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Assessment of the risks of soil contamination with asbestos

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Abstract

Assessing risks of soil contamination with asbestos.

A methodology based on a tiered (three-step) approach was developed to enable site-specific assessment of risks of soil contamination with asbestos. Along with the presentation of this methodology, we have endeavoured to underpin the Intervention Value for soil remediation for asbestos, which was recently released by the Dutch Ministry of Housing, Spatial Planning and the Environment in its interim policy on asbestos in soil. Because risks to humans after inhalation of asbestos are the most critical, the risk assessment was based on the probability of asbestos fibre emission from soil to air, making a distinction between chrysotile and amphibole asbestos, bound and friable asbestos, and the respirable and non-respirable asbestos fraction in soil. Because the behaviour of asbestos in soil is different from the behaviour of any other soil contaminant, the CSOIL exposure model was not used. Instead, use was made of measuring results, i.e. the concentrations of asbestos in soil and air, for deriving the Intervention Value. Guidance on measurement procedures has been incorporated into tiers 2 and 3 of the methodology for determining site-specific human risks of soil contamination with asbestos.

Foreword

In recent years interest in asbestos has increased considerably from the perspective of soil contamination. Consequently many queries have been received by the VROM Ministry, the RIVM and TNO. Another sign of the great significance of soil contamination with asbestos was the large attendance at the NARIP (National Risk Platform soil) conference on this topic in March 2002.

As far as behaviour in the soil and effects on the human body (which both form the basis for the risk assessment of contaminants) are concerned, asbestos occupies an exceptional position. For example, compared with all other contaminants regulated in the Soil Protection Act, asbestos is a mineral. The availability of asbestos in the soil cannot be described with current natural law and is determined more than is the case for the other regulated contaminants by factors that are dependent on the soil. The effects of asbestos on the human body, which occur principally after inhalation of asbestos fibres, are heavily dependent on the shape and dimensions of these fibres. Moreover, this is much less applicable to the other regulated contaminants. Much is known about the relationship between human activity and environmental factors and the prevention of asbestos fibres in the air. TNO in particular has conducted much research into this matter in the last ten years.

On the basis of the great significance of asbestos in the soil and thus the need for a normative framework, the VROM Ministry asked the RIVM and TNO to develop a procedure to be able to assess the risks as a result of *asbestos in the soil*. In this instance use will be made of the results from the UI[1] sub-working group, which discussed the assessment of asbestos in the soil in the period 2000-2001 under the secretaryship of Grontmij. This resulted in an initial framework for risk assessment of asbestos in the soil. However, it was concluded that a number of aspects merited further examination. Attention is given to these aspects in this report and a definite procedure proposed for assessing asbestos in the soil.

The authors are indebted to colleagues who rigorously reviewed an earlier draft of the report: Jan Tempelman of TNO-MEP, who, as an experienced asbestos expert, was able to contribute various useful approaches; Johannes Lijzen of RIVM for his useful suggestions with regard to inclusion of the assessment of asbestos in the accessible risk analysis and Ton Breure of RIVM who examined the legibility and accessibility of the text. Finally, the contribution should be mentioned of the asbestos consultation group, which provided valuable support in discussions about incorporating the proposed methodology in policy terms in the Soil Protection Act.

[1] The UI (Emergency Systems and Intervention Values) Working Group is a working group established by the VROM Ministry (DGM), in which various authorities (VROM, LNV and V & W Ministries; IPO, VNG, Water Boards Union) are represented, as well as the RIZA and the RIVM.

Table of contents

Extended summary

Significance and purpose:
Asbestos is often found in the soil or on the soil surface. Therefore it is essential to have a framework that enables the assessment of risks related to the presence of asbestos in or on the soil and an announcement of the approach to the site. According to the Soil Protection Act the assessment of contaminated soils takes place on the basis of generic Intervention Values and, if these values are exceeded, with the Remediation Urgency methodology (SUS) based on site-specific risks.
For asbestos a generic Intervention Value has recently been declared as interim policy by a letter to the Lower House of Parliament. In the present report a proposal is described for a procedure on the site-specific assessment of soils contaminated with asbestos for determining remediation urgency. In addition, a scientific foundation of the Intervention Value, as declared in the interim policy, is given.

Objects for protection:
For asbestos, risks to the ecosystem are negligible. Risks of dispersal only occur through wind blow, not via the groundwater. The main concern is human risks. According to the Soil Protection Act, human risks are based on the ‘average’ human being in a standard situation (not on susceptible groups or individuals that work in or with soil). Because the risks of asbestos are caused by the inhalation of asbestos fibres, the emission of fibres from soil to air is crucial. The concentration of asbestos in air is determined by primary emission (the release of asbestos fibres from materials containing asbestos in or on the soil) and the secondary emission (the (re)mobilisation (re-suspension) of asbestos fibres that were already released and deposited, initiated by specific activities or wind). In both cases the characteristics of the materials, like (the degree of) friability and the type of asbestos (chrysotile or amphibole) play a significant role.

Characterisation of exposure:
Two types of exposure occur:
- inhalation of asbestos fibres in outdoors air (*direct exposure*)
- inhalation of asbestos fibres in indoors air after ‘tracking in’ of asbestos fibres, possibly attached to soil particles (*indirect exposure*).

The behaviour of asbestos in the soil differs from other contaminants incorporated in the Soil Protection Act. For that reason the standard procedure, based on a calculation using the CSOIL exposure model[2] is not unquestioningly applicable. Except for the asbestos concentration in soil, human exposure to asbestos is dependent on a large number of factors which can be sub-divided into material and soil characteristics, weather influences, activity on the site and the place of occurrence and extent of the contamination.
For determining human risks, a distinction is made between:
- chrysotile asbestos (or white asbestos) and amphibole asbestos (all other types of asbestos;
- friable asbestos (as found in insulating materials and free asbestos fibres) and bound asbestos (asbestos in asbestos concrete, amongst others);
- respirable fibres (fibres smaller than 200 μm) and non-respirable fibres in soil.

[2] With CSOIL the exposure for humans that live, work or spend their leisure time on a contaminated site can be calculated. The model was developed in the period from 1988 to 1990 with the aim of calculating the human-toxicological part of the new remediation standards (Intervention Values). In the meantime the model has been revised several times. Since 1994 CSOIL has also been used in combination with measurements in the contact media for calculating the site-specific exposure as the basis for determining the remediation urgency.

Effects on human health:
The major effects on human health after inhalation of asbestos fibres concern:
- mesothelioma (cancer of the pulmonary membrane and peritoneum);
- asbestosis (brown lung disease);
- increased risks of bronchial carcinoma (lung cancer).

The latent period between first exposure to asbestos and the appearance of a disease can be substantial (up to several decades). The effects on public health depend on the type of asbestos, shape and size of the asbestos fibres, period of exposure, the sustainability and cleavability of the asbestos fibres, the concentration to which one is exposed and individual human characteristics.

Policy:
In 1993 RIVM derived a so-called *ad hoc Intervention Value*[3] for asbestos of 100 mg/kg_{dw} up to 2,000 mg/kg_{dw}[4] depending on the type of asbestos. The shape and size of the asbestos fibres were not taken into account. For deducing this ad hoc intervention value it was concluded that the calculation forming its basis with the CSOIL exposure model for asbestos was regarded as being of limited value. In the occupational safety and health legislation from 1999 (letter to Lower House of Parliament, no. 25 834, 6th December 1999), the residual concentration for bound asbestos was increased from 0 to 10 mg/kg_{dw}. This decision was based on the data available from TNO experiments at that time, including a safety factor. Furthermore, this residual concentration was also declared applicable to the use and re-use of soil materials in the *Ministerial Circular on Target and Intervention Values* [for] *Soil Remediation* (Staatscourant 2000, no. 38). In the *Interim policy on asbestos in soil, soil material and debris (granulate)* (letter to Lower House of Parliament, 28600XI, no. 81), a useful alternative was recently provided, i.e. an Intervention Value of 100 mg/kg_{dw} for the sum of the concentration of chrysotile asbestos (or serpentine asbestos or white asbestos) and ten times the concentration of amphibole asbestos (other asbestos types)[5]. This value is applicable as a residual concentration for the re-use of soil material, sludge and debris (granulate) and as a remediation target for roads and private property. As a consequence the desirable harmonisation between the different political frameworks has been achieved in the interim policy. For the missing methodology for assessing the site-specific risks to humans, the basis for determining remediation urgency, a proposal is given in the present report.

[3] An ad hoc Intervention Value can be derived by the RIVM when an Intervention Value is needed in a specific case for a contaminant that has not been incorporated in the Ministerial Circular on Target Values and Intervention Values for soil remediation (Staatscourant 2000, no. 38). Such an ad hoc Intervention Value is only valid for this specific case.

[4] The concentration of asbestos in soil is analogous to the concentration of other contaminants expressed as weight of asbestos per kilogram of dry soil (dry weight, dw): mg/kg_{dw}.

[5] The Intervention Value of 100 mg/kg_{dw}, as defined in the interim policy on asbestos in soil, considers a weighted value for chrysotile asbestos (also serpentine asbestos or white asbestos) and amphibole asbestos (other types of asbestos). The reason for this is that amphibole asbestos has a roughly tenfold higher carcinogenic potency than chrysotile asbestos (see Chapter 2.4, Effects on human health). Consequently the asbestos concentration in soil equals the Intervention Value if 10 mg/kg_{dw} amphibole asbestos or 100 mg/kg_{dw} chrysotile asbestos is present in the soil. However, the weighted concentration in soil also equals the Intervention Value in the case of, e.g., 50 mg/kg_{dw} chrysotile asbestos in combination with 5 mg/kg_{dw} amphibole asbestos (50 + 5 x 10 = 100) or 10 mg/kg_{dw} chrysotile asbestos in combination with 9 mg/kg_{dw} amphibole asbestos (10 + 10 x 9 = 100).

Limit values for risks:
The following acceptable limit values for the annual average concentration of asbestos in air have been defined:

- Maximum Permissible Risk (MPR) level: 100,000 fibre equivalents per m^3 air;
- Negligible Risk (NR) level: 1,000 fibre equivalents per m^3 air.

The following equivalent factors were assumed:

- 1 chrysotile fibre with a length > 5 µm: equivalent factor 1
- 1 chrysotile fibre with a length < 5 µm: equivalent factor 0.1
- 1 amphibole asbestos fibre with a length > 5 µm: equivalent factor 10
- 1 amphibole asbestos fibre with a length < 5 µm: equivalent factor 1

Determination of human exposure:
The value of a CSOIL calculation to determine the potential exposure to asbestos for the derivation of an Intervention Value for asbestos is assumed to be limited. For the calculation of the site-specific human exposure, two problems arise:

- When defining an appropriate scenario for a site, including the relevant input parameters, at least the influence of activity on the site and the humidity of the soil on the emission of asbestos into the air must be included. However, these parameters are not incorporated in the CSOIL exposure model. Besides, no quantitative relations are known between both parameters and the respirable fibre concentration in the air;
- Although a protocol for assessment of the risks in and around buildings and structures is available (draft O-NEN 2991[6]), this protocol is not directly suitable for the present goal, i.e. assessment of outdoors air quality too.

Experimental data:
The following conclusions can be drawn from several experiments carried out by TNO and from an additional survey of data from the literature and from daily practice:

- Increased fibre concentrations in the air that exceed the MPR level could only be measured for highly contaminated soils and materials with bound asbestos (at least 10,000 mg/kg_{dw}). In such situations even the smallest activity in combination with dry air (no *worst case* conditions) is sufficient for exceeding the NR level in the air.
- Exceeding the MPR level in air is virtually only measured close to the asbestos source with intensive activity, like digging, tipping or driving on the site. The fibre concentration decreases sharply with distance and is always lower than the NR level at a distance of more than some 100 metres from the source.
- In the case of less contaminated soils and mainly bound asbestos (not less than 1,000 mg/kg_{dw}), no asbestos fibres were measured in the air, even in the case of activity like digging, tipping and sieving.

Determination of asbestos concentration in soil:
If asbestos is suspected, a site investigation has to be performed in conformity with NEN 5707 'Inspection, soil sampling and analyses of asbestos in the soil'. In this standard a description is given of a methodology for the determination of asbestos in soil and soil materials. All aspects of investigation are included in this standard, like investigation strategy, inspection, soil sampling and analyses. The investigation is sub-divided into the following three stages:

1. a preliminary asbestos investigation (in accordance with NVN 5725);
2. an exploratory asbestos investigation (in accordance with NEN 5740);
3. a more detailed asbestos investigation.

6 A summary of the (draft) NEN standards is given in Appendix 2a.

Intervention Value:
Only rough conclusions can be drawn from the experimental data. Nevertheless, from these data it can be concluded that for friable asbestos the Intervention Value of 100 mg/kg_{dw} for the sum of the concentration of chrysotile asbestos (also serpentine asbestos or white asbestos) and ten times the concentration of amphibole asbestos (other asbestos types), as defined in the *Interim policy on asbestos in soils, soil materials and debris (granules) (VROM, 2002)*, is a suitable value for the 'standard' Dutch situation. A 'standard' Dutch situation implies circumstances in which there are no systematic activities like digging, depositing or sieving of soil material and the (upper) soil (layer) is relatively wet most of the year. In the case of bound asbestos, the concentration in the air will hardly ever exceed the background concentration. Since it is difficult to determine when bound asbestos turns into friable asbestos due to human activity and/or weathering, it is proposed to include this appraisal in the stage of determining site-specific risks.
In summary it is proposed to maintain the Intervention Policy from the interim policy, i.e. 100 mg/kg_{dw} for the sum of the concentration of chrysotile asbestos (or serpentine asbestos or white asbestos) and ten times the concentration of amphibole asbestos (other asbestos types) for bound and friable asbestos.
Based on expert judgement, it is proposed to use an *area* criterion (instead of a volume criterion) for 'serious soil contamination', i.e. a minimal area of 25 m^2 of the site contaminated with asbestos in which the concentration exceeds the Intervention Value.

Determination of site-specific human risks:
On the basis of asbestos concentrations in the soil and air as measured in the field and the use of measurement protocols, a guideline has been proposed for determining the site-specific human risks in respect of sites contaminated with asbestos. Similarly to other contaminants, a site-specific human risk is assumed unless it can be proved otherwise ("risk unless…"). As with the Remediation Urgency Methodology (SUS), the framework includes three tiers:

- Tier 1, Simple test: investigating the possibilities/likelihood of exposure.
- Tier 2, Determination of the respirable fraction in soil: investigating the possible site-specific exposure for humans, irrespective of the actual site use or site-specific elements, based on the determination of the respirable concentration of asbestos fibres in soil in conformity with NEN 5707.
- Tier 3, Measurement of the concentration of asbestos fibres in outdoors and indoors air.

Re tier 1: When *bound asbestos* in weathered condition is not present, a risk standard of 1,000 mg/kg_{dw} is proposed for the sum of the concentration of chrysotile asbestos (also serpentine asbestos or white asbestos) and ten times the concentration of amphibole asbestos (other asbestos types).
Re tier 2: A limit value of 4.3×10^{10} fibre equivalents is proposed for the respirable fibres in soil. This limit value corresponds to a risk limit of 10 mg respirable fibres (with a diameter of less than 3 μm and a length smaller than 200 μm) per kg soil (dry weight) for the sum of the concentration of chrysotile asbestos (also serpentine asbestos or white asbestos) and ten times the concentration of amphibole asbestos (other asbestos types).
Re tier 3:
Outdoors air. Two options are given for measuring the asbestos fibre concentration in outdoors air (to facilitate the choice between these options, an overview is given of the advantages and disadvantages or both methods):

- measurement of the concentration of asbestos fibres in the outdoors air on the site under 'standardised *realistic worst case* circumstances' ($tier3_{outdoors}a$);
- measurement of the concentration of asbestos fibres during a laboratory simulation under *worst case* circumstances ($tier3_{outdoors}b$) (availability test).

Indoors air. Site-specific measurement of the concentration of asbestos fibres in the indoor air ($tier3_{indoors}a$) should be performed when houses or other buildings border on the contaminated site (less than 100 m) and the contamination involves bound asbestos. In that instance the concentration of asbestos fibres in indoor air under ‘standardised conditions’ should be measured in conformity with O-NEN 2991.

Recommendations:
The following recommendations are made for further research in the future:

- A database is included in which all relevant data for human exposure that are measured under practical conditions, i.e. asbestos concentration in soil and air, type of asbestos, condition of bound asbestos, soil type and soil characteristics, measurement conditions.
- Additional experiments should be carried out to improve assessment of the emission of asbestos fibres in the range of 100 and 10,000 mg/kg_{dw}.
- With the aim of incorporating the influence of site-specific factors on human risks, further research should be conducted into the relationship between the following factors and the emission of asbestos fibres to the air:
  - soil type;
  - soil characteristics (clay and organic matter content);
  - soil humidity;
  - type of vegetation;
  - weather characteristics;
  - activity on the site.

  Where possible it should be aimed at quantitative description of the influences of these factors. In the first instance a feasibility study for deriving qualitative and quantitative relationships could be carried out.

