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Public Health Risks of Exposure to Asbestos

Report of a Working Group of Experts prepared for the Commission of the European Communities, Directorate-General for Social Affairs, Health and Safety Directorate

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PUBLIC HEALTH RISKS
OF
EXPOSURE TO ASBESTOS

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PUBLIC HEALTH RISKS OF EXPOSURE TO ASBESTOS

Report of a Working Group of Experts
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Health and Safety Directorate

Rapporteur
Professor R. L. ZIELHUIS

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Preface

The Programme of Action of the European Communities on the Environment requires that an objective evaluation of the risks to human health and the environment from pollution is carried out. This necessitates the compilation of as complete a bibliography as possible on the effects of the pollutants under consideration and a critical analysis of this information so that for certain of these pollutants, criteria (exposure/effect relationships) can be determined.

In this Programme of Action a list of pollutants was drawn up for priority investigation. These pollutants were chosen on the grounds of their toxicity and of the current state of knowledge of their significance in the health and ecological fields. Asbestos is included in this list.

This work has been undertaken by the Health and Safety Directorate of the Directorate General for Social Affairs. Meetings of the group of experts directed by the Health and Safety Directorate have discussed this report and agreed its contents. This report, for which the principal rapporteur was Professor R.L. Zielhuis is therefore the reference document on which a report to the Council of Ministers will be made.

P. Recht
Director of Safety and Health Directorate
Commission of the European Communities

INTRODUCTION

The principal rapporteur was R.L. Zielhuis, Coronel Laboratory, University of Amsterdam, the Netherlands, who acted on behalf of a group of colleagues. The group consisted of the following members: K. Biersteker (physician), C.H.J. Elzenga (engineer), A.R. Kolff van Oosterwijk (engineer), P.B. Meyer (engineer), H.T. Planteijdt (physician), J. Stumphius (physician), R.L. Zielhuis (physician).

The guidelines only refer to public health, and not to occupational health, plants, animals or materials. Therefore this report only discusses the facts as far as they are relevant for the objective stated.

There has been an enormous output of data on asbestos in the last decennium: technical, experimental and epidemiological. A choice had to be made from those data which appeared relevant for guidelines serving to protect public health. Data on pathogenetic mechanisms, mainly based upon animal experiments, have been largely omitted. Existing epidemiological data mainly refer to occupational health; these have only been reviewed in a general sense, in order to indicate the possibilities of health effects in overexposure (intensity, duration), and to portray the maximum potential hazards from the viewpoints of public health.

At a meeting in Luxembourg November 11 and 12, 1975, an interim report was extensively discussed (see Acknowledgment). In addition workshops were convened to discuss specific points and the conclusions of these have been included in the text.

Several participants in the November meeting sent in written comments. As far as possible, these valuable comments have been incorporated in the present report.

The rapporteurs wish to express their sincere thanks to Mrs. M.van der Aa-de Bruin for her extensive secretarial help, to Mrs. M. van de Poel-Bot for her most important documentary work, to Miss M.A. de Graaf for drawing a few diagrams and to Mr.A. Tollenaar for his help in bringing the report in its present shape; without their great cooperation the work could not have been carried out.

SUMMARY

This report contains in 14 chapters a preparatory study basic for the setting of guidelines for asbestos exposure, as regards public health. It has been written by seven Dutch specialists in a collaborative effort.

Chapter I presents a review on the types of asbestos, and on physical and chemical properties.

Asbestos refers to a group of inorganic silicates which occur naturally and have a distinct fibrous crystalline structure, which is largely responsible for its unique properties: tensile strength, stiffness, heat resistance, and ability to split into finer fibres.

The usage of asbestos and asbestos-containing materials in the EEC is discussed in Chapter II.

Mining only occurs in Italy. In Western Germany, however, asbestos fibre is produced from imported concentrate. The main fields of application are in industries such as building, construction, engineering and ship building; in addition to these main fields there are many other outlets. A list of goods in which asbestos is incorporated is given. Asbestos content as such is not necessarily an indication of health risk: only where asbestos fibres are set free does such a health risk potentially exist. The estimated asbestos fibre production within the EEC is about 130.000 tons/year, the estimated consumption however is over 800.000 tons/year. The usage of asbestos fibres in asbestos cement products makes easily the largest contribution; however many other products exist in considerable amounts and variety. Also of importance are transportation, demolition, removal and storage of waste. There has been a tremendous growth in usage over the past decades, although in the last few years the growth trend has declined.

Several possibilities of exposure can be distinguished (Chapter III) : 1a. direct occupational exposure; 1b. indirect occupational exposure (for workers in vicinity of asbestos contamined work situations); 1c. occupational exposure in agriculture; 2a. para-occupational domestic exposure to members of household; 2b. para-occupational exposure through leisure time activities; 3. neighbourhood exposure: vicinity of asbestos mines, textile factories, etc.; 4. true environmental exposure through ambient air, food, water, beverages, etc., representing the true public health hazard. The distinction between the various possibilities of exposure is not sharp, and is more quantitative than qualitative. Occupation and occupation related conditions determine the main hazard of exposure. Because of this lack of distinction and the possibility of combined or subsequent exposure, greater reliance should be put on biological monitoring, i.e. measuring the lung burden, than on measuring concentrations in air, food, etc. In-depth history taking may elucidate that asbestos-related diseases, particularly tumours, up till now regarded as evidence of true environmental exposure, may in fact be caused by unexpected and insufficiently explored possibilities of (para-) occupational exposure.

Chapter IV reviews the methods of sampling and detection of asbestos in air, food and water. The state of the art allows only very general guidelines; rapid development of several methods is occurring but lack of standardisation, inadequate experience and data are still prominent features. Sampled asbestos has to be separated from the carrier medium; for air this is done by high efficiency filtration, electrostatic precipitation, and thermal precipitation; for water mainly by ultracentrifugation and filtration. At this moment the most reliable method of obtaining qualitative and quantitative information on the "asbestos burden" is examination of the mineral content of the lung.

Qualitative and quantitative determinations follow two approaches: 1a. morphological recognition followed by identification of a selected number of fibres with optical crystallographical methods using polarisation microscopy or dispersion staining techniques; or 1b. electron diffraction as part of an electron microscopic investigation; 1a. has the lowest detection limit, largest reproducability and requires least time; these methods are characterised by an extremely high sensitivity and resolution but are cumbersome,

tedious and costly. 2. techniques which determine all the asbestos in the sample at the same time; 2a X-ray diffraction or 2b infrared spectroscopy; these methods are convenient but the minimum amount of asbestos which can be determined is in the µg range, while the asbestos percentage in the sample should not be lower than 1% weight.

Due to the small size of asbestos fibres in the ambient environment electronmicroscopy plays an important role; large magnifications have to be used, resulting in relatively rough estimates of asbestos content. For the ambient environment there is a growing tendency to report data in weight concentrations, as there is a tendency for larger fibres to fall apart into small fibrils during assessment. For occupational conditions,numbers of fibres/ml air are to be preferred. Without information on fibre size distribution, weight/volume data cannot be converted into fibre/volume data and vice versa.

In Chapter V exposure levels in the ambient environment are given, as far as they are available. However there is still little known about the actual occurrence of asbestos. The concentration of asbestos fibres in ambient air is found generally up to 10^{-9} g/m^3, except in the neighbourhood of asbestos processing industries. The fibres have a length between 0.1 and 1 µm and a diameter 0.02-0.1 µm. Concentrations in beverages have been reported to be 1.1-12.2 x 10^6f/l. In raw water sources (Canada,USA) concentrations ranged from 173 x 10^6f/l (polluted) to 3 x 10^3f/l (unpolluted). Concentrations in drinking water range from 100 x 10^6f/l (USA, polluted) to 0.1 x 10^6 - 9.5 x 10^6f/l in supply systems from ground and surface waters. 0.001-1.69 µg/l have been reported in several distribution systems in USA. In the Netherlands asbestos fibre counts in drinking water from asbestos cement watermains range from 0.06 x 10^6 - 0.24 x 10^6f/l. Due to the fact that classification of the relation between fibre size and health risk is central to the problem, reporting of fibre dimensions in addition to concentration is imperative.

In practice asbestos enters the human body predominantly through two pathways (Chapter VI). Uptake through the respiratory tract is facilitated by the property of asbestos of splitting up into numerous fibres with very small diameters: passage is highly related to diameter and much less to fibre lenght.

Uptake through the digestive tract occurs either directly or indirectly (ingested sputum). Fibres will reach deep lung tissue and pleura and pass through to lymph nodes and spleen; the possibility of penetration of the intestinal wall is still questionable; it certainly is much less than from the lung. Amphibole fibres reach lung tissue and pleura more efficiently than chrysotile, and clearance is less efficient, particularly for diameters below $\leq 3\mu$, particularly $<1\mu$, with length-diameter ratio >10; such fibres are biologically most important, and particularly responsible for health effects. Those mineral fibres other than asbestos which have a similar physical shape will behave like asbestos, and so may induce similar effects; in practice however, most non-asbestos mineral fibres have a larger diameter. If improved technology is going to produce increasingly thinner mineral fibres, the risk for health effects may increase. In monitoring ambient air one has to concentrate on determining the quantitative and qualitative concentrations, the size distribution and the chemical composition of all mineral fibres.

Because health effects occur after long term exposure to a variety of sources (occupational, para-occupational, etc.), with a large variability in concentration, size distribution, etc. it is not possible to measure the long term dosage adequately. Therefore it is more feasible to estimate the dose indirectly by means of biological monitoring (Chapter VII). This can be done by demonstrating asbestos fibres or asbestos bodies (fibres surrounded by protein and iron coating) in the human body, particularly the lung, or its excreta, e.g. sputum. For demonstration of fibres, electronmicroscopy combined with electron diffraction should be applied; light microscope and phasecontrast microscopy do not elucidate fibres $<5\mu$, and so may highly underestimate the presence of possibly biologically effective submicroscopic fibres. It has been frequently established that in lungs of the non-occupationally exposed population asbestos bodies are present, more so in urbanised and industrialized than in rural communities; the prevalence presents a fair indicator of past asbestos exposure; the figures found are highly dependant on the techniques applied. It is also possible to estimate past asbestos exposure through measuring the prevalence of health effects, e.g. asbestos-related tumours. Occurrence of asbestos fibres and bodies present evidence of past exposure, the occurrence of health effects evidence of response. Effective indicators should occur early and be harmless from the view

point of health; so, only the presence of fibres and bodies and to a lesser extent - not being early responses - of plaques, may serve as practicable indicators of past exposure.

Because health effects predominantly occur in (para-)occupational exposure, and because the estimation of the public health risk to a large extent depends upon extrapolation from these data, a short review of occupational health risks is given in Chapter VIII. Asbestosis, a progressive lung fibrosis, is restricted to rather intensive occupational exposure, and as such does not present a risk for the general public. The risk for bronchial cancer appears to run fairly parallel to that of asbestosis; however whether bronchial cancer can also occur as a public health risk, needs further reassessment, particularly because occurrence appears to be highly promoted by cigarette smoking. Induction of mesothelioma of the pleura and peritoneum usually is not associated with asbestosis; this tumour may occur after a very long latency period, and probably constitutes the main risk for public health. In occupationally exposed groups an increased prevalence of gastrointestinal tumours is also observed, also without evidence of asbestosis; the relation with exposure intensity and duration is much less clear than for mesothelioma. Wart like formations in the skin are only observed under occupational exposure. So, only those occupational diseases which have a malignant character, and which are almost always fatal, appear to be relevant for the estimation of the public health risk.

Chapter IX discusses the public health risks; mainly bronchial carcinomas and mesotheliomas. Chapter IX-1 reviews the relationship between respiratory exposure and mesothelioma. Crocidolite appears to provide the greatest risk, followed in decreasing order of risk by amosite, chrysotile and anthophyllite; however it is not justifiable to exclude chrysotile from a contribution to this risk. Smoking does not constitute an extra risk factor. Past asbestos exposure may have been relatively small if compared with the exposure necessary to induce asbestosis; short term or intermittent exposure to peak concentrations may also constitute a considerable risk. Although duration of exposure may have been only short (<1 yr), the latency period is usually very long, up to 40-50 years. The prevalence has to be studied retrospectively; several studies performed have used insensitive techniques of history taking, and so underreport past (occupational) asbestos exposure.

On the other hand, there is no reason to assume that asbestos exposure is the only causative factor. The frequency of "true" environmental exposure may be between 0 and 15% of all mesotheliomas. The overall prevalence is estimated at 1.0 to 6.0 per million population, more so in areas with a concentration of large ship yards, other large asbestos producing plants, asbestos mines (mainly crocidolite). So, within the EEC priorities for study and for actions taken should be directed at those areas. Evaluation of the health risk can only be based upon adequate registration of histologically proven cases; within the EEC such registers have been set up in the UK, The Netherlands and the Fed. Rep. of Germany. Caution is needed in interpreting present evidence about a public health risk, because existing evidence may not be available, inadequate or biased; the long latency period means that the effects of a marked increase of imports of amphiboles in the last 15 yrs might not yet be detectable. At this moment there is no convincing evidence yet that "true" environmental (excluding (para) occupational) exposure is a contributive factor to the occurrence of mesotheliomas through respiratory exposure.

Chapter IX-2 discusses respiratory exposure and bronchial carcinoma. A clear relationship with asbestos exposure has been established, with cigarette smoking as a highly contributive factor, and usually in combination with existing asbestosis. Occupational exposure need not necessarily be of long duration, but a high intensity usually has occurred. Such an exposure is almost certainly greater than in "true" environmental exposure. However, there is not yet enough evidence to exclude the risk of environmentally related induced bronchial carcinoma as a public health risk; this is still an area for concern and for proper study.

Other malignancies related to respiratory asbestos exposure are discussed in Chapter IX-3. There are indications of excess prevalence of larynx carcinoma in past-occupational asbestos exposure, probably of severe intensity. One study found an unconfirmed relationship with mammary carcinoma.

Chapter IX-4 reviews the possible relationship between an excess prevalence of malignancies and gastrointestinal or parenteral exposure. An increased prevalence of carcinoma of stomach, colon, rectum, oesophagus has

appeared in occupationally exposed workers, particularly in insulators. However, other studies could not find such an excess, particularly if workers had been employed in a controlled factory environment. The geographical prevalence of gastrointestinal tumors usually is not consistent with asbestos exposure; so exposure at most could be regarded as one of the causal factors; the relationship certainly is much less clear than, for example mesothelioma. The majority of mesotheliomas are pleural; in most studies peritoneal mesothelioma constitutes less than 10% of all cases, although in other studies the incidence of peritoneal mesothelioma has been higher. At this moment there is no solid evidence from epidemiological studies that gastrointestinal exposure may induce peritoneal mesothelioma.

There is little doubt that under experimental conditions fibres may penetrate into and pass through the gastrointestinal wall; however it is inadequately known what happens under natural conditions.

Experience from drinking water authorities has not shown any relation between the prevalence of gastrointestinal tumors and the presence of asbestos fibres in drinking water (composition of source, use of asbestos cement pipes). At this moment there is no evidence that there exists any increased health risk from asbestos fibres present in drinking water, beverages, food, and in fluids used for administration of drugs. However, some modes of parenteral administration, either by physicians or illicitly, at least constitute a possibility for such an event. An extensive study of the presence of asbestos fibres in drugs used in the EEC appears to be needed.

In Chapter X the available data on dose-response relationships are reviewed. The long term exposure, the changes in technical development and so in exposure over a period of time, the long latency period of asbestos induced tumors, the changes in methods of sampling and analysis make it very difficult, almost impossible, to present reliable dose levels, and so of quantitative dose-response relationships. There apparently exist qualitative dose-response relationships. With decreasing intensity of exposure health risks appear in the following order: asbestosis → bronchial carcinoma → pleurahyalinosis → mesothelioma; as for decreasing duration of exposure the following order of sequence exists: mesothelioma → bronchial carcinoma → pleurahyalinosis → asbestosis. In heavy mixed exposure an inverse relationship appears to exist between asbestosis and mesothelioma.

It is not possible to come to a reliable quantitative assessment of the risk of malignancies for the general public. Present evidence does not point to there being a threshold level of exposure, but there is very likely a practical level of exposure below which it will be impossible to detect any excess mortality or morbidity due to asbestos, despite the presence of this mineral in the tissues, expecially in the lung.

Chapter XI presents various existing permissible limits, mainly for occupational exposure. In many countries permissible limits for workroom air are (or will be in the near future) 2 fibres/ml (>5 µm); there is a tendency to lower these levels, particularly for crocidolite (in UK 0.2 f/ml). These levels aim at prevention of early asbestosis, and not of malignancies; small fibres (>5 µm) are taken into account. With regard to the general environment adequate quantitative standards are scarcely available; most are expressed in terms of required control practices. There is no way of extrapolating from occupational permissible limits to environmental permissible limits for ambient air, water, etc.

Chapter XII evaluates the health risk of true environmental exposure. Two approaches are discussed which try to extrapolate from the occupational to the public health risk. However, the approaches appear to be too deficient to allow quantitative extrapolation. Nevertheless, they both indicate that true ambient air exposure of the general public is of an order of two to three magnitudes smaller than in well controlled industry. It seems possible that a factor of 1000 or more may be large enough to reduce the risk of tumors to a negligible level compared to other risks.

The 1972 Conclusions of the Advisory Committee on Asbestos Cancers of the International Agency for Research on Cancer which state that there does not exist evidence of an increased risk of mesothelial tumors in respiratory or gastrointestinal exposure of the general public are not contradicted by the data presented in this report. On the other hand present evidence is not conclusive enough to make a statement in a positive way.

The general conclusions of this chapter can be summarized as follows:

- there exists enough reason to minimize asbestos fibre exposure of the general public as much as possible; this is particularly the case for

crocidolite fibres;

- there is no established evidence that true ambient exposure through air, water, drugs, beverages, food, as prevalent in the Western European countries at this moment carries a definite risk; however there exist too many uncertainties to deny the existence of such a risk, though if the risk was substantial, it is likely it would have been detected by now;
- the possibility of para-occupational exposure (families), and neighbourhood (industry, mines, transport) exposure is an area for concern;
- the working of asbestos containing products by the general public (leisuretime activities) is an area for concern;
- iatrogenic or accidental administration of asbestos fibres carry a potential risk, and should be minimized as much as possible.

Chapter XIII sums up studies which should be promoted in order to fill gaps in knowledge; only those studies important for guidance of overall policy of the EEC to prevent public health risk are mentioned. Fourteen topics are mentioned, six of which have the highest priority:

- study of quantities and usage of asbestos (containing products) within the EEC
- study of the biological significance of the physical properties of asbestos and other mineral fibres, particularly as regards diameter and length
- study of the presence of asbestos bodies, asbestos, and other mineral fibres in lung tissue in mesothelioma cases
- study of the relationship between the presence of asbestos bodies, asbestos, and other mineral fibres in human organs, and the cause of death
- study of the incidence of malignant tumors in relation to exposure conditions.
- methods of measurement of levels in the ambient environment.

In this list of priorities the need for biological monitoring is stressed, taking into account the considerable difficulties of sampling the ambient environment in a way which is economical and readily interpretable in terms of health risk.

The studies mentioned require the input of highly specialized manpower and equipment. It will be necessary to combine the effects of specialized institutes within the EEC; a high degree of cooperation and coordination - also with institutes outside the EEC - will be a condition sine qua non.

Chapter XIV recommends measures to be taking within the EEC at the community and at the national level:

- further studies to be carried out, as mentioned in Chapter XIII.
  A mesothelioma register should be set up in those countries of the EEC where none exist, in accordance with criteria and procedures agreed upon by a panel of pathologists
- minimizing of asbestos in the environment. The amount should be reduced as much as possible; this applies particularly to crocidolite fibres.
  Actions require a thorough control of hygienic conditions in processing, industrial use, transport, and disposal. Due attention should be paid to the effects of the presence of asbestos containing products in the every day life of the general public;
- support to the usage and development of substitutes which technically are at least as safe as asbestos and after proper evaluation of their economic and technical feasibility and of the health risks attached to them. A high priority should be given to substitutes for application where sufficient control regarding dust emission is difficult to maintain in practice;
- regulations for prevention of asbestos exposure. Effective control of hygienic conditions in the occupational field is of real assistance in reducing the presence of asbestos fibres in the ambient environment. It is important to reach to uniformity in these regulations at the Community and the national level. Drafting and publications of codes of practice should be actively pursued. Asbestos and asbestos containing products should be clearly labelled; where possible the sale of asbestos fibres to the general public should be forbidden. A close coordination between the Public Health and the Occupational Health Authorities at the community and the national level should be achieved.

The Health and Safety Directorate of the European Communities should coordinate, in collaboration with the Member States, the recommendations and their follow up. It should also pay due attention to the possible health risk from the use of mineral fibres other than asbestos.

I. ASBESTOS: TYPES, OCCURRENCE AND PROPERTIES*

Asbestos is the name given to a group of inorganic silicates which occur naturally and have a distinct fibrous crystalline structure. They are distinguished from man made fibrous silicates such as rockwool and glass wool by this true crystallinity and by the extreme fineness of the fibres and fibrils.

The inorganic nature and the crystalline structure of asbestos is largely responsible for its unique properties which have found a ready and still increasing application in modern technology. This may be illustrated by mentioning that at present some five million tons of asbestos are mined annually compared with a few hundred tons produced around 1890. There are six main types of asbestiform mineral which belong to two large groups of rockforming minerals i.e. the serpentines and the amphiboles. Serpentine was formed through hydrothermal action from olivines and pyroxenes and which partly produced the fibrous variety. The major amphibole fibres occur in metamorphosed sedimentary strata known as banded ironstones.

Table I-1 shows a classification of these minerals together with their chemical formulae.It should be noted that whilst the names actinolite, tremolite and anthophyllite apply equally to the fibre and the crystalforms of these minerals, the name crocidolite is given to the fibrous form of riebeckite and the name amosite to the fibrous form of grünerite.

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References : Hodgson 1966 and Asbestos Inform. Comm. 1975

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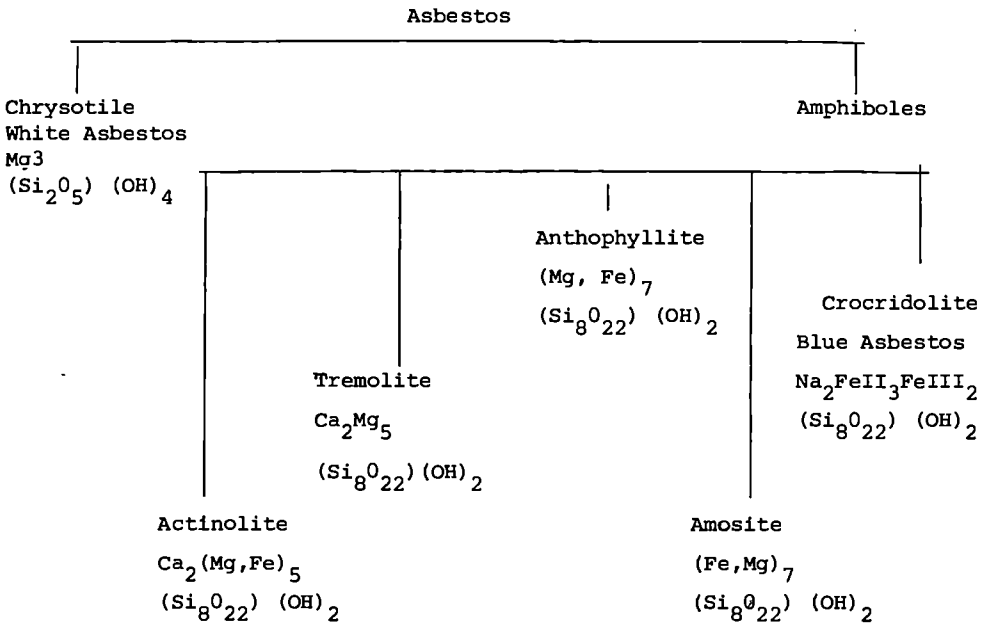
Table I-1: Varieties of asbestos



Asbestos has been known to mankind for a long period of time, early evidence of its use going back to the stone-age. As a material of commercial importance, asbestos commenced its role in technology around 1880 when largescale mining operations of chrysotile started in Canada and Russia. The mining of crocidolite and amosite on anything like a commercial scale began somewhat later, around 1900. While chrysotile occurs abundantly in several deposits throughout the world, this is not true of the amphibole fibres which can only be found in a few specific regions, which are commercially important. They are more widely distributed in smaller quantities. Of these amphibole fibres only crocidolite and amosite are at present produced on a commercial scale. Fibrous tremolite is of little economic importance. Fibrous anthophyllite was mined in Finland but this was discontinued during 1975. Fibrous actinolite is no more than a curiosity. Approximately 95% of all asbestos produced is chrysotile whilst the remainder consists mainly of amosite and crocidolite. An EEC country in which

chrysotile-deposits of some importance are mined is Italy. The mining of the fibres necessitates the removal of large quantities of the hostrock, which in the case of chrysotile may reach proportions of a yield of fibre of no more than two percent of the total amount of rock removed.

Having reviewed the natural occurrence of asbestos it is perhaps relevant also to mention the possibility of synthesizing asbestos fibres. In the past decades chrysotile was thus succesfully made from magnesium oxide and silicic acid. This method could possibly be made commercially viable if the demand for this type of asbestos continues to increase or if for another reason shortages of the fibre develop. The synthesizing of fibrous amphiboles has proved far more difficult. There are as yet no indications that a commercial process would be feasible although there are perhaps some interesting possibilities for chemically modifying natural amphiboles.

Although man-made mineral fibres do not possess true crystallinity as shown by natural and synthetic asbestos fibres, the fineness of these man made fibres through new manufacturing processes is approaching that of asbestos fibres. Ceramic fibres mainly consisting of aluminium silicates may reach a fibre diameter of 1.5 µm, whilst glass fibres for special applications can be made with a diameter of 1-3 µm. The bulk of the mineral fibres which is mainly used for thermal insulation in shipping, housing and industry has a fibre diameter of the order of at least 10-20 µm.

The chemical nature and the crystalline structure of asbestos are of essential importance for their technical application. For instance fibres containing a high proportion of magnesium generally show a white silky nature and may have a diameter less than 0.03µm. On the other hand fibres with a high iron content have a harsh, spiky texture and do not have a diameter much smaller than 0.1µm. Chrysotile having a high magnesium content can be described as a sheet silicate in which the flat structure is rolled about an axis to form a narrow tube (termed fibril) possessing both strength and flexibility. The macro-fibre is made up of a large number of fibrils, the interstitial voids being filled with amorphous material probably consisting of a magnesium silicate gel. The structure of the amphiboles essentially consists of two chains of silica tetrahedra separated by a band of cations. The cations most frequently occurring are Mg^{II}, Fe^{II}, Fe^{III}, Na^{I}, and Ca^{II}.

Substitution by minor amounts of Al^{III}, Ti^{IV}, K^{I} and Li^{I} is possible. This rigid lath-like structure explains the harsher and more brittle nature of these fibres. Within each species there is a relatively wide variation in texture, probably dependent upon slight variations in crystalline structure. The differences in the structure of the various fibres also lead to differences in chemical and physical properties which can be explained consistently from the former. However this does not need to be discussed in detail in this document.

The ability of asbestos fibres, as found bundled in the mineral, to split into finer fibres through suitable treatment is one of their most valuable and characteristic properties (see also next para.) One should be well aware of this when discussing the health hazard of asbestos as this hazard is dependent on the length and diameter of the asbestos fibre and cannot be attributed in general to asbestos. It should also be emphasized that great care has to be taken when measuring exposure whether fibrous bodies are asbestos fibres. More is said on this subject in chapter IV.

The characteristics of the main types of asbestos fibres are compiled in Table I-3. As was already referred to on page 18, tremolite and actinolite are of little or no importance to the asbestos industry. Very little is also known about the biological effects of these types of asbestos compared to chrysotile, crocidolite, amosite and anthophyllite. They have been included in table I-3 for the sake of completeness.

The best known chemical quality of all types of asbestos fibres is their heat resistance. All types of asbestos progressively break down to simpler structures through dehydroxylation or dehydrogenation when heated to temperatures between 400°C and 1000°C. In this connection it should be noted that asbestos fibres as such do not have melting points but the decomposition products formed on heating will themselves eventually melt. The reactivity of asbestos towards acids and alkalis is fairly well known. Strong acids rapidly decompose chrysotile but amphibole fibres show various degrees of resistance against attack by acids. Strong alkalis have little influence on all asbestos fibres, in particular on chrysotile which makes the latter fibre an excellent reinforcing agent in cement. Tensile strength is the most important and the most commonly quoted physical property of asbestos fibres.

Tensile strength and stiffness are the most important properties of asbestos fibres, which make possible their use in composite structures, the fibres carrying the load while the matrix distributes the applied stresses between them. The tensile strength of the composite is therefore a function of the tensile strengths of the reinforcing fibres and the volume fraction which they occupy. Fibre/polymer strength ratios of the order of 100 to 1 are achieved and, similarly, figures of between 20 and 40 to 1 are attained for stiffness ratios. From a consideration of the strength of the stable silicon-oxygen structure as prevalent in asbestos and which was referred to earlier one would expect very high tensile strengths of the order of as sometimes suggested more than 100000 kg/cm^2. These are not reached in practical tests (see Table I-3) probably because of repetitive flaws occuring in the fibres. These flaws may in some instances become the cause of failure in composite structures through the reduction of the length of the fibres and consequently a failure of the interfacial bond between fibre and matrix. It is evident that the strength of this interfacial bond is also of importance. It probably cannot solely be described in terms of the simple forces of adhesion. Chemical and mechanical bonding may also occur to some extent.

The ability of asbestos fibres to split into finer fibres is one of their most valuable properties. Industrially this is achieved by either mechanically or chemically processing the raw asbestos. This process is called opening or fiberizing. The degree of fiberization determines the surface area of the fibres which is a most important parameter for all their industrial applications. Degree of fiberization can be expressed directly in terms of the measured surface area of the fibres. Raw asbestos as shipped from the mines has a surface area varying from 6000 cm^2/g - 30000 cm^2/g. This may be increased by additional milling in the manufacturing processes by a factor of five or six. It should be mentioned that each manufacturing process involving asbestos fibre requires a degree of fiberization which within limits is critical for reaching optimal properties in the finished product.

The length of the asbestos fibre may vary considerably and is dependent upon the type of asbestos, the seams from which the raw fibre has been mined

and the degree and method of fiberization. In Table I-2 there have been compiled data on fibre diameter and fibre lengths. The average range of fibre length for different uses are also shown.

Table I-2: Fibre length and diameter

	textiles	insulating board	asbestos cement	friction-materials, paper, millboard	plastic fillers, floor-tiles
fibre length (mm)	8-24	5-17	2-13	2- 4	1- 3
fibre diameter (µm)	0.03-100	0.03-100	0.03-100	0.03-100	0.03-100

The data shown in Table I-2 should be considered as typically average only, and do not necessarily relate to a specific product. As was discussed earlier, the fibre diameter of chrysotile is generally at the lower end, whilst the amphibole fibre diameters are at the upper end of the range shown. The relative ease with which fibre (bundles) split into smaller ones implies that asbestos products normally contain fibres with a range of diameters with a minimum diameter for chrysotile fibrils of 0.03 µm and for amphibole fibres of 0.1 µm.

