

Bertram Price
Richard Wilson

Department of Physics and Energy and Environmental Policy Center
Harvard University
Cambridge, 02138, MA

Risk assessment for Asbestos and Management of Low Levels

Introduction: Medical Effects of Asbestos

There are a number of medical effects of asbestos with different locations (see figure 1) which will be discussed in more detail below.

- (1) Benign conditions of the pleura, and in particular pleural plaques.
- (2) Asbestosis. Observed as early as 1906 by Auribault it was defined as fibrosis of the lung caused by asbestos dust, and first called asbestos silicosis. It was only defined as a separate disease after use of X rays became usual. According to Doll and Peto (1982) the disease is indistinguishable from a rare "cryptogenic fibrosing alveolitis", although asbestosis is usually assumed if there has been evidence of exposure, simply from a weighing of probabilities. There is in the literature some confusion as to what is to be called asbestosis. Most reserve the term for interstitial fibrosis; others have separated pathological reactions in the respiratory bronchioles and alveolar ducts, and called them small airways disease. This distinction is useful, because the small airways disease can be caused by a wide variety of nonasbestos minerals, silica etc., which do not cause interstitial fibrosis, or at least not frequently. (Churg 1983)
- (3) Lung Cancer. (Bronchial carcinoma)
- (4) Mesothelioma of the pleura or peritoneum.
- (5) Other cancers. A number of other cancers have been suggested by Selikoff et al (1979) as being caused by asbestos.. Few of these other cancers have been reliably attributed to asbestos, and even if they occur, are negligible additions to the risk.

The Risk Assessments

- (1) Benign conditions of the pleura may cause temporary problems, but are not usually considered a danger at all. They are often asymptomatic, however they are considered as indicators of exposure (but not of risk), but are not definitive ones in all cases. (Churg 1982,1983), (Hillerdahl 1978).
- (2) The risk assessment for asbestosis is very simple. It seems to appear only after heavy accumulated exposure, and seems to have a threshold-type effect. If exposure is low, the accumulated dose will never exceed the threshold. This is shown, for example in figure 2. The threshold is higher than any environmental or occupational level of present concern, so details are of no present interest.
- (3) The risk of lung cancer is always assessed on the basis of historical experience. The

procedure is, in principle, simple. One finds a cohort of people exposed to a definite quantity of asbestos, and asks what, if any is the incidence of lung cancer compared to the incidence in a group of unexposed people who are otherwise similar. The ratio of incidence is called the Risk Ratio, and if greater than unity indicates a carcinogenic effect. The Risk attributable to asbestos that a group of people similarly exposed would undergo (often called the excess risk) is equal to the (Risk Ratio - 1), multiplied by the natural incidence.

Problems arise in determining the exposure (defined as the concentration multiplied by the occupancy) of the people in the cohort, and even worse of determining the dose (the amount of asbestos that enters the lung). Different studies do not agree. There are also issues about what parameters of the dose are relevant, and whether all forms of asbestos are the same. Rather than discuss these in detail, I merely refer to a risk assessment carried out for the EPA by William Nicholson. This calculation agrees with numerical calculations of other authors, provided similar assumptions are made (Hughes and Weill 1986)

For lung cancer Nicholson assumes (following the work of Selikoff and Seidman (19xx) that lung cancers begin to appear 20 years after start of exposure but cease 40 years after exposure. He assumes that in the study cohort that exposure was at the low end of what was reasonable, and therefore derives a higher risk than many authors. He assumes a linear (proportional) relationship between exposure (or dose) and response. He assumes that the relevant parameter of exposure is the exposure averaged over a long period - of the order of years rather than minutes, and then corrects for the fact that people were exposed occupationally for only a portion of the day. He does not distinguish between smokers and nonsmokers and therefore his risk is applicable to a mix of persons (roughly half smokers and half non-smokers). He then presents a risk in tabular form for each age group and exposure period.

(4) For risks of mesothelioma, I also take the calculations of Nicholson. However, for mesothelioma the latent period is longer. Nicholson used a formula developed by Peto et al. (1982) and fitted to the data that describes the fact that mesotheliomas appear 30 years after exposure and go on appearing till death from other causes. There seems to be no indication that mesothelioma risk depends upon smoking history. For non-smokers, and particularly for children, it dominates the calculated risk.