Furthermore, further research should focus on the following topics:

- The influence of the ‘tracking in’ of asbestos fibres from soil to the indoor environment (attached to shoes and to a lesser extent to clothing) on indoor exposure and the influence of the material and soil characteristics, such as soil humidity, on this process;
- The transition from bound asbestos to friable asbestos (relevant processes/activities, time span);
- Evaluation of the quality and practical inclusion of the measurement procedures for determining the outdoors concentration of asbestos fibres (at the site and with the laboratory simulation) and the indoor concentration of asbestos fibres which are part of tier 3 of the determination of the site-specific human risks.

Workshop:
Before the methodology to assess the site-specific risks of asbestos in soil is implemented, a workshop will be organised to present the methodology and to learn from feedback. The conclusions from this workshop will be incorporated before any implementation.

Extended summary (in English)

NB: This has not been translated.

1. Introduction

1.1 Soil contamination with asbestos

Materials containing asbestos are frequently encountered in the soil or on the ground. Since asbestos is a carcinogenic contaminant, it is important in such cases to investigate whether the risks are unacceptable. Moreover, the presence of asbestos often results in social unrest. For these reasons there is a need to have an assessment framework to be able to estimate the risks from the presence of asbestos and to reach a verdict on the approach for the site.

The presence of asbestos in the soil or on the ground currently results in stagnation of the remedial action and additional costs whereas a speeding-up is being aimed for within the scope of BEVER (Soil renewal policy) (*Versteeg et al., 2002*). According to the authors, the policy aimed at asbestos in the soil must be simpler, cheaper and link better into the manner in which other contaminants are assessed within the scope of the Soil Protection Act.

According to the Soil Protection Act, the severity and urgency must be determined in the event of a (possible) soil contamination. Serious soil contamination is involved if the intervention value for soil is exceeded in a soil volume of at least 25 m^3. In that instance the functional characteristics the soil has for humans, plants or animals are seriously reduced or are threatened with reductions. If a case of serious contamination is involved, the competent authority must determine whether urgent remediation should be implemented. In this instance the site-specific risks[12] for humans and ecosystems, as well as the risks of propagation are decisive. These are closely associated with the use of the soil and the site concerned. If there is any change in the use of the soil, the site-specific risks and urgency must be reassessed.
Remediation urgency is determined using the SUS (remediation urgency methodology) computer program. However, a methodology to enable determination of urgency is currently lacking for asbestos. An interim policy for asbestos was recently stipulated (VROM, 2002; for details see Chapter 1.4). Amongst other things, it includes an intervention value for asbestos.

1.2 Objective of the research

The objective of the research described in this report is the description of a methodology to enable determination of the remediation urgency for soils contaminated with asbestos. Many groups have had a need for such a methodology for a number of years (*Olland, 1998*). As with the existing urgency methodology, this methodology must be based on site-specific risks. This report also investigates the underpinning of the intervention value for asbestos, the criterion for determining the severity of the contamination, as recently stipulated in the interim policy.

12 In various VROM circulars and RIVM reports the term “current risks” is often used instead of “site-specific risks”. This term is in fact a mistranslation of the English “actual risks”. When translated into Dutch this term means both “risks at this moment” and “actual risks”, whilst current risks may only be used in the first meaning (both “risks at this moment”) in Dutch. On the other hand, the term “current risks” is incorporated in daily practice in soil science research under the meaning of “actual risks”. In view of the fact that the time factor plays a role in assessing asbestos in the soil, the term “site-specific risks” is used in this report for the sake of clarity.

As with any other contaminant, the duty of care is applicable (Article 13, Soil Protection Act) is applicable to asbestos contamination in the soil caused with effect from 1 January 1987. In these instances remediation must take place as quickly as possible in spite of the content and risks encountered with the aim of restoring the previous condition as far as is possible on the basis of the current state of the art (ALARA principle). Determination of the severity of the soil contamination and the remediation urgency play no role in this. For asbestos a duty of care date of 1 July 1993 has also been used since the prohibition on the working, processing and storage of asbestos came into effect after that date. Furthermore, the investigation is not applicable:

- to determining the risks of other types of material, such as dumped materials, road-metal or (highway) construction material;
- if asbestos is only present on the ground as a result of fire or explosion, for example;
- to actions involving earth and sediment, to which the Working Conditions Act is applicable.

1.3 Protection objectives

The Soil Protection Act is aimed at protecting people, the ecosystem and groundwater. However, effects of asbestos on plants and the soil ecosystem cannot be excluded.
As regards soil contamination with asbestos, there is no relevant dispersion to the groundwater and there are therefore no dispersion risks involved. Dispersion of asbestos via sludge transport or wind could be involved. These dispersion routes have not been elaborated in detail in the urgency methodology and the decision on any site-specific risks as a result of dispersion via such routes is incumbent on the competent authority.
Risks for humans and any higher animals are caused principally by inhalation of asbestos fibres. Although the link between oral absorption of asbestos and damage to health cannot be completely ruled out, the risk resulting from this is negligible compared with the risk of absorption by inhalation.

Consequently, this investigation solely concerns human risks as a result of inhalation. Just like the Soil Protection Act, it deals with the ‘average’ person under standard conditions and not with susceptible groups or individuals who work in or with earth.

1.4 Policy

Ad hoc intervention value, 1993

A so-called ad hoc intervention value for asbestos was produced by RIVM in 1993 (*RIVM, 1993*). Such an ad hoc intervention value is intended to make assessment possible for a specific instance of soil contamination. As the need grew for an assessment framework for asbestos in the soil increased in subsequent years, the ad hoc intervention value unintentionally gained a more generic range of application. Ad hoc intervention values are often derived in a short period of time and are subject to less strict quality requirements than regular intervention values.
The value for the ad hoc intervention value was derived with the aid of the CSOIL exposure model (see box for more details information on CSOIL) and the MPR (Maximum Permissible Risk) for asbestos.

CSOIL DETAILED INFORMATION

The exposure of persons working, living or indulging in recreation on a contaminated site can be calculated with the aid of the CSOIL model (see Chapter 4.1 for a diagrammatic summary and an extensive description). The model was developed over the period 1988 to 1990 with the aim of calculating the human toxicological-based section of the new remediation standards (intervention values). The model has been adjusted on a number of occasions in the meantime and has also been used since 1994, in combination with measurements in contact media, to calculate site-specific exposure within the scope of determining the remediation urgency.

An ad hoc intervention value of 4.10^{12} fibre equivalents/kg_{dw} resulted from this. One fibre equivalent is considered to be equivalent to 1 chrysotile fibre with a length greater than 5 μm or an amphibole asbestos fibre with a length smaller than 5 μm. Furthermore, it is assumed that amphibole asbestos fibres have a tenfold greater carcinogenic potency than chrysotile fibres and longer fibres (greater than 5 μm) have a ten times greater carcinogenic potency than shorter fibres (smaller than 5 μm). Thus an amphibole asbestos fibre with a length greater than 5 μm is equal to 10 fibre equivalents and a chrysotile fibre smaller than 5 μm equal to 0.1 fibre equivalents.
The quantity of fibre equivalents is translated in practical terms into an ad hoc intervention value of 100 mg/kg_{dw} to 2,000 mg/kg_{dw}[13], depending on the type of asbestos and fibre dimensions.

However, for asbestos the CSOIL calculation for derivation of an intervention value on the basis of fibre equivalents per kg_{dw} and the conversion into weight per kg_{dw} is considered to be of limited value. See Chapter 3.5 for a comprehensive analysis of a risk value for asbestos calculated with CSOIL. A useful alternative for an intervention value has recently been provided in the *Interim policy on asbestos in soil, soil material and debris (granulate)* (see further on in this section).

Asbestos Roads Decree

According to the Asbestos Decree, part of the Environmentally Hazardous Substances Act, a remediation obligation is applicable to roads, paths and compounds in which the sum of the concentration of chrysotile asbestos (also serpentine asbestos or white asbestos) and ten times the concentration of amphibole asbestos (other types of asbestos) exceeds a value of 100 mg/kg_{dw}. The Asbestos Roads Decree is still in effect.

Soil remediation target values and intervention values circular (2000)

In the run-up to the drafting of the *Soil remediation target values and intervention values circular* (VROM, 2000), the significance of the 1993 ad hoc intervention value was evaluated by the UI working group[14]. As a consequence of this evaluation, it was decided that the underpinning of the ad hoc intervention value was too limited for it to be incorporated in the circular as a definitive intervention value. Of course, an overall guideline was included in the circular about how asbestos in the soil must be dealt with. With reference to the data available to TNO at that time and taking a safety factor into account, a residual concentration standard for bound asbestos of 10 mg/kg_{dw} from working conditions regulations was declared applicable to the use and reuse of soil as an important component of the circular.

[13] As a consequence, the asbestos concentration in the soil, as with the concentration of other contaminants, is expressed as weight of asbestos per kilogram of dry soil (dry weight; dw): mg/kg_{dw}.
[14] The UI (Emergency Systems and Intervention Values) Working Group is a working group established by the VROM Ministry (DGM), in which various authorities (VROM, LNV and V & W Ministries; IPO, VNG, Water Boards Union) are represented, as well as the RIZA and the RIVM.

Reuse of earth, spoil and rubble (granulate)

Until the end of 2002 a residual concentration of 10 mg/kg_{dw} of bound asbestos, as stipulated in Working Conditions Decision 4.9-4 (*Ministry of Social Affairs & Employment [SZW], 1999*), was used for the reuse of earth, spoil and rubble (granulate). For friable asbestos the analysis method's lower assessment limit of 2 mg/kg_{dw} was used as the residual concentration. However, these values were reviewed in the interim policy on 1 January 2003 (see below in this section).

Interim policy of asbestos in soil, earth and rubble (granulate)

With the aim of resolving the most urgent sticking points the VROM Ministry recently drew up a transitional policy (*VROM, 2002*). It was also announced in this letter that an integral policy on asbestos in soil, spoil and rubble (granulate) would be drafted in the second half of 2003. A more definitive policy would be drawn up for the longer term in this integral policy.
An intervention value is defined as an important component of the interim policy. This value is based on survey results of the quantity of asbestos in the air as a function of bound and friable asbestos in the soil and the circumstances under which the measurements are taken. From this there results a value of 100 mg/kg_{dw} for the sum of the concentration of chrysotile asbestos (also serpentine asbestos or white asbestos) and ten times the concentration of amphibole asbestos (other types of asbestos) as an intervention value (*see calculation example in the box below*). Since bound asbestos can change into friable asbestos due to processing, activities on site and/or weathering, the intervention value is declared to be applicable to both types of asbestos-containing materials. For friable asbestos and bound asbestos the value is regarded as a safe standard for Dutch conditions as regards soil conditions, weather conditions and activities on the site. The intervention value is applicable with effect from 1 January 2003.

USE OF INTERVENTION VALUE CALCULATION EXAMPLE

Regarding the intervention value of 100 mg/kg_{dw}, as set out in the interim policy, chrysotile asbestos (also serpentine asbestos or white asbestos) and amphibole asbestos (other types of asbestos) are considered 'weighted'. The reason for this is that the carcinogenic potency of amphibole asbestos is roughly ten times higher than that of chrysotile asbestos (see Chapter 2.4, Effects on health). As a result of this, the asbestos concentration in the soil is exactly equal to the intervention value in the event of 10 mg/kg_{dw} amphibole asbestos or 100 mg/kg_{dw} chrysotile asbestos being present, However, the weighted concentration in the soil is also equal to the intervention in the case of, for example, 50 mg/kg_{dw} chrysotile asbestos in combination with 5 mg/kg_{dw} amphibole asbestos (50 + 5 x 10 = 100) or 10 mg/kg_{dw} chrysotile asbestos in combination with 9 mg/kg_{dw} amphibole asbestos (10 + 10 x 9 = 100).

This report describes a proposal for a methodology for determining the site-specific risks of asbestos. The exact role of this methodology in soil policy is a point of discussion for the integral 'asbestos in soil, spoil and granular rubble' policy line which is currently being drawn up by the VROM and Social Affairs & Employment (SZW) Ministries. In addition to this, before a possible change is made to implementation of a methodology for determining site-specific risks, a workshop will be organised by the VROM Ministry with the aim of providing information about the proposed methodology and to hear about responses from its practical use. The conclusions from the workshop will be incorporated in any implementation.

1.5 Risk perception

Since asbestos is associated with health risks by the majority of the population as a result of media attention, the presence of asbestos in the soil frequently results in social unrest. This effect is reinforced due to the fact that asbestos products, in contrast to most other contaminants, are often visible. The largest health problems that can be related to asbestos exposure result from situations where people have worked intensively with asbestos for several days a week as part of their job for several years or a few decades. However, in general it can be stated that the perception of people who have to deal with asbestos *in the soil* – whether professionally or otherwise – is more negative than is apparent from research into the risks of asbestos in the soil. That is not to say that the dangers to health would not be present, even if asbestos were present in the soil. However, a serious danger to health is by definition not involved in all instances where asbestos is visibly present in the soil or on the ground. How the risk perception must be handled in the case of asbestos in the soil or on the ground falls outside the tasks of the authors and does not even form part of this report, although for the reasons set out above it is even more important than for other contaminants that the risks of the presence of asbestos are made clear to all involved.

1.6 Bookmarks

The background, aim of this report, relevant protection objectives in the event of asbestos in the soil and current policy in respect of asbestos are the subject of Chapter 1 (*Introduction*). In Chapter 2 (*Occurrence and behaviour of asbestos in the soil*) the forms and behaviour of asbestos in the soil are illustrated. With the aim of gaining insight into the factors which can influence human risks, a summary is also given in this chapter of the effects on health and the influence of various factors on human exposure to asbestos. In Chapter 3 (*Assessing human risk based on calculation*), calculation of human exposure to asbestos forms the central theme, whilst assessment of the human risks on the basis of survey results is discussed in Chapter 4 (*Assessing human risk on the basis of practical survey results*). In Chapter 5 (*Discussion*) there follows a critical analysis of the usefulness of calculation models and practical survey results. On the basis of this, in Chapter 6 (*Assessment of asbestos in the soil*) – an important chapter - a guideline is proposed for assessing site-specific risks (Chapter 6.3) and the intervention value as incorporated in the interim policy is evaluated (Chapter 6.2). Finally, conclusions and recommendations follow in Chapter 7 (*Conclusions and recommendations*).

2. Occurrence and behaviour of asbestos in the soil

2.1 Forms appearing in the soil

Asbestos is a collective name for a number of minerals occurring in nature that are composed of long, thin fibres. Since asbestos has good resistance to high temperatures, acids and alkalis and is moreover resistant to wear, fire-resistant and is an insulator (noise and heat), asbestos was widely used for decades in some 3,000 products (*Locher, 1995*). The word asbestos is derived from the Greek 'asbestos' meaning imperishable and indestructible.
Processing and stocking asbestos or products containing asbestos has been prohibited since 1993. Asbestos can be placed wittingly in or on the ground with the aim of paving roads or compounds. In addition to this, a lot of waste containing asbestos has turned up in the soil.

Three main types of asbestos, which are mostly sub-divided on the basis of colour, occur in the soil:

- white (or chrysotile) asbestos;
- blue (or crocidolite) asbestos;
- brown (or amosite) asbestos.

Both the total production of asbestos in the world and that in the Netherlands consisted for the most part (more than 90%) of chrysotile asbestos with a certain proportion (a few per cent) of crocidolite and amosite asbestos (*Copius, Peereboom and Reijnders, 1989*).

According to an alternative terminology, as used in the interim policy (*VROM, 2002*), a distinction is made between:

- serpentine asbestos (chrysotile asbestos; also even white asbestos); this type of asbestos has a more layered structure; and
- amphibole asbestos (all other types of asbestos, i.e.: amosite, crocidolite, anthphylite, tremolite and actinolite); these asbestos types have a linked structure.

Asbestos occurs in two forms appearing in or on the soil:

- in friable form as isolated fibres or fibre bundles or lightly bound in, for example, sprayed asbestos, asbestos board or fire-resistant sheets containing asbestos;
- in bound form, bound to a matrix, generally of cement or synthetic resin (e.g. as asbestos cement).

The extent to which fibres can actually be regarded as loose fibres or bound varies by product and is dependent on the extent of weathering. Although the extent of bonding is in fact a sliding scale, it makes sense to use a sub-division into bound and friable asbestos for assessing the risks in the soil.

Finally, the difference between whether or not the asbestos fibres in the soil are respirable is of importance. Only fibres with certain dimensions are regarded as respirable and only these fibres are relevant in the context of their risk to humans as soon as they reach the air from the soil.

2.2 Behaviour in the soil

Asbestos is to a large extent resistant to chemical and biological degradation and consequently remains in the soil for a virtually unlimited time (*Slooff and Blokzijl, 1987*). Humus acids that can occur in the soil can in theory degrade asbestos. However, this process occurs over a time period of dozens to millions of years, on account of which this degradation can be disregarded. There has also been a recent report of degradation and immobilisation of asbestos fibres by moulds (*Martino et al., 2003*). These moulds are capable of extracting the iron from the asbestos fibres and by so doing appreciably reduce the carcinogenic potency of these fibres. However, the effectiveness of these processes for releasing fibres from matrix-bound products appears small (*J Tempelman, personal announcements, 2003*).