Table I - 3 Characteristics of main types of asbestos fibre**

Characteristic	Chrysotile	Crocidolite	Amosite	Anthophyllite	Tremolite	Actinolite
Theoretical Formula	$Mg_3\{Si_2O_5\}(OH)$	$Na_2FeII_3FeIII_2\{Si_8O_{22}\}(OH)_2$	$(Fe, Mg)_7\{Si_8O_{22}\}(OH)_2$	$(Mg, Fe)_7\{Si_8O_{22}\}(OH)_2$	$Ca_2Mg_5\{Si_8O_{22}\}(OH)_2$	$Ca_2(Mg, Fe)_5\{Si_8O_{22}\}(OH)_{22}$
Chemical Analysis (range of major constituents - per cent)						
SiO_2	38–42	49–56	49–52	53–60	55–60	51–56
Al_2O_3	(0–2)*	(0–1)	(0–1)	(0–3)	(0–3)	(0–3)
Fe_2O_3	(0–5)	13–18	(0–5)	(0–5)	(0–5)	(0–5)
FeO	(0–3)	3–21	35–40	3–20	(0–5)	5–15
MgO	38–42	(0–13)	5–7	17–31	20–25	12–20
CaO	(0–2)	(0–2)	(0–2)	(0–3)	10–15	10–13
Na_2O	(0–1)	4–8	(0–1)	(0–1)	(0–2)	(0–2)
H_2O+	11.5–13	1.7–2.8	1.8–2.4	1.5–3.0	1.5–2.5	1.8–2.3
* Bracketed figures denote substituents often present in asbestos.						
Colour	Usually white to pale green yellow[1], pink[1]	Blue	Light grey to pale brown	White to grey pale brown	White to grey	Pale to dark green
Decomposition temperature* (°C)	450–700	400–600	600–800	600–850	950–1040	620–960
Fusion temperature of residual material (°C)	1500	1200	1400	1450	1315	1400
Density g/cm^3	2.55	3.3–3.4	3.4–3.5	2.85–3.1	2.9–3.1	3.0–3.2
Resistance to acids	Undergoes fairly rapid attack	Good	Attacked slowly	Very good	Very good	Attacked slowly
Resistance to alkalis	Very good	Good	Good	Very good	Good	Good
Mechanical properties of fibre as taken from rock samples:						
Tensile strength 10^3 kg/cm^2	31	35	17	(<7)	5	5
(Average) (10^3 psi)	(440)	(495)	(250)	(< 100)	(<70)	(<70)
Young's Modulus 10^3 kg/cm^2	1,620	1,860	1,620	–	–	–
(Average) (10^4psi)	(23)	(27)	(23)			
Texture	Usually flexible, silky and tough	Flexible to brittle and tough	Usually brittle	Usually brittle	Usually brittle	
Producing countries	USSR Canada China Rhodesia USA Italy South Africa Swaziland	South Africa	South Africa	Finland USA Mozambique	USA Italy	

Notes: *Dehydroxylation or dehydrogenation accompanied by disruption of crystal lattice and major loss of strength.
[1]From serpentinised dolom to deposits.

** This table is used with the permission of the Asbestos Information Committee, England.

II. USAGE OF ASBESTOS AND ASBESTOS-CONTAINING MATERIALS IN EEC

This section is concerned with the usage of asbestos and asbestos-containing products in the EEC, i.e. how and to what extent asbestos is used in the various countries. A quantitative analysis has been attempted to indicate the relative importance of processes and products using asbestos fibres. The types of asbestos fibre which are commercially important are shown together with the quantities involved and the processes and products in which they are used. It does not deal with possible exposure levels, permissible exposure limits in the environment and existing legislation (see Chapters V and XI).

Compared with the total amount of asbestos used in the EEC countries for the purposes of manufacturing asbestos products, the only mining operation in those countries is in Italy where some 130.000 tons of asbestos fibre (mostly short chrysotile) are produced annually. It should, however, be noted that asbestos fibre is produced in Western Germany from concentrate imported from Canada; the total quantity involved in this operation is about 100.000 metric tons of fibre annually. Milled fibre as produced at the mines is not necessarily in a form suitable for direct use in the processes employed. This may mean that a further milling operation is necessary in order to obtain the correct degree of fiberization.

Because of its versatility (incombustibility, heat resistance, chemical resistance, reinforcing properties), asbestos is used in many products which find applications in industries such as building, construction, engineering and ship building. In addition to these main fields of application, there are many other outlets. It has been estimated that asbestos in one form or another is used in over 3000 products. To obtain a clearer picture of the types of asbestos goods which find a use in modern society, it is perhaps useful to list the ones in which asbestos is incorporated in various end-products. Fig. II-1 provides a highly schematised picture of this, dividing the products into three main groups: a) loose fibre mixtures, b) bonded asbestos composites and c) asbestos textiles.

As asbestos by itself has low mechanical strength, the products in group (a) cannot all be regarded as end products but are generally used in conjunction with water as insulating plasters, cement or spray mixtures. The

greatest use of asbestos fibre lies in the manufacture of composites (group(b)). The cement variety, i.e. asbestos-cement, constitutes by far the largest component of this group. Other products of major importance here are friction materials, insulation boards, jointing, millboard and paper, reinforced plastics and vinyl tiles and sheets. Asbestos can be spun into yarn and woven into cloth. The resulting textile products (group (c)) may be used for further processing into friction materials, packings and laminates or may find direct applications such as insulation covering, protective clothing, fire protection and electrical insulation.

Table II-1 provides a list of the most important asbestos products and their approximate fibre contents; the references in the righthand column relate to Fig. II-1. For some years dust-suppressed techniques have been in operation. These are particularly important for treating such asbestos products which in their application have to be manipulated, handled, etc. Dust-suppressed textiles, millboard, paper and rope lagging are all available. Table II-1 also refers to the different types of asbestos used in the product groups. It might be noted that the use of crocidolite fibre*) in products manufactured in the U.K. and Ireland has been discontinued. In other states of the EEC some crocidolite is still used in certain products, which are indicated in Table II-1. Low density insulation boards and other thermal insulation materials contain a high proportion of amosite fibre. The major use of crocidolite is in asbestos-cement pressure pipe where it enhances the reinforcement, the dispersion of the fibre, and the drainage properties of the asbestos-cement mix. Up to 30% of amphibole fibres may be used for this purpose in the fibre mix. To a small extent, crocidolite fibres are also used in acidresisting products and in asbestos plastic composites where a high strength and modulus combined with a high chemical resistance are required. It should, however, be noted that the greatest bulk of asbestos fibre going into the products listed in Table II-1 is chrysotile.

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*) although crocidolite fibre as such is not used anymore in the UK because of the stringent levels of crocidolite dust permitted, a small amount of crocidolite yarn which is imported is still used to manufature certain products (for example gaskets) where high resistance to thermal and acid attack is an overriding consideration.

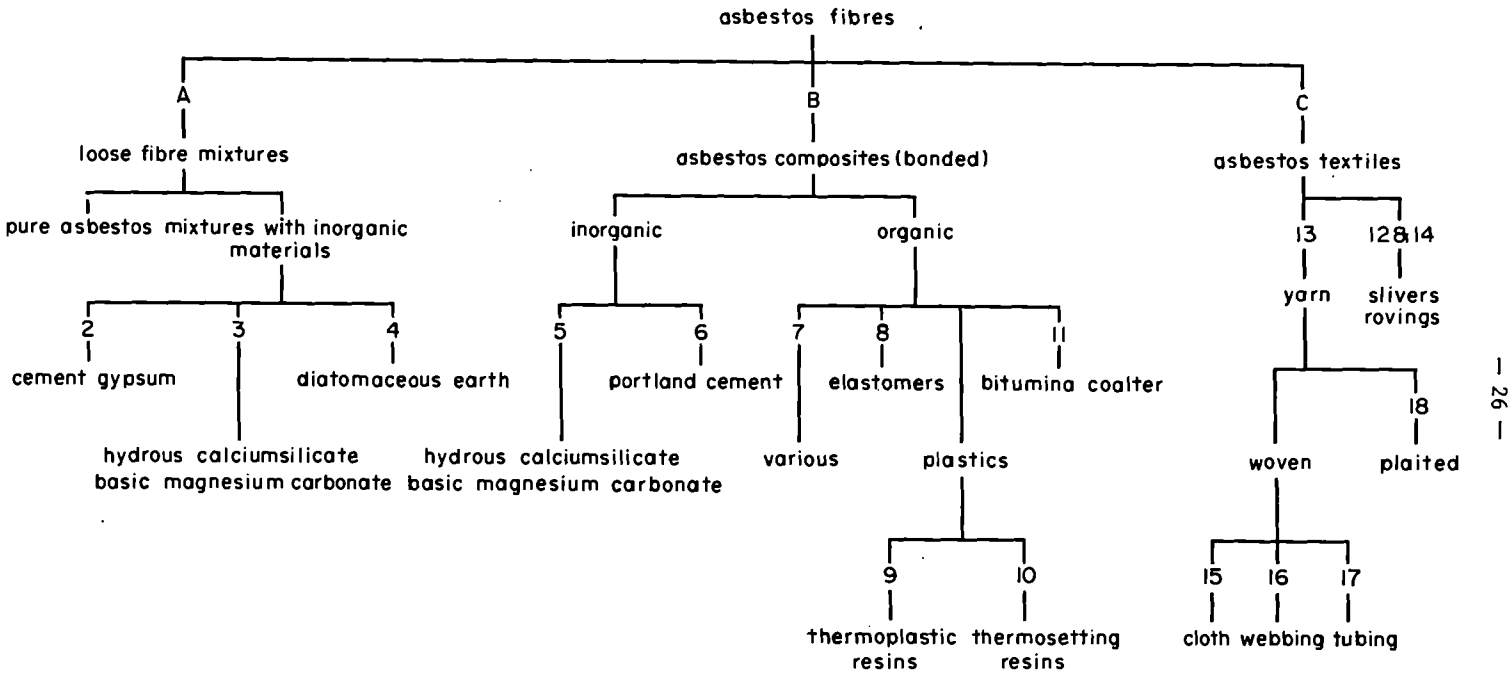


Fig. II-1. Applications of asbestos fibres

Table II-1. Asbestos products and asbestos contents

	approx. asbestos content % (wt.)	asbestos fibre type	Ref. Fig.1
1. Asbestos-cement building products	10 - 15	C A (Cr)	B6
2. Asbestos-cement pressure, sewage and drainage pipes	12 - 15	C (Cr) A	B6
3. Fire-resistant insulation boards	25 - 40	A C	B6, B5
4. Insulation products including spray	12 - 100	A C (Cr)	A1, A2, A3, A4, B5
5. Jointings and packings	25 - 85	C (Cr)	B8, C18
6. Friction materials	15 - 70	C	B10
7. Textile products not included in (6)	65 - 100	C (Cr)	C
8. Floor tiles and sheets	5 - 7½	C	B9
9. Moulded plastics and battery boxes	55 - 70	C (Cr)	B9, B10
10. Fillers and reinforcements and products made thereof (felts, millboard, paper, filter pads for wines and beers, underseals, mastics, adhesives, coatings, etc.)	25 - 98	C (Cr)	B7, B11

Explanation of asbestos fibre types :

A = Amosite

C = Chrysotile

Cr = Crocidolite

(Cr) = not used in all EEC countries

It should be remembered that the asbestos content is not necessarily an indication of the relative health risk. In many products the asbestos fibres are wholly or largely encapsulated.*)

Another point which should be kept in mind when evaluating the possible effect of asbestos on the environment is the influence of heat. Chrysotile asbestos rapidly decomposes at temperatures of 500°C - 600°C. This explains why very little asbestos is found in the dust arising from braking. This dust seldom contains more than 1% (wt) of asbestos.

Table II-2 provides statistics of world production of asbestos fibres in 1973. The total includes 170.000 tons of crocidolite, 75.000 tons of amosite and 12.000 tons of anthophyllite. The USSR figures include a considerable tonnage of very short fibres. The production of Finnish anthophyllite was discontinued during 1975.

Table II-2 : Asbestos fibre production - year 1973 (short tons)

Canada	1.974.000
U.S.S.R	2.200.000
South Africa	350.000
China	100.000
Italy	130.000
United States	130.000
Rhodesia	170.000
Brazil	30.000
Swaziland	45.000
Cyprus	28.000
Japan	20.000
India	3.000
Finland	12.000
Yugoslavia	15.000
Other countries	5.000
Total	5.212.000

*) for measures to be taken when machining or otherwise mechanically handling asbestos containing products see page 32 Codes of Practice etc.

Estimated figures for the consumption of asbestos fibres in the EEC countries in 1973 are shown in Table II-3. Separate figures for the industrially most important types of asbestos are included in this table.

Table II-3 : Estimated asbestos fibre consumption in EEC-countries year 1973 (metric tons).

	chryso-tile	amosite	croci-dolite	antho-phyllite	Total
Belgium & Luxemburg	76000	5000	5000	---	86000
Denmark	28200	4800	---	---	33000
France	150000	2800	3100	100	156000
Italy	130600	2200	6200	---	139000
Ireland	6400	600	---	---	7000
Netherlands	37400	---	600	---	38000
United Kingdom	147700	24000	---	300	172000
West Germany	173300	1900	3300	1700	180200
Total	749600	41300	18200	2100	811200

While it is not too difficult to estimate the consumption of asbestos fibre in the various EEC countries, it is much more of a problem to compile a breakdown of fibre usage into the main products in which asbestos fibres are used. As a result of the friendly cooperation of the asbestos industries in the various countries, such a breakdown is set out in Table II-4 but it must be stressed that the figures are approximate only. As there are no official statistics, the figures produced rely to a great extent on intimate knowledge of the market by individuals and organisations. They might be described as reasonably accurate for the United Kingdom but no more than very approximate for Italy. Even allowing for a due margin of error, the figures provide a useful analysis of the total quantities of asbestos fibre used in the asbestos manufacturing industries in the EEC countries. These should not be confused with the usage of asbestos-containing products in these countries. The latter statistics are impossible to obtain as they would have to include all imports and exports of asbestos-containing products.

Table II-4. Estimated breakdown of asbestos fibre usage in EEC countries 1973

	Belgium & Luxembourg	Denmark	Ireland	France	Italy	Nether-lands	United Kingdom	West Germany	Total
1. Asbestos-cement building products	46.400	25.800	4.700	62.700	80.000	11.000	55.600	85.000	364.200
2. Asbestos-cement pressure, sewage and drainage pipes	15.000	600	1.700	49.200	38.000	5.000	9.000	35.000	160.500
3. Fire-resistant insulation boards	5.000	3.000	600	1.300	-	-	22.500	400	32.800
4. Insulation products including spray	-	300	-	3.200	800	-	4.000	300	8.600
5. Jointings and packings	100	1.300	-	1.600	2.000	-	11.400	11.000	27.400
6. Friction materials	600	1.500	-	4.300	4.000	-	17.000	15.000	42.400
7. Textile products not included in (6)	800	-	-	4.300	4.000	-	8.300	5.600	23.000
8. Floor tiles and sheets	-	500	-	14.500	1.000	-	16.200	13.000	45.200
9. Moulded plastics and battery boxes	2.000	-	-	1.000	2.000	-	2.800	1.000	8.800
10. Fillers and reinforcements and products made thereof (felts, millboard, paper, filter pads for wines and beers, underseals, mastics, adhesives, coatings, etc.)	16.600	-	-	13.900	7.200	22.000	25.700	13.900	100.300
TOTAL	86.500	33.000	7.000	156.000	139.000	38.000	172.500	180.200	812.200

It may be seen from Table II-4 that the usage of asbestos fibres in asbestos-cement products is easily the largest. The U.K. has a comparatively large production of fire-resistant insulation boards. Insulation products used a relatively small tonnage in 1973 and this was probably due to the availability of acceptable substitutes. Group 10 in Table II-4 is made up of many products of which felts, millboard and paper can be regarded as the most important.

Although this chapter is primarily concerned with the usage of asbestos and asbestos-containing products in the EEC, a few remarks may be added on activities which are non-specific for these products, but nevertheless, involve them and could cause the emission of asbestos dust. These concern the transportation of asbestos fibres and finished asbestos goods, demolition of asbestos-containing structures and the removal and storage of asbestos waste.

Asbestos fibres are generally packed in impermeable bags and shipped loose, on pallets or in containers; containers can be filled with loose bags or with units containing 20 or more bags. It is fairly certain that the movement of the loose bags constitutes a greater hazard through the possibility of bag damage and the consequent release of fibres. This hazard is considerably reduced by palletisation and is completely eliminated when containers are used. It is difficult to provide precise information as to the proportions of the three methods, as they vary from country to country. In the U.K. the largest part is containerised while the remainder is shipped on pallets. For the other countries in the EEC, it is likely that about half of the total tonnage is containerised and the remaining tonnage is in loose bags. The bags are in the majority made of an impermeable plastic. Jute and paper bags are still used, mainly in shipments from the USSR and Italy but these are now gradually being replaced by the plastic bags. It appears likely that by 1978 most of the fibre tonnage for EEC countries will be shipped in containers with the asbestos fibre packed in impermeable plastic bags.

Shipments of asbestos-containing products rarely provide any risk as the asbestos fibres are bonded and cannot easily escape into the atmosphere. Fibrous mixtures are normally packed in impermeable bags and shipped as in the case of fibres.

Removal of old insulation, demolition of buildings, plants and ships in which asbestos has been used may be the cause of uncontrolled dust emissions unless adequate precautions are taken. Codes of Practice are already in use in some EEC countries, aiming at the control of dust emission through special techniques and other protective measures. These codes were developed mainly through the effort of the manufacturers to control the dust emissions in factories as well as the dust from factories escaping into the environment. Similarly, Codes of Practice apply to the removal and disposal of asbestos waste where dust emissions may also occur. Most of the work concerned with the preparation of Codes of Practice has been undertaken in the U.K. by the Asbestosis Research Council.

In the general context of this chapter, mention might also be made of talc, a natural mineral with a chemical structure resembling that of asbestos. Normally talc is crystallised in layers, although some fibre formations occur and some deposits may contain varying amounts of asbestos fibre, such as tremolite, anthophyllite or chrysotile. Industrially, talc is widely used in manufacturing rubber articles and paints. In cosmetics, talc is used in toilet powders where it is often mixed with other ingredients, although the talcs employed are almost always asbestos free. Little is known about the health effects of talc except in some occupational exposures, but several studies are currently in progress to obtain a clearer insight into the material and its health effects.

There has been a tremendous growth*) in the usage of asbestos and asbestos containing products over the past decades. This growth has occurred for several reasons :

- growth of the market for products in which asbestos and/or asbestos containing products are used

*) Although varying from country to country the growth trend over the past few years seems to have lost a great deal of its former magnitude. This development is thought to be due rather to unfavourable economic factors which are more and more felt in all industrial sectors than to the replacement of asbestos and/or asbestos containing materials by other materials. A slight influence might have come from a switch in thermal insulating contracting to nonasbestos materials.

- the developing of new markets for asbestos and/or asbestos containing products because of
  - economic factors
  - technical factors
  - a combination of both.

It is rather obvious that the markets for products which contain asbestos in some form have grown extraordinarily since 1945, thus causing a similar increase in asbestos usage. Good examples of these are the building and the automotive markets. Besides this, what might perhaps be called parallel growth has also occurred, in that there has been an increased demand for asbestos as a result of ever increasing wage costs, which, for instance, in the building industry could be kept down by a relatively cheap and easily prefabricated asbestos composite like asbestos cement. Improved technology in several fields as, for instance, engineering, has made higher demands on the strength and heat resistance of materials, which could be met by suitably designed and compounded asbestos products. It should also be pointed out that the safety rules in various fields have been given closer attention over the years which have resulted for instance in many governments issuing stringent regulations regarding the fire protection of buildings and ocean going vessels. Asbestos products were eminently suited to fulfil the requirements made by those regulations.

It is difficult to precisely assess the influence of economic and technological developments on the usage of asbestos. That this influence has been and still is important and concerns widely different fields of application ranging from rockets to simple household appliances may safely be stated.

III. POSSIBILITIES OF EXPOSURE

When discussing the health risks of exposure to asbestos for the general population, one should first of all distinguish between the various possibilities of exposure. Particularly in the case of malignancies, it is not sufficient to look only for the relationship between recent exposure and health effects as there is a very long latency period (often over 30 years) with perhaps short term (even below 1 year) exposure. Subjects not recently occupationally exposed over the years before a diagnosis of malignancy is made, may too easily be classified under neighbourhood exposure or exposure of the general population as such, although in fact occupational exposure 20 to 40 yrs previously may have taken place. In addition neither occupational nor non-occupational exposure can be indentified as one entity; the distinction between both types of exposure is rather quantitative than qualitative.

It should be stressed that it is not the presence of asbestos (containing materials) as such, but the presence of asbestos fibres which constitute a relevant exposure, as will be discussed in this chapter. One should always take the hazard into account: a health risk only exists if there is the possibility of inhalation or ingestion of fine asbestos-dust, i.e. in fibre form.

The following possibilities of exposure should be distinguished:

1a. direct occupational exposure: work in asbestos mines, in asbestos textile, asbestos-cement, asbestos-insulation board factories, in insulation work, etc. However, it becomes more and more evident that for example mesothelioma may occur in subjects who performed jobs in which direct exposure to asbestos was not the typical characteristic of the job itself: e.g. mesothelioma in a male stage hand, or in a femal ironer in a laundry (Zielhuis et al 1975). In addition to the classical jobs as mentioned above, there exists an increasing number of jobs in which asbestos containing materials have to be handled: workers in building industry, cutters and layers of waterpipes, blowing out of brake linings,etc.

1b. indirect occupational exposure: the subject usually has not handled asbestos himself, but has worked in the vicinity of such jobs e.g. non-asbestos workers in shipbuilding industry, etc.

1c. occupational exposure in agriculture: particularly in Eastern Europe (a.o. Bulgaria) pleural plaques have been observed in agricultural workers engaged in growing tobacco on stony mountainous soil; anthophyllite, tremolite and sepiolite have been found in regions with endemic pleural calcification (Burilkov et al 1972, Burilkov 1971). However, it is questionable whether these plaques were due to asbestos or to associated minerals (see ad 3). This category more or less corresponds to category 4 (true environmental exposure) albeit of a rather special variety. It differs from all the other types of exposure in that the asbestos in the environment has not been introduced by man, although he may have been instrumental in causing it to become airborne.

With regard to group I exposures: In several epidemiological studies the occupational history apparently has not been evaluated in such a way that such unexpected exposures could be brought to light. Too often one only regards well-known-jobs as an insulator, or a worker in an asbestos processing factory as relevant. However, if a certain amount of detective work is carried out by an experienced and inquisitive investigator, hitherto unexpected occupational exposure is brought into the open. Examples were recently presented by Zielhuis et al (1975).

2a. para-occupational domestic exposure: women married to asbestos exposed males, or other members of the household can be exposed as a result of handling contaminated clothing, etc. (Newhouse et al 1965, Greenberg et al 1974). There are not sufficient data to estimate the size of the population at risk. Experience from the Rochdale asbestos industry (U.K.) does not reveal any increased prevalence of diseases in relatives; in this case however rather strict hygiene measures are being taken: workers are not allowed to take working clothes home; laundering is performed within the factory (Holmes, pers. comm.).

2b. para-occupational exposure: particularly leisuretime activities, serving as a "second" job (Zielhuis et al 1975). Notwithstanding a recommendation by USA government officials, asbestos products are still easily bought without a warning label. In particular the cutting and working of asbestos containing sheets invariably release some asbestos in to the atmosphere.

Handyman products in the USA are unlikely to contain crocidolite (McGinty 1975). Rohl et al (1975) showed that when professional construction workers used materials similar to do-it-yourself products, the concentration of asbestos in the air exceeded USA safety standards by a factor as great as 10. In home applications, members of the entire household or other occupants of the building may inhale asbestos fibres.

neighbourhood exposure: vicinity of asbestos mines, asbestos processing factories, asbestos dumps, etc. In 252 cases of mesothelioma with a known history of exposure Webster (1973a) observed about the same percentage (30-45%) of past occupational exposure as of environmental exposure; the last group had mainly lived near a mine or a mill or in towns situated in an asbestos area. In East London, Newhouse et al (1965) found 14.5% of cases living in the vicinity of an asbestos factory; afterwards Newhouse (1973) emphasized that these vicinity cases might have had "considerable" exposure. In Hamburg, Hain et al (1974) found 13.3% of such cases among 150 patients. Bohlig et al (1973) even mentioned that the distribution of mesotheliomas in Hamburg in the vicinity of an asbestos factory was dependent upon the prevailing wind; a visible snowfall like air pollution had formerly been emitted from the factory. Navratil et al (1971) investigated the prevalence of pleural plaques, and found 5.8% in subjects living in the vicinity of a factory; the authors pointed out however that this type of exposure often may be coincident with paraoccupational exposure as mentioned under 2a. Finnish workers (Raunio 1966, Meurman 1966) studied the prevalence of pleural plaques in East- and South-West Finland; living in the vicinity of anthophyllite asbestos appeared to be at least one of the causative factors. In Bulgaria (Burilkov et al 1971) there was exposure in the vicinity of anthophyllite mines as well as due to the presence of it in the soil. In the literature, the vicinity to asbestos mines or factories as such is not defined clearly: sometimes it is a distance of 1 km, sometimes it is a poorly circumscribed but much wider area that is taken as a criterion. However, the general environmental exposures in Bulgaria, Finland and Czechoslovakia apparently did not - as far as is known - seem to be associated with any cancer risk (see Chapter IX); this contrasts markedly with the exposure to crocidolite as reported by Webster (1973). There is evidence that the pleural calcification may have been linked with, for example tremolite, and not with, for example, crocidolite; so, the evidence is that pleural calcification

due to environmental exposure does not necessarily carry a health risk, e.g. cancers.

4. true general environmental exposure, not due to specific fixed sources as mentioned above: presence of asbestos in ambient air, food, beverages, water, wear and tear of asbestos insulation layers in public buildings, etc., a multitude of sources and possibilities of exposure as discussed in II and V. This represents the true public health exposure at large in modern societies.

As mentioned before, in some epidemiological studies the investigation of the past exposure history of malignancies, by the taking of an adequate history was not carried out in depth; one may conclude too easily that it was true environmental exposure, whereas in reality (para)-occupational exposure has taken place. Although the classical jobs, with typical asbestos exposure have become wellknown, various occupational health risks for individuals, exposed in small scattered groups, are still neglected, in this way mimicking true general environmental exposure.

Because of the lack of clear distinctions between the various possibilities of exposure and because of the possibility of combined or subsequent exposures, greater reliance should be put upon biological monitoring i.e. measuring the lung burden, (chapter VII), than on environmental monitoring i.e. measuring external exposure in e.g. air, water, food (chapter V).

Conclusions

The EEC workshop on the biological significance of asbestos fibre morphology, in 1975 concluded that:

1. Because asbestos remains in the lung it is scientifically profitable to measure the content of the lungs which indicates the integrated exposure of the individual.
2. To establish the significant factors in disease, the aim should be to measure and identify the total mineral dust in the lungs.
   Total mineral dust is defined as the inorganic residue remaining after suitable treatment which does not alter the chemical and physical characteristics of the particles. Forms of ashing using temperatures below 450^{o}C are the most generally used methods, but other methods are used for more specific studies.
3. Measurement in the general environment should also take place.

IV. SAMPLING AND DETECTION OF ASBESTOS IN AIR, FOOD, SOIL AND WATER

Sampling

A serious obstacle in the study of the interaction between potential toxic substances in the environment - like asbestos - and man is that the quantities of pollutants fluctuate in space and time. Keeping the latter factor in mind, it is the purpose of proper sampling techniques to arrive at a quantitative estimate of the exposure which results in an increase of the "body burden" of the general population.

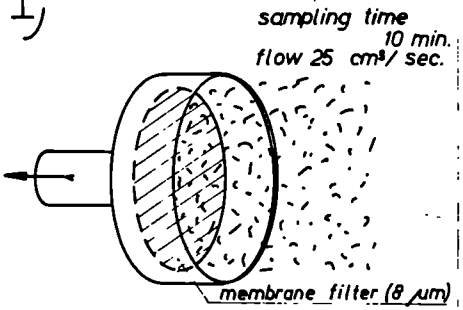
On the basis of present knowledge on the biological effects of asbestos it primarily seems that the average exposure over a period of time is of interest. This simplification means that for an inventory of exposure levels a large number of samples (e.g. 8 hrs. samples) taken consecutively can be added together (averaging in time). When the presence of asbestos in ambient air, water and food is investigated, it is often preferable to sample synchronously in several places in the vicinity following the same sampling procedure (averaging in space). For the investigation of the asbestos content of soil it will be, in general, sufficient to investigate a large number of samples from different locations since time fluctuations are in many cases of lesser importance.

Though sampling is of primary importance in the described investigations only very general guidelines on sampling procedures can be given at this stage. This combined with the lack of standardisation of analytical procedures is the reason that the results of individual investigations can only be compared with reservation.

For the determination of the asbestos content of air and water the solid content is in general separated from the carrier-medium. Due to the small size of the asbestos fibres in ambient air and water the separation methods which can be used are in practice limited (Air Sampling Instruments 1972).

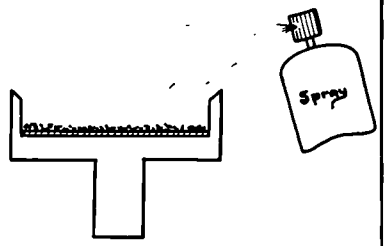
For air they are: high efficiency filtration (Deworm et al 1974, Nichol-

I)



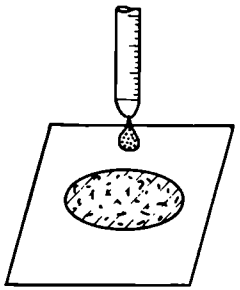
SAMPLING

II)



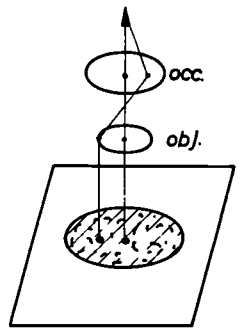
FIXATION OF THE DUST

III)



FILTER IS MADE TRANSPARENT

IV a)



time for counting
1½ h.

ENLARGEMENT 500x FASE-CONTRAST

IV b)

$$\frac{N}{W} \times \frac{n}{V} = \text{fiber conc./cm}^3$$

N = total number of fields covering the whole filter area.
W = number of fields examined.
n = number of counted fibers.
V = volume of sample.

counted as fibers:

diam. < 3 µm.
length > 5 µm.
$\frac{\text{length}}{\text{diam.}} > 3.$

FIG. IV-1

MICROSCOPICAL DETERMINATION OF THE ASBESTOSCONCENTRATION IN AIR

I The separation of dust from a measured volume of air.
II After fixation the filter can be moved to the laboratory.
III Before microscopic examination the filter is treated with glycerol-tri-acetate.
IVa Symbolises counting of fibers. 100 fields are examined or if there are more than 2 fibers/field, 200 fibers are counted in total.
IVb From the observed data the fiber-concentration is calculated.