Assumption of Low dose linearity

The actual data on lung cancers or mesotheliomas caused by asbestos arise from workplace exposure, with concentrations in the workplace of 1 fiber per millilitre of air and above. This is roughly equivalent to continuous exposure to a concentration of 0.1 fibers per millilitre and above. It is important to realise that any assumption of a risk at concentrations below this, does not rely upon direct data, but upon an INTERPOLATION (often, even usually erroneously called an EXTRAPOLATION) between the cancer incidence at the lowest measured increase and cancer incidence at zero concentration.

Before 1980, most authorities were willing to state that there was a non-linear dose-response relationship or a threshold. A good review of the theories and of the data about dose-response relationships for carcinogens generally has been written by Zeise et al (1987). Enterline (1981) discusses possible dose-response relationships for asbestos related cancer in some generality, explaining how, in

proceeding from data in occupational settings, one might, with various assumptions, derive a prediction for the lower doses of environmental settings. Included in this discussion was a model that he had used earlier (Enterline 1976) with a dose-response relationship which is linear, but with time-to-tumor increasing as the dose decreased. Druckery had seen this increase of latency for animal bioassay of several chemicals, and Davies (1985) had observed it for mesothelioma following peritoneal infection of asbestos in rats. Jones and Grendon (1975) had suggested a formula for risk based on these observations. This procedure leads to an effective nonlinearity at low doses. Mehir et al (1978) describe the procedure of the Consumer Products Safety Commission which followed the same method. Since then, the CPSC changed its' policy (CPSC 1983) and now all authorities assume a dose-response relationship which is linear at low doses, without any modifications because of a varying time to tumor.

At the time of the report of Mehir et al (1978) one of us was starting a campaign among scientists in industry to persuade them to calculate risks for carcinogens using a linear dose-response relationship. There were several reasons for this. It is possible that the linear relationship is correct and many academic scientists believe so. It seemed to me unwise for industrial leaders to take a rigid position where there were many academic scientists "on the other side". Peto (1979), an academic scientist, was arguing for a linear dose response relationship for asbestos. It was also clear that very shortly scientists in the regulatory agencies would use it, largely because they perceived it to be their duty "to be on the safe side." Indeed, in 1984 a committee of the National Academy of Sciences stated, "This assumption may not always be justified in application ... but it should lead to an appropriate upper bound for the committee's risk assessments for asbestos. Furthermore, and more importantly, ruling out a linear dose term for exposure does not seem justified by the data now available." Doll and Peto (1984), while adhering to the appropriateness of a linear dose-response relationship for public policy purposes, point out that there is no model for asbestos carcinogenesis that is as plausible as the model for cancer produced by mutagens for which a linear dose-response relationship is strongly suggested. However, this does not mean that the linear dose-response relationship can be proven correct, and as noted above, there can be no direct data on this question.

The idea that asbestosis might exhibit a threshold and lung cancer might not is not new. But a crucial question is the mechanism. Thus the Chief Inspector of Factories in the UK asked "Does silica or asbestos or the fibrosis of the lung they produce tend to inhibit cancer of the lung or to produce it? If the latter, do either of these two substances act as specific carcinogenic agents like tar, or is it that the disease they produce only prepares the soil for the occurrence of cancer? ... With asbestosis, among 103 fatal cases in which asbestosis or asbestosis with tuberculosis were present, cancer of the lung was associated in 12 cases (11.6%)" (Merewether 1938).

This is not an empty question even now, for it bears upon the "prior" belief of a scientist about the dose response relationship for asbestos-related lung cancers. We say here "prior" belief, because it is the belief before there exist any direct data; and at the doses of public concern today (0.01 fibers/cc or less) there can be no direct data. If asbestosis is a necessary precursor to lung cancer, then the dose response relationship for lung cancer would be expected to be the same as that for asbestosis and most scientists believe the dose-response for asbestosis to follow a threshold. Then the risk at doses of present concern is not merely small, but zero. If on the other hand lung cancer can arise where there is no asbestosis, a linear

dose-response relationship is possible, even though there is no direct data to prove any response in the dose region of interest. Unfortunately the question remains unanswered today, although some authors are willing to give the answer YES, asbestosis is a necessary condition for lung cancer (Browne 1986, Weill 198x), and thereby to imply that there is a threshold for lung cancer and no risk at all at the low exposures and doses of present concern.