The sole form of transport that is important for asbestos in the soil is co-called physical transport. Biological transport and chemical transport can be disregarded for asbestos fibres in the soil (*Tromp and Tempelman, 1994*). There are two forms of physical transport which are closely related to each other:

1. movement on soil particles, in which the soil composition (sand, silt and clay) is decisive and
2. movement via the pores, in which the soil structure (mass density and compactness, dampness) is decisive.

The extent of physical transport is thus heavily dependent on soil composition and soil structure. The different types of earth can be sub-divided with the help of immobilising capacity (extent of bonding). From strong to weak immobilising capacity: clay, loam, sandy clay, sandy loam, loamy sand and sand. The experiments by the *Institute of Occupational Medicine* (*Addison et al., 1988*) show a similar pattern. Here it appears that two to three times as many fibres are released from sandy soil than from clay soil or an 'average' soil type.
The movement of asbestos fibres in the soil can be estimated with the help of the movement of soil particles by exclusively physical processes. Soil particles with a diameter greater than 2 μm are immobile in the soil. For clay particles from 0.1 to 2 μm the estimated migration speed is 1 to 10 cm per 3,000 to 40,000 years (*Water and Engineering, 1977*). The asbestos fibres in the soil will probably have a movement speed of the same order of magnitude, on account of which the migration of asbestos fibres in the soil can be regarded as negligible.
Animals such as rabbits, rats and above all moles are to a small extent capable of working already buried contamination to the surface. However, human activity is of appreciably greater significance for movement of asbestos in the soil.

Even the migration of asbestos fibres to the groundwater is negligible. The sole route along which asbestos can come into contact with the groundwater is the tipping of waste containing asbestos at the level of the water table. In addition to this, asbestos fibres can seep into the groundwater through cracks or large pores in the soil. However, this transport is of very limited extent. Asbestos fibres do not dissolve in water.

Asbestos fibres do not evaporate. Asbestos particles can indeed be moved over large distances through the air (*ATSDR, 2003*).

2.3 Human exposure to asbestos

2.3.1 Background exposure

Small quantities of asbestos fibres can occur in the urine, the faeces, the phlegm or in the lungs even without the presence of a clearly perceptible asbestos source (*ATSDR, 2003*). This happens due to the fact that a small quantity of asbestos occurs in the air and in water (*NSW Health, 2003*).

Average contents of asbestos fibres in the air are in the range from 10 – 100 fibres/m^3 and are generally higher in urban areas and industrial areas (*ATSDR, 2003*). As background values the *Alewife Study Group* (*1995*) gives 0.3 – 3 fibres/m^3 in outside air well removed from specific sources and 3 – 300 fibres/m^3 (with spikes up to 3,000 fibres/m^3) in urban areas. As an average for the United States, 70 asbestos fibres/m^3 is assumed.
Asbestos fibres from water pipes containing asbestos or (but not in the Netherlands) from naturally occurring sources can be present in drinking water.

2.3.2 Emission to the air

Since damage to health is caused principally by inhalation of asbestos fibres, the concentration of asbestos fibres in the air is the basis for human exposure. The controlling process by means of which fibres can enter the air is the emission of asbestos fibres from the soil (mostly from the soil surface) to the air. Primary and secondary emission can play a role in the emission of asbestos fibres from a contaminated soil to the air.

Primary emission

This form of emission occurs due to the release of asbestos fibres from materials containing asbestos in/on the soil and can be broken down into two forms of emission: momentary emission (due to specific, short-term activities) and continuous emission (under the influence of weather conditions). Momentary emission is caused by 'active' contact with the material surface, such as breaking, rubbing, etc. The asbestos concentration occurring in momentary emission is principally determined by the extent of bonding of the asbestos in the material (age, brittleness and weathering), the nature of the activities and the dampness of the material. In an outdoors situation the contribution of continuous emission is low. This form of fibre emission is principally caused by ageing and weathering of the matrix in combination with airflows over the material's surface. Even in this instance the extent of bonding and the dampness of the material are important factors. In addition, weather conditions, i.e. the wind speed, (air) humidity and amount of sunshine, play a major role. Continuous emission only occurs if the contamination is on the surface (ground level).

Secondary emission

Secondary emission is also called resuspension. This form of emission is caused by the movement (once again) of asbestos fibres (already released previously and sedimented) under the influence of certain activities or weather conditions. In secondary emission a combination of adsorbed asbestos fibres on (soil) particles and loose asbestos fibres is assumed. In the first instance the (soil) particle acts as a 'carrier' for inhalation (*EPA, 2002*). The availability of asbestos fibres in the air is determined by the emission speed (speed of transition from the soil to the air) and the extent of atmospheric dispersion (diffusion to and dilution in the atmosphere out of the range of humans). In addition to the wind speed, the resuspension process is also influenced by mechanical and/or human activity, soil dampness and other soil characteristics and air humidity. Resuspension takes place to the maximum extent from smooth hardened surfaces, such as tiles. Resuspension is small for unhardened surfaces with no mechanical activity. The chance of resuspension is also less the damper the surface is (*Tromp and Tempelman, 1994*). Resuspension increases with the speed of air movement. On the other hand, it generally seems that close to sources the asbestos concentration is higher when there is little air movement than if there is more wind. A slight air movement is enough to release fibres from the subsoil but is insufficient to ensure dispersion in the atmosphere.
There is no known threshold value for the wind speed at which no further resuspension occurs, or above which dispersion is so high that the fibres get beyond the range of humans. Limit values are indeed perceived for the speed of motor vehicles at which the accompanying airflows cause no further resuspension. For particles with a length of 4 μm and 9 μm no further resuspension is observed for vehicles with a speed of less than 24 and 32 km/h respectively. In general terms, larger particles are more easily resuspended than small particles (*Tromp and Tempelman, 1994*).

A particle moves directly from the soil into the airflow if the aerodynamic forces are greater than the adhesion forces tending to hold the particle on the ground surface. It seems that these forces can be different for (soil) particles and loose asbestos fibres (*EPA, 2002*):

1. Three adhesion forces are described in the literature. For soil particles the van der Wals force, or molecular attraction force, is dominant, along with the surface tension caused by the water adsorbed on the particles. For asbestos fibres which are inclined to have an electrical charge, the electrostatic force can be stronger than the above-mentioned forces.
2. The balance of forces on the particle is such that a critical airflow is required to release the particle from the soil. The most important parameter determining whether a particle enters the airflow from the soil surface is the particle's aerodynamic diameter. Of the particles which can be conveyed by the wind, it is the 'larger' particles (with a larger aerodynamic diameter) that can be released relatively easily at low wind speeds. The aerodynamic diameter for asbestos fibres is much smaller than the length of the fibres. Asbestos fibres can therefore need more wind than (soil) particles to enter the air.

The above-mentioned factors are of significance in model calculations, in which the concentration of asbestos fibres in the air is calculated and the asbestos fibres are regarded as (soil) particles. The calculated emission from the soil the air, and thus the fraction of respirable asbestos fibres, is probably overestimated in that instance.

The (extent of) bonding in the material containing asbestos has a very large influence on the emission of fibres to the air. In *friable* materials fibres can be released from the material even if there is minor activity, such as running or extensive excavation works, in combination with 'favourable' conditions (dry and sunny weather, slight wind) (*Tromp, 2002*). Irrespective of activity in and on the soil, friable materials constitute an exposure risk sooner.
An exposure risk is indirectly involved in *bound* (principally cement-bound) asbestos products. The emission is determined by the force that is required to release fibres from the material matrix. This force is decisive for the primary emission from the material. To this end the material must first be broken or heavily damaged by 'destructive' activities such as tipping, breaking, sifting or driving over before a fibre emission can occur. For bound asbestos materials the actual fibre emission is dependent to a greater extent than for friable materials upon the activity on the site.
For asbestos cement and Colovinyl (plastic matrix in the form of floor tiles containing asbestos) the fibres seem to be bound to the matrix to such an extent that hardly any fibre emission takes place even when the material is broken. From a series of survey results it seems that when asbestos cement containing 10-15% chrysotile asbestos is broken an average 140 (100-220) fibres per cm of breech plane are able to enter the air. In addition, it seems hardly any loose fibre *bundles* are released; all released fibre bundles seem to be bound to the matrix (*Tromp and* [sic]*, 1994*). This implies that after a brief (momentary) emission of asbestos fibres caused by the breaking process, no further emission occurs are a result of subsequent 'non-destructive' activities.

In addition to the (extent of) bonding, the type of asbestos plays a significant role. The type of asbestos is of course crucial to the friability of asbestos fibres. Amphibole asbestos types seem to be more friable than chrysotile asbestos (*Slooff and Blokzijl, 1987*). From the experiments by the *Institute of Occupational Medicine* (*Addison et al., 1988*), it is also apparent that fibres are released more easily from amphibole asbestos types, especially amosite, than from chrysotile asbestos. On average two to five times higher concentrations in the air are measured in experiments with amphibole asbestos than in experiments with chrysotile asbestos.

2.3.3 Characterising of exposure

Depending on the site and the contamination situation, people can be exposed to asbestos in or on the ground in two ways, i.e.:
- inhalation of asbestos fibres and (soil) particles containing asbestos in outdoors air (*direct exposure*);

- inhalation of asbestos fibres in indoor air after the ‘tracking in’ of asbestos particles from a contaminated site to the indoor environment (via footwear and to a lesser extent clothing) (*indirect exposure*).

In most instances direct exposure in the outdoors air does not result in a local long-term increased concentration in the air and to high exposure to asbestos. The dilution process in outdoors air (ventilation collapse) is many times greater than in the indoor environment and the asbestos concentration in the air will, depending on wind and airflows, rapidly decline.

Indirect exposure is relevant if the asbestos soil contamination occurs in the vicinity of a dwelling or a building. From TNO research it seems that the chance of indirect exposure is great, especially in respect of adjoining dwellings (*Tromp and Tempelman, 1995*). In that instance remnants containing asbestos and fibres/fibre bundles are frequently tracked in, transported indoors via clothing and/or blown in so that indoor exposure can be slightly greater. Remnants containing asbestos and fibres/fibre bundles can be tracked in on footwear mainly if the ground is wet, whereas blowing in occurs mainly if the soil is dry. Walking around and vacuuming in the home ensures a further distribution and ‘crumbling’ of the asbestos remnants. Since there is far less ventilation indoors than outdoors, the released asbestos fibres will also be present for a long time in the home and be involved in a continuous process of suspension and resuspension. Resuspension is much higher indoors than outdoors because the surface is dry. From TNO’s measurements it appears that this problem occurs mainly in homes fitted with carpet, since wooden floors, floor tiles and floor-cloth are mostly cleaned by wetting, by means of which the source of contamination is removed (*Tromp and Tempelman, 1995*).

In addition to the asbestos concentration in the soil, human exposure to asbestos is determined by a large number of factors. These factors can be sub-divided into five groups:

1. Material characteristics:
   - the (extent of) bonding of the material;
   - the type of asbestos;
   - the shape of the asbestos fibres;
   - the fraction of respirable fibres.
2. Soil/floor characteristics:
   - soil type;
   - (micro) relief;
   - degree of moisture;
   - vegetation;
   - type of floor (covering).
3. Weather influences:
   - air humidity;
   - precipitation;
   - sun;
   - frost;
   - wind.
4. Activity on the site:
   - type of activity;
   - duration of activity.
5. Place of occurrence and extent of the contamination:
   - concentration of the asbestos contamination;
   - volume or surface area of the soil contaminated with asbestos;
   - depth in relation to ground level (on the soil, in the soil’s top layer or deeper in the soil);
   - distance from the asbestos source.

Calculating the exposure to asbestos, which is described extensively in Chapter 3, is beset with a relatively large number of uncertainties.

2.4 Effects on health

2.4.1 Clinical picture

People can be exposed to asbestos from the soil via the air, in the course of which a health risk occurs. The WHO (*World Health Organisation*), the DDHS (*Department of Health and Human Services*) and the US EPA (*United States Environmental Protection Agency*) have labelled asbestos as a human carcinogen (*ATSDR, 2003*). The most important health effects of exposure to asbestos fibres by inhalation are:

- mesothelioma (pulmonary membrane and abdominal membrane cancer);
- asbestosis (dust in the lungs);
- increased chance of the occurrence of bronchial carcinomas (lung cancer).

The three illnesses are discussed in more detail in Appendix 3 ('Clinical picture details'). In summary, it can be stated that mesothelioma and asbestosis are caused principally by exposure to asbestos. Both illnesses occur rarely and are in nearly all instances related to many years of occupational exposure. Lung cancer can also have other causes, principally smoking. The latency period between the initial exposure to asbestos and the appearance of the above-mentioned illnesses can be very lengthy, especially in the instance of mesothelioma: 10-40 years (*ATSDR, 2003*).

No scientific link has been shown between the inhalation of asbestos fibres and forms of cancer other than those mentioned above with the probable exception of cancer of the larynx. Even a link between the swallowing of asbestos fibres and the occurrence of cancer (e.g. of the oesophagus) has not been shown (*Slooff and Blokzijl, 1987*). However, a causal link between asbestos inhalation and oesophageal cancer cannot be completely excluded, but the risk of oesophageal cancer is considered to be much lower than for lung cancer.
Children form a risk group in respect of exposure to asbestos fibres, not because they are more sensitive to asbestos fibres, but because they will carry these fibres around in their bodies for the lengthy lifespan they still have before them. In addition, they often play on, in or close to the ground, on account of which they have a greater chance of inhaling fibres. They can also carry the fibres on their clothing (*IMH, 1994*).

Smoking or not smoking is also important for contracting lung cancer due to asbestos. The chance of contracting lung cancer through exposure just to asbestos fibres is smaller than through just smoking. The combination of inhaling asbestos fibres and smoking gives a greater chance of lung cancer than smoking on its own (*IMH, 1994*). The summary below sets out the relative chance of lung cancer for both smokers and non-smokers (*IMH, 1994*). These relative chances are based on exposure in earlier work situations. It is unclear whether this relative chance is also applicable to much lower concentrations, as frequently occur in the outdoors environment.
Relative chance of lung cancer:

- non-smoker, no asbestos exposure: 1
- non-smoker, with asbestos exposure: 5
- smoker, no asbestos exposure: 10
- smoker, with asbestos exposure: 50-90

Exposure during heavy physical exertion constitutes another increased risk, since the quantity of fibres inhaled is greater in that instance than with no physical exertion. The average breath volume for adults is on average 12 m^3/day (24 hours). For children the average breath volume is 10 m^3/day. During heavy physical exertion, e.g. running hard, the breath volume of adults can amount to 24 m^3/day (*IMH, 1994*). Moreover, there is an increased risk of asbestos fibre emission from the soil to the air due to sporting activity on a site.

2.4.2 Determining factors

Harm to health is caused by inhalation of asbestos fibres. The subsequent effects on health are determined by the following factors:
- the type of asbestos;
- the fibre dimensions;
- the duration of exposure;
- the durability and friability of the asbestos fibres;
- the concentration to which one is exposed;
- personal characteristics.

The first three factors do not only influence the effects on health (the carcinogenic potency of the asbestos fibres), but also determine the inhalatory exposure to asbestos.

The factors that determine the harm to health are described in greater detail in Appendix 3 ('Determining factor details').

2.4.3 Acceptable fibre concentration

The estimated fibre concentrations at different risk levels for mesothelioma and lung cancer for the general population for lifelong exposure to asbestos in the air are illustrated in Table 2.1 (*Slooff and Blokzijl, 1987*). In this instance a distinction is made between amphibole fibres and chrysotile fibres and between measurements with an optical microscope (phase contrast microscope, PCM) and with an electron microscope (scanning electron microscope, SEM) (*Slooff and Blokzijl, 1987*).

Table 2.1 The estimated fibre concentration for mesothelioma and lung cancer for risk levels10^{-4} and 10^{-6} for the general population for lifelong exposure to asbestos in the air (measured with an optical microscope, PCM, and an electron microscope, SEM, respectively).

Effect	**Risk level**	**Fibres/m^3 measured with PCM**	**Fibres/m^3 longer than 5 μm measured with SEM**
Mesothelioma (for both smokers and non-smokers)	10^{-6} 10^{-4}	5-50[1] 50-5,000[2] 500-5,000[1] 5,000-500,000[2]	10-100[1] 100-10,000[2] 1,000-10,000[1] 10,000-100,000[2]
Lung cancer (for both smokers and non-smokers)	10^{-6} 10^{-4}	50-500 5,000-50,000	100-1,000 10,000-1,000,000

1) for amphibole asbestos
2) for chrysotile asbestos

It is apparent that the risk from exposure to amphibole asbestos (including amosite and crocidolite) principally concerns mesothelioma, whilst chrysotile asbestos increases the risk of lung cancer in particular (*Slooff and Blokzijl, 1987*). A risk of 10^{-6} for lifelong exposure is roughly equivalent to a risk of 10^{-8} per year, which can be regarded as the negligible risk level (NR) within the regulatory policy. A risk of 10^{-4} for lifelong exposure, being equivalent to a risk of approximately 10^{-6} per year, is regarded as a Maximum Permissible Risk (MPR) within this framework. In this report the following acceptable fibre concentrations are used:

- NR = 1,000 fibre equivalents/m^3;
- MTR = 100,000 fibre equivalents/m^3.