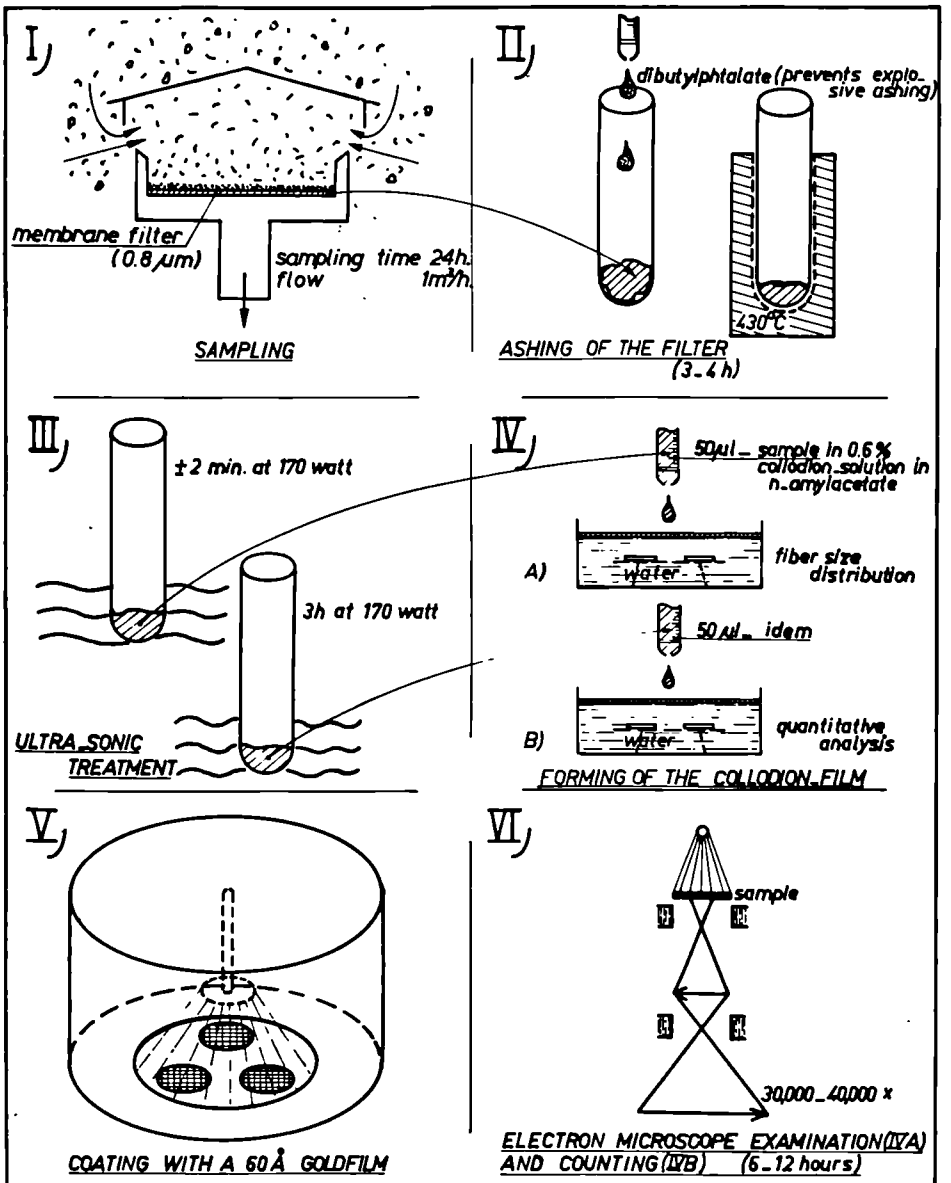


FIG. IV-2

DETERMINATION OF THE CONCENTRATION OF SUB-MICROSC. ASBESTOS FIBERS IN AIR.

I Separation of fibers from air. II Ashing of the filter

III/IVa Part of the ashed sample is dispersed in a gentle way. Electron-microscopical examination of the specimen gives the size-distribution of the fibers in the original sample.

III/IVb Part of the sample is dispersed using high intensity ultra-sonic treatment which disperses the asbestos homogeneous through the liquid in the form of fibrils.

V/VI The fibrils are counted and measured. The particle concentration is converted into a gravimetric concentration.

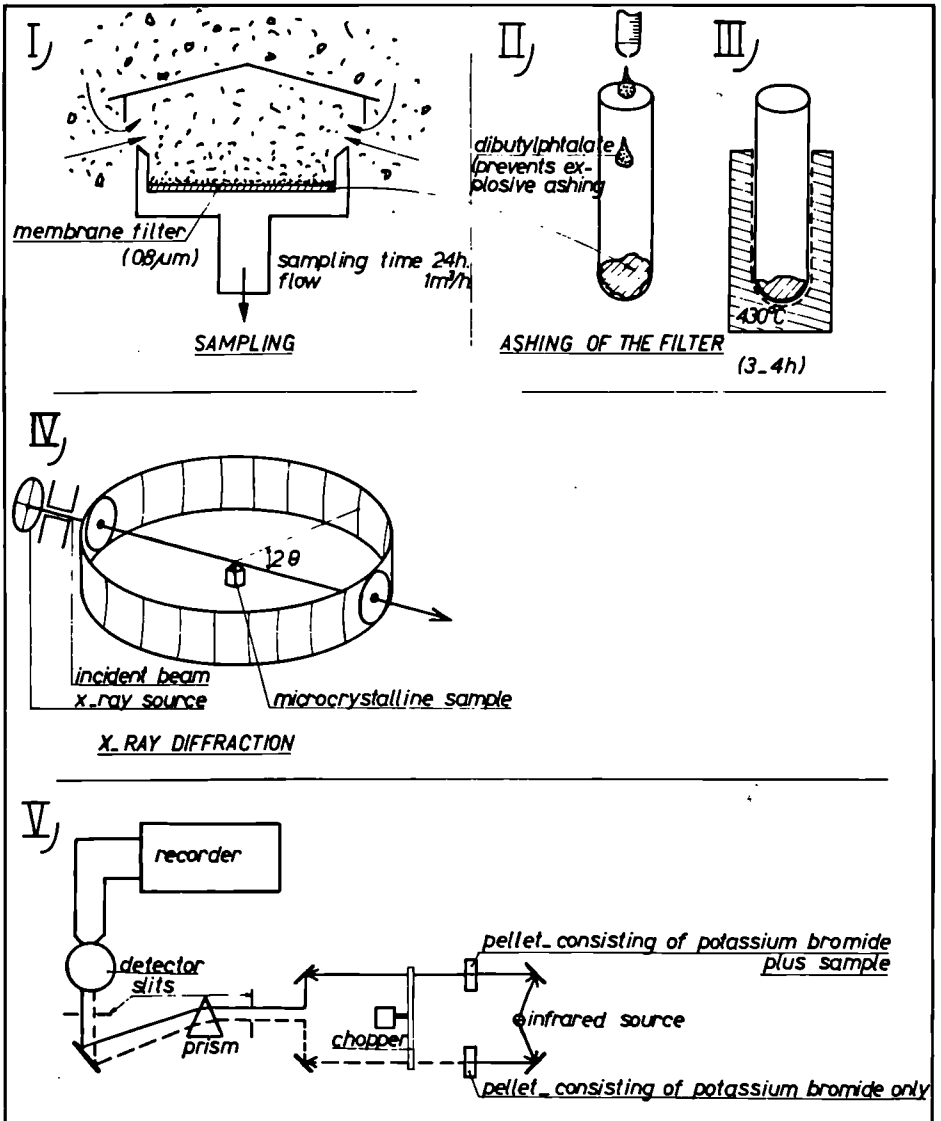


FIG. IV-3

DETERMINATION OF THE ASBESTOS-CONCENTRATION IN AIR WITH X-RAY DIFFRACTION / INFRARED SPECTROSCOPY.

I The separation of dust from a measured volume of air.
II/III Ashing of the filter.
IV/V Residue from III is subjected to x-ray diffraction (IV) and /or infrared analysis (V).

son et al 1970, Spurny et al 1976); electrostatic precipitation (Rickards 1973); and thermal precipitation (Swift 1972). For water analysis mainly ultra centrifugation (Cunningham et al 1971, American Water Works Ass. 1974) and filtration techniques are applied.

When filtration is used additional steps have to be taken in general before the asbestos content of the sample can be determined. This is shown in Figures IV-1 and 2. The most universal method to get rid of the filter is destruction by low temperature ashing. This can be done at low pressure with activated oxygen (Gleit 1963). Satisfactory results are also obtained by ashing in an oven at 430°C, using a few drops of dibutylphtalate to prevent explosive destruction of the filter material with subsequent overheating of the sample resulting in decomposition of the asbestos fibres.

As the asbestos fibres which are found in ambient air and water are in general of submicroscopic size, the sampling speed has little influence on the composition of the sample. Sampling velocity should be chosen in such a way that on the one hand the efficiency of the precipitation is not too much impaired while on the other hand enough material had been collected. When the samples are investigated microscopically, low sample rates - e.g. 1 m^3/hr - are used. When X-ray diffraction (Rickards et al 1971, Rickards 1972) or infrared analyses methods (Bagioni 1975) are used for the determination of the asbestos content, high volume sampling rates - e.g. 600 m^3/hr - are sometimes preferable. The reason for this difference in sampling rate will be explained in the next paragraph.

Food and soil are in principal analysed in the same way as air and water. A representative sample is subjected to low temperature ashing and is treated as shown in Figures IV-2 and 3. Before heating the samples are often inspected microscopically.

Finally it should be pointed out that examination of the mineral content of lungs obtained from autopsies is at the moment the only reliable way to obtain qualitative and quantitative information on the "asbestos body burden" caused by exposure to asbestos containing air during an individual's life time. The effect of lung clearance is neglected which is a fair approximation for amphiboles and a much more uncertain approximation for chrysotile.

After selective destruction of the organic tissue for which a number of methods (e.g. ashing below 430°C) exist, and the removal of iron by washing with diluted acid, the subsequent examination of the inorganic residue does not pose any significantly different problems from investigations of other samples.

Qualitative and quantitative determination of asbestos in samples

Two different approaches can be used when determining asbestos in samples.

1. Morphological recognition of asbestos followed by identification of a selected number of fibres (Holmes 1965):
   a. Identification with optical crystallographical methods using the results of polarisation microscopy (Schmidt 1960) or dispersion staining techniques (Julian et al 1970). It has to be mentioned that the fibre diameter has to be approximately 5 µm or larger to get satisfactory results.
   b. Confirmation of the asbestoid character of the fibres using electron diffraction as part of an electron microscopical investigation of a sample (Figure IV-3) (Clark et al 1974, Keenan et al 1970, McFarren et al 1974, Mueller et al 1973, Murchio et al 1973, Skinne et al 1971). It should be understood that the electron microscopic methods described are only good for identifying chrysotiles and the amphiboles. They will not identify individual amphiboles. This can only be done by using in addition to diffraction techniques, X-ray emission analysis whereby the chemistry of the fibre is recorded (Pooley 1975). The advantage of the morphological method which is in general carried out with the aid of optical or electron microscopes, is its high sensitivity - the weight of one small but still detectable fibre is approximately 10^{-12}g when optical microscopy is used and approximately 10^{-17}g when electron microscopy is used - compared with physical-chemical methods of analysis. There is no theoretical limit to the minimum concentration which can be detected with microscopical methods. This is a function of time spent on the investigation. Minimum concentrations of 1 fibre: 100.000 other particles have been attained in practice.

2. Techniques which determine all the asbestos in the sample at the same time.

   a. X-ray diffraction (Figure IV-3). Based on the property that X-rays are diffracted by crystalline matter under angles which are characteristic for the minerals which are contained in the sample, qualitative and quantitative analysis is in principle possible. One of the methods which can be used is the determination of the ratio of the intensity of radiation from calibration samples - containing known quantities of asbestos and irradiated under the same circumstances as the sample containing an unknown quantity of asbestos - with corresponding diffraction points or lines from the latter. From this ratio the unknown quantity of asbestos can derived. A more detailed treatment is given in more specialised articles on this subject (Goodhead et al 1965, Keenan et al 1970, Rickards 1972).

   b. Infrared spectroscopy (figure IV-3). Based on the property that there are characteristic absorption wavelengths in the infrared belonging to the stretch if the O-H bond in chrysotile (Bagioni 1975, Gadsden et al 1970, Keenan et al 1970). By comparing the transmittance at 2.72µm of a sample with an unknown asbestos content with the transmittance at the same wavelength of calibration samples, the unknown asbestos content can be established.

   For both X-ray diffraction and infrared spectroscopy the most suitable sample size is approximately between 100 µg and 10 mg. The limits of both methods are described in table IV-3.

Table IV-1. Data on microscopical techniques used to determine the asbestos concentration of air

technique	estimate of minimum concentration	relative reproducibility *) at the 95% conf. level	total time necessary to analyse one sample
optical microscopy	1 fibre/ 100 cm^3	~ 60%	~ 1/4 days
transmission electron microscopy	10^{-10} g/m^3	~ 100 - 1000%	~ 2 days

* (See following page)

Table IV-2. Data on microscopical techniques used to determine the asbestos concentration in water

technique	estimate of minimum *) concentration	relative reproducibility **) at the 95% conf. level	total time necessary to analyse one sample
optical microscopy	10-100 f/cm^3 10^{-1} µg/l	~60%	~ 1 day
combination of scanning and transmission electron microscopy	100-1000 f/cm^3 10^{-5} µg/l	~100-1000%	~ 5 days

Table IV-3. Limits of infrared and X-ray diffraction analysis of asbestos

Type of analysis	Type of asbestos	Minimum detectable asbestos amount	Minimum wt.% detectable asbestos	Time main apparatus is used	Total time incl. prep. of sample
X-ray diffraction	all types	~ 1 µg	~ 1	~ ½ hr	~ hrs
Infrared spectroscopy	chrysotile only	~20 µg	~ 1	~ 3 min	~1 hr

*) Smallest fibre which can be detected with an optical microscope; under prevailing conditions the following approximate dimensions length >2 µm, diameter >0.3 µm can be given; for the electron microscope these dimensions are length >0.1 µm, diameter >0.01 µm. Finally it should be mentioned that there is a growing tendency to report the results of electron microscopical determinations of the asbestos content of a sample in weight units. The principal reason is that during the quantitative determination of asbestos - especially chrysotile - larger fibres fall apart into fibrils. Sizes found during the qualitative investigation give an indication of the fibre size as it is found in the environment and should be reported separately.

**) The stated reproducibilities can only be attained with highly experienced personnel.

Remarks

1. The figures quoted hold good for small series of samples. When large series of comparable samples have to be analysed, streamlining and automatisation of procedures can result in considerable total time gains.
2. The relative error in the determinations is 5-10% when quantities and concentrations of asbestos in the sample are larger than 10 times the minima stated in the table.
3. When no asbestos can be detected the sensitivity and minimum concentration is, under favourable conditions, an order of magnitude lower
   < 0.1 µg and < 0.1 wt. % for X-ray diffraction
   < 1 µg and < 0.1 wt. % for infrared spectroscopy.
4. Lower detection limits than the ones collected in table IV-3 are reported in the literature and were probably obtained under more favourable conditions.

3. Other analytical methods

For the sake of completeness, a third collection of analytical methods is mentioned. They are based on the detection of one or more constituent elements of asbestos. Selection of these elements is on the basis of sensitivity and the ease of the analytical technique.

From the empirical formulae of asbestos which are collected in chapter I it can be shown that the constituent elements of asbestos are very aspecific. All the elements described in chapter I are present in many compounds which in general are frequently present in air, water, soil and food at concentrations which are orders of magnitude higher than the asbestos fibres. They can only be used when it is known that samples contain considerable amounts of asbestos. This may be the case in asbestos processing industries and in their immediate vicinity. Techniques which are used under the latter circumstances are atomic absorption, emission- and flame spectroscopy. X-ray fluorescence (Keenan et al 1970). Data on these methods are collected in table IV-4.

The relative error in the determinations is approximately 5 - 10%, when quantities and concentrations of asbestos or constituents of asbestos which are determined are larger than 10 times the minima stated in the table.

Table IV-4. Data on analytical techniques used to detect asbestos

		Name of technique							
		Atomic. abs.		Flame spect.		Emission sp.		X-ray fluor	
		min. amount µg	min. conc. wt.%	min. amount µg	min. conc. wt.%	min. amount µg	min. conc. wt.%	min. amount µg	min. conc. wt.%
Element	Mg	0.1	0.01	0.1	0.01	0.2	0.001	10	0.01
	Si	20	2	-	-	0.2	0.001	10	0.01
	Fe	1	0.1	0.1	0.01	0.2	0.001	10	0.01
Time equipment is in use		minutes		minutes		minutes		½ hr	
Order of magnitude total time of determination		hrs		hrs		hrs		hrs	
Remarks		elements have to be dissolved in water				sample can be analysed without pretreatment			

4. Future development

It can be expected that in the next decade a number of automatic techniques for the determination of asbestos will be perfected:

1. Improved scanning electron microscopes linked to computers using pattern recognition techniques combined with X-ray fluorescence (Eichen, Heinrich, Maggiore, White: pers. comm.). Advantage: flexible, can be used for many purposes; disadvantage: very expensive, 1-2 x 10^6 "European conversion units" (f.3.60).
2. Separation of asbestos from other materials followed by simple analysis. Use could be made of strongly nonhomogeneous magnetic fields which is a promising alternative approach (Kolm 1975). Advantage: flexible, specific, might be relatively simple; disadvantage: might be costly.

5. Conclusions

Due to the small size of the asbestos fibres present in the ambient environment, electron microscopy plays an important role in their qualitative and quantitative determination. For the same reason large magnifications have to be used, which means that only very small samples can be investigated in a reasonable time resulting in relatively rough estimates (order of magnitude) of the asbestos concentrations which have to be determined.

It should be noted that there is a growing tendency to report investigations in weight concentrations* as there exists a tendency for larger fibres to fall apart into small fibrils during the qualitative assessment of the concentration. Sizes determined during the qualitative investigation give an indication of the fibre size as found in the environment and should be reported separately. Without this information the conversion of weight concentration (weight of fibres/volume of air) into a numerical concentration (number of fibres/volume of air) and vice-versa is not possible.

The E.E.C. Workshop on metrology in 1976 concluded that:

Air

1. Ambient air is and has been monitored for asbestos in some of the Member States, but only a few of the monitoring programmes are systematic in nature and carry out a detailed examination of the nature of the fibres.

2. In view of the possible importance, from the public health standpoint, to determine and identify fibres in air which are sub-microscopic in size, analytical techniques using the electron microscope are required.

   The availability of analytical facilities for such measurements being limited and each determination being time consuming and costly, the number of analyses, even in a comprehensive monitoring programme, must be limited.

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*) To prevent misunderstandings it should be pointed out that this statement concerns the ambient environment. For the maximum allowable concentrations which are applicable under occupational conditions there is an increasing tendency to follow the methods used by HM Factory Inspectorate, reporting the concentrations in fibres/cm^3.

3. Such monitoring programmes should concentrate primarily on areas where potential sources of asbestos emissions are present.

4. The monitoring should be done at fixed sites with continuous sampling on filters. In view of the biological importance of integrated exposures and to reduce the number of samples, each filter should sample continuously for one week or more.

   Gravimetric determinations should be done on most of the samples; a fibre count and size and limited identification (chrysotile and amphiboles) on a selected number; and a detailed identification on a few samples.

5. An intercomparison programme has been initiated by the Commission in order to gain knowledge about the magnitude of the possible differences which may be found in the results. Standardisation of sampling and sample preparation methods would be considered, as necessary, in a second stage. The results of this programme will help determine the point in time when routine monitoring for asbestos in air could be undertaken.

Water

6. Drinking water is not monitored systematically for asbestos in most Member States; however, a few specific studies have been conducted.

7. The analytical techniques applicable to air samples can also be used for water. In general, the monitoring programme for asbestos in water at the tap may be much less extensive than for air, but attention should be paid to areas where water may come in contact with asbestos material. Most of the samples might be examined by optical microscopy with a few random samples checked by electron microscopy with the same procedure as described for air.

8. The sampling and preparation problems involved with the determination of asbestos material in other beverages and food items is more complicated than for drinking water, and monitoring could be envisaged only when there is a suspicion of contamination.

V. EXPOSURE LEVELS IN THE AMBIENT ENVIRONMENT

Due to the low absolute quantity and - from a analytical point of view even worse - the extremely low relative quantity of asbestos compared with other inorganic solid substances generally found in samples, it is of little wonder that there is still insufficient knowledge about the general occurrence of asbestos in the ambient environment.

In the following paragraphs a summary is given of pertinent work on this subject. It has to be kept in mind that results of different investigators even if reported in the same units, are often difficult to compare (see Chapter IV).

1. Air

1.1. In buildings

In the U.K. a survey has been made in buildings of different age where the principle types of asbestos-based buildings materials have been used (Byrom et al, 1969). More than 60 buildings of various types were included in the survey. Sampling and assessment were carried out along guidelines which were described by Holmes (see Chapter IV). The basic method is air filtration using membrane filters of suitable pore size (8 µm or lower). The filters are examined using phase-contrast light microscopy enlargement 500 x. Fibres with a diameter <3 µm are taken into consideration only.(see Chapter V).

The results of the survey are summarized in the Tables 1 and 2.

From Table 1 we can deduce - though with reservations - that asbestos is emitted in decreasing quantities in the series: insulation board, sprayed asbestos, asbestos cement sheeting, other asbestos containing products.

Summarizing the results of numerous measurements carried out in subway stations and public buildings with exposed sprayed insulations containing asbestos, concentrations of 10 fibres per 1000 cm^3 were found using the light microscope techniques which are used in occupational hygiene. They represent a weight concentration of the order of magnitude of $10^{-6} g/m^3$ which is low, but considerably higher than the asbestos concentrations found in the open air

(Wagg, pers. comm.).

Detailed investigations have been carried out in buildings in France (Bignon et al 1975) and Germany which support these data.

Table V-1. Asbestos dust concentrations according to materials used

concentration (fibre/1000 cm^3)	type of material				total	
	insulation board	asbestos cement sheeting	sprayed asbestos	others *)	(No)	(%)
0 - 5	17	2	7	8	34	46
> 5 - 10	8	3	5	0	16	22
>10 - 20	6	2	2	0	10	14
>20 - 30	2	1	3	0	6	8
>30 - 40	2	0	0	0	2	3
>40 - 50	2	0	0	0	2	3
>50 - 80	2	0	1	0	3	4

*) Includes fully compressed flat sheets, partition board and low density rigid planels

Table V-2. Asbestos dust concentrations according to type of building

concentration (fibre/1000 cm^3)	type of building								total	
	Hospital	Education	Factory or Storage	Office	Shop	Place of assembly	Residential	Miscellaneous	(No)	(%)
0 - 5	4	15	3	6	1	2	3	0	34	46
> 5 - 10	1	3	2	2	4	2	1	1	16	22
>10 - 20	1	0	4	0	1	1	2	1	10	14
>20 - 30	2	0	2	0	0	0	2	0	6	8
>30 - 40	0	1	0	1	0	0	0	0	2	3
>40 - 50	0	0	0	1	0	0	1	0	2	3
>50 - 80	0	0	0	2	0	0	0	1	3	4

1.2. Outdoors at several sites

Table V-3. Average chrysotile asbestos concentrations at several sites in 10^{-9} g/m^3

Location	U.K. Rickards (1971, 1973)	Netherlands I.G. TNO (1976)	U.S.A. Nickelson (1970) Munchio (1973)	CSSR Simecek (1971)	France Bignon et al (1975)	Germany*** Roböck (1973)
At the site of an asbestos processing industry, down wind	1	100*	u	1000**	u	u
Town center	0.1	< 0.1	25 - 60	u	0.2-1.5	<0.1
Industrial area	0.1	u	45 - 100	u	u	u
Rural area	0.1-1	u	20	u	u	u

u = unknown

* Down wind, at a height of 1.5 m, 150 m from an asbestos processing industry

** Down wind, at a height of 2 m, 300 m from an asbestos processing industry

*** Personal communication: measurements have been carried out by CERCHAR-France in Essen. Fibres were found but no asbestos. Batelle (Frankfurt) found fibres in Frankfurt with optical microscopy; a fraction of these fibres had properties resembling those of asbestos. This would result in a concentration of approximately 100 x 10^{-9} g/m^3.

Apart from what has been pointed out in the beginning of this chapter on the comparison of the results of different investigators, it should also be kept in mind that the practical detection limit of asbestos in air, using electron microscopy as an analytical tool lies between 10^{-7} and 10^{-10} g/m^3.

It should be noted that the majority of fibres detected in the preliminary Dutch investigations, see Table 3, had a diameter of approximately 0.02 µm and a length of approximately 0.5 µm, which means that they could only be detected with the aid of an electron microscope. These results are -

as far is known - in agreement with the results of other investigators. Finally it should be noted that there is an increasing tendency to report results of electron microscopic asbestos fibre determinations as gravimetric concentrations. The reason for this is that during preparation of the specimen the original fibres are broken down into fibrils, which means that there probably is no correlation between number of asbestos fibres counted with the electron microscope and the number of fibres originally present in the environment.

2. Food (see also 4, Beverages)

No pertinent data on the asbestos content of food is available. Qualitatively it can be said that its content depends on two kinds of asbestos sources:

a. the natural background which depends on the natural asbestos content of soil and water. By passing through asbestos containing geological formation, the latter can pick up considerable numbers of asbestos fibres (vide paragraph 4);
b. asbestos which is introduced by man's action.

In this connection filtration using asbestos filters and the use of talcum, which can contain asbestos, in food, medical preparations, etc. should be mentioned.

3. Soil

Asbestos is the generic term for a number of hydrated silicates which can be separated into flexible fibres (see Chapter I). Though commercial deposits are found mainly outside Western Europe, the minerals are widely distributed and in some regions the soil can contain large amounts of asbestos. This is well known in regions of Finland and Bulgaria but holds too for regions in Italy and France. It is clear that at these places the asbestos exposure level can be considerable but no quantitative data are available.

4. Water and beverages

A restricted number of data are available for asbestos particles in ground, surface and drinking water in mains and at the tap of the consumer. Most of the data relates to serpentine rock containing areas in Canada and in the U.S.A. The first published data origined from Cunningham and Pontefract

in 1971 dealing with a quantitative approach to asbestos in drinking water, in melted snow and river water in Canada and some beverages. Asbestos fibres were detected by transmission electron microscopy at a magnification of 2000x. (see Chapter IV).

It should be noted that in general it is only practicable to recognize chrysotile fibres due to their chatacteristic hollow tube structure. This is an important restriction as many varieties of asbestiform minerals can occur in water, and crocidolite is a common ingredient of asbestos-cement pipes.

1 to 11 million chrysotile asbestos fibres/litre were detected in city drinking water, soft drinks, vermouth, port, sherry and beer. River water contained more asbestos fibres than water passed through a city filtration system, and melted snow contained higher amounts than river water. Fibres were mostly smaller than 1 µm in length. Unfiltered tap water drawn from a lake in the asbestos mining region of Quebec gave a value of 173×10^6/l. The data obtained are given in Table 4.

In 1973 Sargent reported the results of a premilimary survey and a survey of 30 of the 300 water systems in the state of Vermont, U.S.A.. Quantitative analysis of water samples for asbestos have been carried out mainly by the National Environmental Research Centre by a technique using light microscopy at 450 x magnification. Identification of asbestos fibres were carried out visually. This technique has two disadvantages, firstly that the size of the fibres in most instances is below the limits of resolution of the optical microscope and secondly that identification is uncertain. Two samples, one from the source and one from a distribution point were examined in each water system. In 17 out of 23 systems initially sampled the number of asbestos fibres increased from the source to the distribution point while it decreased in 6 systems. Cast iron as well as most of the AC systems showed increased fibre counts from the source to the distribution point. Of 32 distribution systems sampled, 30 contained asbestos. Of the 25 water system sources that were sampled, six showed no sign of asbestos. Of these, four were wells and two were surface sources. The median result for all source samples was 3000 fibres/l and for distribution samples it was 14.000 fibres/l. The data range from 1000/l to 247.000/l. The well sources were generally found to be lower in asbestos fibre count than the surface water

Table V-4. Asbestos fibres in beverage and water

Sample	Source	No of fibres x $10^6 l^{-1}$
Beer	Canadian 1	4.3
Beer	Canadian 2	6.6
Beer	U.S.A. 1	2.0
Beer	U.S.A. 2	1.1
Sherry	Canadian	4.1
Sherry	Spanish	2.0
Sherry	South African	2.6
Port	Canadian	2.1
Vermouth	French	1.8
Vermouth	Italian	11.7
Soft drink	Ginger ale	12.2
Soft drink	Tonic water I	1.7
Soft drink	Tonic water II	1.7
Soft drink	Orange	2.5
Tap water	Ottawa, Ottawa river (F)	2.0
Tap water	Toronto, Lake Ontario (F)	4.4
Tap water	Montreal, St Lawrence river (F)	2.4
Tap water	Hull, Quebec, Ottawa river (NF)	9.5
Tap water	Beauport, Quebec, St Lawrence river, (6 km below Quebec City) (NF)	8.1
Tap water	Drummondville, Eastern Townships, Quebec, St Francois river (F)	2.9
Tap water	Asbestos, Eastern Twonships, Quebec, Nicolet river (F)	5.9
Tap water	Thetford Mines, Eastern Townships, Quebec, Lac à la Truite (NF)	172.7
Melted snow	Ottawa, top 30 cm (2-3 weeks precipitation)	33.5
River water	Ottawa river, at Ottawa	9.5

*) F = Filtration plant used
NF = No Filtration plant used

sources, with respective median values (all samples) of 2.500/l and 12.500 fibres/l. The author suggested that fall out, natural erosion by surface water flowing over serpentine containing fibrous mineral and sewage contributed to asbestos in the surface water sources.

Finally Sargent mentioned the fact that 38 random samples recently picked by the N.E.R.C. from all over the United States ranged from <1000 fibres/l to 46.000 with a median value of 3000. Counting and identification techniques were the same as the Vermont study.

In 1973 Kay reported the first results of asbestos fibre counts concerning drinking water from 22 cities in the Province of Ontario using surface waters for their supplies. The samples were examined by the Ontario Research Foundation. Concentration, counting and identification techniques were basically the same as those used by Cunningham and Pontefract in 1971, being restricted to chrysotile asbestos fibres. The samples were examined at a direct screen magnification of 25.000 x and in some instances magnifications of 50.000 x were used for proper identification. Fibre counts ranged from 0.136×10^6 in Ottawa's tap water to 3.87×10^6 chrysotile asbestos fibres/l in Sarnia's. Table 5 shows the results. Additional surveys in the distribution system of the municipality of Metropolitan Toronto resulted in 0.72×10^6 to 4.06×10^6 asbestos fibres per litre. Asbestiform fibre counts concerning drinking water in the city of Duluth, Minnesota have been reported to be 1×10^6 to 100×10^6 fibres/litre (Kay, 1973).