Sine the issue of linearity or non linearity is a matter of expert judgement, expert elicitation may be appropriate. A preliminary attempt at such a study has been done by D'Agostino and Wilson (1990). We note that they failed to find anyone who believed that the Nicholson calculation is an underestimate of risk.

But even if linearity is assumed, the distinction between a situation where there is a measured small risk at low exposures (such as a risk of being run down by a car even on an almost deserted road) and a risk that is merely calculated may be important for some societal problems. Indeed Crawford and Wilson (1995) argue that a low dose linearity can be calculated for a very large number of societal issues, of which asbestos may not be the most important. Here we argue that an individual. Was a company acting responsibly in installing asbestos in a school in 1955, and should they be responsible for taking it out in 1988? A company should be cautious about health effects, but they could not reasonably be asked to predict vagaries of the regulatory agencies.

If it can be justified that the levels of asbestos in schools were not believed to cause a hazard in 1955, and even now, if the risk is small enough that the hazard is not large and not imminent, then the actions of the companies in 1955 were not unreasonable. There is another reason for choosing a linear dose-response for base-line risk estimations. The appropriate measure of concentration is, in all linear models, the long-term average. This remains an upper bound in other models. Then it becomes unnecessary to make special allowance for occasional exposures to high concentrations, provided that the average concentration is properly estimated. This is important for addressing the concern of Selikoff (1990) and Brody (1990) about intermittent high exposures of maintenance workers.

Are all fibers the same?

This question is all important for understanding the mechanism of asbestos related health effects, but here we merely assume that only fibers of length greater than 5 μm and with aspect ratio, length/diameter greater than 5 can cause cancer (Lippmann 1988). There are some scientists (Langer and Nolan 1988) who argue that chrysotile asbestos is less potent than other types such as crocidolite in causing lung cancer, but others contest this (Nicholson 199x). We therefore pessimistically assume that Nicholsons tables for lung cancer apply to chrysotile as well as to other types of asbestos. But chrysotile asbestos seems to be less potent both in producing mesothelioma than other types of asbestos such as crocidolite. This is shown in Table IV from Peto (1981).

The reason for this reduction is less clear than the effect itself, but it is generally considered to be due to a shorter clearance time for chrysotile fibers in the lung, so that the ratio of dose to exposure is less.

Risk at low doses
Example of a detailed calculation:
the risk of school exposure

The present public interest is in reducing the risk at low doses. Recently public policy has been addressed primarily to exposure in schools which has raised a lot of emotion. We therefore make a calculation for a "typical" school, in which chrysotile asbestos was used for fire retardant or thermal insulation. In this calculation, we will use the calculations of Nicholson for the EPA (1985) and especially his table 6.3. However, we note several important assumptions made by Nicholson.

Table 6.3 is calculated for continuous exposure, whereas exposure in a school is only for part of the day. We assume that in a typical school the exposure of the children to asbestos occurs during 6 hours per day, and 150 days per year. This is 1/10 of the total hours in the year. We assume that this is for the ten year period 6 to 16 years. The exposure for a teacher we assume to be for a thirty year period age 25 to 55. In the absence of specific reliable measurements for the school, we take the reports on measurements of concentrations in schools by Crump (1990), Corn (1991) or McCrone (1991) that concentrations in schools are 0.0002 fibers/ml.

Following the suggestion of Doll and Peto, we might allow a factor of 5 reduction of mesothelioma risk if chrysotile is used, but since the correct reduction factor may be much more, we may still be overestimating the risk. We assume as Nicholson does, that there is a linear dose-response relationship at low doses.

The table does not differentiate between smokers and nonsmokers. For the adults, we assume that his male risk is doubled for smokers, and is negligible for nonsmokers.

Table I

Typical lifetime risk due to asbestos in a school.

Based upon Nicholson's table 6-3 and (where noted) a modified average school-time exposure to chrysotile at 0.0002 fibers/ml (fibers greater than 5 microns):

	Age group	Lifetime Risk
Mesothelioma risk to females	10-15	1 X 10 ⁻⁶
	0-5	1.6 X 10 ⁻⁶
Interpolated age group	6-16	2.4 X 10 ⁻⁶
Adjusted for chrysotile only (the reduction by a factor of 5 noted in the text)	6-16	5 X 10 ⁻⁷
Mesothelioma risk to males	10-15	6 X 10 ⁻⁷
	0-5	1 X 10 ⁻⁶
Interpolated age group	6-16	1.6 X 10 ⁻⁶
Adjusted for chrysotile only	6-16	3 X 10 ⁻⁷
Mesothelioma risk any asbestos	25-55	3 X 10 ⁻⁶
Adjusted for chrysotile only	25-55	6 X 10 ⁻⁷
Lung cancer risk (smoker)	25-55	4 X 10 ⁻⁶
Lung cancer risk (non-smoker)	25-55	4 X 10 ⁻⁷
Risk if there is a threshold at 0.1 f/ml	0	

We deliberately refrain from calculating the risk for smoking children because of our belief that there should be no children who smoke, and that public policy analysts should consider the problems of any who do in a different way than the problems of those who do not.