By way of comparison: the *Occupational Safety and Health Administration* in the United States has stipulated 100,000 fibres longer than 5 µm/m^3 as the limit to which a worker may be exposed during a working week of 40 hours, split into 5 days of 8 hours (*ATSDR, 2003*).

Material characteristics

The fraction of respirable fibres in the soil (this is the faction with a fibre length of less than 200 µm), as a function of the bonding of materials found in the soil is set out in Figure 2.1 for amphibole asbestos and chrysotile asbestos. Both plots are based on soil analyses that TNO has carried out over the last ten years. From these soil analyses, it is apparent that, for unbound materials containing amphibole asbestos, the fraction of respirable fibres can amount to 5 to 10% of the total asbestos concentration. The fraction of respirable fibres for unbound materials with chrysotile asbestos is appreciably lower. For bound materials such as asbestos cement, the respirable fibres fraction is nil and as a rule less than 0.1%, even for weathered materials.

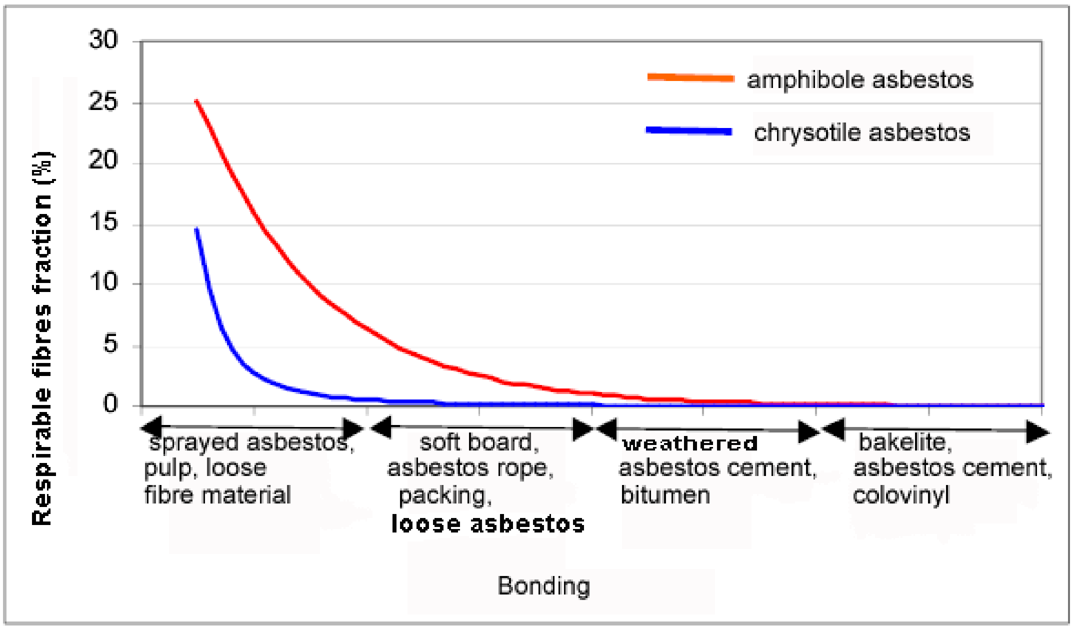

Figure 2.1 *Respirable asbestos fibres fraction for amphibole and chrysotile asbestos according to bonding.*
[Estimates are based on soil analyses carried out by TNO over the last ten years.]

The degree of bonding declines due to weathering. Weathering of asbestos cement products is caused by ageing combined with leaching of the cement matrix. This process occurs mainly in a strongly alkaline or acid environment, such as occurs for, e.g., asbestos cement roofs of pigsties and henhouses. In the soil the pH is relatively neutral and this leaching process will take place less rapidly. From various asbestos soil investigations carried out by TNO, it is apparent that the majority of asbestos cement products only show a slight amount of weathering after decades.

The results of field measurements for *bound* asbestos are set out Figure 2.2 (the squares are averages from several measurements during one experiment; the small bars give the 95% reliability interval or is the lower assessment limit in instances where no asbestos is encountered). From this summary of practical measurements it is apparent that in only one single instance out of 350 measurements could an increased asbestos fibre concentration in the air (fibre length > 5μm) be measured for one contamination with bound asbestos only. In this practical measurement was the NR level for asbestos fibres in the air (1,000 fibre equivalents/m^3) exceeded. Here, this concerned a few simulation measurements while driving over an asbestos road, of which more than 10% consisted of broken asbestos cement. In all the other practical measurements no asbestos in the air in excess of lower assessment limit are found. In these cases the lower assessment limit is illustrated as a small bar in the figure. As regards these measurements a marginal note should be added that measurement conditions were frequently not well defined and the soil was often (made) damp, on account of which relatively 'favourable' conditions (suppression of fibre emission) prevailed.

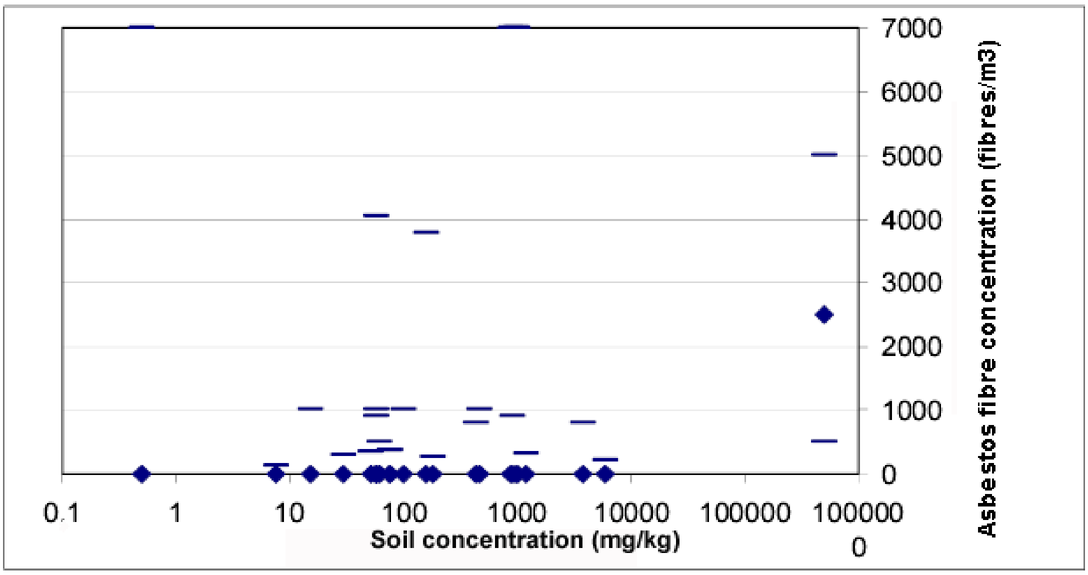

Figure 2.2 *Asbestos fibre concentration (in fibres with a length > 5μm per m^3 of air), as a function of the* bound *asbestos content in mg of asbestos per kg of soil and/or rubble material.*
[Based on 350 practical measurements for various activities and under different measuring conditions. The small bars indicate the 95% reliability interval of the concentration levels measured or are the lower assessment limit if no asbestos is encountered (see the points on the '0' line). The points on the '0' line are the result of several measurements.]

In practical situations with *unbound* asbestos, it seems that the air concentration exceeds the NR level (1,000 fibre equivalents/m^3) in almost half of the 200 measurements and the MPR level (100,000 fibre equivalents/m^3) in a number of instances (Figure 2.3). In this instance it mostly concerns rather high asbestos contents (> 10% asbestos) with mostly unbound to friable asbestos, such as pulp, loose asbestos, sprayed asbestos and unbound fibre material. The waste was present in the soil in highly concentrated form and local concentrations could amount to tens of per cent by weight.

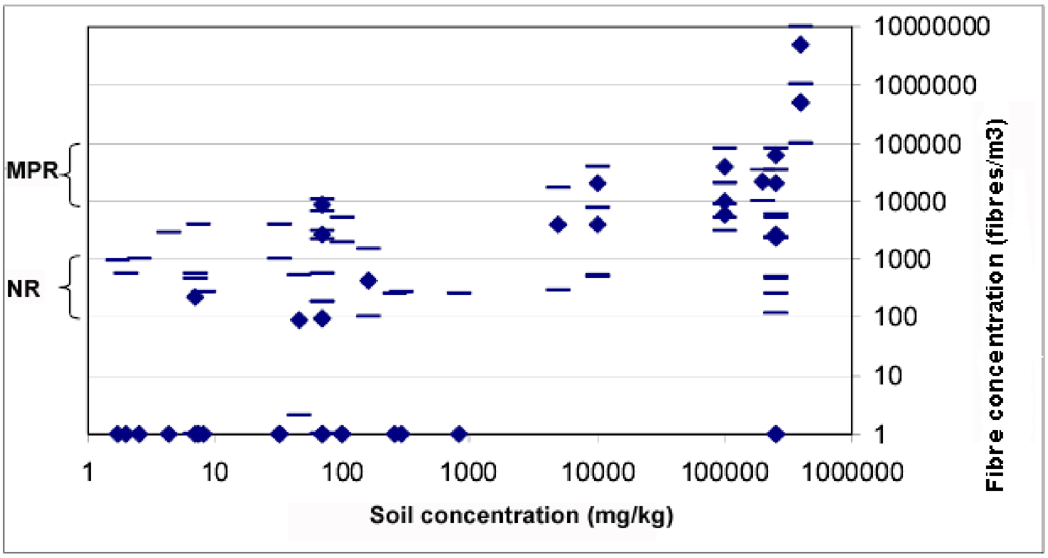

Figure 2.3: *Asbestos fibre concentration (in fibres with a length > 5µm per m^3 of air), as function of the* unbound *asbestos content in mg of asbestos per kg of soil and/or rubble material (log scale).*
[Based on 200 practical measurements for various activities and under different measuring conditions. The asbestos fibre concentrations are averages based on several measured values. The small bars indicate the 95% reliability interval for the concentration levels or are the lower assessment limit if no asbestos is encountered (see the points on the 'log = 1' line). The NR and MPR levels are based on 1,000 and 100,000 fibre equivalents per m^3 respectively. Expressed in fibres/m^3, this corresponds to 100 (amphibole) – 1,000 (chrysotile) fibres/m^3 and 10,000 (amphibole) – 100,000 (chrysotile) fibres/m^3 respectively.]

2.6 Influence of soil characteristics

In Chapter 2.2 it is stated that the amount of physical transport is heavily dependent on the soil composition and soil structure. However, the soil's degree of moisture has the greatest influence on the release of asbestos fibres from the soil (*Tromp, 2002*). From TNO's experiments, it seems that as a consequence of a low soil moisture of 5-10%, the emission of asbestos fibres to the air is reduced from the MPR level to below the NR level (a factor of 100). In the experiments of the *Institute of Occupational Medicine* (*Addison et al., 1988*) this effect is slightly less strong, but even here the emission is reduced by a minimum of a factor of 10 with low soil moisture of 5-10%.

From both investigations the link between moisture and fibre emission seems to be exponential and it is also apparent that the degree of moisture has the greatest influence in the case of sandy soil (Figure 2.4). The cause of this is possibly that sandy soil has a very low humus and loam content, on account of which fibres are not totally adsorbed in a dry situation. A small percentage of water contributes heavily to increasing the adhesion force and reducing fibre emission.

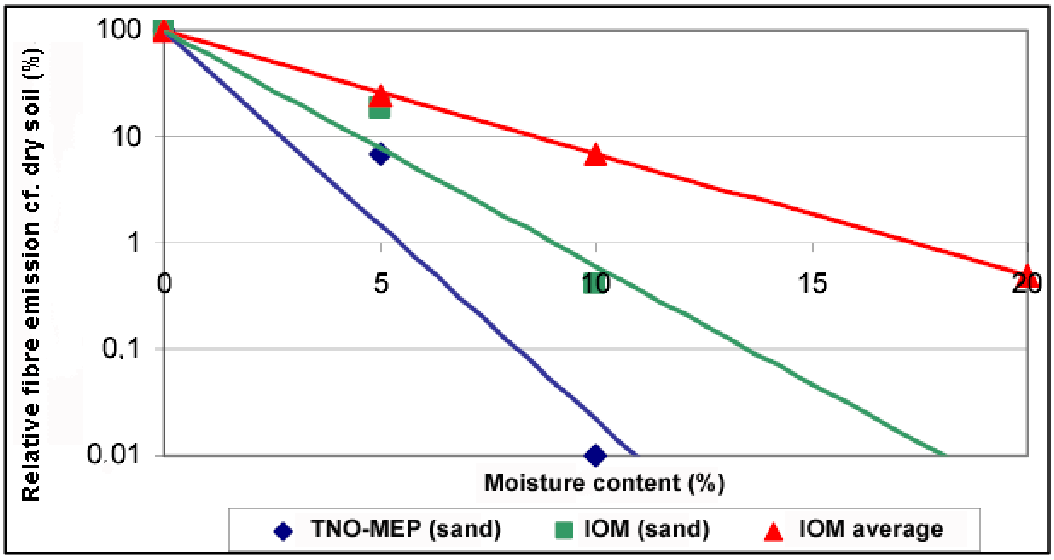

Figure 2.4: The relative fibre emission (compared with dry soil) (%) as a function of the moisture content in the soil (%) on the basis of experiments by TNO (Tromp, 2002) and the Institute of Occupational Medicine (Addison et al., 1988). [IOM average concerns a mix of various soil types.]

The moisture of a soil various sharply over time and with depth and is dependent on the hydraulic characteristics of the soil, the time at which a certain volume of precipitation has fallen, temperature and sunshine and the organic matter content of the soil. The presence of vegetation likewise has a great influence on the soil's dampness. Under Dutch conditions the soil's damp regime is almost always limited by the permanent wilting point (pF = 4.2) and field capacity (pF = 2). This implies that the moisture content of sandy soils fluctuates between 2% and 40% and between 20% and 60% for clay soils (*Koorevaar et al., 1983*). In particular the lower limit is heavily dependent on the specific soil type. By itself, the moisture profile of a soil is or limited significance for the emission of asbestos to the atmosphere, since this emission takes place from the topmost centimetre or centimetres of the soil. And it is just this topmost layer that will dry out quickest as a result of evaporation. A loamy, sandy soil typical of the Netherlands, upon which winter-rye is grown, has a relatively high moisture content in its topmost centimetres compared with deeper soil layers in the early part of the year (*Scheffer and Schachtschabel, 1989*). However, in the summer the entire soil profile dries out, including the top layer, quickly dries out. The period in which the soil's top layer has a 'critical moisture content' is difficult to quantify. In addition, there is a connection between the period in which the soil's moisture content is critical and other risk factors, such as wind speed and human activity in and on the soil.

The structure of the top layer and the characteristics of the top layer's vegetation likewise have an influence on the resuspension of asbestos fibres from the soil. It is stated in Chapter 2.3.2 that resuspension mostly takes place from smooth, hardened surfaces. Resuspension is small for unhardened surfaces without mechanical activity. Vegetation such as grass, shrubs and foliage affects the flow of air over the surface.

2.7 Influence of weather conditions

Precipitation and sunshine have a great influence on fibre emission. This effect is to a large extent indirect since they influence the moisture of the soil. Soil moisture has a greater influence on the emission of fibres. The influence of soil dampness on fibre emission has already been discussed in Chapter 2.6.
In addition to the indirect effect, precipitation and sunshine also influence air humidity. Precipitation and air humidity ensure that fibres that have already been emitted are quickly picked up and suspended to the soil. Little is known about the exact influence of air humidity. In an American investigation no direct link could be demonstrated, although a small effect was indeed perceptible in combination with other influence factors such as activity and air flows (*Guillemin et al., 1989*).

Wind also has an influence on fibre emission. It has already been stated in Chapter 2.3.2 that fibre emission through resuspension increases with wind speed. On the other hand, it is apparent that concentrations close to asbestos sources are generally higher if there is slight air movement than if wind is involved. A slight air movement is enough to release the fibres from the subsoil, but is insufficient to ensure dispersion in the atmosphere, by means of which the asbestos fibres would disappear beyond the range of humans. Dispersion in the atmosphere is an important factor. Asbestos fibre concentrations in the air have indeed been measured by TNO is some (half open) sheds with road-metal containing asbestos in certain situations, whilst no asbestos fibres have been encountered in the air in comparable situations in the open outdoors air.

Frost can also influence fibre emission. The water in damp ground freezes, by means of which the asbestos fibres in the earth can be immobilised.

2.8 Influence of activity on the site

From the simulation trials by TNO, it seems that activity in or on the soil has a clear influence on the emission of fibres. The simulation trials principally concerned resuspension experiments using a fan for fibres that had already been released. There seemed to be an exponential link between the extent of activity and fibre emission.

