the employees. All employees were divided into two subgroups, one with asbestosis, the other without asbestosis, two equations could be given by using the least square method separately:

$$Y = 3.4806+0.1174X \quad (7)$$

$$Y = 1.9858+0.1867x \quad (8)$$

where Y is the probit
X is the working duration (in year).

Columns (2) and (3) are estimated from equations (7) and (8) respectively. Columns (4) and (5) are the reverse transformations from columns (2) and (3). The values in column (6) are calculated according to equation (9).

$$P=B/A.K.1000\% \quad (9)$$

where K is called prevalence rate of asbestosis. In the last column are the expected cumulative prevalence rates estimated from equation (10).

$$P = -11.8064+4.47X \quad (10)$$

where X is the mid-value of working duration.

Table III

Estimation of Asbestosis Prevalence Rate with Different Length of Working Time

Length of Working time X	probability units: exposed workers	probability units: workers with asbestosis stage I	cumulative frequency: exposed workers A	cumulative frequency: workers with asbestosis stage I B	P (B/A.K. 1000‰)	$\hat{P}$ (‰)
5	4.0677	2.9191	0.176	0.019	9.34	10.54
7	4.3025	3.2924	0.243	0.044	15.66	19.48
9	4.5374	3.6657	0.322	0.092	24.71	28.42
11	4.7722	4.0391	0.410	0.169	35.65	37.36
13	5.0071	4.4124	0.503	0.279	47.98	46.30
15	5.2419	4.7857	0.596	0.416	60.38	55.24
17	5.4767	5.1590	0.684	0.564	71.32	64.18
19	5.7116	5.5323	0.762	0.703	79.80	73.12
21	5.9464	5.9057	0.829	0.818	85.35	82.06
23	6.1813	6.2790	0.882	0.900	88.27	91.00
25	6.4161	6.6523	0.922	0.951	89.22	99.94

Table IV

Recommended Concentrations Under Different Models (in mg/m^3

Cumulative Prevalence	Life Table Model	Regression Model
0.005	2.26	1.83
0.010	3.09	2.19

For the 532 employees, another equation was given where the variable is working duration, and the dependent variable here is the cumulative asbestos exposure.

$$D = 23.7015 + 13.1195X \quad (11)$$

where D is the expected asbestos exposure, X is working duration.

By combination of equations (10) and (11), the temporal variable working duration will be eliminated, we get equation (12) which reveals the relationship between the cumulative prevalence rate and the cumulative asbestos exposure.

$$D = 58.3668 + 2.9350P \quad (12)$$

Equation (12) could be used to estimate the recommended criteria for asbestos concentration (Table IV).

The recommended concentration is defined in such a way that the probability of asbestosis for the employees who have worked for 40 years under this concentration will not precede 0.5% or 1%.

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