These risks are smaller than the risks that people regularly accept such as automobile driving (200 X 10⁻⁶ per year or 15,000 X 10⁻⁶ per lifetime). Some people reject such a comparison because automobile driving is voluntary, but the average risk for pedestrians killed by automobile driving of 2,000 X 10⁻⁶ per lifetime is surely involuntary. So also is the risk of drinking chlorinated surface water in a typical US city. This is 200 X 10⁻⁶ calculated by the EPA methodology which may be expected to be as conservative, but no more conservative than the calculations here. It is also smaller than the risk of childhood death among blacks and minority groups (5 X 10⁻²), to which many people believe that society should preferentially pay attention. This comparison may be taken as partial justification for the statements of many persons quoted earlier that a concentration of 0.01 fiber/cc is safe.

This conservative risk calculation has led many persons to state that there is, in most cases, no risk from installed asbestos in good condition, left in place. While conceding this, Selikoff (1990a) has pointed out the importance of ensuring that maintenance workers do not suffer greatly increased risks. This presumably means especial attention to exposures, just as maintenance workers already have to pay

especial attention to other risks such as those of electrocution. Unfortunately it is not as easy to monitor average asbestos exposure as it is, for example, to monitor radiation exposure by means of a "film-badge". Attention to development of a simple portable monitor for workers would seem to be important. In a recent report, Selikoff (1990b) has studied custodians in NY schools. He finds a large number of plaques and suggests that these may indicate asbestos exposure. As noted earlier, (Churg 1982,1983) these may not be good indicators, and further work is necessary before such indicators can be accepted.

Population Integrated Exposure

It has been assumed by advisory and regulatory bodies for 70 years that ionizing radiation follows a linear (proportional) dose response and that radiation exposure to a population should be reduced to As Low As Reasonably Achievable. Individual exposures are to be kept below natural background, and if there are a large number of people exposed, an integrated population exposure in Man-Rem, now more correctly person-Sievert, is calculated. In 1974 after a two year long public hearing the Nuclear Regulatory Commission (RM-30-2 and copied in federal regulations 10 CFR 50, appendix I) ruled that if integrated exposures could be reduced for a cost of \$1000 per Man rem (\$100,000 per person Sv) the expenditure should be made. More recently this figure has been doubled to account for inflation (Kress 1995). On a linear dose response relationship this corresponds to about \$4,000,000 per calculated life saved. Other organizations have used cost benefit analysis, often for situations (automobile safety) where a linear dose response relationship is more certain. These situations have been reviewed by Guenther and Thein (1997) who find an average "Willingness To Pay (WTP)" of \$4,000,000 per calculated life saved. We suggest here that this concept be used for asbestos exposures.

It is important to realize that background exposures are large. In the USA they are about 0.3 Rem = 0.003 Sv of which radon gas in buildings forms the largest part. Thus 250 million Americans have an integrated population exposure of 75 million Man Rems or 750,000 person Sv. The rule suggests that if that background can be eliminated (which it cannot) it would be worth an expenditure of \$150 billion. We spend far less than this even are exposed to

In order to illustrate how this might work, we assume the above school where 500 children, 250 males and 250 females are exposed for the 50 year life of the school buildings. 5 groups of children will spend 10 years there. Then the probability that ONE will develop mesothelioma in the 50 year period becomes:

$$5 \times 250 (2.4 + 1.6) \times 10^{-6} = 5 \times 10^5 \times 10^{-3} \text{ or } 1 \times 10^{-3} \text{ if a 5 fold reduction for chrysotile is assumed.}$$

5/3 groups of 30 adults will be in the school, and if we pessimistically assume that they are smokers, the probability that one will get lung cancer FROM THIS CAUSE in the 50 year period is

$$5/3 \times 30 \times 4 \times 10^{-6} = 2 \times 10^{-4}. \text{ This is 10times less for nonsmokers.}$$