With little ventilation (comparable with wind force 1-4 on the Beaufort scale) very few fibres seemed to be released; in this instance the fibre concentration in the air remained below the NR level (1,000 fibre equivalents/m^3) for an asbestos content in the soil of 70 mg/kg_{dw} of loose fibre material. With more ventilation (comparable with a wind force of 8-10 on the Beaufort scale) a clear increase in fibre emission seemed to occur with concentrations of 10,000 to 100,000 fibre equivalents per m^3 of air (exceeding the NR level, but not exceeding the MPR level). However, it is difficult to deduce a quantitative link between activity in and on the soil and the asbestos fibre concentration in the air (*Tromp, 2002*).

In practical situations fibre emission by resuspension in particular also appears to be limited as a consequence of minor ‘non-destructive’ activities such as running and cycling, but also fieldwork activities. A fibre emission to the air was demonstrated in none of the measurements that were carried out in respect of such activities (*Tromp, 2002*). In this instance measurements were taken, inter alia, on pulp yards with friable asbestos in concentrations above 10,000 mg/kg_{dw} in the soil.
With bound asbestos the proportion of respirable fibres will be nil, so that resuspension virtually does not occur (see Chapter 2.5). However, in addition to the resuspension of asbestos fibres under the influence of certain ‘non-destructive’ activities and/or airflows, asbestos fibres can also be released from the matrix itself of materials containing asbestos. In this instance, it involves in particular intensive activities such as rubble crushing, excavation,

tipping and dry cleaning (sifting), in the course of which materials can break or ‘crumble’ with fibre emission as a consequence.

Fibre emission as a result of resuspension of previously released fibres or fibre emission caused by ageing or weathering of the matrix is a continuous or long-term emission mechanism. In view of the low fibre emission, the ultimate exposure as a consequence of the continuous emission will be low and could only result in an increased exposure risk with extremely high asbestos contents (such as asbestos roads and yards).

Intensive activities such as rubble crushing, excavation, tipping and dry cleaning (sifting) are more often than not of short duration so that one must cope with a short-term peak load of asbestos fibres (momentary emission). In the incidental occurrence of such activities, this hardly ever results in an unacceptable risk since their contribution to the total fibres inhaled during life is small.

2.9 Place of occurrence and extent of the contamination

In the methodology of the Soil Protection Act a soil volume of 25 m^3 is used, above which there is a serious risk if the intervention value is exceeded. In the event of soil contamination with asbestos, the asbestos in and on the top layer of the soil in particular forms the greatest risk so that a volume criterion is no longer relevant. A surface criterion could be considered to determine severity. Asbestos contamination that is not in or on the top layer will present no direct risk to people. The living layer principle, as stated in BEVER, is perfectly suitable for reducing the human risk for contamination with asbestos. If a living layer of a minimum 50 cm is applied, no asbestos fibres are measured in the air even with minor excavation works in the top layer. Even asbestos contamination that is covered with tiles, concrete or asphalt will only be able to constitute a risk after human intervention. In the Asbestos Roads Decree, such a durable capping layer must be some 10 cm thick. A durable capping layer of sand, granulate or gravel must be a minimum of 20 cm thick. However, asbestos, much more than other contaminants, constitutes a direct risk when it is brought to the surface once again by human activity (e.g. during excavation works or as a consequence of lifting the tiles). This implies that a risk for humans is *indirectly* involved if asbestos is present deeper in the soil.

The distance to the contamination or soil activity is decisive for the exposure concentration. Due to dispersion in the atmosphere under the influence of wind the asbestos fibre concentration in the air decreases sharply with increasing distance. From various practical measurements (approximately 100 measurements) it seems that the asbestos concentration in the air at a distance of some 50 metres only exceeds the NR level in the air (1,000 fibre equivalents per m^3) one single time (Figure 2.5). These situations occur mainly in dry weather and moderate wind. Furthermore, it is apparent that at a distance of 100 metres or more, an increase in the background level is measured, but that the NR level is never exceeded (*Tromp, 2002*). Due to the limited number of environmental measurements and the not always accurate assessment of the distance to the source, it is not possible to comment in greater detail.

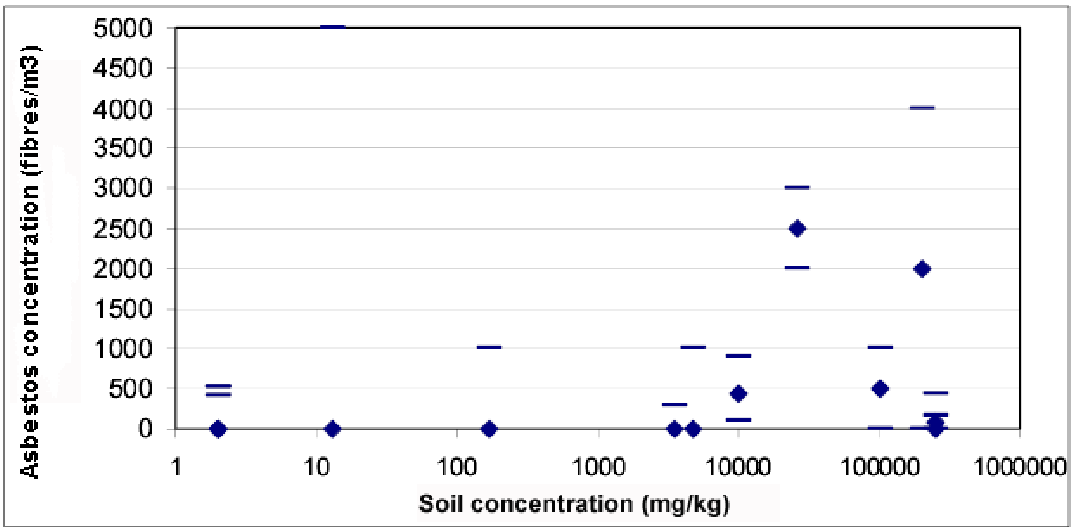

Figure 2.5: Asbestos fibre concentration (in fibres with length > 5µm per m^3 of air) measured in the vicinity of activities with material containing asbestos as a function of the asbestos content in mg of asbestos per kg of soil and/or rubble material.

[Based on 110 measurements in respect of various activities with both bound and unbound asbestos and under different measuring conditions with a distance to the source varying from 5 metres to 100 metres. The asbestos fibre concentrations are averages based on several measured values. The small bars indicate the 95% reliability interval of the concentration levels or the lower assessment limit if no asbestos is encountered (see the points on the 0 line).]

3. Assessing human risk based on calculation

3.1 Soil Protection Act

The HUM-TOX SSCC (human toxicological serious soil contamination concentration; this is the human section of the intervention value) for the contaminants for which there is currently an intervention value is deduced on the basis of the potential lifelong average exposure and the MPR (Maximum Permissible Risk) for exposure; see Figure 3.1.

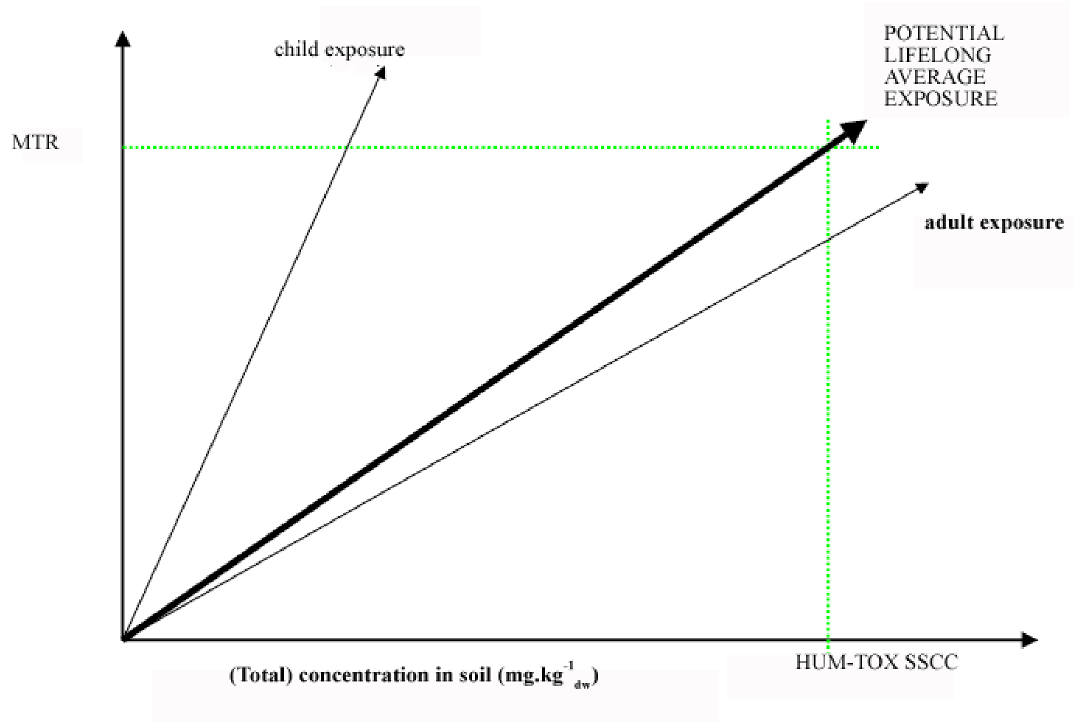

Figure 3.1: Deduction of the HUM-TOX SSCC (human toxicological serious soil contamination concentration) as function of potential exposure and the MPR (Maximum Permissible Risk) for exposure.

The potential exposure is defined as the exposure that would occur under standardised conditions in the residential situation. This exposure can be regarded as the representative exposure for humans who spend their whole life on the contaminated site in a residential situation. Calculation of the potential exposure for deducing intervention values takes place with the CSOIL exposure model (*Van den Berg, 1991/1994/1995,* see Figure 3.2). This model was reviewed in 2001 (*Otte et al., 2001; Rikken et al., 2001; Lijzen et al., 2001*).

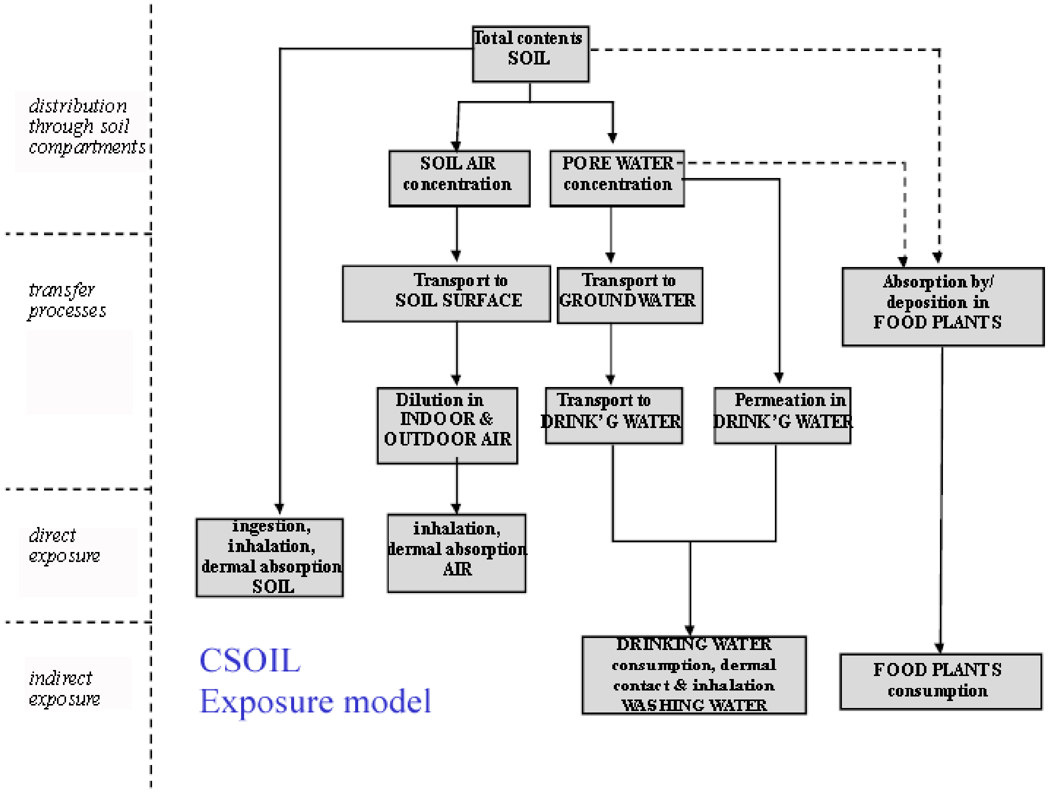

Figure 3.2: Diagrammatic summary of the CSOIL exposure model

Three sections can be recognised in this model:

- distribution of the contaminant via the mobile soil compartments (pore water and soil air);
- transfer of the contaminant from the mobile soil compartments to the so-called contact media (indoor and outdoors air, drinking and washing water and food plants);
- direct and indirect exposure.

For the 100 or so contaminants for which there are intervention values, potential exposure is determined principally by ingestion of earth, the ingestion of food plants from peoples' own gardens and inhalation of indoor air, including the contaminants present therein in gaseous form. Exposure routes that are of less significance for these contaminants concern dermal exposure to soil, indoor air and washing water, inhalation of soil particles and outdoors air and mains water consumption.

To determine remediation urgency, the site-specific risk is determined using the SUS (remediation urgency methodology) programme. The CSOIL exposure model is incorporated in this programme for calculating human exposure. When determining the remediation urgency, there are two important differences from calculating the potential exposure:

- the exposure scenario and the accompanying input parameters must be attuned to the site concerned;
- utilising measurements in the contact media is recommended, particularly the concentration in food plants and in indoor air.

3.2 Exposure routes for asbestos from the soil

The exposure pattern for asbestos is different from that of other contaminants. In fact, only one exposure route, i.e. that of inhalation of (soil) particles, plays a role. This exposure route is significant in indoor and outdoors environments; see Chapter 2.3.3. For all other

contaminants for which there are intervention values the contribution of this route is never more than 1% (*Van den Berg, 1991/1994/1995*: first tranche of intervention values; *Van den Berg et al, 1994*: second tranche of intervention values; *Kreule et al., 1995*: third tranche of intervention values; *Kreule and Swartjes, 1998*: fourth tranche of intervention values). Since asbestos is not absorbed by plants, exposure via consumption of food plants plays no role. On the other hand, asbestos can be acquired by soil ingestion, particularly in children. Oral exposure can also take place if plants are consumed on which asbestos particles have occurred by deposition. Although the connection between oral absorption of asbestos and the occurrence of gastric cancer cannot be ruled out completely, the risks via oral absorption must be regarded as negligible compared with that as a result of inhalatory absorption. Asbestos is not volatile. Consequently, inhalation of indoor air, including the contaminants present therein in gaseous form, is likewise not of significance. Although asbestos fibres occur to a limited extent in drinking water, asbestos in the soil will not permeate through water mains. As a consequence no exposure to asbestos will take place from the soil from drinking water consumption. Finally dermal absorption of asbestos can also be excluded.
As far as mobility and exposure are concerned, the divergent behaviour of asbestos can be used as a counter-argument for the conclusion from *Versteeg et al. (2002)* that there is no justification why asbestos in the soil should be treated differently to other contaminants.

3.3 Permissible exposure

In Chapter 2.4.1 it is elucidated that asbestos can cause mesothelioma (a fatal form of lung, stomach and pleural sac cancer), asbestosis (lung connective tissue) and bronchial carcinoma (lung cancer) in the event of long-term inhalatory absorption.

The carcinogenic potency of asbestos is dependent on the shape and dimensions of the fibres. The fibres with a length between 5 and 40 μm and a diameter between 0.1 and 1 μm are particularly carcinogenic. Durability is also of importance: chrysotile fibres are far less durable than amphibole asbestos fibres, on account of which chrysotile fibres disappear earlier from the lungs. For these reasons permissible exposure is dependent on the type of asbestos and the dimensions of the fibres and is therefore expressed in fibre equivalents.
The Health Council considers the carcinogenic potency of fibres with a length of less than 5 μm in high concentrations as not completely negligible. On the basis of this, the following were chosen in the 'Asbestos in the environment' policy notice for a differentiated stipulation of standards:

1 chrysotile fibre with a length > 5 μm:	equivalence factor 1
1 chrysotile fibre with a length < 5 μm:	equivalence factor 0.1
1 amphibole fibre with a length > 5 μm:	equivalence factor 10
1 amphibole fibre with a length < 5 μm:	equivalence factor 1

In addition to the Health Council's risk evaluation, the VROM Ministry has drawn up quality objectives for asbestos. The environmental policy is aimed at reducing the risks of exposure to asbestos via the air to the Maximum Permitted Risk level under any circumstances and to the Negligible Risk level if possible. As with other contaminants, the Negligible Risk (NR) is stipulated as 1% of the Maximum Permitted Risk level (*VROM, 1989*). On the basis of the equivalence factors mentioned above, the following values result:

- the Maximum Permitted Risk level (MPR) amounts to 100,000 fibre equivalents per m^3 of air (annual average);
- the Negligible Risk level (NR) amounts to 1,000 fibre equivalents per m^3 of air (annual average).

Due to the relatively large uncertainties in determining the number of asbestos fibres in the air as a result of the presence of asbestos in the soil and the special social perception of the presence of asbestos (strong association with health risks), the use of the NR level was chosen as regards policy. This level is associated with the protection level as used by the Employment Inspectorate.