In September 1974 the International Joint Commission from the Great Lakes Research Advisory Board published the report "Asbestos in the Great Lakes Basin" with emphasis on Lake Superior. Figures are presented from the "Preliminary Reports on the Status of non-medical studies on Asbestos in the Great Lakes and St Lawrence River Regions" by Weiler of the Canada Centre for Inland Waters, Burlington, Ontario in January 1974. The average concentration was about 1.7×10^6 asbestos fibres/l. Locations with higher counts were found along the North shore of Lake Superior between Silver Bay and Duluth (this area was affected by discharge of teconite tailings by Reserve Mining Company) along the St. Clair River, downstream from Montreal and in the asbestos mining district in Quebec. At locations sampled by EPA, the fibre count in the water distribution system was often higher than in the raw

Table V-5. Asbestos fibre count (distribution system - water)

sample location	source	fibre count in millions per litre	estimated mass concentration, g/l
Toronto	L. Ontario	1.90	0.000941
Belleville	Bay of Quinte	0.533	0.000937
Brantford	Grand River	0.570	0.00113
Brockville*	St. Lawrence River	0.446	0.000602
Chatham	Thames River	0.595	0.00157
Cornwall	St. Lawrence River	2.11	0.000729
Hamilton	L. Ontario	0.694	0.000154
London	L. Huron	0.456	0.000429
Niagara Falls	Niagara R.	2.58	0.00225
North Bay*	Trout L.	0.384	0.000104
Oshawa	L. Ontario	0.557	0.000159
Ottawa	Ottawa R.	0.136	0.000093
Pembroke*	Ottawa R.	2.85	0.000538
Peterborough	Otonabee R.	1.86	0.00354
Port Colborne	Welland Ship Canal	0.608	0.000847
Sarnia*	L. Huron	3.87	0.00213
Sault Ste. Marie*	St. Marys R.	0.248	0.000141
St. Catharines	Welland Ship Canal	1.03	0.00156
Sudbury*	Ramsay Lake	0.297	0.000542
St. Thomas	L. Erie	1.60	0.000500
Thunder Bay*	L. Superior	0.830	0.000235
Welland	Welland Ship Canal	0.820	0.000479

Note: * means No Filtration plant

intake water. The average background level of asbestos fibre concentrations in the water distribution systems in the Great Lake Basin was 1.6×10^6 fibre/liter and 90% of the areas tested at $<3 \times 10^6$ fibre/l.

Of the various Canadian studies, only at Ottawa and Toronto were samples taken by different investigators at different times. Ratios between the counts ranged from about 2 to 14. Ratios in samples taken at Niagara Falls and Thunder Bay in different years ranged from about 1 to 5. Variability of the counts was within a factor of 2 or 3.

Comparison of the effects of filtration in a water treatment plant are available for Windsor. In Windsor the reduction was as much as 90%. Pang (1975) recorded up to 99.8% removal by flocculation using 10 ppm ferrichloride and 1 ppm polyelectrolyte at pH = 7.5.

Continued drinking water sampling programs of the Canada Centre for Inland Waters produced additional results in May 1974. In the Northern Ontario mining/milling area at Timmins (Natagani River) untreated water had a concentration of 1.78×10^6 and treated water 0.261×10^6 fibres/l. At the Union treatment plant in Leamington on Lake Erie values were 2.17 and 5.15×10^6 (untreated) and 0.957×10^6 (treated).

The American Waterworks Association Research Foundation published "A study of the problem of asbestos in water" in September 1974 (13). A facsimile of report no. E404-79 of the John-Manville Research and Engineering Centre concerning the removal of chrysotile fibre from the inner walls of asbestos cement pipe by potable water in water systems has been incorporated. Two municipal systems were selected: Malvern, Pennsylvania and Glendale, Arizona. Both systems utilised well water sources. The Malvern well was drilled in a serpentine rock belt containing chrysotile fibre while the Glendale system was outside any serpentine-bearing area. Table 6 gives some characteristics and data summary.

Statistical analyses of the fibre level data resulted in an average of all well site samples for Malvern of 0.04 µg/l and 0.005 µg/l for Glendale. There was a 90 percent probability of an increase in fibre level between the well site and the domestic site at both Malvern and Glendale. It was also shown

that there was no significant correlation between the initial fibre level and the amount of increase. It was concluded that it thus appeared that the water is picking up fibres from the pipe wells. The average fibre level increase at Malvern is 0.07 µg/l, while at Glendale the average increase is 0.004 µg/l. From Table 6 it can be seen that there is not a large difference in pipe area exposed per gallon of water between the Malvern and Glendale pipe systems.

Table V-6. Municipal system characteristics and data summary

	Malvern	Glendale*	
Pipe system			
diameter (inch)	8	12	6
length (ft)	2800	1300	12000
area exposed to water (sq ft)	5860	4150	18700
water volume flow rate (gal/min)	125	800	80
water linear flow rate (ft/min)	48	138	54
pipe area exposed (sq ft/gal)	0.80	0.54	**1.06
water volume in pipe		0.96**	
Water properties (well site)			
total hardness (mg/l $CaCO_3$)	49	94	
Calcium hardness (mg/l $CaCO_3$)	27	61	
alkalinity (mg/l $CaCO_3$)	110	114	
dissolved solids (mg/l)	106	328	
pH	7.8	8.0	
Average initial fibre level (g/gal) (well site)	0.17	0.023	
Average fibre level increase (g/gal)	0.28	0.015	

* The first 1300 ft of the Glendale system utilized 12. inch diameter pipe, followed by 12000 ft of 6. inch diameter pipe

** Overall system

Chrysotile fibre counts in water from municipal water systems and water from the rivers Juniata and Connecticut were also carried out. In all cases approximately 151 samples were taken. Table 7 shows the results.

Table V-7. Chrysotile asbestos content of river water

	3/71	4/71	5/71	6/71	7/71	8/71	9/71	10/71	11/71	12/71	1/72	2/72	3/72
Junia a River Breetewood PA	0.0	0.0	0.34	0.12	0.0	1.07	2.42	0.16	0.05	0.77	0.48	1.48	0.0
Newton-Hamilton	0.0	0.0	0.0	0.0	0.0	0.62	0.0	0.0	0.32	1.63	1.44	1.09	2.28
Lewistown	0.78	0.16	0.62	0.88	-	2.84	0.0	0.0	0.29	2.26	3.94	-	-
Amity Hall	1.59	1.66	0.78	0.0	-	2.53	0.0	0.0	0.06	0.0	3.90	-	-
Connecticut R.													
Canaan, Vt.	12.46	3.67	0.39	0.33	0.0	1.77	0.48	0.78	0.11	0.42	0.0	0.13	0.0
Littleton, NH	0.69	0.0	0.14	0.73	0.13	0.0	3.63	0.22	0.33	0.0	0.52	0.49	0.0
Lebanon, NH	0.64	0.0	0.0	0.82	0.69	0.51	0.0	0.44	0.45	0.30	0.37	0.27	0.0
Greenfield, Mass.	1.68	6.18	0.90	0.0	0.18	1.07	0.18	1.17	0.44	0.27	3.18	1.21	0.51
Middeltown, Conn.	1.67	3.05	1.21	2.66	1.78	3.81	0.0	0.23	0.13	-	0.79	1.13	2.28

Note: All data in micrograms per litre.

All values were determined by electron microscopic observations. No fibres were visible in any of the samples using the optical microscope at 450 x magnification.

The only publication dealing with asbestos fibre counts in drinking water within the EEC countries was published in 1974 by Elzenga, Meyer and Stumphius. Data were reported from a preliminary investigation in the Netherlands carried out in 1969 and 1970 dealing with watersamples from 22 mains and connected domestic pipes. Asbestos fibres were detected with light microscopy at a low magnification of 50 x. In 1972 water samples were taken at the same place as in 1969 and 1970 from a 31 and a 35 year old AC watermain through which a calcium carbonate aggressive type of water had been distributed. Fibre counts were carried out by electron microscopy and light microscopy at magnifications of 10.000 x and 500 x. Identification of the particles was carried out by shape-recognition supplemented with the results of electron diffraction and microprobe analysis.

In the Netherlands all the waterworks mentioned are deal with ground water supply. No influence of asbestos containing serpentine can be expected in the Netherlands.

Fibre counting was complicated by the presence of a great number of other inorganic particles up to 50.000-100.000 for each asbestos fibre. The mean diameter and length of the asbestos particles detected by REM and TEM ranged from 0.2-0.3 µm and 5-10 µm.

Fibre counts in drinking water from AC mains detected by light microscopy at an enlargement of 50x ranged from not detectable to smaller than 10 fibres per litre. Fibre counts in tap water were always smaller than 1 fibre per litre and in general not detectable. At a magnification of 500 x fibre counts in water from the two mains amounted to 24×10^3 and 33×10^3 fibres per litre. Tap water supplied by the above mentioned mains contained 6×10^3 to 13×10^3 fibres per litre. Fibre counts by REM and TEM of the same samples resulted in respectively 60×10^3 and 85×10^3, and 60×10^3, and 240×10^3 fibres per litre.

Assuming that the above mentioned samples are representative for the Netherlands, asbestos fibre concentrations in mains and tap water are about 100×10^3 fibres per litre.

No investigations have been carried out as regards the source of the asbestos fibres but it is very likely that asbestos cement mains are the main contributors.

Conclusions

Very little quantitative information on the occurrence of asbestos in the ambient environment is at present available. The presented data were collected from U.S. publications - air and water; Canadian publications - water and beverages; U.K. publications - air; Dutch publications - water.

It is known that in several countries belonging to the European communitiy, surveys of the occurrence of asbestos in ambient air are under way. From personal contacts it is known that the results of the determinations are in agreement with the preliminary results obtained in the Netherlands and the

data from U.K.

The concentration of asbestos fibres in the ambient air is in general lower than 10^{-9} g/m^3 except in the neighbourhood of asbestos processing industries where considerably higher concentrations have been detected. In the immediate vicinity - <500 m - concentrations which are 1000 times higher, have been reported.

The detected fibres have a length between 0.1 - 1 µm and a diameter between 0.02 - 0.1 µm and can only be detected by electron microscopy.

The concentration of asbestos fibres in beer, sherry, vermouth and soft drinks have been reported to be 1.1 - 12.2 x 10^6 fibres/l.

In Canada and the U.S.A. raw water sources for drinking water supply ranged from 173 x 10^6 fibres/l for Lac la Truite in Canada, a lake in which active dumping of asbestos containing tailings takes place, to a rough estimate of 3.10^3 fibres/l for the Saginaw source (unpolluted).

Asbestos concentrations in drinking water range from 100.10^6 in Duluth (USA), which has a raw water source which is directly influenced by dumping of asbestos containing tailings to 0.1 x 10^6 - 9.5 x 10^6 fibres per litre in supply systems from ground and surface waters in Canada including areas of asbestos mining districts. The American Water Works Association reports ranges of 0.001 - 1.69 µg/l in several distribution systems in the USA.

In the Netherlands asbestos fibre counts in drinking water from asbestos cement watermains through which for more than 30 years a slightly agressive type of water has been distributed ranged from 0.06 x 10^6 - 0.24 x 10^6 fibres.

Conversion from numerical to gravimetric concentrations and vice versa is only possible if fibre size distributions are available.

Due to the fact that classification of the relation between fibre size and biological effect is central to the possible environmental hazard of asbestos, the reporting of fibre dimensions in addition to fibre concentration is imperative.

VI. UPTAKE AND DISTRIBUTION OF ASBESTOS, PATHOLOGICAL MECHANISMS

Uptake of asbestos fibres in the human body has two pathways: the respiratory tract and the digestive tract. Contamination of the skin may give rise to formation of asbestos warts, but this does not lead to the uptake of asbestos in the body. Parenteral administration of asbestos is used in animal experiments, and there also exists the possibility of such administration in humans (see chapter IX-4).

Uptake through respiratory tract

Human airways are equipped with defence mechanisms preventing the penetration of dust particles to the lungs. This mechanism consists mainly of the mucous membrane with ciliary epithelium in the nasopharynx and the upper and the lower respiratory tract. Particles in inhaled air will be trapped and subsequently propelled in the direction of the nasopharynx. These mechanisms work very efficiently for particles >5μ. (N.B.: heavy cigarette smoking interferes with the ciliary epithelium activity). For smaller dimensions the efficiency decreases rapidly; for the smallest particles the mechanism has no effect, resulting in deposition in the lung alveoli.

Purification of asbestos-dust containing respiratory air is unfortunately hampered by the property of asbestos fibres to split up easily in numerous fibres of relatively great length and very small diameters (see chapter I). Timbrell (1965, 1973) showed that the passage of asbestos fibres through the airways was only related to fibre diameter; the upper limit of this diameter is 3μ. With regard to the length of fibres there is no clear limit; lengths > 200 μ however lead to more efficient activity of the defence mechanisms. This means, that exposure of a human being to asbestos dust leads to the passage of a substantial part of the inhaled asbestos to the lungs themselves. Subsequently a part of these fibres may be coughed up, either as fibres or in the shape of asbestos bodies (see chapter VII). The clearance of the lungs also depends upon the physical properties of the fibres: the curliness of the fibre, greater in chrysotile than in amphiboles, will influence the deep penetration: so that there is less penetration in chrysotile, more in amphiboles.

The above mentioned physical property of asbestos fibres of splitting up into diameters which are very small in comparison with diameters of most other natural or artificial fibres, leads to the conclusion that fibres found in

lung tissue frequently have to be asbestos fibres. The human body, generally speaking, reveals an excellent defence against non-asbestos fibres, most of them having a diameter >3 µ.

Further data given in this chapter will reveal that the more stiff amphibole fibres, and short chrysotile fibres, may reach the pleura, passing through the lung tissue in a mechanical way. Moreover it has been established that in these circumstances asbestos fibres may be found not only in the lungs and pleura, but also in the lymph nodes and spleen (Meurmann 1966).

Uptake through the digestive tract

Uptake of asbestos fibres through the digestive tract occurs in a direct and an indirect way:

Direct: ingestion of fibres in asbestos exposed persons through the mouth. This happens in eating and drinking, in smoking in asbestos contaminated ambient air, in insufficient hygienic conditions of hands and clothing, and in swallowing of asbestos fibres trapped in the nose and mouth from contaminated respiratory air.

Indirect: sputum, produced in the normal physiological processes from the lungs and lower respiratory tract, will be swallowed regularly. After exposure to asbestos containing ambient air a multitude of asbestos fibres will be found in the sputum, either as fibres or as asbestos bodies (see chapter VII).

Discussions and experiments on the possibility of ingested asbestos fibres penetrating the intestinal wall are still going on (Lee 1974, Cross 1974), in contrast to the proven passage through the lung tissue. This possibility is not excluded and might be responsible for the excess incidence of gastrointestinal cancer in cohorts in heavy occupational exposures (see chapter VIII).

In this way asbestos fibres afterwards may be found in various organs such as the spleen, liver, kidneys, lungs, brains, lymph nodes and blood.

Pathological mechanisms

For various diseases in relation to uptake of asbestos in the human body (see chapters VIII, IX, X) a direct relationship has to be accepted; a precise explanation of the pathological mechanism is not available.

Development of lung fibrosis in asbestosis may originate from asbestos fibres penetrating the alveolar epithelial cells, interfering with cell- and enzyme-activity (Beck et al 1972, 1975). This leads to the conclusion that the fibre form is the most important factor - this will be discussed further on in this chapter.

Asbestosis may develop from exposure to all four important types of asbestos, regardless of the dimensions of the inhaled fibres, the longer ones however seem to be more pathogenic.

In relation to the asbestos induced excess incidence of cancers Gilson (1973) lists the following factors: dose and duration (see chapter X); type of fibre; age; sex; occupation; and cofactors (particularly smoking). The four important types of asbestos apparently differ in their biological effects, as well as in their deposition in the lungs. Epidemiological evidence leads to the conclusion that the incidence of bronchial cancer as seen in asbestosis, does not depend upon the type of asbestos but mainly on the dose level. However, in view of the established fact that there is a multiplicative effect between cigarette smoking and exposure to asbestos dust the statement that in occupationally exposed populations an excess incidence of bronchial cancer is only associated with asbestosis needs reassessment.

The incidence of mesothelioma is linked to the type of asbestos. There is a general agreement that the risk of mesothelioma is fibre-related in the order crocidolite > amosite > chrysotile > anthophyllite; the magnitude of the difference between, for example, crocidolite and chrysotile is not well established. Lewinsohn (1974) presented a review of studies, centered around this theme.

Amphibole fibres usually have a rectolinear shape in contrast to the "curly" shape of chrysotile (see chapter I). Amphibole fibres therefore may penetrate more efficiently through lung tissue, and reach the pleura rela-

tively easily in a purely mechanical way. In addition, chrysotile fibres - especially the longer ones - are more efficiently cleared from the lungs by ciliary action. It is generally concluded that commercial asbestos fibres normally have a length - diameter ratio of approximately or greater than 10:1. From the biological point of view fibres with a diameter below 3μ are considered important, but in man, fibres below 1μ diameter are considered to be most significant.

Timbrell (1973) studied the relationship between fibre diameter and length and the possibility of penetration in the lungs. Fibres of 3μ diameter are the thickest that are likely to be deposited in the alveolar regions. The rectolinear, stiff amphiboles will reach deeper regions than the "curly" chrysotile fibres. In rats exposed to a dust cloud of various types of asbestos in equal concentrations, crocidolite was found near the pleura; amosite fibres were present in lower numbers because of a greater diameter; anthophyllite fibres in still lower frequency, their diameter again being larger ; chrysotile was seldom observed near the pleura since there is not sufficient penetration because of its curly shape. Short chrysotile fibres however, being short arcs, may behave like crocidolite; the same is found in mixed chrysotile - amphibole exposure.

In cohort studies in workers exposed to chrysotile, Mc Donald et al (1973) observed a modest increase in cancers; the prevalence of mesothelioma was relatively low. Webster (1973a) investigated malignancy in relation to crocidolite and amosite in South Africa. Bronchial carcinoma occurred in all asbestos areas (chrysotile, crocidolite and amosite); mesothelioma however mainly occurred in the crocidolite regions. In anthophyllite exposed workers in Finland an excess of bronchial carcinoma and asbestosis were found, but not of mesothelioma (Meurmann et al, 1974) (see chapter IX).

Workers in asbestos textile-, cement-, insulation-industries, etc., are usually exposed to several types of asbestos at the same time or subsequently. Data analysed by Selikoff et al (1973a) revealed no difference in mortality and cause of death between groups in construction-insulation work with exposure mainly to chrysotile and shipyard-insulation work with comparatively more use of mixed chrysotile/amphiboles.

In the USA Enterline et al (1973) studied the mortality experience in retirees from the asbestos industry. After adjustment for cumulative dust exposure, men exposed only to chrysotile revealed a respiratory cancer mortality (not distinguished between bronchial carcinoma and mesothelioma) 2.4 times the expected; exposure to a combination of chrysotile and crocidolite increased the ratio to 5.3. Asbestos cement industry workers only exposed to chrysotile showed a respiratory cancer mortality ratio of 1.4; those exposed to mixed chrysotile and crocidolite had a ratio of 6.1.

These data lead to the conclusion that in relation to mesothelioma crocidolite is more carcinogenic than chrysotile or amosite. This is in agreement with the Report of the Advisory Committee on Asbestos Cancers (IARC 1973).

In rat experiments (Wagner et al 1973) mesotheliomas were observed after intrapleural inoculation with all types of asbestos and other non-asbestos fibrous materials. In asbestos a considerable proportion of animals developed mesothelioma - this happened in lesser proportions with the other materials as aluminium silicate, glass fibres, etc. The risk of developing pleural mesothelioma after injection was proportional to the dose. The chemical properties of the fibres proved to have a minor influence in developing the tumor; their physical properties appear to be responsible for carcinogenesis. Pott et al (1972a, b) came to the same conclusion after intraperitoneal injection of fibrous materials in rats and the following development of tumors. In these animal experiments fibres reach the pleural and peritoneal cavity in a distinctly unnatural way; in asbestos exposed human beings one has clearly to realize the role of these physical properties in relation to the possibility of the various types of fibres reaching the target organs in sufficient quantities.

Stanton (1973) reported the results of experiments in rats of applying various types of asbestos, fibrous glass and fibrous aluminiumoxide to the pleural cavity by open thoracotomy. The incidence of pleural mesothelioma showed that the carcinogenity seems to be related to fibre-sizes <2.5µ in diameter and 10-18µ in length. Present evidence (not yet published) suggests that fibres about 0.25µ and 1.5µ in diameter and between 10 and 60µ length, may be especially important. No tumours developed if crocidolite or chrysotile were pulverized to a non-fibrous form. So the structural properties determine to a great extent whether inhaled asbestos is deposited in the lung, and whether

it has a possibility of reaching the pleural; if this organ is reached in sufficient quantities an increased incidence of mesothelioma results.

Pooley (1973) performed an electron microscopic examination of lung tissue from 120 cases of mesothelioma and 135 control cases, with the following results:

1. in mesothelioma cases the lungs contained larger numbers of asbestos fibres than in controls;
2. in mesothelioma cases amphibole asbestos was more predominant;
3. asbestos bodies were found associated more closely with amphibole fibres than with chrysotile.

These findings are in accordance with the data of the rat experiments mentioned above.

Timbrell (1973) applied these findings in explaining apparent differences in prevalence of malignant tumours in lungs and pleura in relation to the type of inhaled asbestos. This also explains the difference in mesothelioma incidence in Cape-Province and Transvaal in South Africa, the crocidolite and amosite fibres in the latter area being larger in diameter and length. The Transvaal are less respirable, the deposition rate in the upper bronchial tree is higher and there is a less efficient penetration into the deeper lung regions.

Conclusions

From the foregoing it has become evident that:

- fibres with a small diameter (<3μ) - especially those below 1μ - and a relatively great length - the aspect ratio being >10:1 - are carcinogenic if introduced into the pleural or peritoneal cavity;
- carcinogenity seems to be largely independent from chemical composition of the fibres;
- structural properties of inhaled fibrous dust particles determine the amount and place of deposition.

These conclusions are supported by epidemiological evidence that bronchial carcinoma (and asbestosis) occurs from all types of asbestos, whereas mesothelioma particularly occurs from amphibole asbestos (with the exception of anthophyllite)

and short chrysotile fibres in cases of respiratory exposure. Up till now there are no indications that the type of asbestos significantly affects the risk or gastro-intestinal cancers in oral uptake of these minerals.

Stanton (1974) stresses the fact that minute fibres are abundant in our environment, the list of fibres used by man increasing continuously. Fortunately the majority of these (non asbestos) fibres are of such dimensions, that the possibility of deposition in lungs, possibly followed by penetration to the pleura, is slight. However: small fibres, deposited in the lungs might be carcinogenic. Here lies an area for serious concern, also in regard to true environmental exposure to durable fibres. In monitoring ambient air one has to concentrate efforts on determining quantitatively and qualitatively concentrations, size distribution and chemical composition of the fibrous materials. Up till now too few data are available even to give an approximate estimation of their occurrence.

The E.E.C. Workshop on Metrology, in 1976, concluded that :

1. At present results of measurements of asbestos in tissues can not be directly related to environmental levels.

2. For the examination of fibre and mineral content of biological tissues, electron microscopic techniques are indispensable.

3. The order of priority regarding measurements to be made in lung tissues are as follows:

i Numerical concentration of total fibres (asbestos and non asbestos) present per unit weight or volume of tissue.

ii Numerical concentration of all types of asbestos fibre present per unit weight or volume of tissue.

iii Size distribution (length and diameter) of total fibre or individual fibre types.

iv Gravimetric concentration of total and individual fibres of all types present per unit weight or volume of tissue.

v Gravimetric concentration of total mineral dust per unit weight or volume of tissue.

vi In certain cases analysis of this total mineral dust.

For lung tissues special and separate attention has to be given to each of the following steps: sampling, preparation and analysis.

VII. POSSIBLE BIOLOGICAL INDICATORS OF PAST NON-OCCUPATIONAL OR PARA-OCCUPATIONAL ASBESTOS EXPOSURE

In order to get any information about the question "who has been exposed to asbestos", it is necessary to consider the different biological methods that can be used to answer this question. In principle the available methods are:

1. the demonstration of asbestos fibres in the human body or its excreta (e.g. sputum);
2. the demonstration of asbestos bodies (asbestos fibres surrounded by protein and iron coating) in the human body or its excreta. Special attention should be given to the problem of the specificity of these bodies;
3. the demonstration either clinically or at autopsy of pathological processes, which are considered to be pathognomonic, highly specific or highly suggestive of past asbestos exposure. To this group of processes belong asbestosis, pleural plaques and several kinds of malignant tumours.

Asbestos fibres

Only a limited number of studies on asbestos fibres in the human body or its excreta are available. Single fibres with a length less than 5µm and a diameter less than 1µm are too small to be recognized by the lightmicroscope, but bundles of fibres can be seen by this method in some cases. In most cases these bundles or aggregates of fibres are still too small to be seen by the lightmicroscope. This means that the lightmicroscope can show only a small percentage of all fibres; a negative result does not prove the absence of asbestos. Phase-contrastmicroscopy has also been used (Otto 1969) but the limitations mentioned above are valid for this method also. As the morphology with these magnifications is not specific, these methods are not specific for asbestos, but they can be used by those who only wish to have a total count of fibres of lengths greater than 5µm (Lee 1974)(see chapter IV).

These limitations are not present in the case of electronmicroscopy combined with electron diffraction for example as used by Pooley (1972, 1973). He studied lung tissue and slides of lung tissue of mesothelioma patients and controls. In this last group which contains a mixture of control cases from Great Britain, Sweden and the Netherlands he found asbestos fibres in 65 out of 135 cases. In 30 cases one of the amphiboles (probably croci-

dolite) was present and in 41 cases chrysotile. It is not known however to what extent this control group might be considered representative for the whole population.

Gross et al (1974a), using lightmicroscopy and electronmicroscopy, found asbestos fibres in lungs of people presumably not occupationally exposed to asbestos. In addition to identifiable chrysotile fibres they found much larger numbers of mineral fibres of unknown composition; fibres from glass or rockwool and ceramic aluminium silicate were identified; in addition fibres from the skeleton of plants and diatom fragments were found. The authors measured the fibre content of non-occupationally asbestos exposed subjects (more females than males) from Pittsburgh (high industrial smoke emission) and Charleston (relatively clean seacoast community). The average concentration in the Pittsburgh group was more than three times that in the Charleston group; the average concentration of mineral fibres was seven times as high. Nevertheless, the range of concentrations as found was of an entirely different magnitude than in asbestotic lungs: the percentage of mineral fibres identified as chrysotile asbestos was 7%; this is estimated to be over 95% in asbestotic lungs.

The discussion as to which size of fibre should be looked for has not been settled. As Lee (1974) mentioned in his commentary on a conference on the Biological Effects of Ingested Asbestos: "Some stand by the doctrine enunciated several years ago that only fibres whose length lies between 5 and 25μm are significant" and "Many however are firmly convinced that it is the submicroscopic particle that can penetrate cells and cause damage although they may be fairly rapidly degraded, and that these are the ones that should be measured. Since one large fibre can break up into a multitude of small fibres, a resolution of this disagreement is urgently necessary" (see chapter VI).

The existence of this disagreement means that the use of both the lightmicroscope and electronmicroscope is necessary; this implies that the investigations can only be done on a small scale making it impossible to screen larger groups from the population at the moment: electronmicroscopic investigations can be done in only a limited number of institutes and cost much time and money. The screening of larger groups of the population

is however necessary to evaluate the asbestos exposure of these groups of people. A further evaluation and investigation of the sputum of people suffering from a common cold, preferably with an electronmicroscope, should be considered.

Asbestos bodies

Asbestos fibres can enter the human body by way of the lungs or the digestive tract. There is still much discussion whether the fibres can penetrate the intestinal wall and thus be present in the tissue (Lee 1974, Gross et al 1974b and many others, see chapter VI). The fibres entering by way of the respiratory tract are either excreted, presenting the possibility of finding them in the sputum, or are swallowed and enter the digestive tract, or remain in the lung. Acting as a foreign body the fibre or bundle of fibres gets covered with protein and iron, giving it a golden yellow colour and a special form, depending on the form of the fibre. Usually the form is described as dumbbell, drumstick, necklace, sausage etc. The formation of asbestos bodies can thus be considered to be a form of defence of the body against the fibres. Asbestos bodies themselves probably are biologically inactive.

Originally described as "curious bodies", they were later considered to be specific for asbestos and called "asbestos" bodies. Other fibres have been shown to form asbestos bodies also (Gross et al 1968), but there is no agreement about the part played by other fibres in forming asbestos bodies in the general population. Some authors (Gross et al 1969) could not demonstrate a chrysotile core in asbestos bodies from 28 urban dwellers, while Pooley (1973) found an amphibole fibre as the core of all 18 asbestos bodies investigated by electronmicroscope and diffraction techniques in mesothelioma cases. Although from a theoretical point of view these "asbestos" bodies (also called ferruginous bodies) are not specific indicators of asbestos (Davis et al 1973), the answer to the question whether from a practical point of view the specificity is sufficient to make correlations between asbestos bodies and asbestos exposure reliable, seems to depend upon the local circumstances: in Pittsburgh, no chrysotile in 28 bodies (Gross et al 1969); in New York City, chrysotile in most bodies (Langer et al 1970 and 1971); in London, chrysotile in 70% of cases (Pooley et al 1970). All these investigators used electronmicroscope techniques and diffraction patterns.

Most authors nowadays accept asbestos bodies as a reasonably but not absolutely reliable indicator of past asbestos exposure.

The first publication about asbestos bodies in lungs of subjects not occupationally exposed to asbestos, is by Thomson (1963) who demonstrated the bodies in 30% of males and 20% of females in 500 consecutive autopsies over the age of 15 in Cape Town. There were major racial differences ranging from 62% in Bantu males to 14% in Caucasian females; occupational factors may play an important role here. Similar findings were later reported by him from Miami (Thomson et al 1966a, b, c). In many places similar investigations were done yielding similar findings: Pittsburgh USA: 41% (Cauna et al 1965); Montreal Canada 48% (Anjilvel et al 1966); Finland 57% (Meurman 1966); Glasgow Scotland 23% (Roberts 1967); Flushing Netherlands 53% (Stumphius et al 1968 sputum of shipyardworkers only); Michigan USA 9% (Dicke et al 1969); and many other places (Tyneside, New York, Belfast, Milano, Trieste, Perugia etc.).

The percentages mentioned are not comparable however due to technical differences. The techniques that give the best results are those using lung scrapings and Perls' reaction for staining the iron in the protein surrounding the fibre. Other differences are due to the place of work, residential area (higher in urban than in rural areas) and sex (a higher prevalence in males than in females). Most reports contain no data about the number of asbestos bodies found. Estimates are usually unreliable and really quantitative measurements are not practical. A compromise solution might be a simple quantitative approach using routine histological slides of the lung (Planteydt 1973). A classification in 5 groups was suggested:
class 0: no asbestos bodies;
class 1: very sporadic apprearance, difficult to find one body in a slide;
class 2: few bodies, easy to find, but not in every field;
class 3: many bodies, easy to find at least one in every high power field;
class 4: very many bodies, usually many bodies in each field.

This classification might correlate with the categories used by Pooley (1973), thought to be equivalent to the severity and length of asbestos exposure.