At a cost to save a calculated life of \$4,000,000 per calculated life, the TOTAL amount that is justified to spend to reduce this concentration to zero before the building reaches the end of its natural 50 year life is:

$$(\$5 \times 10^{-3} + 2 \times 10^{-4}) \times 4,000,000 = \$20,800.$$

If the 5 fold reduction for chrysotile is assumed this reduces to \$4,800. If the sum is discounted over the period before any mesothelioma is diagnosed, the number is less. If there is a threshold nothing should be spent. Any amount spent in excess of this would be a societal misallocation of resources.

We see at once that this number is dominated by the possibility of mesothelioma in children. The societal preoccupation with the risk to children is to this extent justified, and it becomes important to be sure that we truly understand the model that extends the data to the children.

Long-term risk of worldwide asbestos use.

One of the advantages of asbestos is that it is chemically stable and does not disintegrate. One of the disadvantages is that it is stable and lasts a long time! Further, large asbestos fibers in the environment, perhaps with too large a diameter to be airborne and cause health problems, can split into many fibers with small diameters in the environment. This leads to a fear that continued mining of asbestos can lead to a buildup of asbestos fibers with dangerous shapes and sizes in the environment. If this is coupled with a belief in a linear dose response relationship, predictions can be made of steadily rising background cancers from this cause.

This concern is far from unique to asbestos; it follows for any stable material, e.g. arsenic, which is stable, and for which a linear dose response relationship is suggested. These predictions lead to intense pressure for an absolute ban, even if it can be shown that occupational exposures, and exposures in buildings, can be kept low. It is impossible to disprove, in advance, the reality of such a concern for any material. However, there is no large increase of asbestos levels in rural communities and in urban communities increases seem to be concentrated at busy intersections where automobile brakes are widely used. Background levels of mesothelioma have shown no increase among females, and the small increase among males is attributed to occupational exposures. It can therefore be argued that this problem is hypothetical, and while monitoring might be appropriate, most remedial actions could be deferred without possibility of disaster. Finally we note that chrysotile asbestos is soluble in dilute acids, and asbestos in the environment tends to be comprised of short fibers which are less carcinogenic.

Probability of causation

Often, when there is a victim of bronchial carcinoma, or of mesothelioma, or of asbestosis or someone who has pleural plaques, the question arises, what is the probability that his/her condition was caused by asbestos exposure, and in particular, is it greater than 50% often demanded by law to allow attribution of blame? The answer to this question comes from a weighing of probabilities. The usual approximate formula is that the probability of causation is the risk calculated as above, divided by the probability of developing the same disease from all other causes.

The attribution of bronchial carcinoma to asbestos is much harder, because of the synergism with tobacco. It is simple enough to attribute any bronchial carcinoma in a non smoker to asbestos if there is any history of asbestos exposure. As noted above, mesothelioma is so rare, that anyone who develops mesothelioma, and has been exposed to asbestos, is usually assumed to have developed it from asbestos exposure. Using the above formula for probability of causation calculation, one divides a small number, the probability of getting mesothelioma from asbestos exposure, by the probability of getting mesothelioma from all causes, and get close to 100%. If the cancer appears within 10 years after exposure, however, this must be questioned. I also note that in a small village in Turkey, there are several cases of mesothelioma, and

these are normally attributed to erionite, a local building material of fibrous nature. (Baris et al 1988) Again, fibrosis of the lung would normally be attributed to asbestos if there is any history of exposure, for the same reason. But for a smoker it is even unclear what attribution means since synergism is present. Should one divide the risk for a non smoking asbestos worker by the risk from other causes, dominantly cigarettes? If so, it will always be less than 50%. Or should one divide the risk for a smoking asbestos worker by the risk to a smoker from all causes, which could then often be greater than 50%? We note here that Johns Mansville has gone bankrupt and not Philip Morris, a fact that indicates the way the courts have viewed these matters (whether by calculation or ignorance we do not presume to know). A description of this attitude can be found in Brodeur (1985). However, if we try to apportion blame, cigarette smoking is 5 times as much to blame for these lung cancers as asbestos.