3.4 Calculating exposure via inhalation of asbestos fibres

The calculation of the exposure via inhalation of asbestos fibres can be based on the calculation via 'inhalation of (soil) particles', one of the exposure routes in the CSOIL model.

The 'Intervention values evaluation' project (*Lijzen et al., 2001*) was recently completed. However, in this case only the most relevant exposure routes in CSOIL were evaluated. Since the 'inhalation of (soil) particles' makes no relevant contribution to total exposure for the other contaminants for which there are intervention values, this formula was not evaluated. The formula is as follows (*Van den Berg, 1991/1994/1995*):

IP = IPTS x Cs x fr x fa / W

in which
IP = exposure to inhaled (soil) particles [$mg_{CONTAMINANT}.kg_{BODYWEIGHT}^{-1}.d^{-1}$]
ITSP = inhaled quantity of (soil) particles [$kg_{SOILPARTICLES}.d^{-1}$]
Cs = total concentration in the soil [$mg_{CONTAMINANT}.kg_{SOIL}^{-1}$]
fr = retention factor in the lungs [-]
fa = relative absorption factor [-]
W = body weight [$kg_{BODYWEIGHT}$]

It is assumed that 75% of the particles are retained (temporarily) in the lungs (fr = 0.75). In the absence of a detailed understanding of the precise destiny of the contaminants present in these particles, it is assumed that these are completely absorbed by the lungs (fa = 1.0). For body weight 70 kg is assumed for adults (aged 6 to 70 years) and 15 kg for children (aged 0 to 6 years).

The most sensitive factor in this formula is the inhaled quantity of (soil) particles, which is calculated as follows:

ITPS = TPS x frs x AV x t x ft

in which
TPS = quantity of suspended particles in the air [$mg_{(SOIL)PARTICLES}.m_{AIR}^{3}$]
frs = fraction of (soil) particles (in this instance asbestos fibres) in the total volume of particles in the air [-]
AV = breath volume [$m_{AIR}^{3}.d^{-1}$]
t = exposure duration [d]
tf = time fraction for exposure [-]

The quantity of suspended particles in outdoors air ($TPS_{outdoors}$ = 70 $\mu g_{(SOIL)PARTICLES}.m_{AIR}^{3}$) and the fraction of soil particles in the total quantity of particles in outdoors air ($frs_{outdoors}$ = 0.5) are taken from *Hawley (1985)*. According to the same author the quantity of suspended particles in indoor air is 75% of that in the outdoors air, i.e. TPS_{inside} = 52.5 $\mu g_{(SOIL)PARTICLES}.m_{AIR}^{3}$. The author states the fraction of soil particles in the total quantity of particles in indoor air, frs_{inside}, as 0.8.
The quantity of suspended particles in outdoors air is taken from measurements near a disused refuse tip in the US. The value of $TPS_{outdoors}$, 70 $\mu g_{(SOIL)PARTICLES}.m_{AIR}^{3}$, is the average concentration for the quantity of suspended particles in the air over the period 1980 to 1981. the value of 0.5 for $frs_{outdoors}$, 0.8 for frs_{inside} and 0.75 for converting the quantity of suspended particles in outdoors air into that in indoor air was derived from a number of predominantly

American studies by *Hawley (1985)*. In this instance no details are included regarding the size of the (soil) particles, soil type, soil dampness, weather conditions or housing characteristics. It states in Chapter 2.3.2 that if the wind conditions are identical, the emission of asbestos fibres due to their small aerodynamic diameter will be much less than that of soil particles. Consequently the results of *Hawley (1985)* probably result in an overestimate of the asbestos fibres fraction in the total quantity of particles in the air.

Practical values are used for sojourn times (*Van den Berg, 1991/1994/1995*). It is assumed that an adult spends one day (8 hours) outside on the contaminated site every week and a child every third day (lasting 8 hours). Moreover, it is assumed that, on an annual average, an adult spends 17 hours per day indoors. For a child it is assumed that it spends the whole day indoors or outdoors on the site. No account is taken of passive respiration during the night.

3.5 Calculation of the HUM-TOX SSCC for asbestos

Just as with other contaminants for which an intervention value is calculated, in this chapter the HUM-TOX SSCC for asbestos is calculated based on the MPR. Since the MPR is expressed as concentration in the air, exposure is not calculated for deriving the HUM-TOX SSCC, although the calculated concentration in the air is compared with the permissible concentration in the air. This signifies that respiration and body weight play no role in the calculation.
The calculated concentration of asbestos fibres in the air is derived from multiplying TPS and frs:

TPS x frs	=	annual average asbestos particles concentration outdoors + annual average asbestos particles concentration indoors
	=	$(1/7 \times 8/24) \times (0.5 \times 70) + (17/24) \times (0.8 \times 0.75 \times 70)\ \mu g/m^3$
	=	$31\ \mu g/m^3$

These $31\ \mu g/m^3$ may comprise 100,000 asbestos fibre equivalents to have a risk that is exactly equal to the MPR. Bearing in mind a retention factor (fr) of 0.75, the number of corresponding asbestos fibres in the soil is as follows:

$100{,}000 / 31.10^{-9} / 0.75 = 4.3\ 10^{12}$ fibre equivalents / kg_{soil}.

However, an intervention value and thus a HUM-TOX SSCC too is traditionally expressed on a weight basis (mg of contaminant) per kg of soil. Assuming 2,000 to 40,000 fibres per ng of asbestos (*Slooff and Blokzijl, 1987*), a HUM-TOX SSCC in the range occurs in the range from 100 to 2,000 $mg_{asbestos}/kg_{soil}$.

This HUM-TOX SSCC was deduced as an ad hoc intervention value in 1993. However, as stated in Chapter 3.1, the CSOIL calculation is regarded as having limited value for deducing an intervention value for asbestos. In addition to this, the conversion of asbestos fibres into weight of asbestos is not meaningful for assessing the human risk.

3.6 Calculation of the site-specific human risks of asbestos

In Chapter 3.1 it is indicated that, when calculating the site-specific exposure, there are two important differences from calculating the potential exposure. However, for asbestos both differences simply cannot be accommodated:

- For attuning the exposure scenario and the accompanying input parameters to the site concerned account would in any event have to be taken of the activities on the site and the influence of the soil's dampness on the provision of asbestos fibres in the air. However, these parameters are not incorporated in the CSOIL model. Moreover, no quantitative relationships are known between both these parameters and the fibre concentration in the air.

- There is indeed a protocol available for measuring the asbestos concentration in indoor air (NEN 2991), but this is simply not suitable for use for the present objective (as well as measurement in outdoors air).

An adapted procedure is therefore proposed in Chapter 6.3.

4. Determining human risks on the basis of practical measurement results

Since the end of the 1980s various experiments have been conducted at TNO with the aim of investigating the relationship between the concentration of asbestos in the soil and the concentration of asbestos fibres in the air as a function of various soil and environmental factors (*Den Boeft, 1987; Tempelman, 1998; Arzoni and Tempelman, 2000; Tromp, 2002*). An inquiry was arranged and carried out within the scope of an SKB project (*Versteeg et al., 2002*) with the aim of gathering additional information. The information from TNO research and produced by the inquiry was also evaluated in the SKB project, together with such information from the literature (*Tromp, 2002*).

Building upon this data collection an attempt has been made in this research by means of a second inquiry to collect information in the Netherlands with regard to soil contents versus asbestos fibre concentrations in the air. In the end nine new research reports with some 100 measurement details have been collated. Including the SKB study, a total of 30 research reports with some 1,000 measurement results have been included in the survey. A *database* with a summary of all the collated measurement results in included in Appendix 4.

The newly acquired measurement information shows the same picture as that from the SKB project:

- Increased fibre concentrations in the air to in excess of the MPR level were only measured in respect of heavily contaminated soils and lots with *unbound* asbestos (with average asbestos concentration in the soil higher than 10,000 mg/kg_{dw}) (Figure 2.1). This principally concerns waste originating from the asbestos processing industry or waste containing asbestos released broken up.
- In such situations even minor soil activity is sufficient in combination with dry weather (under realistic conditions and not *worst case* conditions) for the appearance of asbestos fibres in the air above the NR level.
- Fibre concentrations exceeding the MPR in the air are pretty much only measured at a short distance from the source and in respect of heavy soil activity, such as excavation, tipping and [vehicle] driving (Figure 2.5). The fibre concentration in the air declines rapidly with increasing distance and seems in all instances to have diminished to below the NR level at a distance of some 100 metres.
- As regards less heavily contaminated soils in which *bound* materials are mainly present (less than 1,000 mg/kg_{dw}) and in one single case unbound products (less than 100 mg/kg_{dw}), asbestos fibres were not encountered in the air in any of the cases, even in the event of activities such as digging, tipping and sifting (Figure 2.2).
- Only rough conclusions can be drawn from these data since the measurement conditions and soil contents are frequently not precisely known. In addition to this, many of the analyses seem to have been carried out with phase contrast microscopy with a lower assessment limit of 10,000 fibres/m^3. The sites and lots were also frequently kept damp during soil activities to counteract fibre emission.

The measurement results from the practical measurements are too small a basis for determining properly substantiated risk limits for all forms of asbestos in any situation. Rough conclusions can nevertheless be drawn. In Figure 4.1 the 85 measurements in which asbestos was encountered have been turned into a graph; the majority of measurements in which no asbestos was encountered in the air are not included in this graph. The measurements are based on both simulation measurements and on practical measurements solely for contamination with *unbound* asbestos. All simulation measurements and most practical measurements were carried out under *worst case* conditions: dry soil (or dry soil material), dry (weather) conditions, plenty of activity and friable asbestos. The following can be concluded from the figure:

- No asbestos in the air was measured below 10 mg/kg_{dw} (in a *worst case* simulation measurement with a concentration around the NR level).
- In the range between 10 and 100 mg/kg_{dw} no exceeding of the NR level was observed for the asbestos concentration in the air for the practical measurements and only a single (temporary) one for the *worst case* simulation measurements.
- In the range between 100 and 1,000 mg/kg_{dw} a (temporary) exceeding of the NR level, and even the MPR level, is possible for the asbestos concentration in the air. However, at present insufficient survey data are available to be able to draw more far-reaching conclusions.
- In excess of 10,000 mg/kg_{dw} a (temporary) exceeding of the NR level is likely and there is an appreciable chance that the asbestos concentration in the air also exceeds the MPR level.

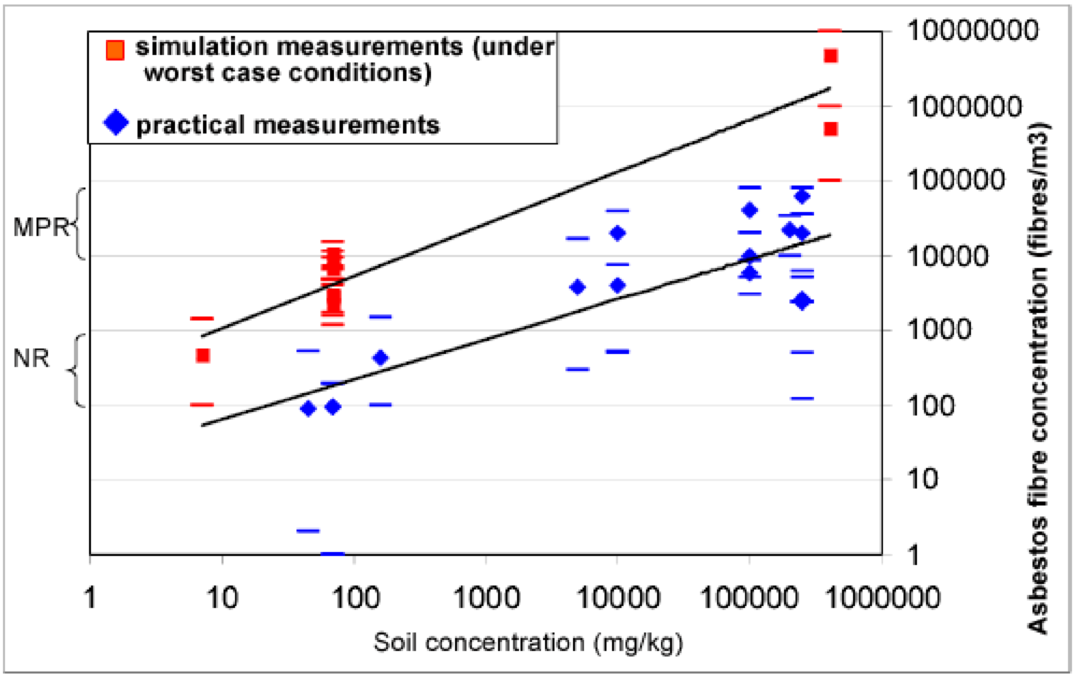

Figure 4.1: *Asbestos fibre concentration (in fibres with length > 5 µm per m^3 of air) for all measurements in which asbestos in the air was measured as a function of the unbound asbestos content in mg of asbestos per kg of soil and/or rubble material.*
[Based on 85 measurements with various activities with unbound asbestos and under various measurement conditions with a positive measurement result (so-called worst case *measurements). The measurements are broken down into simulation measurements (shown in red) and practical measurements (shown in blue). The asbestos fibre concentrations are average values based on several measured values. The small bars indicate the 95% reliability interval of the concentration levels. The NR and MPR levels are based on 1,000 and 100,000 fibre equivalents per m^3 respectively. Expressed as fibres/m^3, this corresponds to 100 (amphibole) – 1,000 (chrysotile) fibres/m^3 and 10,000 (amphibole) – 100,000 (chrysotile) fibres/m^3 respectively.]*

On the basis of the trends from the measurement results a qualitative estimate can be made of the expected fibre concentration in the air in respect of different classes as regards the asbestos concentration in the soil with and without activity in or on the soil (Table 4.1).

Table 4.1: *Qualitative estimate of asbestos fibre concentration in the air as a function of asbestos concentration in the soil with and without activity in or on the soil.*
[Based on simulation measurements and practical measurement results (values in

brackets are estimates since they are still insufficiently reliable, i.e. insufficient or no survey data available).]

Asbestos concentration (mg/kg$_{dw}$)	**No activity[1)]**	**Activity[2)]**	**No activity[1)]**	**Activity[2)]**
	Bound		**Unbound**	
< 5	-	-	-	-
5 – 100	-	-	(-)	(+/-,+)
100 – 1,000	-	(+/-)	(+/-)	(+,++)
> 1,000	(+/-)	(+,++)	(+,++)	++

1) no activity: for open storage/uses without processing of the material.

2) activity: with processing of the material, such as breaking, driving, tipping, digging and sifting, including sampling for field research and remediation and clean-up works;

- no emission of fibres, asbestos fibre concentration in the air at the background level;

+/- asbestos fibre concentration in the air below the NR level;

+ asbestos fibre concentration in the air between the NR and the MPR levels;

++ asbestos fibre concentration in the air above the MPR level.

5. Discussion

In general the reliability of the exposure calculated with CSOIL is limited (*Vissenberg and Swartjes, 1996*). The reliability of the calculation of exposure to inhaled asbestos fibres with the CSOIL exposure model is very definitely limited. Consequently we must discuss whether the standard procedure, as used for the other contaminants for which intervention values have been deduced, can be utilised. As an alternative there is the possibility of using practical survey results. This would be an application of the current standardised method. In this chapter an analysis will be given of the possibility of assessing the human risk from asbestos soil contamination on the basis of calculation on the one hand, and, on the other, survey results for both deducing an intervention value (potential risks) and for assessing the site-specific human risks.