Selikoff et al (1979) found 70% prevalence in men employed in shipyards

and in the building industry, 50% in manual workers, 47% in "white collar" workers and 39% in females. Recently Doniach et al (1975) established similar findings in London, e.g. 61% in workers from the shippping industry, 47.2% in clerical workers, 26% in housewives; there were more positive cases in residential areas of dockland than in (semi-)urban residential areas, which exceeded again the prevalence in a more rural area.

Oldham (1973) reported on the frequency of asbestos bodies in consecutive autopsies in different areas and on the observer variation in viewing these slides. He found: Finland 38% positive; Glasgow and London hospitals (covering areas which include docks and asbestos factories) 22-26% positive; Dresden, Belfast, London RPGS and Liverpool (covering industrial areas which include docks or manufacturers of asbestos products) 13-17% positive; Dorchester and Nottingham (industrial towns without an asbestos industry) 6-9%; and Galway (entirely rural) 1%. He also estimated that in the London area the proportion of of people in whom asbestos bodies can be found in the lungs post mortem appears to be rising by about 1% per year in persons over the age of 30. An increase of the percentage of asbestos bodies can be a real increase or be caused by improved techniques, more attention or a more prolonged search of specimens. Due to the techniques used, the figures given certainly underreport the true prevalence.

From this short review of the literature one may conclude that the presence of asbestos bodies probably provides a useful indicator of exposure to asbestos, both from the occupational as well as from environmental sources. As the number of fibres is nearly always higher than the number of asbestos bodies and many fibres can be found without asbestos bodies (Pooley 1973), the prevalence of asbestos exposure certainly is higher than the number of cases with asbestos bodies. One should realise that the number of asbestos fibres or bodies present is the result of all exposures (old and recent) and elimination (by breakdown, coughing up etc. etc.). Moreover the results of the different methods described in the literature hardly ever are comparable.

Pathological processes

Pathological processes in man, due to asbestos, might also serve as indicators of asbestos exposure. The different possibilities to be considered are:

a. asbestosis (see chapter VIII). As the exposure is always occupational, the use of the disease as an indicator is limited to the discovery of these exposures.

b. pleural plaques consist of fibrous thickening with sometimes calcification of the parietal or visceral pleura. The process in itself is innocent but is nearly always associated with the presence of asbestos bodies (Meurman 1966) and may be considered in most cases as proof of asbestos exposure. Other causes are possible and usually cannot be ruled out. Only a small part of these plaques can be seen radiographically however and in these cases only a small percentage of the patients has a history of definite asbestos exposure (BTTA and MRCPU, 1972). From these and similar studies it can be concluded that pleural plaques can be used as an indicator of probable asbestos exposure in autopsy material only, while radiological studies are useless for this purpose. Autopsy material in itself is however a selection and is not necessarily representative for the population of a certain area.

c. malignant tumours (see chapter IX). People who are known to have been exposed to asbestos, usually several decades ago, show a higher frequency of certain types of malignant tumours e.g. pleural and peritoneal mesothelioma, bronchial cancer, gastric carcinoma, cancer of the colon and rectum and presumably some others. Most of these tumours however usually occur without any evidence of asbestos exposure and can thus not be used as indicators. The only exception might be the pleural and peritoneal mesothelioma. These tumours were until some decades ago thought to be very rare. In chapter IX more detailed information on the definition, identification and mesothelioma registers is given. Apart from a group of mesothelioma cases without any detectable relation to asbestos (known as spontaneous or idiopathic and thought by some investigators to have a frequency of not more than 0.5-1 case per million inhabitants per year), most reported cases show a relationship to asbestos exposure, either in the occupational history or by the detection of asbestos in sputum or tissue (Pooley 1973). Crocidolite is relatively the type of asbestos found in the highest frequency, followed by amosite and chrysotile. The time lapse between the first exposure and the manifestation of the tumour is at least 15 years and usually between 25 and 40 years. The longitudinal study of cohorts of exposed people provides the best information for these data. The exposure may be short (only a few weeks or months) or not very intensive.

Mesothelioma can therefore be used to find groups of persons who have been exposed to a hitherto unknown source of occupational, paraoccupational or neighbourhood exposure to asbestos. As an indicator of true environmental exposure none of the tumours seems to be of any use.

Conclusion

The occurrence of asbestos fibres and bodies can be regarded as evidence of past exposure; however the prevalence of biological processes provides evidence of response . Asbestosis is restricted to occupational exposure; plaques and malignancies may also occur in paraoccupational and neighbourhood exposure; among the biological responses only plaques can be regarded as harmless from the point of view of health: therefore, although all responses mentioned may serve as indicators of past exposure, the prevalence of malignancies cannot serve as an effective means of estimating past exposure; these indicators are based upon mostly fatal disease states. Effective indicators as such should occur early and be harmless from the point of view of health; in this case therefore the presence of asbestos fibres and asbestos bodies, and to a lesser extent - not being early responses - of plaques, can be used as effective indicators of past asbestos exposure.

VIII. OCCUPATIONAL HEALTH RISKS

Although asbestos has been known from the remotest ages - and even diseases of the respiratory system in slaves working in asbestos textures - the link between specific diseases and exposure to asbestos became established with the expansive growth in the use of this mineral and its products in the 20th century. The UK possessed - and possesses - a large asbestos-industry, starting around 1870 in the manufacture of asbestos-textile. So the first case of asbestosis was described in England in 1906; in the course of the following years the link between intensive occupational exposure and harmful effects could be firmly established. The British government took the first measures to protect the workers in these industries around 1930.

In the meantime asbestos was being used in more and more applications other than asbestos-textile: insulation, asbestos-cement, etc. (see chapter II). Exposure to asbestos inside the factories became greatly diminished by technical devices; however outside factories exposure of workers increased with the growth of applications of asbestos and asbestos-products, e.g. building trade, insulation.

In 1935 the first descriptions of bronchial carcinoma as a complication of asbestosis appeared, afterwards confirmed by other observations of this combination. It must be kept in mind, that in those years bronchial cancer was an uncommon disease. Exposure to asbestos, particularly in combination with cigarette-smoking, may cause a steep rise in the incidence of bronchial cancers.

In the 1950's the first observations of an association between asbestos and mesothelioma were published. Up till then mesothelioma was looked upon as an extremely rare disease. Since this publication a multitude of reports followed, linking mesothelioma to occupational or neighbourhood exposure to asbestos in the past - mostly occupational.

In the 1960's an excess incidence of cancer of the gastrointestinal tract

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in association with the uptake of asbestos in the occupational sphere was suggested.

Asbestos exposure in occupation may therefore give rise to the following diseases:

1. asbestosis
2. bronchial cancers
3. pleural mesothelioma
4. peritoneal mesothelioma
5. cancers of gastrointestinal tract
6. asbestos-warts

1. Asbestosis

Asbestosis is a progressive lung fibrosis caused by the inhalation of asbestos dust. It is a typical occupational disease for workers intensively exposed to loose asbestos fibres and asbestos dust. Formerly this disease was chiefly found in the asbestos-textile industry; with the increase of hygienic and technical precautionary measures and with increased usage of asbestos elsewhere, asbestosis became less and less found in those industries, but more and more found in those other industries where such technical measures are more or less unfeasible, such as in the asbestos-insulation industry. Asbestos-spraying especially gives rise to a large number of cases of asbestosis.

The disease causes a progressive incapacity to saturize tissues with oxygen; the passage of this gas from the respiratory air to the blood being blocked by a fibrotic thickening of the alveolar walls.

In the early stages the findings are largely non-specific, giving rise to false diagnoses. The diagnosis is made by taking into account a decrease of the vital capacity of the lungs, special x-ray techniques and the presence of asbestos bodies and -fibres in appreciable numbers.

In all cases of asbestosis, intensive exposure to asbestos in the past is found, even if the duration of this exposure is relatively short.

Asbestosis, being manifest, will progress, whether the patient continues to be exposed or not. It is a serious, disabling and often fatal disease. There is no known treatment.

2. Bronchial cancer (see chapter IX-2)

In connection with asbestosis a clearly excessive incidence of bronchial cancer has been observed. The cause of this relationship is not known; pos-

sible carcinogenic properties of trace metals in machined asbestos (iron, nickel, chromium, cobalt) have been suggested, but not established. The same applies to organic substances, found in asbestos, as waxes, natural oils and traces of well-known carcinogens such as 3.4 benzpyrene.

In the occupational situation the risk of asbestosis seems to run fairly parallel with the excess risk of bronchial cancer; in subjects exposed to asbestos but without asbestosis an excess risk to bronchial cancer has not been unequivocally established.

Cigarette-smoking and intensive exposure to asbestos leads to a marked increase of the incidence of this cancer (multiplicative effect).

3. Pleural mesothelioma (see chapter IX-1)

An association between asbestos and pleural mesothelioma has been discovered relatively recently. This disease was looked upon as extremely rare; nowadays the incidence may be excessive in certain groups of the population.

Although the first cases were discovered in patients living in the neighbrouhood of certain asbestos mines in South Africa, the disease has until now been mainly observed in connection with occupational exposure to asbestos in the past. In these cases not only the typical, directly exposed asbestos workers, such as insulators, are affected, but especially the less and indirectly exposed workers in their neighbourhood (see chapter III).

The disease is found most frequently in areas of heavy industry (e.g. shipbuilding). In many cases the exposure may be looked upon as indirect, and much less intense than in cases of asbestosis. In the same indirect way mesothelioma is found in residents in the nieghbourhood of asbestos-emitting industries and in families of asbestos-workers.

The disease is a malignant tumour, starting from the superficial (mesothelial) layers of the pleura. It is a slowly growing tumour usually without marked metastases, unlike other malignant tumours. For a long time the tumour keeps strictly to the anatomical limits of the pleura. It causes prolonged suffering and is definitely fatal. There is no known cure.

Animal experiments proved that all sorts of asbestos induce mesothelioma if introduced into the pleural cavity. Inhaled asbestos fibres may reach this cavity in a mechanical way; the amphibole types - especially crocidolite - with their peculiar shape of fibre, have to be looked upon as the most dangerous (see chapter IV).

Being mostly an occupational disease in heavy industry mesothelioma is observed more frequently in males than in females; however observations have been made of a high incidence of mesothelioma in females who worked in a factory of crocidolite containing gas-masks during World War II.

There is a long latency period varying from 15 to 40 years.

Diagnosis of mesothelioma is difficult, the symptoms easily leading to false diagnoses (see chapter IX). Both factors - latency period and difficulty of diagnosis - explain the late discovery of the association with asbestos.

4. Peritoneal mesothelioma (see chapter IX-4).

This is the same type of tumour, but now starting from the mesothelial layers of the peritoneum. An association with uptake of asbestos has to be accepted. As in pleural mesothelioma,occupational exposure may lead to an excess incidence.

The asbestos-fibres in these cases are probably ingested in appreciable quantities, either directly or indirectly. In other cases growth of a pleural mesothelioma through the diaphragm is seen.

In peritoneal mesothelioma the latency period is also long. The disease is fatal; there is no known cure.

5. Cancers of gastronintestinal tract (see chapter IX-4)

Epidemiological investigations in cohorts of asbestos-insulators - heavily exposed workers - proved an excess mortality by cancer of the gastrointestinal tract. Comparison with the mortality rates in non-exposed groups leads to the conclusion that asbestos uptake is a cause of this excess incidence.

6. Asbestos warts

These wart-like formations in the skin develop around asbestos fibres which have penetrated into the epidermis. They are found in exposed parts of the skin of asbestos workers. The warts are harmless.

Conclusions

In this chapter health effects of asbestos as prevalent in occupationally exposed subjects have been reviewed briefly. This chapter may serve to indicate that effects as mentioned under 1 (asbestosis) and 6 (skin warts) are purely occupational and as such not relevant for public health. The public health risk of malignancies will be reviewed in this document more fully (see chapter IX).

Because most of the epidemiological data available are based on occupational exposure and a few on indirect occupational or para-occupational and neighbourhood exposure, and hardly any on true public health exposure, occupational health data will still have to take a prominent place in this document.

IX-1 RESPIRATORY EXPOSURE AND MESOTHELIOMA

It has become evident that (para-)occupational exposure to asbestos may greatly increase the risk of mesothelioma. This has been established in retrospective-prospective cohort studies of male and female workers, followed up for many years. However, it is not possible to conduct such studies with regard to neighbourhood or true environmental exposure, because the population at risk can neither be defined retrospectively, nor followed up prospectively. The only means to find evidence of an increased risk is by retrospective case-control studies, i.e. starting from diagnosed cases of mesothelioma and from matched controls, and taking a very painstaking (hetero-)anamnesis of past exposure to asbestos, distinguished into the categories, as discussed in chapter III.

The EEC Workshop on Diagnostic Criteria of Mesothelioma and on Objectives of a Mesothelioma Register, in 1975, concluded the following:

Definition of mesothelioma

Mesotheliomas are tumours arising from the mesothelial lining of the coelomic cavities and consist of a variable mixture of epithelial like and spindle-cell elements.

Diffuse and localized forms occur. The salient characteristic of the diffuse mesothelioma is its predilection to spread along the serosal membrane in which it arises. In the pleural cavity, the entire surface may become replaced by a continuous layer of tumour due to symphysis of the pleural surfaces. This is uncommon in the peritoneum where the surfaces often remain separate but covered by isolated plaques and nodules or diffuse infiltration. Only those mesothelial tumours in which serosal spread is unequivocal should be termed "diffuse". Almost all diffuse mesothelial tumours show evidence of malignancy by direct infiltration of adjacent tissues and organs and metastases to regional lymph nodes.

Characteristically, mesotheliomas form a tubular papillary or tubulo-papillary growth pattern. Most tumours have a biphasic cellular pattern, but some may have an entirely non-specific structure presenting the appearance of a spindle cell sarcoma or of an anaplastic tumour.

Identification

The identification of mesotheliomas depends upon pathological investigation backed by clinical and radiological evidence. Biochemical and histochemical tests may be an aid to the diagnosis.

The reliability of the identification depends upon there being sufficient well preserved material available. All possible means of obtaining this material should be taken into account. Ideally a full necropsy needs to be carried out to exclude all other sources of primary tumour. However, biopsy tissue can be utilized, even needle biopsies, for diagnostic and epidemiological purposes, but this needs considerable pathological experience.

The majority of mesotheliomas can be identified beyond doubt by an experienced pathologist. However there are some cases in which difficulties in confirming the diagnosis persist. In these cases it is useful to have the benefit of the opinions of other experienced pathologists, and/or a panel of experts. This then results in a classification of

a. a definite malignant mesothelioma
b. probable
c. possible: could equally be a mesothelioma or something else
d. improbable
e. excluded

This classification requires statistical evaluation.

International exchange of knowledge and material is required. To do this the Commission of the European Communities has established a Mesothelioma Panel (Annex 1).

Mesothelioma registers

The objects in forming a Mesothelioma Register could be:

1. To record the annual number of deaths from confirmed mesothelioma of the

pleura and peritoneum.

2. To ascertain trends in the incidence rates.
3. To discover the groups of the population apparently associated with the tumours and to estimate the incidence in the occupationally and non-occupationally exposed population as well as the occurrence among those apparently non-exposed (non classified as idiopathic).
4. To establish the dose/effect relationships.

To set up a simple mesothelioma register it is first of all necessary to have unbiased details from death certificates from all parts of the country. These can be obtained from a central or regional register if these are in existence.

Registration of mesothelioma cases can be performed at different levels:

1) Crude data can be collected from the death certificates of people who died from pleural tumours (international code 163 and 212.4). Details taken from the death certificate could include identification of the individual; sex; age; place of normal residence; and if possible details of past occupation, including asbestos exposure. This source does not provide a reliable diagnosis but is available in the EEC countries, while the unreliability of the diagnosis can be presumed to be of the same magnitude in different areas, at least within each country. These data can provide information concerning - regional differences
   - temporal differences
   - unexpected areas of present or past exposure.

2) Well established diagnosis of all primary tumours of the serosal cavities by histological examination.
   Autopsy material is preferable. On a nationwide basis, registration based on these data requires the interest of pathologists in this problem. A national mesothelioma panel of 3-5 pathologists is necessary for verification of the diagnosis. As mentioned above an EEC panel based upon already existing national panels has been formed (Annex 1).

Not all mesothelioma cases will be registered but all cases registered can be considered as definite mesothelioma. This material can provide

- regional differences
- temporal differences

- unexpected areas of present or past exposure
- possible areas of underreporting
- form the basis for the third level, e.g. the identification of risk groups.

3) Research on a limited number of cases, derived from the mesothelioma register, verified by the mesothelioma panel. This may include
   - related in depth exposure history
   - examination of tissue on the presence of total mineral dust especially asbestos by electron microscopy and emission analysis etc.

Cartography

Mapping of mesotheliomas may prove useful in indicating areas where further epidemiological studies can be performed and in identifying other aetiological factors. It has proved useful in indicating:

1. areas of underreporting
2. unexpected areas of present and past exposure
3. related occupational exposures.

It can only be carried out on a National basis when sufficient statistical information is available.

Mapping should be encouraged as it will eventually allow comparisons within the Community of the patterns of occurrence of mesotheliomas and indicate further lines of research.

Sources of information about tumours

All sources of information should be utilized. These could include:

1. Death certificates
2. Other notifications of death
3. Reports from clinicians and pathologists.

Additional sources of information may include notification of deaths through the Public Health and Social Security Authorities. In some countries National Mesothelioma and Cancer Registers already exist.

It is desirable that National Statistical Agencies and Bodies apply the WHO International Classification of Diseases to distinguish between

1. Primary pulmonary and pleural malignant neoplasms, and
2. Primary peritoneal malignant neoplasms.

Certain selective processes operate through the above sources so that the number of cases will not necessarily be the same, and the use of all sources is likely to ensure the most complete cover, both of these believed to be occupationally linked and those in which the occupation was not thought to be involved or in which no adequate investigation of the occupation was made.

In addition an examination of the fibre content of the lung should be performed wherever possible.

Reports through pathologists and clinicians will include both occupational and non-occupational cases. In view of the high and rapid mortality of these cases, the majority will be detected by pathologists or clinicians and appear in official statistics, but there may be exceptions. The reports through the pathologists and clinicians have the advantage that they may provide a means for detailed investigation of the occupational histories while the individual is alive, and this could be of considerable help in improving the information about associated occupations and jobs.

It is a wellknown fact that the diagnostic criteria for mesothelioma, as given above have not always been adhered to, particularly in older studies, and the conclusions sometimes may have to be enweakened.

In 1971 Wagner et al reviewed the evidence available at that time. Their review is summarized as follows:

- Nearly all cases of mesothelioma (pleura and/or peritoneum) in Britain appear to be of occupational origin and not the result of contamination of the general environment. In about 10-15% of cases where information on past history has been complete, no history of asbestos exposure has been recorded and few or no asbestos bodies have been detected in the lung.
- In Britain mesotheliomas particularly occur in ports and in cities with factories where asbestos has been handled in large amounts in the past.
- Exposure to crocidolite apparently carries the greatest risks. Exposure to pure chrysotile or to anthophyllite provides hardly any risk; in the

majority of cases exposure has been to crocidolite and/or amosite with or without chrysotile. (However, more recent data from the UK suggest that, although crocidolite may be regarded as the most important fibre in the aetiology of mesothelioma, it is not justifiable to virtually exclude chrysotile from a contribution). Mesotheliomas are not clearly dose related; (however, recent observations do not confirm this statement: see chapter X); a short but probably heavy exposure already may be regarded as causative.

- In some extensively investigated groups peritoneal mesotheliomata were commoner than pleural ones; this may also be due to a statistical artefact: one may have accepted the diagnosis of peritoneal mesothelioma too easily whereas other primary or secondary abdominal malignancies were present.
- Cigarette smoking is not an important contributive factor.

In a UK asbestos factory with mixed asbestos exposure, among 426 deaths in men who had survived for at least 10 years after first employment, the cause of death was a mesothelial tumour in >3% of all deaths (about equal pleural and peritoneal mesothelioma); in women 8.9% (Newhouse et al, 1975).

Hain et al (1974) presented an extensive review of 30 studies published in 1964-1972: among 956 cases of mesothelioma 533 cases has occupational exposure (category 1), 95 had neighbourhood exposure (cat. 3), 15 had domestic exposure (cat. 2a), whereas in 44% past asbestos exposure could not be established or was denied. However, one certainly may not draw the conclusion that in 44% of cases "true" environmental exposure had taken place: between the various studies the percentage of past exposure (occupational and non-occupational) ranged from 0-100%; extensive underreporting had certainly taken place in some studies. Apparently the design of epidemiological studies may affect the results, and therefore the established association between mesothelioma and asbestos exposure to a large extent. Moreover, there is no reason to assume that in all cases of mesothelioma studied the diagnosis had been adequately established, and - last but not least - mesothelioma may probably occur <u>without</u> previous asbestos exposure, although rarely.

Bohlig et al (1973) summed up criteria for environmentally induced asbestos exposure with regard to histological diagnosis (see also Annex 1), history, latent period, frequency (in comparison to control groups), and evidence of asbestos in tissues.In epidemiological studies it has usually not been possible

to adhere to all these criteria mentioned. Zielhuis et al (1975) discussed other methodological aspects of study design: it is essential that where possible the history taking should be performed by an experienced and inquisitive physician; it should not only be based upon an extensive standard list of possible sources of exposure, but it should also include a free interview, exploring unexpected unlisted possibilities of exposure. In addition the controls should be carefully matched with regard to age, sex, place of residence, time of diagnosis, and state of health (for each deceased case of mesothelioma a deceased control, etc.). An absolute underreporting of past (para-)occupational exposure may easily occur when for instance a too rigid standard questionnaire is followed or when only hospital records are screened, a relative underreporting of past asbestos exposure occurs if deceased mesothelioma cases are matched against live controls.

Hain et al (1974) reported on a case-control study from the Hamburg area: 150 autopsy cases were compared with the same number of live controls; 85 cases had occupational exposure against 35 of the controls; 20 cases had neighbourhood exposure, 1 case domestic exposure; no indication for exposure category 1, 2, 3 had been found in 44, i.e. 29% of mesothelioma cases and in 114, i.e. 76% of controls. The maximal prevalence of true environmental exposure therefore was less than 30%; however, relative underreporting of (para-)occupational, neighbourhood and possibly domestic exposure had very probably taken place, because live controls were compared with deceased mesothelioma cases. In the Dresden and Halle-Magdenburg (DDR) area Sturm (1975) performed a study in 315 mesotheliomas (288 pleura, 26 peritoneal, 1 pericardial); in 246 cases, in which an exhaustive evaluation could be performed (69 cases no history!), 62% had past direct occupational exposure, 20% indirect occupational exposure, 4% domiciliary exposure, 6% were neighbourhood cases.

Studies in Italy (Rubino et al (1972) and Switzerland (Rüttner et al 1974) used non-sensitive history taking procedures which very probably led to serious underreporting; the percentages of absence of past occupational exposure, 90 and 96% respectively, are certainly much too high to be accepted as valid.

In the Netherlands Zielhuis et al (1975) could not establish evidence of definite or probable occupational exposure in 16% of 31 cases from the Rotterdam area (harbour, shipyards, heavy industry) against 71% in matched controls; the percentages were 39 and 83 respectively in 36 cases and matched controls in

another region from the same country in which no concentration of harbours, shipyards, and heavy industry exists. There apparently are regional influences on the possibility of providing evidence of past-occupational exposure. An unexpectedly large number of past occupational exposure in non-typical jobs or in hobbywork was discovered.

In the United Kingdom much work has been done to study past history in mesothelioma cases. In one of the first studies of this kind Newhouse et al (1965) reported that among 76 mesothelioma cases about 12% had domestic exposure (category 2a), and 15% neighbourhood exposure (category 3); no evidence of past asbestos exposure could be found in 33% (see chapter III ad 3). In that country a mesothelioma register has been started (Greenberg et al 1974); among 413 notifications from England, Wales and Scotland over 1967-1968 167 cases were histologically confirmed; of these cases 68% had definite occupational exposure, 7% possible occupational exposure (i.e. 75% category 1), 5% neighbourhood-domestic or hobby exposure (i.e. category 2 + 3), whereas in 15% no past exposure could be detected and in 5% no history could be obtained. The frequency of "true" environmental exposure thus lay between 0 and 15%.

In case-control studies one compares the previous exposure history of mesothelioma cases and of matched controls; also in the last group previous asbestos exposure will be found, e.g. in 10-30%. One should correct the established prevalence of previous exposure in the mesothelioma cases with this percentage, a correction never performed. So, the significance of previous asbestos exposure may be somewhat overestimated: a few of the suggestive asbestos-related mesothelioma cases may in reality not be due to previous asbestos exposure. This does not invalidate the importance of asbestos exposure in relation to mesothelioma, but it may weaken a bit the meaning of the percentages given. A reasonable deduction might be that whereas asbestos was the most important single cause of mesothelioma, the disease also had a "natural" incidence of undetermined causation.

Ashcroft (1973) reported on 35 cases of pleural mesothelioma and 6 cases of peritoneal mesothelioma from the Tyneside region in the UK; 95 percent had definite or probable previous occupational exposure to asbestos, whereas this was the case in only 41% of matched controls; 16 cases of mesothelioma were free from asbestosis; 92% of cases contained coated asbestos fibres in their lungs. The incidence of asbestos bodies in sections from mesothelioma cases was significantly higher than in a series of routine necropsies examined by

lung smear. The large majority (29 of 31) of male mesothelioma cases had fibre concentrations equal to or greater than those of a group of routine autopsies with numerous bodies in the lung; the occupational data for routine necropsies indicated that a large majority of the patients with numerous coated fibres had previous definite or probable exposure to asbestos, in contrast to those with occasional fibres. The author therefore concluded that persons with occasional fibres on analysis have a very small chance of developing pleural mesothelioma compared with people having numerous coated fibres in the lung. This study once again pointed to (para-)occupational exposure to asbestos as an important cause for mesothelioma. Pooley (1973) examined 120 cases of pleural mesothelioma; only in 9 cases could he not find asbestos fibres in the lungs. These data strongly suggest that examination of lung tissue for indications of past exposure (see VII) may provide a more sensitive method of detecting past exposure than history taking; the given percentage of 10-15% may be an overestimate.

There is a general agreement that the risk of mesothelioma is fibre related in the order crocidolite>amosite>chrysotile>anthophyllite, but the magnitude of of the difference between the various types of asbestos is not well established.

Some authors tried to evaluate the prevalence of mesothelioma among the general population. According to Bohlig et al (1973) mesothelioma is found in 0.18 to 0.7% of all autopsies. Nurminen (1975) quotes the following data: 0.27% of autopsy cases in Malmö-Sweden; 34 cases in 6 years in a population of 6 million in Pennsylvania, i.e. about 1 per million per year; in England, Scotland and Wales 2.3 cases per million per year; the author calculated the incidence for pleural mesothelioma in Finland as 1.1 per million per year; there was no clustering related to possible asbestos exposure; the male/female ratio was 1.3; the urban/rural ratio 4.4. Sturm (1975) quotes the following data: mesotheliomas in 0.5% of autopsies in Basel-Switzerland; 1.3% in Zürich-Switzerland; 4.4% in Halle-DDR; 1.5% in Vienna-Austria; 1.25% in Dresden-DDR. (Some data only refer to pleural mesothelioma, others to mesothelioma as such). In most countries there has been an increase in the past decades; awakened interest among clinicians, pathologists, epidemiologists certainly has also contributed to this increase. Nevertheless it has been unequivocally established that in autopsies of asbestos workers the prevalence has been remarkably higher. Hain et al (1974) reported a prevalence of 3.2% of all autopsies in the Hamburg area, probably related to the increase in various possibilities of exposure in this city with harbours, shipyards, heavy industry,

etc. Planteydt (1974) started a mesothelioma register in the Netherlands: since 1969 over 250 cases have been notified by pathologists. However one probably may estimate the annual incidence in the country to be over 100 cases per year. The Dutch Central Bureau of Statistics recorded 332 deaths from primary malignancies of the pleura in 1969-1972 inclusive; if one marks these cases on the map of the Netherlands, most cases appear to have lived (and worked) in areas along the estuaries: shipyards, harbours, heavy industry; asbestos textile factories are not found in that country. In the UK 170 notifications of mesothelioma (pleura and peritoneum) were made in 1967 and 243 in 1968; a definite diagnosis was made in about 120 cases per year; there is again a very clear geographic distribution, most notified and confirmed cases coming from areas with harbour, shipyards, heavy industry (Greenberg et al 1974). A similar trend is seen in France: an increased prevalence in Le Havre, Nantes and Marseilles (Bignon, personal communication).

Recently McDonald et al (1975) presented an extensive review of 176 published papers (4431 cases), from which they draw conclusions on the epidemiology of mesothelioma. Some of their findings were:

- In Canadian and USA-surveys more than three quarters were in males and except in the occupational surveys, mostly pleural.
- In 7 case-control studies from the UK, Italy, FRG, Canada the frequency of definite or probably occupational exposure was on the average two thirds of cases.
- By putting together data from Malmö, Dresden, Glasgow, New York, Philadelphia, Turin, Milan and Pavia, 165 cases of mesothelioma were found in 69,302 autopsies, a rate of 0.24%; the true rate of recognized mesothelioma is probably somewhat higher (perhaps by 50%) than found through pathologists, but if other sources are used, pathological review is needed to exclude false cases.
- Estimated incidence of mesothelioma in Canada and USA ranged for different areas from less than 1.0 per million to 2.0-6.0 per million population. Expected incidence for some other countries (a.o. UK, Sweden, the Netherlands) was calculated based upon the incidence in Canada over 1966-1972; in most countries observed and expected figures agreed fairly well, in selected cities however there was a considerable excess; most of those with excess have either large shipyards, or large asbestos processing plants.

- The incidence of mesothelioma is extremely high in three situations: among insulators; among those who work or live in cities with shipyards; and among those who work or live in certain cities with large asbestos plants. In all three there has been exposure to chrysotile, but also to crocidolite and amosite. (The wording "extremely high" probably could be better put as "relatively high").
- Either chrysotile alone in the form and concentration experienced by insulators is enough, or even construction work insulators and sufficient contact with amosite, or insulation work involves exposure to an important co-carcinogen.
- The occurrence among factory workers and in cities with large asbestos plants fits well with the concept of a gradient in the mesothelioma inducing capacity of asbestos from crocidolite through amosite down to chrysotile, but it is not necessary to postulate such a gradient since variation in exposure and in the physical state of fibre could also explain it.
- The very high incidence in and around shipyards strongly incriminates amphiboles; on the other hand work histories from shipyard cases suggest that relatively few cases were in insulators or in persons heavily exposed to insulation materials (however, these more intensively exposed workers may have used personal protection devices).
- With regard to mining and milling it is hard to escape the conclusion that there is indeed a gradient from crocidolite through amosite and perhaps tremolite down to chrysotile and anthophyllite. However, mining environments may well be free from co-carcinogens of the kind found in factories, ports and industrial cities. Moreover fibre as produced almost certainly differs in length and diameter from that used in application and processing.