Risks caused by other fibers

Although we do not claim to be angels, risk assessors often walk where others fear to tread. In this paragraph we address the risk due to exposure to an alternative fiber, the man-made fiber, fiberglass. In doing this we explore the consequences of the assumption that for equal sizes of fiber, and after any correction for clearance time, fiberglass is as potent in producing each of the ailments caused by asbestos as asbestos itself. What is the risk, and what precautions should we take to reduce it? Unless we ask this question, we will fail to learn from the history of asbestos use and we will be condemned to repeat it. A whole journal once was addressed to this problem of man made fibers (Walton 1987).

It is evident that fiberglass is not used as carelessly as was asbestos. No one sprays it on. Unlike asbestos, fiberglass is not held in place by gypsum, which is subject to deterioration. We must ensure that this is always the case; that fiberglass batts are secure batts, and do not deteriorate. We also note that it is possible and easy to make fiberglass with any dimension of fibers we choose; in particular with a large enough diameter that effects are unlikely. These seem obvious criteria; but we know of no public health authority that watches these matters; no regulation or standard for proper installation of fiberglass, and no studies which confirm or deny our supposition that the fibers are less likely to reach the environment than are the fibers of asbestos. Until these are done, the claim can correctly be made, as we have heard it made by more than one expert in the health effect of asbestos: "there exists no substitute for chrysotile asbestos, properly applied, that is known to be as safe".

Acknowledgements

We acknowledge helpful discussions with many scientists and in particular with Drs. Langer, Nolan and Peto.

References

Albelda SM, DM Epstein, WB Geftter and WT Miller (1982), "Pleural thickening; its' significance and relationship to asbestos exposure", AM Rev Respir Dis, 126, 621-624

Baris YI, Sahin A, et al (1978) "An outbreak of pleural mesothelioma and chronic fibrosing pleurisy in the village of Karain/Unque in Australia", *Thorax* 33, (8)

Breslow L (Chairman) et al, 1984, "Asbestiform Fibers: non occupational health risks" National Academy of Sciences.

Brodeur P. (1985) "The asbestos industry on trial" *The New Yorker Magazine*, June 10th, 17th, 24th, and July 1st

Brody A.R. (1990) "Asbestos, carcinogenicity, and public policy" *Science*, 248, 795 (letter)

Browne K. (1986) "Is Asbestos or Asbestosis the cause of the increased risk of lung cancer in asbestos workers?" (Editorial) *British Journal of Industrial Medicine*, 43, 145-149

Craighead JE (1987) "Eyes for the Epidemiologist: the pathologists role in shaping our understanding of the asbestos-associated diseases " HP Smith Award lecture *Amer. Journ. Clin. Path.* 89, 281

Churg A. (1982) "Asbestos fibers and pleural plaques in a general autopsy population" *Amer Journal Pathology*, 109, 88-96

Churg A. (1983) "Current issues in the pathologic and mineralogic diagnosis of asbestos-induced disease" *Chest*, 84 no 3, 275-280

Churg A and Green FHY, Eds., (1987) "Pathology of occupational lung disease" Igaku-shoin, NY and Tokyo, pp234-246

Churg A (1988) private communication

McDonald J.C. (1980) "Asbestos related disease:an epidemiological review" in *Biological effects of mineral fibers*, vol 2 ed JC Wagner, IARC scientific publications, Lyon France 30,590

CPSC (1983) "Chronic hazards advisory panel on asbestos", Consumer Products Safety Commission, Division of Health Sciences, July.

Crump K.S. (1990) "Asbestos, carcinogenicity and public policy" *Science*, 248,799 (letter)

Davies JMG (1985) "A review of recent experiments on the mechanisms of asbestos pathogenicity" In proceedings of Vth international colloquium on dust measuring technique and strategy Asbestos International Association p. 25

Doll R (1955) "Mortality from lung cancer in asbestos workers" *Brit J Ind Med* 12, 81-86

Doll R and Peto J (1982) "Effects on health of exposure to asbestos" Health and Safety Commission, London (Her Majesty's Stationary Office)

Dupre et al (1984) "Report of the Royal Commission on matters of health and safety arising from the use of asbestos in Ontario" Ontario ministry of Public services, 880 Bay St Toronto, Ontario, Canada

.
H.Druckrey, R.Preussmann, S.Ivankovic und D.Schmahl AOrganotrope carcinogene Wirkung bei 65 verschiedenen N-Nitroso- Verbindungen an BD-Ratten @Zeitschrift für Krebsforschung 69:103-201;1967