5.1 Assessing human risk on the basis of calculation

Calculation of the asbestos fibres concentration in the air using the CSOIL exposure model presents the following problems:

- Distribution of the contaminant via the mobile soil compartments is calculated in the first section of CSOIL. In this instance, only distribution via the fixed phase and (air) soil is significant for asbestos. Unlike other contaminants for which there is an intervention value, asbestos mineral does not bond to soil particles via the 'classic' adsorption process, barely reacts chemically with contaminants in the soil and is not or is scarcely broken down (biologically). In fact, asbestos fibres are potentially present in the soil in a mobile phase and they can enter the air due to activity in or on the soil and/or being raised by the wind. Consequently, the first part of the CSOIL model, in which distribution of the contaminant through the mobile soil compartments is calculated, is not applicable to calculating asbestos exposure. This is applicable to both *the calculation of an intervention value* and *to the use of CSOIL for calculating the site-specific human exposure*.
- Calculating the distribution of asbestos fibres from *bound* asbestos via the mobile (air) and less mobile phases of the soil is even more difficult since the fibres must first be released from the matrix (primary emission) before they can enter into the mobile phase (the air) (secondary emission). Processes that are difficult to quantify, such as the transition from bound asbestos to loose asbestos fibres, also play a role as regards a number of other immobile contaminants. In the instance where rubble is present in a soil, for example, this must frequently first be 'processed' by physical-chemical processes or human activity before the metals it contains are available in metallic or compound form to be absorbed by food plants, for example. A similar theory is applicable to polyaromatic hydrocarbons becoming available from pitch particles. In none of these cases is the breakdown process for the matrices in which these contaminants are found quantified in the CSOIL model. Since intervention values have indeed been formulated for these contaminants, this limitation may not be a reason to decide not to incorporate an intervention value based on a CSOIL calculation solely for asbestos.
- For the sole exposure route that is taken into account for deducing the HUM-TOX SSCC and the ad hoc intervention value, i.e. inhalation of asbestos fibres present in the air, a constant quantity of asbestos fibres in the air is assumed. This is deduced from the total quantity of particles measured in the air and the assumption that half of them originate from the soil. However, more than for the other parameters calculated in the CSOIL model, the value for the quantity of asbestos fibres in the air is determined to a large extent by local circumstances and, under practical conditions, this quantity will fluctuate sharply over time and distance. These local circumstances are difficult to quantify and are not included in the CSOIL model. The asbestos fibre concentration in outdoors air, for example, is to a large extent dependent upon the original material (type and shape of asbestos fibre and material into which this is processed), activity on the site, the dampness

of the soil and weather conditions (*Tromp, 2002*). The quantity of asbestos fibres in indoor air will be determined in particular by the 'tracking in' of asbestos particles from the contaminated site to the indoor environment (via footwear and to a lesser extent clothing), indoor conditions and, to a lesser extent, by the quantity of asbestos fibres in the outdoors air. For these reasons it is difficult to calculate the quantity of (asbestos) particles in outdoors and indoors air at a specific location.
Great variation in the quantity of asbestos fibres in the air over time and distance, whether or not as the consequence of activity on the site or of soil and weather conditions, does not by definition need to be a problem *for calculating the intervention value* if the distribution of the quantity of asbestos fibres in the air, or at least the average (or median) value is known. As is known, the average person needs to be protected below the level of the HUM-TOX SSCC. And for calculating the average exposure, the average (or the median) for the concentration of asbestos fibres in the air is a defensible point of departure. However, the question is the extent to which the average quantity of asbestos fibres in the air is in fact equal to the quantity of suspended particles in the air, as is used in the CSOIL standard model (see Chapter 3.4). In Chapter 2.3.2 it is concluded that, due to the relatively small aerodynamic diameter, the quantity of asbestos fibres in the air could be somewhat smaller than the quantity of material/soil particles in the air.

- Besides the number of asbestos fibres in the air, the shape and dimensions of the asbestos fibres are also of significance: the most harmful fraction concerns chrysotile and amphibole fibres with a length greater than 5 μm and a diameter smaller than 3 μm (in particular fibres with a diameter of 0.1-02 μm are dangerous; see Appendix 3). In fact, this phenomenon is comparable to the relationship between the availability of other contaminants and the form in which this contaminant is present: for example, for polyaromatic hydrocarbons and certainly for metals the human risk is also heavily dependent upon the sort of form in which these occur in the soil. For these contaminants availability is discounted in a limited manner by means of soil type correction. This soil type correction corrects the intervention value to be used as far as availability is concerned on the basis of the organic matter content (organic contaminants) and also on the basis of loam content (metals). For asbestos such a correct is not possible as far as fibre dimensions are concerned, certainly not on the basis of soil characteristics since the fibre shape and dimensions are determined principally by the original material, activity on the site and erosion and weathering of the original material (under the influence of damp and weather effects). The influence of fibre dimensions on the human risk, which is not discounted in the CSOIL model, signifies a limitation of the significance *of the calculated site-specific human risk and of the HUM-TOX SSCC (the intervention value)*.
  The loam and humus content is indeed of importance for the extent of emission of asbestos fibres to the air. However, the influence of these parameters is much smaller than this is for the physical-chemical adsorption of the other contaminants. Moreover, the quantitative relationship between loam and humus content and asbestos emission is not known.
- In the calculation a constant quantity of particles in the air is taken into account, whilst with asbestos there is mostly a short-term increase in the air, e.g. after activities such as breaking or driving. This signifies a limitation of the significance *of the calculated site-specific human risk and of the HUM-TOX SSCC (the intervention value)*.

It is recommended to research in more detail in the future the relationship between the following factors and the emission of asbestos fibres in the air:

- soil type;
- soil characteristics (loam and organic matter content);
- type of vegetation;
- weather characteristics;
- extent of activity in or on the soil.

In this instance efforts should in the first instance be focussed on a qualitative definition of the influence of these factors on emission. Whether a quantitative description is possible is still doubtful. The feasibility of deducing qualitative and quantitative relationships can possibly be investigated in the first instance in a feasibility study.

5.2 Assessing human risks on the basis of measurement results

A HUM-TOX SSCC is traditionally derived by calculating exposure with the CSOIL model and cannot explicitly be determined from practical survey results, although the relationship between the asbestos concentration in the soil and that in the air can be evaluated on the basis of these survey results. A risk limit cannot be explicitly derived from this for the concentration of asbestos in the soil below which no unacceptable quantity will enter into the air. A sort of NOEC (*No Observed Effect Concentration*) can of course be deduced in this manner, i.e. the highest measured soil concentration at which a specific risk level in the air is not exceeded, which can serve as the lower limit for a HUM-TOX SSCC. NOECs lay the foundations for deriving the ECOTOX SSCC (the eco-toxicological serious soil contamination concentration, or the ecological building block for the intervention value). In this sense this starting point is not completely new as regards the assessment of soil contamination. However, for deriving the ECOTOX SSCC a statistical interpretation of NOECs for various organisms is used (*Aldenberg et al., 2002*). Such an elegant procedure is not possible for the empirically determined concentrations for asbestos in the soil and the air.
The intervention value, as incorporated in the *interim policy on asbestos in soil, earth and rubble (granulate)*, must be regarded as a NOEC and can therefore be considered as a lower limit for a HUM-TOX SSCC. The value complies with the HUM-TOX SSCC in the sense that the risk is acceptable if this concentration is not exceeded. However, one difference with the significance of the HUM-TOX SSCC is that at the level of the HUM-TOX SSCC exposure is not by definition equal to, but at least lower than the relevant risk level. Consequently carrying out supplementary practical measurements is recommended in the future.

In the present methodology for assessing soil contamination, measurement plays a role in determining the Remediation Urgency Methodology (SUS) based on site-specific risks. In SUS utilising measurements is the contact media is recommended, especially in indoor air and food plants. In addition to this, an option is also given for calculating the concentration in the contact media. Basing a site-specific assessment of the human risk solely on a calculation is only acceptable if a very clear verdict emerges (definite risk or definitely no risk). In the event that this verdict is less clear, supplementary measurements – if possible – are of great importance. At present no standardised method is available for determining the concentration in indoor air or in food plants by measurement.
Moreover, as regards the site-specific risks of asbestos, the same line cannot be followed as for other contaminants since no reliable calculation method is available to be able to calculate the site-specific concentration of asbestos fibres in the air. Consequently, only the option for measurement remains. A method is proposed to this end in this report (see Chapter 6.3).

6. Assessment of asbestos in the soil

In this chapter a proposal is made for a procedure to enable assessment of soil contamination with asbestos.

6.1 Determining asbestos concentration in the soil

If asbestos is suspected, a soil investigation must be carried out in conformity with NEN 5707 'Soil – Inspection, sampling and analysis of asbestos in the soil and batches of earth'[15]. The standard describes a method for determining the asbestos content in the soil and batches of earth. All facets of the investigation are dealt with in this standard: investigation strategy, inspection, sampling and analysis. The investigation method is divided into three phases, which are defined as follows:

1. a preliminary asbestos investigation (leading on from NVN 5725: preliminary investigation);
2. an exploratory asbestos investigation (leading on from NEN 5740: exploratory investigation);
3. a detailed asbestos investigation.

For assessing asbestos in the soil, it is important to gain an oversight of the information below on the basis of NEN 5707:

- The local situation: the presence of nearby housing, the accessibility of the site or area for third parties.
- The previous or current soil use/use of the site or area. In this instance the soil use of the immediate surroundings is likewise of importance.
- The possible causes of the contamination: the contamination source and the manner in which the contamination entered into the soil.
- Places/areas where the soil has plants, is built upon or covered, including type of vegetation (grass, shrubs, trees), type of covering (sand, gravel, tiles, concrete, asphalt).
- Spatial distribution (spread pattern): the extent and place(s) of occurrence of the contamination; the depth (soil layer) in which the soil contamination occurs.
- The type of contamination: the types of material containing asbestos, the sorts of asbestos (chrysotile, amosite, crocidolite and any other types), the asbestos content in the materials encountered that contain asbestos; the extent of bonding and degree of weathering of the materials encountered.
- The degree of contamination: the content of (visually detectable) asbestos on and near the surface per (part) location, the concentration per sifted fraction, the concentration of chrysotile asbestos and amphibole asbestos, the concentration of bound asbestos and unbound asbestos, the concentration of respirable asbestos fibres (fibres with a length small than 200 μm) and the total asbestos concentration.

6.2 Serious soil contamination

Since there are no ecological risks for asbestos, it is not meaningful to deduce an ECOTOX SSCC (the eco-toxicological serious soil contamination concentration). If the HUM-TOX SSCC (the human toxicological serious soil contamination concentration) is not exceeded, there is automatic compliance with the requirement that the functional characteristics that the soil has for plants or animals are not seriously reduced.

[15] For a summary of the (draft) NEN standards mentioned in this report, see Appendix 2.

As argued in Chapter 5.1, the standard procedure for deducing the HUM-TOX SSCC on the basis of a calculation with the CSOIL exposure model is simply not applicable to asbestos. A human risk level also cannot be explicitly deduced on the basis of the available practical survey data. A lower limit (a sort of NOEC, or a *No Observed Effect Concentration*) for such a risk limit in soil can of course be determined on the basis of the measurement results for the concentration of asbestos in the soil and in the air, in the course of which a certain risk level in the air will not be exceeded under specified conditions.

6.2.1 Unbound asbestos

For *unbound* asbestos the intervention value of 100 mg/kg_{dw} for the sum of the concentration of chrysotile asbestos (or serpentine asbestos or white asbestos) and ten times the concentration of amphibole asbestos (other asbestos types), as included in the interim policy (*VROM, 2002*), is a suitable value for 'standard' Dutch conditions and in this instance this is taken to be a situation in which there is no systematic involvement of activities such as the digging, tipping and sifting of soil material and the (top layer of the) soil is damp for the greater part of the year. The practical measurements indicate that, under these circumstances, it is highly unlikely that the NR level in the air will ever be exceeded. Even in those instances in which such activities are actually involved and the soil will be dry, it is unlikely that the MPR level in the air will be exceeded. And if these activities take place, it will usually last a short time and only a temporary increase in the asbestos fibre concentration in the air in the immediate vicinity will be involved. Moreover, a dry soil will not remain dry for long under Dutch conditions.
It could be argued whether the risks of an asbestos concentration in the soil of between 100 and 10,000 mg/kg_{dw} would also be acceptable under the 'standard' Dutch conditions. At the NR level there is currently insufficient evidence that this level is not regularly exceeded with a concentration of unbound asbestos in the soil in excess of 100 mg/kg_{dw} (sum of the concentration of chrysotile asbestos and ten times the concentration of amphibole asbestos). In the outdoors environment the NR level in the air will most likely not readily be exceeded at a concentration of between 100 and 10,000 mg/kg_{dw} (sum of the concentration of chrysotile asbestos and ten times the concentration of amphibole asbestos). Nevertheless, the number of measurement results and quality of the experiments upon which this conclusion is based is too small to be able at this moment to deduce a concentration in the soil of between 100 and 10,000 mg/kg_{dw} related to the NR level. Moreover, it is uncertain whether an unacceptable risk of exposure indoors and consequent increased concentrations in indoor air does not occur in the indoor environment at such high concentration as a result of the tracking in of asbestos particles from a contaminated site to the indoor environment (via footwear and to a lesser extent clothing).

The calculated HUM-TOX SSCC, which is nevertheless regarded as not being very reliable (Chapter 5.1), is 100-2,000 mg/kg_{dw}. This value is based on the MPR level and not the on NR value as is the intervention value as set out in the interim policy. At the NR level this HUM-TOX SSCC would turn out to be lower by a factor of 100, i.e. 1-20 mg/kg_{dw} and thus be stricter by a factor of about 10 than the value derived from practical measurement values. This could have contributed to overestimating the asbestos fibres in the CSOIL calculation by basing this on the number of ordinary particles in the air.

6.2.2 Bound asbestos

For bound asbestos it is difficult to determine if bound asbestos will change into less bound or unbound asbestos as a consequence of human activity and/or weathering. Since supplementary information is required for this assessment, it is proposed to give this appraisal a role in the phase of determining the site-specific risks. In this instance it is connected with assessing other contaminants, in the course of which it can be concluded within the scope of determining the site-specific risks that the availability of a contaminant and thus the risk is limited. An example of this is a situation in which metals only are available since they are bonded to rubble particles or polyaromatic hydrocarbons of limited availability in pitch particles. For both asbestos and other contaminants the time factor plays a role: can the contaminants become available in the period of time for which the assessment has to have validity?

If, on the basis of the above appraisal, it can be concluded in the site-specific human risks assessment phase that (durable) bound asbestos is involved, using a risk limit of 1,000 mg/kg_{dw} is proposed for the sum of the concentration of chrysotile asbestos and ten times the concentration of amphibole asbestos (other asbestos types). The substantiation below forms its basis:

- An increased quantity of asbestos fibres compared with the background concentration will virtually never occur in the air for bound asbestos. For bound asbestos there is mainly an indirect risk since a fibre emission can only occur with actual breaking, damaging or weathering.
  Since under so-called 'standard' Dutch conditions there is no systematic involvement of activities such as digging, tipping and sifting, the site-specific risk at this concentration level will be negligible.
- From practical measurements it is apparent that for bound asbestos the asbestos fibre concentration in the air nearly always remains below the NR level under dry field conditions even when there is digging, tipping or sifting. Only under extreme conditions such as rubble crushing can an increased asbestos fibre concentration in the air be established for very high concentrations (greater than 10,000 mg/kg_{dw}).
- The respirable fibres fraction (length less than 200 μm) in the soil is very low (< 0.1%) in the event of contamination solely with bound asbestos (based on various analyses carried out by TNO-MEP), so that resuspension results in no significant increased fibre emission.
- Indirect exposure as a consequence of the 'tracking in' and blowing in of material remnants containing asbestos is minimal for bound asbestos. The contamination occurs principally as clearly visible pieces with a diameter > 2 cm with very few fine particles which can be found on footwear, attach to clothing or can blow in.
- The underpinning of the experiments is insufficient to be able to guarantee that, at a concentration higher than 100 mg/kg_{dw}, bound asbestos will not occur in the long term at a concentration in the air above the NR level. As a consequence conducting additional practical measurements is recommended for the future, in particular to investigate fibre emission in the concentration range 100 to 10,000 mg/kg_{dw} more closely.

6.2.3 Respirable fibres

To determine the site-specific human risk irrespective of soil use, the proportion of respirable asbestos fibres in the soil (with a diameter smaller than 3 μm and a length smaller than 200 μm) is of importance. These fibres can be directly inhaled and can also be released under 'standard' Dutch conditions (situation in which activities such as digging, tipping and sifting of soil material are not systematically involved and the (top layer of the) soil is damp for the largest part of the year). A threshold value of 4.3×10^{10} fibre equivalents/kg_{dw} is proposed for the concentration of respirable fibres in the soil. As regards order of magnitude, this corresponds to a risk limit of 10 mg/kg_{dw} of respirable fibres for the sum of the concentration of chrysotile asbestos and ten times the concentration of amphibole asbestos (other asbestos types). The substantiation below forms the basis of this proposal.

As regards the reaching of a threshold value for respirable asbestos in the soil, the same calculation as the HUM-TOX SSCC (Chapter 3.5) was used as a premise. This value is indeed regarded as not being reliable for deriving the HUM-TOX SSCC (Chapter 5.1), but can nevertheless in our opinion be used for deducing the threshold value for respirable asbestos. On the one hand, availability (the original material) no longer plays a role for respirable asbestos, that is to say respirable asbestos is 100% available. On the other hand, the asbestos fibre concentration in the air is also less dependent on site-specific activities since respirable asbestos fibres can be released to the air by minor activities and airflows. In other words, the assumptions made in the CSOIL model are more consonant with the derivation of a threshold value for respirable asbestos than for deriving a HUM-TOX SSCC. The HUM-TOX SSCC calculated with CSOIL is related to the MPR level of 100,000 fibre equivalents per m^3 of air (annual average). In the soil this boils down to a content of 4.3 x 10^{12} fibre equivalents per kg of earth. Conversion into a weight concentration gives a HUM-TOX SSCC of 100-2,000 mg/kg_{dw}. The threshold value for respirable asbestos fibres in the soil must be related to the NR level of 1,000 fibre equivalents per m^3 of air (annual average), since all respirable fibres in the soil are in principle available. In the soil this boils down to a content of 4.3 x 10^{10} fibre equivalents per kg of earth. Conversion into a weight concentration gives a threshold value of 1-20 mg/kg_{dw}.