Some additional remarks should be made:

- The authors calculated incidences for various countries; if the areas with shipyards etc. occupy a relatively larger part of the country, one may expect a relatively higher incidence (e.g. possible explanation for high prevalence in the Netherlands). This does not say that the dose-response relationships in exposed subjects differ.
- The data of McDonald and other information strongly suggest that <u>within the EEC, certain regions</u> (with shipyards, asbestos industry) run the highest health risk. This is important from the standpoint of the <u>priority of actions to be taken</u>.

In the USA Grundy et al (1972) studied 13 histologically proven cases of mesothelioma in children (age at diagnosis 4-17 years), only one of them being an exclusively peritoneal tumour; the latency period apparently was short. There were no adequate environmental data; the cases were not clustered geographically, and this may be an argument against asbestos as a causative environmental factor. A possible relationship with (para-)occupational, neighbourhood or true enviornmental exposure could neither be denied nor suggested.

The absolute prevalence of mesothelioma is still relatively rare, although there appears to have been a definite increase in the last decades. At this moment there is no convincing evidence yet that "true" environmental exposure is a contributive factor to the occurrence of mesotheliomas (IARC 1973).

It is clear that a proper evaluation of the risk on mesothelioma can only be based upon adequate registration of histologically proven cases. Within the EEC such a registration has been set up in the UK, the Netherlands, Federal Republic of Germany but not yet in the other Member States. The registers up to now have not suggested a rise in non-occupational cases. Caution is needed in interpreting present evidence about a public health risk for several reasons, including:

1. Relevant evidence is either not available, inadequate or likely to be biased;
2. The long lapse period means that the effects of a marked increase of import of amphiboles in the last 15 years might not yet be detectable, especially as the lapse period itself is related to intensity of exposure. So, though it seems unlikely that asbestos in the general atmosphere is a cause of mesotheliomas in the general public, more evidence is needed.

IX-2 RESPIRATORY EXPOSURE AND BRONCHIAL CARCINOMA

A relationship between the prevalence of bronchial carcinoma and occupational asbestos exposure has been established beyond any doubt: the first observations already date from the thirties. Wagner et al (1971) reviewed the literature up to that time. Their findings may be summarized as follows:

- A clear relationship with occupational asbestos exposure has been established; workers exposed to improved conditions in the factory had little or no excess risk: there apparently is a dose-response relationship. In short (less than two years) intensive exposure as well as in those with intensive exposure over a longer period an excess risk occurs.
- There is evidence that combined exposure to cigarette smoke is more likely to be associated with lung carcinoma than either alone.
- More than the risk of mesotheliomas, the risk of bronchial cancer is more clearly related to the intensity of past exposure and to the risk of asbestosis. In fact this carcinoma is often regarded as a complication of occupational asbestosis.
- Bronchial tumours are much less clearly linked to the type of asbestos than mesotheliomas.

A few studies deserve to be mentioned:

In two cohort studies in the Quebec chrysotile mines and mills (McDonald 1973) an increased incidence of malignant neoplasms in the two highest dust exposure groups was observed, mainly of tumours of the respiratory tract and to a lesser extent of the gastrointestinal tract; the excess in respiratory cancer, mainly bronchial carcinoma, became evident between 100 and 400 mppcf-years (mppcf = million particles per cubic feet), and was clearly present above this level. Ghezzi et al (1972) did not observe any excess prevalence of lung cancers in workers from a chrysotile mine in Balangero (Italy).

Enterline et al (1973) calculated a time-weighted asbestos dust exposure at the time of retirement (65 years) in a cohort study of 1348 men who completed their working lifetime in the asbestos industry and retired during the

period 1947-1961. There was an excess mortality almost exclusively due to respiratory cancer and non-malignant respiratory disease, if compared with that for the entire population of the USA. There appeared to be no direct relationship between asbestos dust exposure and respiratory cancer mortality below 125 mppcf-years; important increments occurred somewhere between 100 and 200 mppcf-years exposure. In this study the effect of intensity and time of exposure was about the same.

Newhouse et al (1972, 1973a) studied records from British male and female workers. Workers with minor and short exposure showed no excess mortality; however among those with long periods of employment a significant excess from cancer of the lung (a few mesothelioma included) was beginning to show 25 years after first employment. Among workers with severe exposure but short periods of employment, there was a significant excess of death from bronchial cancer after 15 years followup, particularly however in those who worked for longer than 2 years in the factory. There was no effect of sex on the cancer mortality if exposure was similar.

In the USSR Kogan (1972) investigated retrospectively cancer mortality among workers in the asbestos mining and milling industry between 1948 and 1957. For lung cancer the rates exceeded those of the general population in mines in men by 2 times, in those in mills by 2.1 times; in women 2.1 and 1.4 times respectively. No mesotheliomas were reported, but this may be due to insufficient mesothelioma experience of pathologists in that area.

In Finland Meurman et al (1974) also observed excess death due to bronchial cancer and asbestosis in workers exposed to anthophyllite: the relative risk of bronchial cancer was 1.4 for an asbestos worker who did not smoke, 12 for a smoker without exposure and 17 for a smoking asbestos worker.

From these and other studies the conclusion can be drawn that occupational asbestos exposure, of such an intensity that asbestosis occurs, greatly increases the risk of bronchial carcinoma, particularly in smoking asbestos workers. In many groups of asbestos workers, approximately 20% of all deaths are caused by lung neoplasms. There is suggestive evidence that if either no (long term or short term) intensive occupational exposure exists, the risk appears to be zero to minimal (BMJ 1973). Such an occupational exposure is almost certainly greater than in "true" general air pollution with asbestos. It

has often been stated that bronchial cancer should be regarded as a complication of asbestosis, in contradiction to pleural mesothelioma. However, although much evidence points to asbestos related lung carcinoma as an occupational disease (particularly in smokers), there is not yet enough evidence to exclude the risk of environmentally induced lung carcinoma as a public health risk. This is still an area for concern, and for proper study. So, the previous statement that bronchial carcinoma is only associated with asbestosis in the occupationally exposed population, needs reassessment.

A recent unpublished study by Skinner and Castle in Rhodesia (Gilson, personal communication) suggested that there was no detectable excess of bronchial cancer in the asbestos mining area, whereas this was detected in the gold mining regions within that country, probably due to arsenic. So, one should take into account the complete occupational and environmental history, before suggesting too easily a relationship between e.g. asbestos and malignancy. In some studies one may have not been careful enough in this respect.

Recently some doubt arose with regard to the "innocence" of ambient asbestos air pollution in inducing bronchial cancers. Warnock et al (1975) performed quantitative counts of asbestos bodies in lungs of 100 control and 30 cancer patients: the last group had significantly higher levels, according to the authors, probably in general not due to occupational asbestos exposure. However their technique for counting bodies only gave minimal recovery; the occupational history was not very detailed. Doniach et al (1975) recently also performed a similar study in autopsy cases from London (UK); the history with regard to occupation and area of residence was more detailed. The authors could not find any correlation between presence of asbestos bodies and bronchial carcinoma, confirming findings of Elmes et al (1965); they concluded that - smoking apart - the increased incidence of bronchial carcinoma in urban as compared to rural populations is likely to be due to atmospheric pollutants other than asbestos dust. So, the suggestion brought forward by Warnock et al (1975) was not confirmed. This question remains however an area for future studies, emphasizing the application of adequate counting techniques and detailed environmental history.

IX-3 RESPIRATORY EXPOSURE AND OTHER MALIGNANCIES

In recent years attention has been drawn to a possible relationship between asbestos exposure and malignant tumours of the head and neck. Stell et al (1973a) questioned 100 male patients with carcinoma of the larynx, oral cavity, oropharynx, nose, sinuses, and hypopharynx about their exposure to asbestos, in comparison with a matched control series. There was an excess of past asbestos exposure in cases of laryngocarcinoma. This was investigated in more depth (Stell et al 1973b); in 100 patients with this disease 31% had important exposure to asbestos as compared with 3% in 100 controls; the latency period was 1 to 54 years; the maximum incidence was in the 51-60 age group as compared with the usual maximum incidence in the 61-70 age group; there was no difference in smoking habits. The occupations of the carcinoma cases pointed to a possibly intensive exposure; other environmental agents may have been present also. Newhouse (1973b) found 2 deaths due to larynx carcinoma among 4000 workers followed up for many years; in both cases there was severe exposure to asbestos. Libshitz et al (1974) also described three patients who at the same time had evidence of asbestosis. The data available point to a relationship with asbestos exposure, probably of severe intensity. There is not yet any indication of a health risk in case of "true" environmental exposure.

Doniach et al (1975) brought forward a hitherto unconfirmed relationship between the presence of asbestos bodies in lung tissue and mammary carcinoma: 38 observed against 26.3 expected; this did not appear to be due to occupation, area of residence or age. The possible pathogenesis is not understood; the suggestion has been made that asbestos fibres might infiltrate the mammary tissue by direct extension through the chest wall. This single study should be confirmed before it can be accepted as evidence.

Gerber (1970) reported an association between the presence of asbestosis and neoplasis of the haematopoetic system: two cases of multiple myeloma, two myeloproliferative disorders (one a reticulum cell sarcoma), one Waldenström macroglobulinaemia. The incidence was higher than expected. Older literature

also contains reports of similar malignancies, e.g. lymphosarcoma, leukaemia, malignant lymphomas, multiple myeloma. In Gerber's series in only three cases was occupational exposure to asbestos confirmed. However, the presence of asbestosis indicated rather intensive exposure in the past in all cases. So far there is no indication of any risk of such malignancies in case of "true" environmental exposure.

The relationship between respiratory asbestos exposure and gastrointestinal tumours is discussed in chapter IX-4.

IX.4 GASTROINTESTINAL AND PARENTERAL EXPOSURE AND MALIGNANCIES

Asbestos fibres can be present not only in ambient air, but also in water, beverages, beers, wines, etc. (see chapter V). The question therefore is pertinent whether this may constitute a health hazard, particularly with regard to malignancies of the gastrointestinal tract and peritoneal mesothelioma.

Several studies have established an increased prevalence of the above mentioned malignancies in occupationally exposed workers. Newhouse (1973a) studied cancer mortality in male and female workers in a London asbestos textile factory; among workers with a long period of employment an excess mortality from cancers of the lung and from other cancers was beginning to show 25 years after first being employed, also in those with severe exposure but short periods of employment, but not in those with short periods of minor exposure. Peritoneal mesothelioma often was wrongly diagnosed as e.g. carcinomatosis, carcinoma of the pancreas, carcinoma of the rectum. Only in males was there an excess of gastrointestinal carcinoma; however, in 3 of 8 histologically verified cases a diagnosis of mesothelioma could be made. Selikoff et al (1973a) also established an excess prevalence (at 2-3 times the expected level) of gastrointestinal tumours among insulation workers in the United States, confirming other studies, e.g. Elmes et al, 1971 (Belfast-insulators); while these tumours were only responsible for a minor portion of excess deaths, the increased prevalence of carcinoma of stomach, colon, rectum, and oesophagus in occupationally exposed workers nevertheless appeared to be real, particularly in insulators. In Quebec chrysotile mines and mills McDonald (1973) observed a suggestive increased incidence of gastrointestinal tumours (oesophagus, stomach, intestine, and rectum) in workers with high exposure (400 mppcf-years), accounting only for one third of the rate for all malignant neoplasms; the threshold limit is higher than the limit suggested for tumours of the respiratory tract.

Meurman et al (1974) did not observe any increased prevalence of gastrointestinal cancers in workers exposed to anthophyllite, in contrast to an in-

creased prevalence of death due to bronchial cancer and asbestosis. In the UK (Buchanan, personal communication) an evaluation of the causes of death of workers with established asbestosis did not reveal any excess prevalence of gastrointestinal cancers. In a controlled factory environment (Rochdale UK) no increased prevalence was found (Holmes, personal communication).

It is important to note that the geographical prevalence of intestinal tumours is not consistent with that of, for example, mesothelioma and (para-) occupational or neighbourhood asbestos exposure; apparently this exposure may only constitute one of the causative factors; it should be regarded as a less specific inducer for intestinal tumours than for mesotheliomas. Moreover, the geographical pathology of gastrointestinal carcinoma appears to be very complicated; in municipalities in the Netherlands, not very distant from each other, the mortality rates differed considerably, apparently unrelated to known aetiologic factors; this could overshadow a possible weak relationship with asbestos exposure (Planteydt, personal communication). It will be very difficult to establish a small excess.

Doniach et al (1975) examined the prevalence of asbestos bodies in the lung in relation to cause of death; there was an increased prevalence in male patients with stomach carcinoma, unexplained by residential area, occupation, industry or age: their data suggest that the non-industrial environment might be a pathogenic factor. Merliss (1971) has suggested a causative relationship between the well established high prevalence of gastric carcinoma in Japan and the ingestion of rice coated with talcum, which might be contaminated by asbestos fibres. However this has not been confirmed in animal experiments (Smith 1973).

The majority of mesotheliomas due to (para-)occupational exposure probably are pleural. According to Elmes (1973) less than 30%, in most studies less than 10% are peritoneal mesothelioma. The relative incidence of peritoneal mesothelioma probably increases with increasing respiratory exposure. In several studies there may have been an underdiagnosis. In South Africa only a few peritoneal mesotheliomas come from the asbestos area; also gastrointestinal carcinomata probably are not excessive in prevalence. This is attributed to the high pH of water to which calcium carbonate has been added, preventing release of asbestos fibres from asbestos-cement pipes (Webster 1974). At this moment there is no solid evidence from epidemiological studies that gastrointestinal exposure may induce peritoneal mesothelioma.

The apparent increased risk of malignancies in the abdominal cavity however should not be interpreted as direct evidence of the risk of primary ingestion of asbestos fibres: there certainly is a secondary ingestion of inhaled asbestos (sputum); pleural mesothelioma may also penetrate into the abdomen; asbestos fibres may migrate from the pleural cavity. Nevertheless, very probably, at least a part of the increased prevalence mentioned may be due to primary ingestion of asbestos fibres, a possibility of asbestos exposure which also exists for the general population.

If one compares the amount of fibres in various organs of occupationally exposed workers, one is struck by the fact that the amounts in the lungs far outnumber those in other organs, with a factor much larger than the difference in carcinogenic risk for various target organs would suggest. This may indicate that tissues other than pulmonary could be more sensitive, or that other factors in the gastrointestinal tract are contributive (Langer 1974).

Rosen et al (1974) who had been able to demonstrate ferruginous bodies (asbestos and other fibres encrusted with iron-protein complex) in nearly 10% of lung specimens, could not find typical bodies in primary carcinoma of the colon. However, the authors themselves already pointed out that this negative finding does not mean that asbestos cannot contribute to the development of intestinal neoplasms: the structure of chrysotile fibres could have been altered by the chemical environment of the gut; maybe bodies are not formed in colonic tissue. Moreover, carcinogenic properties cannot be denied, when the agent itself is not discovered in the tumour. Matsudo et al (1974) also could not find fibres in cases of gastric carcinoma.

Lee (1974) presented a review of papers and discussions at a conference on Biological effects of ingested asbestos held in the USA. His commentary is summarized as follows:

- It is very difficult to arrive at conclusive data on levels in ingested foods, beverages, water, because asbestos as such is not a chemical identity (see chapter I) and various often sophisticated techniques are applied (see chapter IV); not all fibrous material constitutes asbestos.
- According to some authors 25-50% of inhaled fibres are cleared from the respiratory tract through ciliary movement and subsequently swallowed (secondary ingestion).

- There seems to be little doubt that under experimental conditions asbestos fibres can penetrate into and pass through the gastrointestinal wall. However it should be emphasized that it is inadequately known what happens under natural conditions, and if penetration occurs, whether the dose is sufficient to constitute a serious threat of carcinogenesis in the bowel wall. Angulations in the bowel may hold up material for days, and so contribute to penetration and migration. However, the number of fibres that actually pass would seem to be small.
- Failure to find asbestos fibres in tumours of the abdomen provides no more than a weak negative evidence; carcinogens may have disappeared before malignancy becomes evident.
- At this moment it is too early to tell how great the risk is under natural conditions.

The Americal Water Works Association Research Foundation (1974) studied the problem of asbestos in water in detail. The conclusions of this report are summarized as follows:

1. The same order of excess of gastrointestinal cancers has been reported in those occupations where chrysotile, amosite or a mixture of chrysotile and crocidolite has been used; there is no evidence of an effect of the types of asbestos used, in contradiction to suggestive evidence for such an effect in the induction of pleura tumours (see chapters IX-1 and IX-2).
2. Chrysotile and crocidolite, components of asbestos-cement pipe, have been shown to be associated with excess prevalence of peritoneal mesothelioma in workers; if ingested fibres play a role, it may be dose-related.
3. Occupational exposure suggests a dose-response relationship for gastrointestinal cancer. If one compares the maximal amount ingested from drinking water over 60 years to the quantity likely to be ingested in occupational exposure (the maximum amount of ingested fibres in the general population using 2 litres water a day with highest concentration as found in distribution systems yields for example 0.07 g asbestos per 60 years; approximate amounts of asbestos ingested during working life: 2-336 g), then the very large difference in estimated amounts ingested becomes evident, even a factor 30 for low occupational exposure. The dose-response relationship observed in exposed workers suggests that at lower levels of exposure there was a slight or perhaps no risk of excess of gastrointestinal cancer. This estimate of oral exposure of the general population and of the working population does not indicate any increased risk for gastro_

intestinal cancers in the general public by ingestion of asbestos fibres from drinking water.

4. There are no numerical data defining a dose-response relationship with regard to peritoneal mesothelioma, neither on the proportion of long to short fibres in potable water. The risk for the general population cannot adequately be assessed. However, there is no evidence of increased prevalence of peritoneal mesothelioma in relation to the use of asbestos cement pipes for drinking water, already in use for over 40 years in USA and Europe. Nor has there been evidence of excess gastrointestinal tumours in the population of Asbestos and Thetford in Canada, where the water and certainly the ambient air was contaminated for several years. However, the usage of asbestos cement pipes is so widespread that it is hardly possible any more to find a large enough control group of subjects who have not drunk water transported through such pipes (Elzenga et al 1974). Because gastrointestinal tumours are much less specific as regards causative asbestos exposure than for example pleural mesotheliomas, epidemiological studies have to be based upon large groups out of the general population. Because of this low specificity any relationship with asbestos in drinking water will be very difficult to prove or to disprove.

The approach mentioned in 3 above (extrapolation from occupational to public health) is based upon the assumption that the distribution of fibre length and diameter in both situations is comparable. However, this may be seriously questioned: relatively many more short fibres are present in true environmental exposure.

This review of studies on the potential risks of ingested asbestos supports the conclusions arrived at by the IARC-Working Conference on Biological Effects of asbestos (1973), that such evidence as there is does not indicate any increased risk resulting from asbestos fibres present in water, beverages, food and in the fluids used for administration of drugs.

There is a potential health hazard, not associated with (para-)occupational or neighbourhood exposure, but as such directly relevant for public health: parenteral administration. Selikoff (1973b) pointed to a potential risk in allergy desensitization treatment: a syringe found widely useful is constructed with an asbestos-filled plunger, and therefore loose fibres may be injected

with the material used for treatment. Moreover Nicholson et al (1972) also found fibres in approximately one third of samples from two sets of 17 widely used parenteral drugs, e.g. various antibiotics, cortisone, sodium acetazolamide. In addition talc is often used as an excipient; so drugs may contain asbestos fibres. Moreover, one should be also concerned about contamination of illicit drugs. No malignancies, apparently due to this parenteral exposure, have been reported: however, it might be regarded as extremely difficult to establish such an association in isolated individual cases. An extensive study of the presence of asbestos fibres in drugs, as used in the EEC, appears to be needed. In surgery it has been proposed to sprinkle the surface of the lung after pleurectomy with powdered asbestos, in order to produce vascularization; however, Planteydt (1966) quite rightly sounded a serious note of caution; the procedure is very similar to the one used to induce mesotheliomas in animal experiments.

X. DOSE-RESPONSE RELATIONSHIPS FOR ASBESTOS RELATED CANCERS

In the case of malignancies a dose-response relationship presents the percentage of subjects with a specified tumor which is dependent on the dose (intensity and duration of exposure). There are some a priori difficulties in establishing quantitative dose-response curves: there usually is a very long latency time, data on exposure concentrations from the past can only be roughly estimated retrospectively; workers may have changed jobs; exposure may have been intermittent; technological improvements may have greatly altered exposure conditions; sampling methods undergo rapid developments. This applies to occupational health studies. It is virtually impossible to develop dose-response relationships for true environmental exposure: exposure even in the recent past often is unknown; there is not one main source of exposure but a potential compilation (in space and time) of various minor exposures (see Chapters II & V). It will also be very difficult to compare dosage levels in respiratory and primary gastrointestinal exposure. Moreover, weight/volume measurements do not take into account the difference in length and diameter of fibres; a concentration-years-product assumes a relationship between both that has not been proven to be valid.

Another major difficulty is that asbestos exposure may only constitute one of the factors responsible for carcinogenesis; this is particularly the case for bronchial and gastrointestinal carcinoma, but less for mesothelioma; there very probably is even a multiplicative effect of combined exposure: asbestos + smoking. The influence of the type of asbestos with regard to mixed exposure is another intervening factor.

There is another serious drawback, particularly relevant if one wants to extrapolate occupational health data to public health: epidemiological studies in workers generally examine groups selected because of preemployment examinations, changes of job in susceptible individuals. Established responses are always based upon selected groups ("healthy workers effect"). However, in public health such a selection does not occur, susceptible or diseased subjects have also to be protected. It might at least be postulated that

within the general population with a higher frequency than in workers population, subjects with an increased susceptibility may occur. However, this hypothesis can neither be confirmed, nor rejected; no specific study has been undertaken on this topic. This demands an extra safety factor. On the other hand, taking into account the long latency period of asbestos related cancers, one should realise that 20 to 40 years ago many workers entered employment without any medical selection procedure.

Nevertheless, if one wants to evaluate the public health risk, one has to base oneself on the available data of dose-response relationship, however insufficient they may be, and one has to extrapolate from occupational health to public health.

There apparently exist qualitative dose-response relationships: concentration in air and/or duration of exposure determine the relative number of subjects affected and also the diagnosis. However, very few quantitative data exist. Sturm (1975) quotes Bohlig in stating that necessary previous intensity of asbestos exposure is decreasing in the following order: asbestosis → bronchial carcinoma, pleurahyalinosis → mesothelioma; the duration of development of disease (exposure + latency) decreases as follows: mesothelioma → bronchial carcinoma → pleurahyalinosis → asbestosis. In heavy mixed asbestos exposure there does seem to be some inverse relationship between asbestosis and mesothelioma. Very heavy exposures perhaps kill by asbestosis and/or bronchial cancers before mesotheliomas arise, or in some way may modify the ability of fibres to reach the periphery of the lung. It may also be that those who develop asbestosis, bronchial cancers or mesothelioma have something in common, and which one develops depends on the dose; this might fit as the dose-response relationship is less clear for the mesotheliomas.

In a cohort study in a U.K. factory with mixed exposure there was a mesothelioma incidence rate per 100,000 subject years ranging from 6 (10-15 year exposure) to 318 (30+ year), and from 31 (<2 year exposure slight to moderate) to 195 (>2 year, severe exposure) in males (Newhouse et al 1975), i.e. a clear dependance on duration and severity of exposure.

Enterline et al (1972) calculated the cumulative dust exposure in mmpcf*

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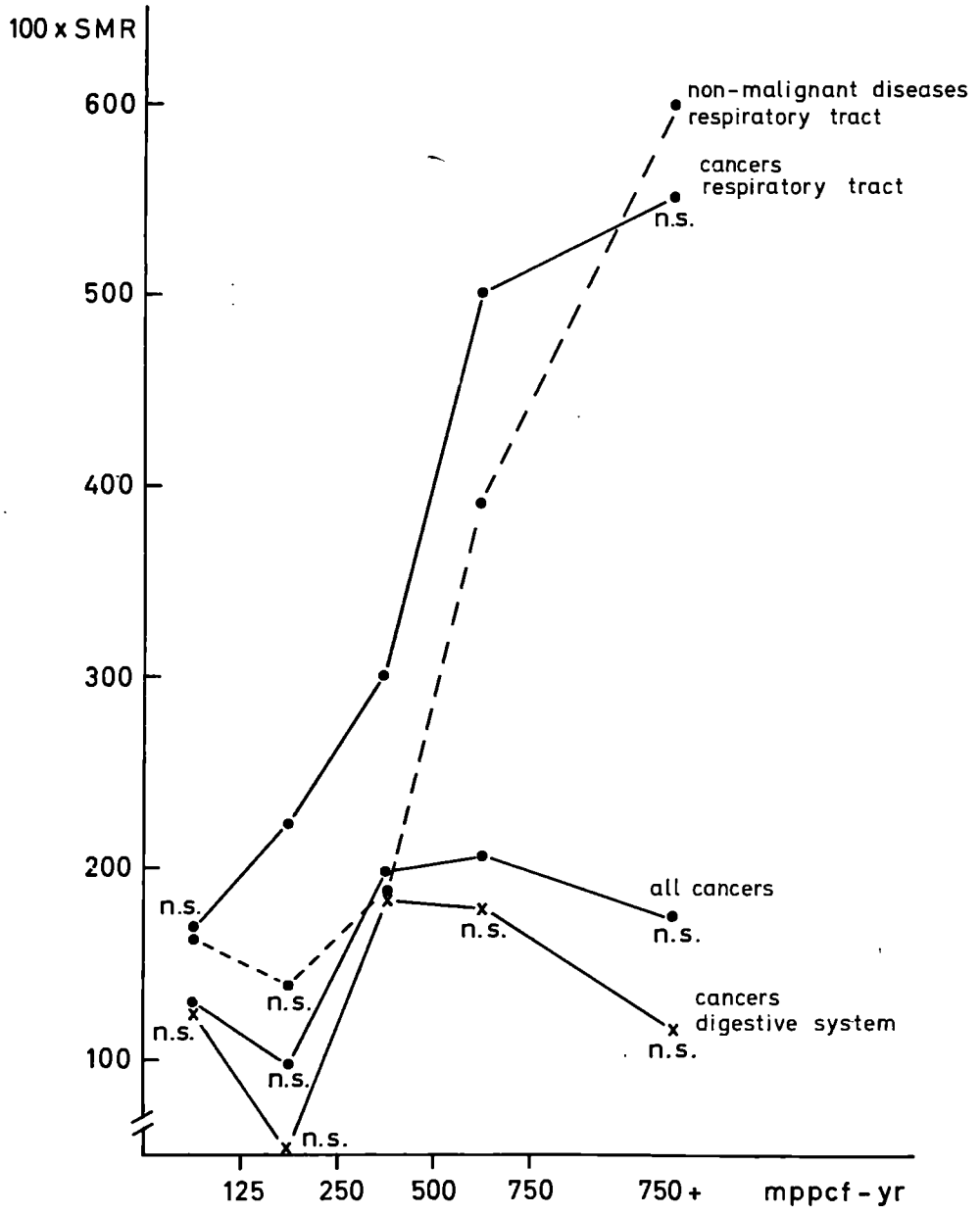
* - mmpcf = million particles per cubic foot.

-years and related this to mortality in 1464 retired (≥65 year) male workers from asbestos production and maintenance; the standard mortality ratio (SMR) was used as parameter in comparison with mortality of US white males. At <125 mmpcf-yr there was a SMR = 131.4 for all cancer death and a SMR = 162.5 for non-malignant diseases of the respiratory tract; at 125-249 mmpcf-yr for cancers of lung, bronchus, trachea and pleura the SMR was 224.5; for 250-449 mmpcf-yr for cancers of the digestive system SMR was 190.0 and for non-malignant diseases of the respiratory system SMR was 191.0 (all mentioned SMR's significant at P=0.05). The subgroup of retired maintenance workers (n=438) had higher SMR's than the subgroups of the production workers, particularly for respiratory cancer, probably because of intermittent high exposure and more exposure to crocidolite. This study did not distinguish between bronchial carcinoma and mesothelioma. The data suggested that a significant increase of non-malignant respiratory diseases (asbestosis) already may occur at the same dosage levels as that of all cancers; in the group of production workers, a significantly increased prevalence of death due to non-malignant respiratory diseases already occurred at a much lower dosage level than death due to all cancers; this was however not the case in maintenance workers. This could suggest that in case of the long-term rather stable exposure, fibrotic changes may occur at lower dosage levels than malignancies, whereas in intermittent high exposure (to crocidolite) - which is not to be expected in neighbourhood or "true" environmental exposure - the induction of malignancies may be induced more readily. This is not inconsistent with an observation made by Zielhuis et al (1975): amongst 48 mesothelioma cases with definite/probable past exposure to asbestos, 60% had intensive exposure, but in 71% this was intermittent. If the particular risk of peak exposure may prove to be true, then exposure levels averaged over many years will not provide a relevant indicator of exposure.

Data from the study by Enterline et al (1972) are presented in Fig. X-1: particularly an excess death occurs due to cancers and non-malignant diseases of lungs, bronchus, trachea, pleura. SMR's become significant (P<0.05) with 125-249 mmpcf-yr; the curves for SMR all cancers and cancers of digestive system are too inconsistent to allow any suggestive trend. According to the Am. Water Works Association Research Foundation (1974) one mmpcf will correspond with 2-6 fibres/ml (lightmicroscope).

In 1973a Enterline et al produced new data on 1348 retired (≥65 yr) wor-



X–1 SMR's in relation to cumulative asbestos exposure according to Enterline et al (1972); n.s. = non significant ($P > 0.05$).

kers; there was a relationship not inconsistent with linearity between mortality from respiratory cancer and cumulative asbestos exposure, except at the highest dose level (abour 1000 mppcf-yr); a subdivision of the group with <125 mmpcf into three exposure levels did not yield any consistent trend; so a definite relationship for respiratory cancer in exposure <125 mppcf could not be established, nor adequately denied. The authors tentatively suggested a cumulative exposure level of 100-200 mppcf-yr for workers not to be excessive. A serious drawback of Enterline et al's studies is that death before 65 years of age was not taken into account.

McDonald (1973) reported on equivalent average death rates for malignant disease for 9692 workers (87% traced) in chrysotile mines and mills in Quebec. Evidence for increased mortality due to cancer was clearly evident in workers exposed to >400 mppcf-yr; respiratory cancers (only a small minority were mesotheliomas) were not elevated <200 mppcf-yr, and most evidently increased >400 mppcf-yr; death due to all gastrointestinal tumours was also higher >400 mppcf-yr (suggestive trend). The lowest exposure groups had rates lower than the general population. Ghezzi et al (1971) could not find any case of mesothelioma in 90.8% of the total population of an Italian chrysotile mine (Balangero), employed for at least one month.

Recently Howard et al (1975) reevaluated the mortality of cohorts of a Rochdale factory, U.K., particularly paying attention to the effect of a decreasing intensity of asbestos exposure due to technical devices. In workers entering in 1933-1950 there was a decrease of mortality, and more so in those entering after 1950, i.e. the "modern period" (dust sampling was initiated, although in some areas dust levels remained high for at least 6 years after this). In this last category there still appears to be an excess death due to lung cancer (including mesothelioma) after 15 or more years of exposure (5 observed, 1.86 expected, all smokers). Dust levels had fallen in the period from 1953 to 1957 by approximately 50-80 percent throughout the factory, the largest reduction being in areas where levels were highest in 1951. A follow-up of workers entering after 1951 may give more quantitative evidence of the dose-response relationship. Up till now this study once more makes clear that cancer mortality is highly dependent upon intensity of exposure, but quantification is still not possible.

The Am. Water Works Association (1974) used the data of Enterline et al

and of McDonald to suggest a dose-response relationship for gastrointestinal tumours after intestinal exposure. The authors came to the following tentative conclusions: "the Enterline data are possibly consistent with a threshold somewhere above 10 mppcf-yr, the McDonald data show no evidence of a threshold" and: "the dose-response observed in the occupationally exposed populations suggest that at the lower levels of exposure there was a slight or perhaps no risk of excess gastrointestinal cancer. Thus, there appears to be even less probability that the ingestion of asbestos from the higher (0.119 µg asbestos/l tap water) of the two potable asbestos-cement pipe systems would reach the risk level for gastrointestinal cancer of the occupationally exposed groups". However, this report did not take into account possible differences in fibre length and/or diameter.

Dohner et al (1975) observed 5 patients with known occupational asbestos exposure, each of whom had 2 definite or probable primary malignant tumours; however, with high exposure levels one may expect statistically that such combinations occur.

In the U.K. the BOHS published occupational hygiene standards for airborne chrysotile (1968) and amosite (1973) asbestos dust. They concluded that the risk of being affected with the earliest demonstrable effects on the lung due to asbestos will be less than 1 percent for an accumulated exposure of 100 fibres/ml yr, e.g. 2 fibres/ml for 50 years exposure. However, this limit protects 99% of selected (!) workers only against early asbestosis. According to the BOHS (1973) "the quantitative relationship between intensity of exposure and risk of cancer is less well defined. Evidence at present available indicates that if a standard is maintained such that the risk of asbestosis is small, the risk of cancer of the lung attributable to asbestos will be smaller still. The position in relation to mesotheliomata of pleura and peritoneum is still uncertain". It should be remembered that Enterline et al (1972) provided evidence that intermittant exposure to high concentrations might induce excess cancer mortality and not excess asbestosis mortality.

This review of data makes it clear that at this moment inadequate data exist on which to base a quantitative dose-response relationship for asbestos-related malignancies. On the other hand, it is also clear that there is often a clear dependency on dose:duration of exposure, type of jobs (intensity of exposure) but quantitation is not adequately possible.

The quantitative statement can be made that in developed countries the use of asbestos has increased rapidly, particularly after the second world war. Concurrently mortality due to lung cancer and mesothelioma has increased, whereas gastric cancer mortality has decreased; death from laryngeal carcinoma has remained stationary, but this may be due to better treatment. A concurrent trend does not indicate any causal relationship; moreover the long latency period does not strengthen the concept of such an ad hoc relationship. However a future induced increase of, for example, mesothelioma may still be possible, even expected.

There is much evidence that with decreasing respiratory and/or intestinal exposure the risk also decreases; there is suggestive evidence for a threshold limit, below which an excess risk is extremely small or non-existent. However adequate data to establish such a threshold limit are not available. There apparently is a great need for epidemiological research. One may even seriously doubt the possibility of deriving a valid measure for (external) dose as an inductor of mesothelioma: long latency period, probable significance of peak exposure. Probably one can only derive an indirect measure of dose through biological monitoring of lung tissue: presence of asbestos fibres. However, if a relationship between external dose and lung burden cannot be established, one will never come to exposure-effect (response) levels, let alone a no-effect (response) level.

One should also not forget that in oncogenesis generally the percentage of subjects affected decreases and the latency time increases with decreasing external exposure. Even if a valid threshold limit does not exist, isolated possibly asbestos related cases will not be found among similar cancers (particularly bronchial and gastrointestinal cancers) induced by other environmental factors, or the latency time will become so large that the life span is exceeded. However, the distribution of increased susceptibility to asbestos within a general population may differ from that in studies groups of workers; this decreases the margin of safety in extrapolation from occupational health to public health.

XI. EXISTING PERMISSIBLE LIMITS

This chapter reviews existing permissible limits for exposure of workers and of the general public, as proposed and/or enforced in different states. Such a bird's eye view of existing limits may serve as a guide for the orientation with regard to public health risks of environmental exposure, to be discussed in chapter XII.

Workroom air

United Kingdom

Chrysotile, amosite, fibrous anthophyllite: 2.0 fibres/ml averaged over a four hour sampling period; 12 f/ml over a 10 min. sampling period. Crocidolite: 0.2 f/ml averaged over a 10 min. sampling period. Fibres mean particles with length >5 µm, length to breadth ration 3:1, observed by transmitted light by means of a microscope at magnification of appr. 500x (Techn. Data Note 13 (Rev) 1969).

Federal Republic of Germany

Chrysotile-fine dust 0.15 mg/m^3; chrysotile containing fine dust 4.0 mg/m^3, to be regarded as technical guide. (Komm. Prüfung gesundheitsschädlicher Arbeitsstoffe 1975). These values are under review, especially for chrosotile and for amosite.

Italy

5 fibres/ml, to be lowered to 2 fibres/ml.

France

Suggested by the INRS (Lardeux 1975):

- <2 fibres/cm^3: acceptable
- >2 -<12 fibres/cm^3: take a 4 hour sample
- if <2 fibres/cm^3: acceptable

- if >2 fibres/cm^3: exposure should be lowered
- >12 fibres/cm^3: take a 10 min. sample; if >12 fibres/cm^3: take strict protective measures
- only taken into account fibres >5 µm, with ratio length/diameter >3.

Denmark

2 fibres/ml; ban on asbestos for insulation work; crocidolite not to be employed without special permission.

Netherlands

Excerpt of proposed legislation on the use of asbestos and asbestos containing materials in the Netherlands.

It is prohibited:

a) to have in stock, to manufacture, to machine or to use crocidolite and/or crocidolite containing materials or products.

b) to apply or to manufacture asbestos and/or asbestos containing materials or products for thermal insulation and/or for acoustical, preservative or decorative purposes.

c) to apply or to manufacture asbestos and/or asbestos containing materials or products for other purposes than those mentioned sub (b) if a concentration of asbestos dust occurs dangerous to health (at present there is a permissible unit of 2 fibres/ml averaged over a 4 hour sampling period).

d) to spray asbestos and/or asbestos containing materials or products.

e) exemption from these measures is possible.

United States of America

2.0 fibres/ml, >5 µm, time weighted average for 8 hour work day; peak concentration 10 fibres/ml. Valid from 1 July 1976; at this moment 5.0 fibres/ml permissible (Nat. Inst. Occ. Safety and Health 1972). However, recently OSHA proposed a standard of 0.5 fibre/ml as time weighted 8 hour exposure, and a ceiling of 5/ml for a period of 15 min. (Dept. Labor, OSHA 1975).

U.S.S.R.

2 mg/m^3 if asbestos content >10% total dust (WHO, 1974).

German Democratic Republic

100 particles/ml if asbestos content >40% (WHO, 1974). According to Sturm (1975) this standard has to be lowered.

Canada

2 fibres/ml, >5 µm.

South Africa

2 fibres/ml, from end 1975; at this moment 5 fibres/ml.

Finland

5 fibres/ml, to be lowered to 2 fibres/ml; crocidolite banned; ban on spraying.

Norway

5 fibres/ml, to be lowered to 2 fibres/ml; 10 fibres/ml for 15 min.

Sweden

2 fibres/ml; ban on crocidolite except on special permission.

Discussion

- In recent years most western countries proposed or enforced permissible limits of 2 fibres/ml, >5 µm, i.e. counted by light phase contrast microscopy, therefore small fibres are not taken into account.
- In some countries special regulations have been published for crocidolite: ban or 1/10 of level for chrysotile.
- Counting of fibres has in most countries replaced methods based on measuring weight/volume, at least in occupational health.
- In most countries the permissible limit has been lowered in recent years, or will soon be lowered; there generally is a trend for more strict limits.
- The 2 fibre/ml limit is mainly based upon a proposal by the BOHS (1968, 1973) in the UK. However this limit aims at the protection of up to 99% of workers with exposure up to 50 years for early incipient asbestosis (signs of basal rates), and is not based upon protection of malignancies (mesothelioma).

- The original recommendation by BOHS (1968) stated: "Such early clinical signs will be less than 1% for an accumulated exposure of 100 fibre years per cm^3". Conversion of this recommendation into a standard of 2 f/ml does not fully comply with the BOHS recommendation which was based upon accumulated exposure.
- Berry (1973) commented critically on the 2 fibre/ml limit: it has mainly been based upon one study in workers of an asbestos-textile factory who worked for at least 10 years; workers who had already left, may have been more susceptible. The 1% limit has a 95% range of confidence up to about 3%; so 99% of workers would be protected with an accumulated dose <51 fibre-years, and more than 97% with a dose of <100 fibre-years.
- The NIOSH criteria document (1972) sums up the following constraints in applicability of research data in the development of recommendations:
  a) - few epidemiological data or clinical reports with supporting evidence are available;
  b) - available environmental data on practically all studies were collected only over the last few years and/or collected by other techniques and expressed in terms other than fibres/ml;
  c) – environmental samples were expressly collected in many cases for control purposes and not for research;
  d) – there is a lack of data to define with any degree of precision the threshold of development of neoplasms resulting from exposure to asbestos and the relationship of the latent period between exposure and development of neoplasms.
- The approach which led to the permissible limit of 2 fibres/ml is based upon an epidemiological study; one started fibre counts as a measure of exposure, because in animal experiments such an exposure had induced asbestosis. However, there is a very long way to go from such experiments on animal health regarding occupational health (asbestosis) to public health (malignancies).
- The U.K. standard for chrysotile was based upon epidemiological evidence, but the standard for crocidolite was purely based upon an administrative decision, and not on research data.
- According to Weiss (1975) Gillam of NIOSH has found that the lung cancer risk among hard rock miners exposed to an asbestiform material, mostly amosite, was three times that expected, despite the fact that fibre counts (>5 µm) were well below the 1976 standard of 2 fibres/ml; most of the fibres were short; however arsenic was considered a possible factor.

General environment

USA

Because routine standardized techniques for sampling and analysing asbestos emissions are not available, the proposed standards are not given in terms of numerical values. The standards are expressed in terms of required control practices that limit emissions to an acceptable level, e.g. use of filters to clean forced exhaust gases from mining, milling, manufacturing industries, fabricating operations; eliminating visible emissions of particle matters from dumps, storage areas, conveyors, etc.; prohibition of certain applications by spraying processes. A safe exposure level to asbestos has not been established (EPA 1971).
The State of Illinois: 2 fibres/ml in emissions.

USSR

Immission limits for ambient air: 0.15 mg/m^3/24 hour; 0.5 mg/m^3 as maximum concentration in a sample of total dust (WHO 1974).

Conclusion

- In recent years in many countries permissible limits for workroom air of 2 fibres/ml, >5 µm, have been imposed. There is even a tendency to lower the permissible limits. These limits do not aim at prevention of malignancies. There still exist many constraints in recommending a permissible limit for workroom air.
- For the ambient environment practically no permissible limits for air, water, beverages, etc. exist.

XII. ORIENTATION REGARDING HEALTH RISK OF TRUE ENVIRONMENTAL EXPOSURE

Some conclusions from the previous chapters relevant for the topic to be discussed may be summarised as follows:

- The public health risk is restricted to increased incidence of malignant tumours (chapter VIII).
- Bronchial carcinomas (Chapter IX) occur in asbestos exposed workers, more or less independent from the type of asbestos. Smoking increases the risk considerably. The tumour is regarded by some as a complication of occupational asbestosis, however this statement needs reassessment: the possibility of asbestos related bronchial carcinoma as such cannot be excluded.
- Larynx carcinoma (Chapter IX) may be associated with past asbestos exposure; evidence of a causal relationship is not proven.
- Gastrointestinal carcinomas (Chapter IX) have a slightly higher indicence in occupationally exposed workers, also in those with severe but short periods of exposure; the geographical distribution in the general population is not consistent with that of (para-)occupational and neighbourhood exposure to asbestos.
- The incidence of mesothelioma (Chapter IX) is probably related to the type of asbestos; an effect of smoking is not evident; there exist indications that intermittent even short term exposure may suffice to induce a mesothelioma after a long latent period.
- The prevalence of mesothelioma shows a typical geographical distribution: increased in regions with shipyards, heavy industry, asbestos industry, some asbestos mines (especially crocidolite).
- Occurrence of mesothelioma is much more specific (although not absolute) for previous asbestos exposure than occurrence of the other malignant tumours mentioned above. In most cases (para-)occupational exposure to asbestos exists when history taking is done with great care.
- There is general agreement that the risk of mesothelioma is fibre related in the order crocidolite > amosite > chrysotile > anthophyllite, but the magnitude of the difference in risk is not well established.

- There exists a qualitative dose-response relationship, insofar that in the occupational setting the risk decreases with decreasing exposure.
- The intensity and/or duration of asbestos exposure necessary to induce a malignant tumour probably is the lowest/smallest in the case of mesothelioma.
- At present there is no established evidence of general "true" environmental exposures to the public causing an increased incidence of asbestos-related tumours by inhalation or ingestion, but such a risk cannot be conclusively excluded on present evidence.
- There is no theoretical evidence for an exposure threshold below which cancers will not occur.
- The currently proposed or enforced permissible limits for occupational asbestos exposure by inhalation centre around 2 fibres/ml length (>5μ); this limit aims at preventing minimal asbestosis, and not malignancies (Chapter XI). Moreover, there is no consensus yet whether only fibres longer than 5μ carry a biological risk (Chapter VI), whereas the general public is exposed relatively much more to short fibres (<5μ) than in occupational exposure (Chapter V). It is not possible to estimate, with a reasonable degree of accuracy, the number of short fibres (<5μ) from the number of long fibres (>5μ) (Chapter IV). The relationship between short and long fibres varies widely with the source of the fibrous dust. Too little information exists to estimate adequately the respiratory and/or gastrointestinal exposure of the general public either to long or to short fibres (Chapter V).
- It is not known whether some groups or members of the general public have a high susceptibility (Chapter X).

From this it can be concluded that it is impossible to come to a reliable quantitative assessment of the risk of malignancies for the general public: present evidence does not point to there being a threshold level of dust exposure below which tumours will never occur. There is very likely a practical level of exposure below it will be impossible to detect any excess mortality or morbidity due to asbestos, despite the presence of this mineral in the tissues, especially in the lung. Thus, there is possibly a level of exposure (perhaps already achieved in the general public) where the risk is negligibly small.

Two semi-quantitative approaches to compare the health risk of exposure

of occupationally exposed workers and of the general public in case of true exposure will be given.

In Chapter V exposure levels of the general public are presented; these levels have as an order of magnitude in the case of true environmental exposure:

- in air: $<10^{-8}$ g/m^3 (long and short fibres)
- in water and beverages: $<2.10^{-6}$ g/l.

In the case of occupational exposure the permissible limit is 2 fibres/ml, i.e. $\sim 10^{-4}$ g/m^3 (for long fibres >5μ); the additional fibres <5μ will add very little to the weight. The total exposure may be estimated to be $\sim 10^{-4}$ g/m^3 at the permissible level for occupational exposure (40 hour/week), corresponding to $\sim 2.10^{-5}$ g/m^3 for 168 hour/week.

From this calculation, which is based to a large extent on assumptions as to the distribution of fibre sizes and diameters, one may conclude that the general public in the case of true enviornmental exposure is exposed to a concentration in air which is about 1000 times lower than the stated converted occupational exposure limit, which however is not given for prevention of malignancies but of incipient asbestosis.

Bruckman et al (1975) tried to derive an air quality standard for asbestos. Their way of reasoning was as follows:

- in industrial settings 2% of all asbestos fibres are counted by phase contrast microscopy (by number); so 2 fibres (>5μ)/ml correspond to 100 fibres (total)/ml; 1000 asbestos fibres (total) weigh about 10^{-9} g; 100 fibres (total)/ml correspond to 10^{-10} g/ml, i.e. 10^{-4} g/m^3;
- a hypothetical dose (fibres >5μ/m^3)-response (probability of contraction mesothelioma)-"envelope" based upon industrial air exposure is developed; industrial (40 hour/week) exposure is extrapolated to ambient exposure by dividing with a factor of 4.2;
- the smallest possibility of contracting mesothelioma corresponds to 30.10^{-9} g/m^3 in ambient air, which may induce a number of tumours, which correspond to 1/10 the total nationwide number of fatalities from airplane accidents (150) and approximately the same number of deaths as from train mishaps; this could be taken as an air quality standard;

- non-urban and remote urban airborne asbestos concentrations are $<10^{-9}$ g/m^3; urban airborne concentrations are $<30.10^{-9}$ g/m^3, except in heavily industrialized areas around construction sites, and toll booths;
- the OSHA standard (2 fibres/ml, >5μ) is equivalent to $25.000.10^{-9}$ g/m^3, which corresponds to 25.10^{-6} g/m^3, for continuous (168 hour/week) exposure of general public in ambient air; the proposed air quality standard of 30.10^{-9} g/m^3 is approximately $\frac{1}{1000}$ of the converted OSHA-standard. However, recently a standard of 0.5 f/ml has been proposed in the USA; (see Chapter XI.)

However, Plumlee (1975) summed up many deficiencies in the proposal by Bruckman et al, inter alia:

- the authors' own data do not suggest a dose-response relationship between exposure and the frequency of mesothelioma; this might be due to the concurrent mortality by other cancers or asbestosis, so hiding a possible mesothelioma inducing effect of high exposure intensities;
- the incidence is underreported, because many physicians and pathologists do not recognize the diagnosis;
- there are only 12 points on the graph; more data may be expected to lower the minimum and raise the maximum level;
- extrapolation from occupation to public health does not take into account a possible increased risk for exposure of children, who carry an asbestos lung burden for a longer period of time;
- transportation mishaps may be regarded by the population as unavoidable; it is not allowed to suggest the same acceptance of asbestos exposure risks, because such exposure may not be regarded as essential;
- conversion of fibre >5μ to total fibres is based upon an educated guess, and not adequately reliable to introduce in extrapolation; equivalents which apply to the workplace may not apply to ambient air level.

Plumlee concluded with the justified remark "that the exposure level data from occupational studies, as well as present analytical methodology, are so unreliable as to make the results of this exercise meaningless".

Both approaches should be regarded as highly deficient:

- they are based upon a deficient number of well controlled basic data
- they rely too much on average concentrations and not on the unknown maybe more relevant peak exposures in the past

- they rely too heavily on assumptions, e.g. similar distribution of fibre lengths in occupational and ambient air; similar respiratory volume; it is clear that a simple extension of the principles of sampling within factories to the general environment is inappropriate, both because of the very much lower concentrations in air and water, and the need to identify positively the type of mineral and size distribution of fibres;
- they compare an environmental quality standard for preventing malignancy with an occupational permissible limit for preventing asbestosis;
- in sampling air (and water) in the ambient environment the ratio of asbestos to other fibrous particles may be too low to permit neglecting the non-asbestos minerals, as is normally done in the factory and the mine.

Nevertheless they both indicate that ambient air exposure of the general public, except in case of para-occupational and neighbourhood exposure, is an order of two or three magnitudes smaller than in well controlled industry. It seems possible that a factor of 1000 or more may be large enough to reduce the risk of tumours to a negligible level compared to other risks.

The conclusion given before that it is not possible to come to a quantitative assessment of the risk of malignancies for the general public, is not contradicted by the two approaches mentioned.

In 1972 the Advisory Committee on Asbestos Cancers to the Director of the International Agency for Research on Cancer (IARC 1973) discussed the following question: "Is there evidence of an increased risk of mesothelial cancers at low levels of exposure to asbestos, such as have been encountered by the general population in urban areas?" The answer was: "There is evidence of an association of mesothelial tumours with air pollution in the neighbourhood of crocidolite mines and of factories using mixtures of asbestos fibre types. The evidence relates to conditions many years ago. There is evidence of no excess risk of mesotheliomas from asbestos air pollution which has existed in the neighbourhood of chrysotile and amosite mines. There are reported differences between urban and rural areas, the causes of which have not been established. There is no evidence of a risk to the general public at present".

The data discussed in this report, not available at the time of the Lyon Conference in 1972, have not brought conclusive evidence that the conclusion of the Advisory Committee has to be changed. This report has stressed that

isolated cases of mesothelioma occur among members of the general public, which at first sight might be thought to be due to ambient exposure, but which after careful review of life history pointed to unexpected (para-)occupational or neighbourhood exposure (Chapters III and IX). The dividing line between occupational and public health risk appears not to be sharp. The presence of asbestos in factories and in asbestos containing products in the general environment - in cases of sawing, drilling, demolition and of transport and storage of asbestos fibres, wear and tear of sprayed walls - may carry a definite risk, although it is difficult to prove the causal relationship in isolated cases because of the long latency period. As discussed in Chapter II the use of asbestos has increased considerably in the last decades. This risk particularly applies to regions with dockyards, asbestos industries, heavy industry and some mining sites. It should be emphasized that, as in the case of other cancers, there is likely to be more than one cause of mesothelioma of the pleura.

In Chapter IX the risk of ingestion of asbestos fibres and induction of gastrointestinal tumours was discussed. As in the case of respiratory exposure, no quantitative assessment of health risk can be given. The American Water Works Association Research Foundation (1974) compared the maximal amount ingested from drinking water over 60 years to the quantity likely to be ingested in occupational exposure; low occupational exposure was expected to correspond to at least 30 times higher gastrointestinal exposure (Chapter V). However, this comparison does not take into account possible differences in fibre length and diameter. Moreover the factor 30 is small in comparison to the difference in respiratory exposure. Peritoneal mesothelioma probably is related to rather intensive occupational exposure; other gastrointestinal tumours are much less specific for asbestos exposure; any relationship with, for example, drinking water will be very difficult to prove or disprove.

The Advisory Committee on Asbestos Cancer (IARC 1973) answered the question: "Is there evidence of an increased risk of cancer resulting from asbestos fibres present in water, beverages, food or in the fluids used for administration of drugs?" as follows: "Such evidence as there is does not indicate any risk". This report does not bring any new facts to disclaim this conclusion. It should however be pointed out that the available quantitative evidence on the risk of gastrointestinal exposure is even more deficient than on the risk of respiratory exposure, and also that the causative factors for in-

ducing gastrointestinal tumours are much less well understood than for bronchial carcinoma.

This report (Chapter IX) has mentioned the possibility of iatrogenic or accidental administration of asbestos fibres. No health effects have been reported. It will be extremely difficult to detect isolated cases; moreover, the patients themselves will not be aware of this type of asbestos exposure.

The general conclusion of this chapter on the public health risk of asbestos exposure can be summarized as follows:

- exposure to asbestos fibres may carry a definite health risk: induction of malignancies; this is enough reason to minimize asbestos fibre exposure of the general public as much as possible; this is particulary the case for crocidolite fibres.
- there is no established evidence that true ambient exposure through air, water, drugs, beverages, food, as prevalent in Western European countries at this moment carries such a definite risk; however there exist too many uncertainties to deny such a risk, though if the risk was substantial, it is likely it would have been detected by now.
- the possibility of para-occupational exposure (families) and neighbourhood (industry, mines, transport) exposure is an area for concern. This particularly applies to regions with shipyards, asbestos industry, some mining sites.
- the working of asbestos containing products by the general public (leisuretime activities) is an area for concern.
- iatrogenic or accidental administration of asbestos fibres carry a potential risk, and should be minimized as much as possible.

XIII SUGGESTIONS FOR FURTHER STUDY

In suggesting further studies within the framework of the EEC, emphasis should be put upon those studies, which may be expected to yield data important for guidance of overall policy of the Community to achieve prevention of public health risk in the future. With this restriction the following studies are suggested:

1. Study of quantities of asbestos mined, transported, imported, exported, produced, applied and of usage of asbestos (containing products) within the EEC;
   - this study should produce data on total quantities, specified to type of asbestos, to type of product, and to locality,
   - the data should quantify overall presence within the EEC and indicate areas with higher risk, so facilitating the setting of priorities.

2. Study of the size of the population potentially at risk, as mentioned in chapter III, as 2a and 3; the number of relatives of workers and of persons living in the vicinity of polluting mines and production industries.

3. Study of the biological (particularly with regard to the induction of tumours) significance of physical and chemical properties of asbestos and other mineral fibres: length and diameter.

4. Study of methods to measure quantitatively and qualitatively the presence of asbestos and other mineral fibres in air, beverages, drinking water, etc.: standardization of criteria for quantitative and qualitative measurement, comparability of data, development of "simple" methods; the methods should be geared to the biological significance of physical properties of fibres.

5. Study of the presence of pathogenically significant fibres in the ambient environment (e.g. air, river water, soil), in the indoor environment

in houses and public buildings, in beverages, drinking water, drugs, etc. with priority for those localities and situations which possibly may present a higher public health risk (see 1 and 2); study of the relative importance of asbestos fibres within the total number of fibres present; diagnostic study of the type of fibres.

6. Study of the release of fibres from asbestos insulating layers in buildings during application, demolition and normal use.

7. Study of the asbestos content of talcum, particularly as applied in manufactoring rubber articles and paints; study of release of fibres in the vicinity of industries, and under conditions as mentioned ad 6.

8. Study of the natural fibre content of drinking water from a variety of sources and the contribution to this of asbestos cement pipes; effect of usage conditions, age, soil and water (pH); effect of treatment in water purification plants.

9. Study of the comparability and validity of methods to measure quantitatively and qualitatively the presence of asbestos bodies and asbestos and other mineral fibres in organs of human subjects.

10. Study by means of a register of histologically verified cases of mesothelioma as to the content (quantitatively and qualitatively) of asbestos bodies and asbestos and other mineral fibres in pulmonary tissue.

11. Studies of the relationship between the presence (quantitatively and qualitatively) of asbestos bodies and asbestos and other mineral fibres in various organs (particularly the lung) of human subjects with cause of death, sex, age and possibilities of exposure.

12. Prospective study of the incidence of malignancies in subjects with known (quantitatively and qualitatively) occupational, para-occupational and neighbourhood exposure; in practice this particularly may be feasible in case of occupational exposure; attention should be paid to the significance of discontinuity of exposure (peaks, intermittency).

13. Study of the predictive validity with regard to past exposure intensity

and duration and comparability of history taking procedures for evaluating past asbestos exposure; study of the significance of (para-)occupational exposure situations.

14. Study of the age and sex standardized incidence of malignant tumours in the general population according to areas of living-working: urban-rural, industrialisation in general, presence of asbestos industries, presence of dockyards and harbours, presence of asbestos mines and presence of other potential asbestos emitting sources.

A general remark on the feasibility of epidemiological studies appears to be appropriate. The question is whether an epidemiological approach can be found, that delineates the contributory role of asbestos and other mineral fibres to induction of malignant tumours. With retrospective techniques, it has been possible to establish past exposure to asbestos in most cases of mesothelioma. It is probable that with more complete history taking only a relatively small number of mesothelioma patients will remain having no (para-) occupational exposure. How we can regard this remaining group is still unclear. A logical assumption is that this group contains:

a) not recognized (para-)occupational or neighbourhood exposure,
b) cases due to true environmental exposure,
c) cases due to other pollutants (mineral fibres?),
d) cases not related to asbestos or other pollutants.

To study this, one would need fairly large numbers of cases, one would also like to compare large communities, and one would like to know the "normal" fibre burden of the lung. At present the number of mesothelioma cases in, for example, the Netherlands may be too small to study an urbanization effect. So, the question can only be solved, it seems, by waiting until higher numbers become available, or by performing a rigidly coordinated international study.

Within the EEC, mesothelioma registration sometimes appears to be related to the social insurance system and reports only occupationally related cases, which have to be financially compensated. Such a system will underreport the total prevalence.

As for bronchial cancer, the perspectives may be brighter. There is still a clear urban-rural gradient in most countries; this gradient is diminishing however, at least in the UK and in the Netherlands. Still if we could

quantify the past exposure for urban communities, exceptions to this trend might help to delineate the role of asbestos. In the occupational situation the excess risk of bronchial cancer seems to run fairly parallel to the risk of asbestosis; however, the evidence is insufficient to state that asbestos-induced bronchial carcinoma does not occur without asbestosis. The importance of bronchial cancer as a cause of death requires that adequate research effort be put into clearly establishing the role of asbestos as an inductor of bronchial carcinoma in the general population. The same may be true for laryngocarcinoma. As for gastrointestinal carcinoma, the ability to find a role of mineral fibres in water, would depend upon a similar approach, comparing trends with fibre counts in individual communities. A mapping of past and present sources of asbestos in communities and a mapping of trends in specific mortality, is recommended in this connection.

In this chapter studies are suggested to improve the body of data, which is desirable for arriving at an adequate policy. However, it appears appropriate to set priorities. Studies numbers 1, 3, 10, 11 and 14 should have the highest priority:

1. Study of the quantities and usage of different types of asbestos (containing products) within the EEC. This could point out those situations with the highest potential risk; in several cases wellknown hygienic measures could be applied, minimizing exposure.

3. Study of the biological significance of the physical properties of asbestos and other mineral fibres. If it could be established with confidence that small fibres (<5μ) do not carry any health risk, then the procedure of environmental monitoring could be very much simplified, whereas it might greatly diminish the number and size of environmental situations, up till now regarded as carrying a potential risk.

10. Study of the presence of asbestos bodies, asbestos, and other mineral fibres particularly in lung tissues in case of histologically proven consistently registered cases of mesothelioma.

11. Study of the relationship between the presence of asbestos bodies, asbestos, and other mineral fibres in human organs and cause of death. Studies ad 10 and 11 could clarify the causal relationship between asbestos

exposure and disease, and also the specificity (with regard to asbestos exposure) of mesothelioma.

14. Study of the incidence of malignant tumours in relation to exposure conditions.
Studies ad 10 and 14 could clarify the true risk of induction of malignancies in relation to body burden and to external exposure.

In this list of priorities the need for biological monitoring is stressed. The considerable difficulty in sampling the ambient environment in a way which is economical and readily interpretable in terms of the risk of asbestos-related disease recommends the biological monitoring approach, particularly of the asbestos and other mineral burden in the lung; however limited monitoring of asbestos in air near potential sources of asbestos emissions should be carried out.

It should be realized that the studies mentioned may require the input of highly specialized manpower and equipment; they will not give an adequate answer within a short period of time, e.g. within 3-5 years. It will be necessary to combine the efforts of specialized institutes within the EEC; a high degree of cooperation and coordination - also with institutes outside the EEC - will be a condition sine qua non.

XIV. RECOMMENDATIONS

This chapter recommends measures to be taken within the EEC at the Community and at the National level. The recommendations are listed under four headings, i.e.:

a. Further studies to be carried out
b. The minimizing of asbestos in the environment
c. Support to the usage and the development of substitutes
d. Regulations for the prevention of asbestos exposure

These recommendations do not go into details but broadly define the fields in which further action is considered necessary and are meant as general guidelines for this action. This should result eventually in specific recommendations, regulations and codes of practice. The following recommendations are put forward:

a. Further studies to be carried out

The studies as mentioned in chapter XIII should be carried out. The highest priority has to be attached to

- Study of quantities and usage of asbestos containing products.
- Study of the biological significance of physical and chemical properties of asbestos fibres and other mineral fibres.
- Study of the presence of asbestos bodies, asbestos and other mineral fibres in lung tissues in cases of mesothelioma. A mesothelioma register should be set up in the various countries of the EEC in accordance with criteria and procedures as agreed upon by a supervising panel of pathologists.
- Study of the relationship between the presence of asbestos bodies and fibres in human organs and cause of death and past exposure.
- Study of the relationship between the incidence of malignant tumours and exposure conditions.
- Limited comparative study of the presence of asbestos fibres in air.

b. Minimizing of asbestos in the environment

The amount of asbestos fibres in the ambient environment (air, food, water, beverages and drugs) should be reduced as much as possible. This applies in particular to the presence of crocidolite fibres. Through a thorough control on hygienic conditions at asbestos and asbestos goods processing factories and on activities relating to the industrial use of asbestos including the transport and packaging of raw asbestos and asbestos goods and the disposal of asbestos waste the concentration of asbestos in the environment can be favourably influenced. Attention should also be paid to the effects of the presence of asbestos containing products in everyday life in such a form as to give rise to a health risk to the general public through the release of asbestos fibres into the ambient and home environment.

c. Support to the usage and the development of substitutes

The usage of substitution products which technically are at least as safe as asbestos should only be encouraged after a proper evaluation has been made of the economical and technical feasibility of those products and the health risk - both occupational and environmental - attached to the use of them. The development of new substitutes complying with reasonable requirements with regard to technical and economical feasibility and health risk should be stimulated. High priority in this respect should be given to substitutes for applications where a sufficient control on hygienic conditions regarding asbestos dust emission is difficult to maintain in practice.

d. Regulations for prevention of asbestos fibre exposure

As referred to under (b) an effective control on hygienic conditions in the occupational field is of real assistance in reducing the presence of asbestos fibres in the environment. There have been issued already regulations in the former field by several EEC countries (see chapter XI). It is important to try and effect a measure of uniformity in these regulations at the Community and at National level. Codes of practice for the usage of asbestos and asbestos containing products are of great importance for an efficient dust control.

The drafting and publication of such codes should be actively pursued and they should apply to occupational situations as well as possibly widely exis-

ting situations of health risk to the general public e.g. modes of transport of raw asbestos and asbestos goods, asbestos products in public buildings, contamination of drinking water, contamination of talc. If at all practicable the sale of raw asbestos fibres to the general public should be forbidden.

Asbestos and asbestos containing products should be clearly labelled and carry a warning as to the health risk involved in handling and usage and a reference to the prescribed handling practice.

As already observed, because of the influence of measures taken in the sphere of occupational health on the risk to public health a close coordination between the Public Health and the Occupational Health Authorities at Community and National level should be achieved.

e. General

A few specialized institutions should be designated to carry out research required to provide relevant information for which purpose financial support by the EEC is necessary.

The Health and Safety Directorate of the Commission of the European Communities should coordinate, in collaboration with the Member States, the recommendations and their follow-up. It should also pay due attention to the possible health risk from the use of mineral fibres other than asbestos.

ANNEX I

EEC MESOTHELIOMA PANEL

Terms of Reference

1. The EEC Mesothelioma Panel has as one of its basic objectives the standardization of the pathological diagnosis of mesothelioma, by exchange of information between Members of National Panels.

2. In addition it seeks to provide data which, combined with information from Clinical and Epidemiological sources, can be used for the compiling of the EEC Mesothelioma Register.

3. The Panel should consist of one pathologist from each Member State, who has experience of primary tumours of the serosal cavities and of asbestosis.

4. It should be able to co-opt pathologists with specialized knowledge, e.g. of gastrointestinal tumours, of the female genital tract.

5. It is essential to have statistical advice in the whole planning of the panel's function.

6. If biopsy material is to be considered the panel must decide the amount of tissue that will be acceptable. It should be a primary task to determine the validity of needle biopsies.

7. It is important that the Panel should determine whether or not deleterious effects occur following biopsies from open thoracotomy.

8. To establish the dose/effect relationships the panel can only consider cases on which a full post-mortem examination has been performed and when both tumour tissue and a complete sagittal section of tissue from the least affected lung is available for sampling. The actual amount and type of asbestos present can only be assessed by a mineralogist with the necessary sophisticated equipment.

9. The Panel should also agree on a classification scheme for mesotheliomas, and the grading and severity of asbestosis present in the lung tissue submitted.

REFERENCES

ADVISORY committee on asbestos cancers to director of International agency for research on cancer. In: Biological effects of asbestos; ed. by P. Bogovski e.a, p. 341 Lyon, IARC, 1973

AIR sampling instruments for evaluation of atmospheric contaminants; 4th ed. Cincinnati, Ohio, American conference of governmental hygienists, 1972

AMERICAN water works association. A study of the problem of asbestos in water. Amer. Water Works Ass. J. (1974) sept., part 2

ANJILVEL, L. and W.M. THURLBECK. The incidence of asbestos bodies in the lungs at random necropsies in Montreal. Canad. med. Ass. J. 95 (1966) 1179

ASBESTOS information committee. Asbestos; its special attributes and uses. London, 1975

ASBESTOSIS research council. The measurement of airborne asbestos dust by the membrane filter method; rev. ed. Rochdale, Lancashire, 1971. Technical note no. 1

ASBESTOSIS research council. Dust sampling procedures for use with the Asbestos regulations 1969. Rochdale, Lancashire, 1971. Technical note no. 2

ASHCROFT, T. Epidemiological and quantitative relationships between mesothelioma and asbestos on Tyneside. J. clin. Path. 26 (1973) 832

BAGIONI, R.P. Separation of chrysotile asbestos from minerals that interfere with its infrared analysis. Environm. Sci. Technol. 9 (1975) 262

BECK , E.G., P.F. HOLT and N. MANOJLOVIC. Comparison of effects on macrophage cultures of glassfibre, glasspowder and chrysotile asbestos . Brit. J. industr. Med. 29 (1972) 280

BECK, E.G. Biologische Wirkung von faserförmigen Stäuben. Arbeitsmed. Sozialmed. Präventiv Med. 10 (1975) 178

BERRY, G. Hygiene standards; theory and application. In: Biological effects of asbestos; ed. bz P. Bogovski e.a., p. 145. Lyon, IARC, 1973

BIGNON, J., M. BIENTZ, J. GONI , M.C. JAURAND et P. SEBASTIEN. La métologie des asbestes présents dans l'environnement en relation avec le risque pour la santé publique. Luxembourg, EEC. 1975. Doc. no. 3497/75 F

BOHLIG, H.and E. HAIN. Cancer in relation to environmental exposure. In: Biological effects of asbestos; ed. bz P. Bogovski e.a., p.217. Lyon, IARC, 1973

BRIT. Med. J. Asbestos hazard. Editorial. Brit. Med. J. IV (1973) 312

BRITISH occupational hygiene society (BOHS). Hygiene standards for chrysotile asbestos dust. Ann. occup. Hzg. 11 (19 68) 47

BRITISH occupational hygiene society (BOHS) Hygiene standards for airborne amosite asbestos dust. Ann. occup. Hyg. 16 (1973)1

BRITISH thoracic and tuberculosis association (BTTA) and Medical research council pneumoconiosis unit (MRCPU). A survey of pleural thickening: its relation to asbestos exposure and previous pleural disease. Environm. Res. 5 (1972) 142

BRUCKMAN, L. and R.A. RUBINO. Asbestos: rationale behind a proposed air quality standard. J. air Pollut. Contr. Ass. 25 (1975) 1207

BURILKOV, T. Epidemiologie und Äthiologie der endemischen pleuraplaques in Bulgarian. Proc. 4th int. Pneumoconiosis Conf., Bucharest 1971, p. 280

BURILKOV, T. und L. MICHAILOVA. Über den Sepiolitgehalt des Bodens in Gebieten mit endemischen Pleuraverkalkungen. Int. Arch. Arbeitsmed. 29 (1972) 95

BYROM, J.C., A.A. HODGSON and S. HOLMES. A dust survey carried out in buildings incorporating asbestos-based materials in their construction. Ann. occup. Hzg. 12 (1969) 141

CAUNA, D., R.S. TOTTEN and P. GROSS. Asbestos bodies in human lungs at autopsy. J. Amer. Med. Ass. 192 (1965) 371

CLARK, R.L. and C.O. RUND. Transmission electron microscopy standards for asbestos. Micron 5 (1974) 83

CUNNINGHAM, H.M. and R. PONTEFRACT. Asbestos fibres in beverages and drinking water. Nature 232 (1971) 332

CUNNINGHAM, H.M. and R.D. PONTEFRACT. Asbestos fibers in beverages, drinking water and tissues; their passage through the intestinal wall and movement through the body. J. Ass. Offic. anal. Chem. 56 (1973) 976

DAVIS, J.M.G. and P. GROSS. Are ferruginous bodies an indication of atmospheric pollution byasbestos? In: Biological effects of asbestos; ed.by P. Bogovski e.a., p. 238. Lyon, IARC, 1973

DEPT. of Labor, Occ. Safety and Health Administration. Occupational exposure to asbestos. Federal Register Oct. 9, 1975, part. 2, 47652

DEWORM, J.P., J. PAUWELS and G. FIEUW. Measurement of asbestos in ambient air as preparation and support for an epidemiological study Mol, Belgium. Health Physics Department, S.C.K./C.E.N., 1974

DICKE, T.E. and B. NAYLOR. Prevalence of "asbestos" bodies in human lungs at necropsy. Dis. Chest. 56 (1969) 122

DOHNER, V.A., R.G. BEEGLE and W.T. MILLER. Asbestos exposure and multiple primary tumors. Amer. Rev. resp. Dis. 112 (1975) 181

DONIACH, I., K.V. SWETTENHAM and M.K.S. HATHORN. Prevalence of asbestos bodies in a necropsy series in East London; association with disease, occupation and domiciliary address. Brit. J. industr. Med. 32 (1975) 16

ELMES, P.C. and O.L. WADE. Relationship between exposure to asbestos and pleural malignancy in Belfast. Ann. N.Y. Acad. Sci. 132 (1965) 549

ELZENGA, C.H.J., P.B. MEYER en J. STRUMPHIUS. Oriënterend onderzoek naar het vóórkomen van asbest in het Nederlandse drinkwater. H2O (1974) 406

ENTERLINE, Ph.E., P. DE COUFLE and V. HENDERSON. Mortality in relation to occupational exposure in the asbestos industry . J. occup. Med. 14 (1972) 897

ENTERLINE, Ph.E . and V. HENDERSON. Type of asbestos and respiratory cancer in the asbestos industry. Arch. environm. Hlth 27 (1973) 312

ENTERLINE, Ph.E., P. DE COUFLE and V. HENDERSON. Respiratory cancer in relation to occupational exposures among retired asbestos workers. Bit. J. industr. Med. 30 (1973) 162

ENVIRONMENTAL protection agency (EPA). Brackground information; proposed national emission standards for hazardous air pollutants: asbestos, beryllium, mercury. Research Triangle Park, North Carolina, EPA, 1971

FRIEDRICHS, K.H. und F. POTT. Faserförmige Stäube in der Aussenluft und ihre gesundheitliche Bedeutung. In: Proc. int. clean air congr. , Düsseldorf 1973. Düsseldorf, VDI– Verlag, 1973

GADSDEN, I.A., J. PARKER and W.L. SMITH. Determination of chrysotile in airborne asbestos by infrared spectrometric techniques. Atmosph. Environm. 4 (1970) 667

GERBER, M.A. Asbestosis and neoplastic disorders of the hematopoietic system. Amer. J. clin. Path. 53 (1970) 204

GHEZZI, I., G. ARESINI e E.C. VIGLIANI. Il rischio di asbestosi in una miniera di amianto crisotilo. Med. d. Lavoro 63 (1972) 189

GILSON, J.C. Asbestos cancer: past and future hazards. Proc. roy. Soc. Med. 66 (1973) 395

GLEIT, C.E. Electronic apparatus for ashing biological specimens. Amer. J. med. Electr. 2 (1963) 112

GOODHEAD, K. and R.W. MARTINDALE. The determination of amosite and chrysotile in airborne dusts by an X-ray diffraction method. Analyst 94 (1969) 985

GREENBERG, M. and T.A. LLOYD DAVIES. Mesothelioma register 1967-68. Brit. J. industr. Med. 31 (1974) 91

GROSS, P., R.T.P. deTREVILLE, L.J. CRALLEY and J.M.G. DAVIS. Pulmonary ferruginous bodies. Arch. Path. 85 (1968) 539

GROSS, P., R.T.P. deTREVILLE and M.N. HALLER. Pulmonary ferruginous bodies in city dwellers; a study of their central fiber. Arch. environm. Hlth 19 (1969) 186

GROSS, P. Is short-fibered asbestos dust a biological hazard? Arch. environm. Hlth 29 (1974) 115

GROSS, P., R.A. HARLEY, L.M. SWINBURNE, J.A.G. DAVIS and W.B. GREENE. Ingested mineral fibers, do they penetrate tissue or cause cancer? Arch. Environm. Hlth 29 (1974) 341

GROSS, P., R.A. HARLEY, J.M.G. DAVIS and L.J. CRALLEY. Mineral fiber content of human lungs. Amer. industr. Hyg. Ass. J. 35 (1974) 148

GRUNDY, G.W. and R.W. MILLER. Malignant mesothelioma in childhood. Cancer 30 (1972) 1216

HAIN, E., P. DALQUEN, H. BOHLIG, A. DABBERT und I. HINZ. Katamnestische Untersuchungen zur Genese des Mesothelioms. Int. Arch. Arbeitsmed. 33 (1974) 15

HODGSON, A.A. Fibrous silicates. Royal institute of chemistry, 1966. Lecture series, no. 4

HOLMES, S. Developments in dust sampling and counting techniques in the asbestos industry. Ann. N.Y. Acad. Sci. 132 (1965) 288

HOWARD, S., L.J. KINLEN, H.C. LEWINSOHN, J. PETO and R. DOLL. A mortality study among workers in an English asbestos factory. 18th int. Congr. occup. Hlth, Brighton 1975

INTERNATIONAL agency for research on cancer. IARC monographs on the evaluation of carcinogenic risk of chemicals to man; vol. 2: some inorganic and organometallic compounds. Lyon, IARC, 1973

INTERNATIONAL joint commission from the Great lakes research advisory board. Asbestos in the Great Lakes Basin with emphasis on Lake Superior. 1974

INSTITUUT gezondheidstechniek en milieuhygiene. Werkrapport nr. F 1498 and F 1519. Delft, 1976

JONES, J.S.P. and G.SHEERS. Pleural plaques. In: Biological effects of asbestos; ed. by P. Bogovski e.a., p. 243. Lyon, IARC, 1973

JULIAN, Y. and W.C. McCRONE. Identification of asbestos fibres by microscopical dispersion staining. Microscope 18 (1970) 1

KAY, G. Ontario intensifies search for asbestos in drinking water. Water Pollut. Contr. (1973) Sept., 33

KEENAN, R.G. and J.R. LYNCH. Techniques for the detection, identification and analysis of fibres. Amer. industr. Hyg. Ass. J. 31 (1970) 587

KOGAN, F.M., N.A. GUSELNIKOVA, M.R. GULEVSKAYA. The cancer mortality rate among workers of asbestos industry of the Urals. Gig. i Sanit. 37 (1972) no. 7, 29

KOLM, H.H. Tackling the sixth state. Physics Teacher 13 (1975) 78

KOMMISSION zur Prüfung gesundheitsschädliche Arbeitsstoffe. maximale Arbeitsplatzkonzentrationen 1975. Bonn, Deutsche Forschungsgemeinschaft, 1975

LANCET. Asbestos lung cancer mesothelioma. Editorial. Lancet I (1973) 815

LANGER, A.M., I. RUBIN and I.J. SELIKOFF. Electron microsprobe analysis of asbestos bodies. In: Pneumoconiosis; proc. int. Conf. Johannesburg 1969; ed. bz H.A. Shapiro, p.57. Cape Town enz., Oxford University Press, 1970

LANGER, A.M., V.BADEN, E.C. HAMMOND and I.J. SELIKOFF (1971). Inorganic fibers, including chrysotile in lungs at autopsy. In: proc. Brit. occup. Hyg. Soc. Symp. London 1970; ed. by W.H. Walton, p. 683. Old Wking, Unwin, 1971

LANGER, A.M. The subject of continuous vigilance. Environm. Hlth Perspectives 9 (1974) Dec., 53

LARDEUX, M.P. Poussières d'amiante; limites de concentrations dans l'air des atmosphères de travail. Cah. Notes docum. (1975) nr. 80, 339

LEE, D.H.K. Biological effects of ingested asbestos; report and commentary. Environm. Hlth Perspectives 9 (1974) Déc., 113

LEWINSOHN, H.C. Health hazards of asbestos; a review of recent trends. J. Soc. occup. Med. 24 (1974) 2

LIBSHITZ, H.I., M.S. WERSHBA, G.W. ARKINSON and M.E. SOUTHARD. Asbestosis and carcinoma of the larynx. J. Amer. med. Ass. 228(1974) 1571

McCULLAGH, S.F. The biological effects of asbestos. Med. J. Australia II (1974) 45

McDONALD, A.D. and J.C. McDONALD. Epidemiologic surveillance of mesothelioma in Canada. Canad. med. Ass. J. 109(1973)359

McDONALD, A. and CORBETT McDONALD. Epidemiology of mesohtelioma from estimates of incidence. 18th Int. Congr. occup. Hlth, Brighton 1975. Preliminary report.

McDONALD, J.C. Cancer in chrysotile mines and mills. In: Biological effects of asbestos; ed. by P. Bogovski e.a., p. 189. Lyon, IARC, 1973

McEWEN, J., FINLAYSON. A., MAIR. A. and GIBSON. A.A.M. Mesothelioma in Scotland. B.M.J. 1970, 4, 575-578

Mc FARREN, E.F., J.R. MILLETTE and R.J.LISHKA. Asbestos analysis by electron microscope. Cincinnati, Ohio, Water supply research laboratory, National environmental research center, U.S. environmental protection agency, 1974

McGINTY, L. Asbestos danger to do-it-yourselfers as government ignores own study. New Scientist 3 July 1975, p. 34

MATSUDO, H, N.M. HODGKIN and A. TANAKA. Japanese gastric cancer; potentially carcinogenic silicates (talc) from rice. Arch. Path. 97 (1974) 366

MERLISS, R.R. Talc and asbestos, contaminant of rice. Letter to the editor. J. Amer. med. Ass. 216(1971) 2144

MEURMAN, L. Asbestos bodies and pleura plaques in a Finnish series of autopsy cases. Acta path. microbiol. scand. (1966) suppl. 181

MEURMAN, L. Pleural fibrocalcified plaques and asbestos exposure. Environm. Res. 2(1968) 30

MEURMAN, L.O., N. KIVILUOTO and M. HAKAMA. Mortality and morbidity among the working population of anthophyllite asbestos miners in Finland. Brit. J. industr. Med. 31 (1974)105

MURCHIO, J.C., C. COOPER and A.DE LEON. Asbestos fibers in ambient air of California, prepared for the Air resources board, March 1973. Distributed by NTIS Dept. Commerce.

NATIONAL academy sciences (NAS). Asbestos, the need for and feasibility of air pollution controls; report by the committee on biological effects of atmospheric pollutants, Division of medical sciences, National research council. Washington; National academy of sciences, 1971

NATIONAL institute for occupational safety and health (NIOSH). Occupational exposure to asbestos. Washington, U.S. Dept health, education and welfare, Public health service, 1972. Criteria for a recommended standard.

NAVRÁTIL, M. and F. TRIPPÉ. Epidemiological study of pleural calcifications in persons living in the area close to an asbestos factory. Proc. 4th int. Pneumoconiosis Conf., Bucharest 1971, p. 277

NEWHOUSE, M.L. and H. THOMPSON. Mesothelioma of pleura and peritoneum following exposure to asbestos in the London area. Brit. J. industr. Med. 22 (1965) 261

NEWHOUSE, M.L., G.BERRY, J.C. WAGNER and M.E. TUROK. A study of the mortality of female asbestos workers. Brit. J. industr. Med. 29 (1972) 134

NEWHOUSE, M.L. Asbestos and laryngeal carcinoma. Letter to the editor. Lancet II (1973b) 615

NEWHOUSE, M.L. Cancer among workers in the asbestos textile industry. In: Biological effects of asbestos; ed. by P. Bogovski e.a., p. 203. Lyon, IARC, 1973a

NEWHOUSE, M.L. Asbestos in the workplace and the community. Ann. occup. Hyg. 16(1973)97

NEWHOUSE, M.L. and G. BERRY. Predictions of mortality from mesothelial tumours in asbestos factory workers. 18th int. Congr. occup. Hlth, Brighton 1975

NICHOLSON, W.J., A. ROHL and E.F. FERRAND. Asbestos air pollution in New York City. 2nd int. clean Air Congr. of the Int. union air pollution prevention ass., Washington 1970.

NICHOLSON, W.J., C.J. MAGGIORE and I.J. SELIKOFF. Asbestos contamination of parenteral drugs. Science 177 (1972)171

NURMINEN, M. The epidemiologic relationship between pleural mesothelioma and asbestos exposure. Scand. J. Work Environm. Hlth 1 (1975) 128

OLDHAM, P.D. Asbestos in lung tissue. In: Biological effects of asbestos; ed. by P. Bogovski e.a., p.231. Lyon, IARC, 1972.

OTTO, H. und J.G. VON FRAGSTEIN. Zur Häufigkeit von Asbestnadeln in menschlichen Lungen. Int. Arch. Gewerbepath. Gewerbehyg. 25 (1969) 193

PANG, T.W.S. Removal of asbestos fibres by coagulation and filtration. Water research 9 (1975)397

PLANTEYDT, H.T. A risk from asbestos in pleurectomy. Letter to the editor. J. Amer. med. Ass. 196 (1966)373

PLANTEYDT, H.T. (1973). Discussion summary. In: Biological effects of asbestos; ed. by P. Bogovski e.a., p. 80. Lyon, IARC , 1973.

PLANTEYDT, H.T. Voor wie is asbest gevaarlijk (For whom is asbestos dangerous)? TNO-Project 2 (1974)285

PLUMLEE, L.A. Discussion paper Bruckman e.a. 1975. J. Air Pollut. Contr. Ass. 25(1975)1212

POOLEY, F.D. Electron microscope characteristics of inhaled chrysotile asbestos fibre. Brit. J. industr. Med. 29 (1972)146

POOLEY, F.D., P.D. OLDHAM, C.H. UM and J.C. WAGNER (1970). The detection of asbestos in tissues. In: Pneumoconiosis; proc. int. Conf., Johannesburg 1969; ed. by H.A. Shapiro, p.108. Cap Town, Oxford University Press, 1970.

POOLEY, F.D. (19 73). Mesothelioma in relation to exposure. In; Biological effects of asbestos; ed. by P. Bogovski e.a., p. 222. Lyon. IARC, 1973.

POOLEY, F.D. Asbestos fibre in the lung and mesothelioma; a reexamination of the Malmö material. Acta path. microbiol. scand. Section A 81 (1973) 390

POOLEY, F.D. The identification of asbestos dust with an electron microscope microprobe analyser. Ann. occup. Hyg. 18 (1975) 181

POTT, F., F. HUTH und K.H. FRIEDRICHS. Tumoren der Ratte nach i.p. Injektion von gemahlenem Chrysotil und Benzo(a)pyren. Zbl. Bakt. Hyg. 155(1972a)463

POTT, F. und K.H. FRIEDRICHS. Tumoren der Ratte nach i.p. Injektion faserförmiger Stäube. Naturwissenschaften 59(1972b) 318

RAUNIO, V. Occurrence of unusual pleural calcification in Finland. Ann. Med. intern. Fenn. (1966) suppl. 47, 1-61

RICKARDS, A.L. and D.V. BADAMI. Chrysotile asbestos in urban air. Nature 234 (1971) 93

RICKARDS, A.L. Estimation of trace amounts of chrysotile asbestos by X-ray diffraction. Anal. Chem. 44 (1972) 1872

RICKARDS, A.L. Estimation of submicrogram quantities of chrysotile asbestos by electron microscopy. Anal. Chem. 45 (1973) 809

ROBERTS, G.H. Asbestos bodies in lungs at necropsy. J. clin. Path. 20 (1967)570

ROHL, A.N., A.M. LANGER, I.J. SELIKOFF, W.J. NICHOLSON. Exposure to asbestos in the use of consumer spackling, patching and taping compounds. Science 189 (1975)551

ROSEN, P., A. SAVINO and M. MELAMED. Ferruginous (asbestos) bodies and primary carcinoma of the colon. Amer. J. clin. Path. 61 (1974) 135

RUBINO, G.F., G.SCANSETTI, A. DONNA and G. PALESTRO. Epidemiology of pleural mesothelioma in North-Western Italy (Piedmont). Brit. J. industr. Med. 29(1972) 436

RÜTTNER, J.R., H. EIDENBENZ und W. WÜST. Pleuromesothelioma in Zürich. Schweiz. med. Wschr. 104 (1974)340

SARGENT, H.E. Asbestos in drinking water. J. New Engl. Waterworks Ass.(1973)44

SCHMIDT, K.G. Asbestsorten ihre Untersuchung mit optischen Mitteln und ihre krankmachende Wirkung. Staub 20(1960)173

SELIKOFF, I.J., J. CHURG and E.C. HAMMOND. Asbestos exposure and neoplasia. J. Amer. med. Ass. 188 (1964)22

SELIKOFF, I.J., J.CHURG and E.C. HAMMOND. Relation between exposure to asbestos and mesothelioma. New Enlg. J. Med. 272 (1965)560

SELIKOFF, I.J. and E.C. HAMMOND. Asbestos bodies in the New York City population in two periods of time. In: Pneumoconiosis; proc. int. Conf. Johannesburg 1969; ed. by H.A. Shapiro, p. 99. Cape Town, Oxford University Press, 1970.

SELIKOFF, I.J., W.J. NICHOLSON and A.M. LANGER. Asbestos air pollution. Arch. environm. Hlth 25 (1972)1

SELIKOFF, I.J. and H.E. STOKINGER. Cancer risk to allergy patients from syringes with asbestos-wound plunger. Questions and answers. J. Amer. med. Ass. 225 (1973)423

SELIKOFF, I.J., E.C. HAMMOND and H. SEIDMAN. Cancer risk of insulation workers in the United States. In: Biological effects of asbestos; ed. by P. Bogovski e.a., p209. Lyon, IARC, 1973.

SIMECEK, J. Staubuntersuchungen in einem Betrieb für Asbestverarbeitung und in seiner Umgebung. Staub 31 (1971)493

SKIKNE, M.I., J.H. TALBOT and R.E.G. RENDALL. Electron diffraction patterns of U.I.C.C. asbestos samples. Environm. Res. 4 (1971)141

SMITH, W.E. Asbestos, talc and nitrites in relation to gastric cancer. Amer. industr. Hyg. Ass. J. 34 (1973)227

SPURNY, K.R., W. STOBER, H. OPIELLA et G. WEISS. Microscopie et analyse des aerosols d'amiante en air atmosphérique. 2ème Coll. int. sur les atmosphères polluées; Paris, 5-7 May 1976.

STANTON, M.F. Some etiological considerations of fibre carcinogenesis. In: Biological effects of asbestos; ed. by P. Bogovski e.a., p. 289. Lyon, IARC, 1973.

STANTON, M.F. Fiber carcinogenesis: is asbestos the only hazard? Editorial. J. nat. Cancer Inst. 52 (1974) 633

STELL, P.M. and T.McGILL. Asbestos and cancer of head and neck. Letter to the editor. Lancet I (1973a)678

STELL, P.M. and T.McGILL. Asbestos and laryngeal carcinoma. Lancet II (1973b)416

STUMPHIUS, J. and P.B. MEYER. Asbestos bodies and mesothelioma. Ann. occup. Hyg. 11 (1968)283

STURM, W. Bericht über die 2. Mesotheliom-Konferenz vom 3. bis 5. Mai 1974 in Wien. Z. ges. Hyg. 21 (1975)254

SWIFT, D.L. Air sampling instruments; 4th ed., p. 82. Cincinnati, Amer. Conf. governm. industr. Hyg.; 1972.

TECHNICAL Data Note 13 (Rev.). Hygiene standards for airborne asbestos dust concentrations for use with Asbestos Regulations 1969. H.M. Factory Inspectorate Dept. of Employment U.K., 1969

THOMSON, J.G., R.O.C. KASCHULA and R.R. McDONALD. Asbestos a modern urban hazard. S. Afr. med. J. 37 (1963)77

THOMSON, J.G. Asbestos and the urban dweller. Ann. N.Y. Acad. Sci. 132 (1966) 196

THOMSON , J.G., F.C.PATH and W.M. GRAVES. Asbestos as an urban air contaminant. Arch. Path. 81 (1966)458; 82 (1966)195

TIMBRELL, V. The inhalation of fibrous dusts. Ann. N.Y. Acad. Sci. 132(1965)255

TIMBRELL, V. Physical factors as etiological mechanisms. In: Biological effects of asbestos; ed. by P. Bogovski e.a., p.295. Lyon, IARC, 1973.

WAGNER, J.C., C.A. SLEGGS and P. MARCHAND. Diffuse pleural mesothelioma and asbestos exposure in the North-West Cape Province. Brit. J. industr. Med. 17 (1960)260

WAGNER, J.C., J.C. GIBSON, G. BERRY and V. TIMBRELL. Epidemiology of asbestos cancers. Brit. med. Bull. 27 (1971)71

WAGNER, J.C. and G. BERRY. Investigations using animals. In: Biological effects of asbestos; ed. by P. Bogovski e.a., p.85. Lyon, IARC, 1973.

WARNOCK, M.L. and A.M. CHURG. Association of asbestos and bronchogenic carcinoma in a population with low asbestos exposure. Cancer 35 (1975)1236

WEBSTER, I. Malignancy in relation to crocidolite and amosite. In: Biological effects of asbestos: ed. by P. Bogovski e.a., p. 195. Lyon, IARC, 1973.

WEBSTER, I. Asbestos and malignancy. S. Afr. med. J. 47 (1973)165

WEBSTER, I. The ingestion of asbestos fibers. Environm. Hlth Perspectives 9 (1974), Dec., 199

WEILER, R.R. Preliminary reports on the status of non-medical study on asbestos in the Great Lakes and St. Lawrence River regions. Burlington, Ont., Canada centre for inland waters, 1974.

WEISS, W. Occupational carcinogenesis, conference report. Newsletter Amer. Col. prev. Med. 16 (1975) nr. 3, p.3

WORLD health organization. Effects of asbestos on health. Geneva, WHO, 1974

ZIELHUIS, R.L., J.P.J. VERSTEEG and H.T. PLANTEYDT. Pleura mesothelioma and exposure to asbestos; a retrospective case-control study in the Netherlands. Int. Arch. occup. Hlth 36 (1975)1

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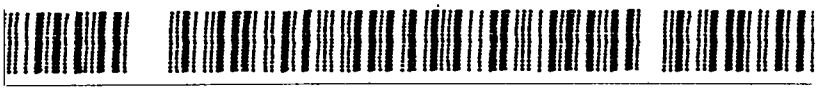

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