A conversion factor of 2,000-4,000 fibres per ng of asbestos is used for the conversion from a fibre concentration to a weight concentration (*Slooff and Blokzijl, 1987*). If the same conversion is made on the basis of the soil samples analysed by TNO-MEP over the last ten years, it is apparent that the conversion of a fibre concentration of 4.3 x 10^{10} fibre equivalents/kg_{dw} into a weight concentration always produces higher concentrations than 10 mg/kg_{dw}. In the *worst case* simulation trials within the scope of the SKB project (*Tromp, 2002*) very friable asbestos with a respirable fraction of some 5% was used as the initial material. In translating the respirable asbestos fibre concentration in the soil into the NR level in the air, this corresponds to some 2.5 mg/kg_{dw}. If the same material is used in trials under practical conditions the NR level in the air is only exceeded with a 10 times higher concentration in the soil: 25 mg/kg_{dw}. Amongst other things, this is apparent from Figure 4.1, where the results from laboratory simulations come out higher than the results under practical conditions by a factor of at least 10.

6.2.4 Intervention value

In summary, it is proposed to use the intervention used in the interim policy, 100 mg/kg_{dw} for the sum of the concentration of chrysotile asbestos (also serpentine asbestos or white asbestos) and ten times the concentration of amphibole asbestos (other asbestos types), as the definitive intervention value for both bound and unbound asbestos.

In the future conducting further research into the following is recommended:

- The creation of a *database* in which the data measured under practical conditions and relevant to the human risks (fibre emission) of asbestos are incorporated (asbestos concentrations in the soil and in the air, type of asbestos, condition of bound asbestos, soil type and characteristics and measurement conditions).
- The carrying out of specific supplementary practical measurements regarding the human risks (fibre emission) in the concentration range from 100 to 10,000 mg/kg_{dw}.
- The durability of bound asbestos.

6.2.5 Area criterion

In addition to assessing the total concentration, a volume criterion is used to determine the severity of the soil contamination: serious soil contamination is involved if the intervention value is exceeded *in a soil volume of at least 25 m^3*. However, for asbestos the risk of fibres that are situated in the topmost centimetres is decisive. Although this is also applicable to a greater or lesser extent to the other regulated contaminants, especially in the instance of a dominant contribution by the earth ingestion exposure route, this effect is nevertheless much greater for asbestos. Asbestos that is located deeper than the top few centimetres cannot be transported to the soil surface as a result of transport in the soil (evaporation) or absorption in plant roots. The only possibility by means of which asbestos fibres from deeper layers can enter the range of humans is as a consequence of human, and to a lesser extent animal, activity. Since the quantity of asbestos in the topmost centimetres is particularly important for the human risk, an area criterion could be considered instead of a volume criterion.

An area criterion of 50 m^2 would be the most convenient for inclusion in the further research, in which sampling takes place in some instances in a 7 x 7 grid. Nevertheless, the volume criterion is based on an area of approximately 50 m^2 (49 m^2 to be precise) – this is the area enclosed by the four angles of a 7 x 7 grid – and a depth of 0.5 m. However, we cannot rule out there being an unacceptable risk for humans above the proposed intervention value in instances of unbound asbestos in very high concentrations over an area of less than 50 m^2. There is no criterion on the basis of which a meaningful area criterion can be calculated. On the basis of expert judgement it is proposed to use a value of 25 m^2.

6.3 Remediation urgency

In the event of soil contamination with asbestos the remediation urgency is determined on the basis of the site-specific risks for humans. A calculation with the CSOIL model is not considered suitable for determining this site-specific risk (see Chapter 5.1). Consequently a guideline has been derived for determining the site-specific risk of soil contaminated with asbestos from the concentrations of asbestos in the air and in the soil perceived under practical conditions and on the basis of measurement records.
As stated in the introduction to this report, this investigation and thus this methodology too is not applicable to the following:

- assessing the risks of other sorts of material, such as tipped material, road-metal or (road) building material;
- if asbestos is present solely on the ground, e.g. as a consequence of fire or explosion;
- for dealing with land and sediment containing asbestos for which the Working Conditions Act is applicable.

With regard to this final item, 'not applicable for dealing with land and sediment containing asbestos ' it makes sense in this context to emphasise the fact that, within the scope of the Soil Protection Act, the human risks are focused on the 'average' person under standard conditions (not focused on vulnerable groups or individuals working with or in the soil.

6.3.1 Framework

The framework proposed here for assessing the site-specific human risk of soil contamination with asbestos is analogous to the current urgency methodology (*Koolenbrander, 1995*). That is to say, the methodology has a structure phased in three tiers.

Even for asbestos it holds true that it is assumed that a site-specific risk for humans is involved unless the opposite can be demonstrated ('risk, unless…'). To this end the following tiers of the procedure are pursued. The amount of complexity and the effort required increase in every higher tier. If it cannot be demonstrated in a specific tier that a site-specific human risk is *not* involved, the following tier must be carried out. If it cannot be disproved in one of the first two tiers that a site-specific risk for humans is involved, the procedure shall end in tier 3. When implementing tier 3 a possible choice is given between a site-specific outdoors air measurement and a laboratory simulation measurement. If secondary contamination of indoor areas cannot be ruled out, measurements in indoor air must also be taken during tier 3.
The following tiers of the procedure are described in detail in the sections below:

- Tier 1, simple assessment;
- Tier 2, determination of respirable asbestos fibres in the soil;
- Tier 3, measurement of the asbestos fibre concentration in outdoors and/or indoor air.

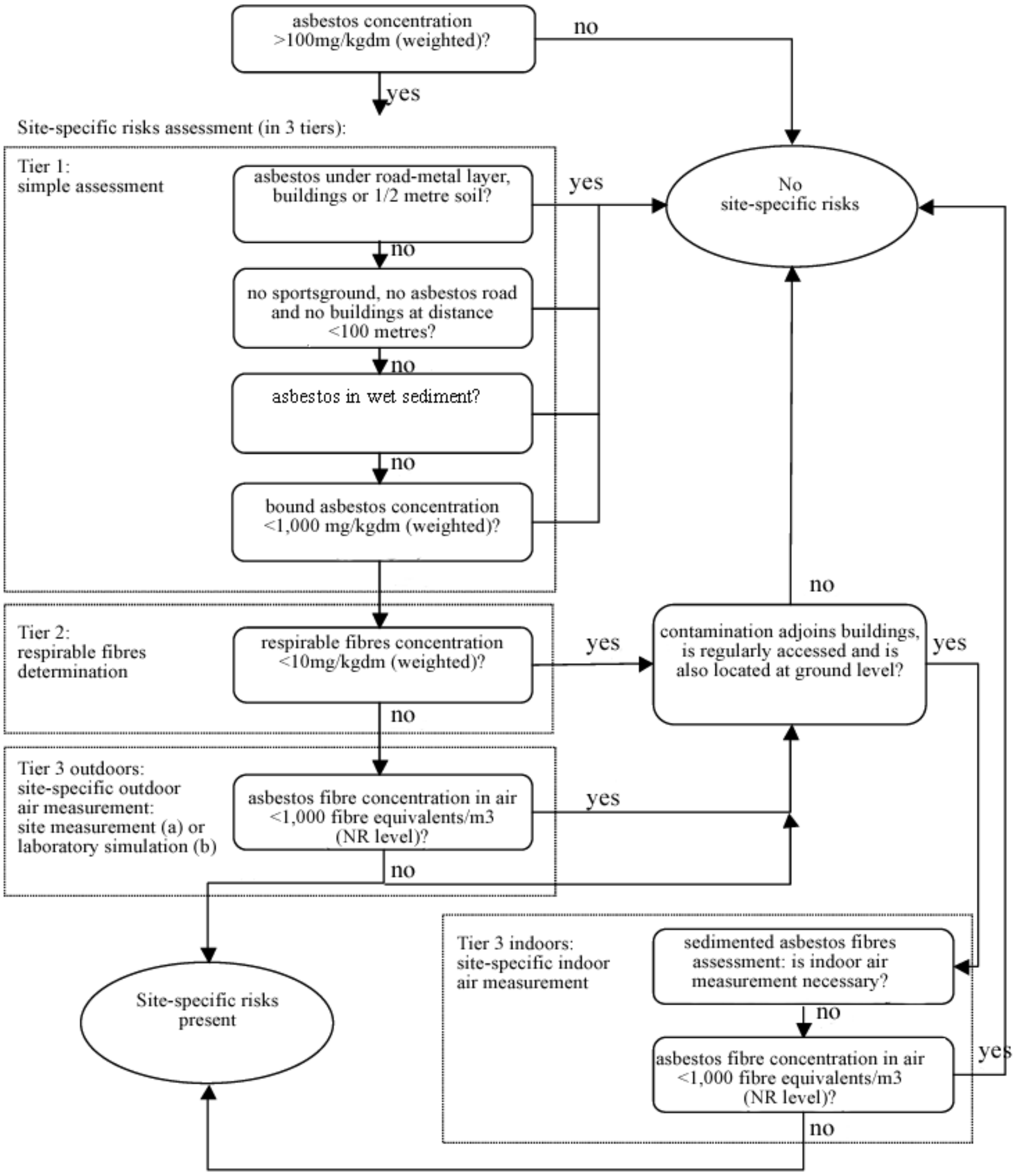

Figure 6.1: Diagrammatic representation of tiered 'site-specific human risk assessment' plan for asbestos soil contamination

6.3.2 Tier 1: simple assessment

According to the Remediation Urgency Methodology, a simple assessment of the site-specific human risks is carried out initially. In this instance it is ascertained whether exposure is impossible of even very unlikely. If so, the procedure can be halted and it can be concluded that there are no site-specific risks for people as a consequence of the presence of asbestos in the soil. Each part location (as described in NEN 5707) must be assessed separately. In addition, testing the most contaminated spatial unit or the most contaminated sampling site must also be carried out at the risk limits for bound asbestos and for respirable asbestos fibres. The concentration per soil layer and the concentration on and near the surface must also be included separately for testing.
Exposure to asbestos is regarded as impossible or very unlikely if one (or more) of the following situations occurs:

1. The asbestos contamination is situated deeper than 0.5 metres below ground level and it is not plausible that (mechanical) earthworks activities are going to take place regularly.
   If the asbestos contamination is situated deeper than 0.5 metres below ground level, no emission of asbestos fibres to the air can occur, even in the event of light activities such as running or extensive excavation works. Asbestos can indeed reach the surface, and asbestos fibres likewise enter the air if intensive, mostly mechanical, excavations works are implemented. This can be the case on industrial sites, for example, upon which earthworks are regularly carried out. If greater earth removal takes place, e.g. as a result of house building, it is assumed that a change of use is involved in such instances and the remediation urgency must be reassessed.

2. The contamination is situated under a layer of road-metal asphalt, concrete, tiles or clinker with a minimum thickness of 5-10 cm and it is not plausible that (mechanical) earthworks activities are going to take place regularly or other activities in the course of which the road-metal layer is raised.
   See 1.

3. The contamination is situated under buildings and not in the ventilation space or is indeed in the ventilation space, but this is not accessible.
   Under these circumstances people cannot come into contact with asbestos fibres.

4. The land is not a sports ground and not a road metalled with asbestos and there are no buildings within a 100 metres radius.
   From the survey results from practical measurements it is apparent that, even under extreme conditions (high concentrations of unbound asbestos, much activity and a dry sandy soil), the fibre concentration in the air at a distance of 100 metres shows virtually no increase compared with the background concentration. This being so, the risk of inhaling asbestos fibres in the outdoors air is regarded as small unless there is frequent involvement of sports (lots of activity on the ground which can result in asbestos emission, combined with a higher breathing volume) of a road, where asbestos emission can occur as a result of driving.
   Moreover, it is assumed that, as a result of the stipulation of a distance of at least 100 metres, there will be no ‘tracking in’ of asbestos particles into a home or building, so that in the absence of buildings within a 100 m radius the risks for people as a consequence of inhaling indoors will be nil.

5. The contamination is in a wet sediment.
   If asbestos is in a wet sediment, no asbestos fibres can enter the air and no inhalatory exposure will occur as a result. Risks cannot be excluded if sediment is brought onto the

bank. At that time it becomes soil and it is assumed that in such instances a change of function is involved and remediation urgency must be reassessed.
A comparable line of reasoning is applicable to wet soils. However, it is difficult to determine whether the (topmost centimetres of the) soil is continuously wet throughout the year. For this reason this situation is only applicable to marshy natural areas, concerning which it is known that the (top) soil is saturated the whole year.

6. The bound materials are not in a weathered condition and the sum of the concentration of *bound* chrysotile asbestos (also serpentine asbestos or white asbestos) and ten times the concentration of *bound* amphibole asbestos (other asbestos types) is lower than 1,000 mg/kg_{dw}.
   The extent of bonding has an important influence on fibre emission and thus on exposure. From the survey results from practical measurements it is apparent that with contents lower than 1,000 mg/kg_{dw} of bound asbestos, the fibre concentration in the air is virtually not increased compared with the background concentration even under extreme conditions (high concentrations of bound asbestos, lots of activity and a dry soil).

   The extent of weathering plays a major role in determining bonding. The bonding of materials must be determined in conformity with NEN 5707. Since bonding plays no role when evaluating the intervention value, there is the risk that evaluation of bonding is not carried out properly. In this simple assessment all types of materials found must be evaluated once again for bonding, in the course of which the extent of weathering must likewise be indicated. The extent of weathering is subjective, on account of which differences in interpretation can arise. The following criterion can be used as evidence: if the material containing asbestos can be in two by hand, the (cement) matrix of the material is so weathered that it is no longer (durable) bound material. In this instance the material must be evaluated as unbound. This test must of course be carried out in accordance with the provisions of working conditions regulations. In the event of doubt there must be a move to implementation of the subsequent tier (tier 2).

In the simple assessment there has still been no detailed information provided of the following site-specific factors, into which further investigation should be devoted in the future:

- The soil type: its influence on emission is insufficiently clear;
- The soil characteristics (loam and organic matter content): idem;
- The type of vegetation: although emission of asbestos fibres to the air is very unlikely if there is dense vegetation, this criterion is difficult take down on record; moreover, vegetation has a heavy seasonal influence and is therefore not a robust parameter.
- Weather characteristics: although wind speed in particular has a great influence on fibre emission, its influence is difficult to quantify or take down on record. In addition, weather characteristics are difficult to predict.
- The extent of activity in or on the soil (except for (mechanical) earthworks activities and increased activity on sports grounds), such as working the topsoil or driving on the site. It is of course assumed that such activities must be able to take place safely at all times and in all places.
- Soil dampness: if the top layer of a soil has a moisture content of at least 10% at all times, this can in principle be evaluated in the same manner as a wet sediment. However, soil dampness is a parameter that varies appreciably over time and under practical conditions only the top layer at ground level will dry out quickly so that the moisture content rapidly diminishes. In addition to this, remnants of material containing asbestos and fibres/fibre bundles can easily be brought indoors on footwear, especially if the soil is wet, and present an indirect exposure risk.

In order to be able to take account of these factors on the risks for humans, further research must be carried out in future into the connection between these factors and the emission of fibres to the air. In this instance, efforts must primarily be directed at a qualitative definition of the influence of these factors; whether a quantitative description is possible is still doubtful.

6.3.3 Tier 2: Determination of respirable asbestos fibres in the soil

With the determination of the concentration of respirable asbestos fibres in the soil an assessment is given of the site-specific risks for humans on the basis of availability of these fibres. The objective is to be able to estimate the expected emission of asbestos fibres from the soil to the air irrespective of the actual use situation and environmental factors. Respirable asbestos fibres are taken to mean those fibres that are available for inhalation and which can enter the lungs. It is assumed that this is the fibre fraction with a diameter smaller than 3 μm and a length smaller than 200 μm. Determining the concentration of respirable asbestos fibres shall be carried out in conformity with NEN 5707.

Determining the concentration of respirable asbestos fibres in conformity with NEN 5707 shall proceed in accordance with the following prescription:

- Take a representative soil sample of the most contaminated spatial unit within each part location in conformity with NEN 5707. To this end take 20 batches of at least ½ kg randomly distributed over the spatial unit concerned and in the soil layer to be considered and place the batches together in a combined sample of at least 10 kg.
- Determine the weight of the damp combined sample in conformity with Section 10.1 of NEN 5707.
- Dry the combined sample and determine the weight of the dried sample in conformity with Section 10.1 of NEN 5707.
- Sift the total dry sample through a 4 mm riddle in conformity with Section 10.1 of NEN 5707.
- Mix the sifted sample smaller than 4 mm and take 20 batches of at least 5 grams randomly distributed throughout the sample and combine the batches into a part sample of at least 100 grams.
- Analyse the fraction for respirable asbestos fibres in conformity with Section 10.4 of NEN 5707.
- Calculate the respirable asbestos fibres fraction in conformity with Section 10.5 of NEN 5707.
- Assess whether it can be refuted that there are site-specific human risks: there are *no* site-specific human risks if the concentration of 'available' respirable asbestos fibres (diameter smaller than 3 μm and length smaller than 200 μm) is lower than the risk limit of 10 mg/kg_{dw} for the sum of the concentration of chrysotile asbestos (also serpentine asbestos or white asbestos) and ten times the concentration of amphibole asbestos (other asbestos types).

It is noted that the sample pre-treatment procedure described here is different in comparison with NEN 5707. In NEN 5707 a part sample is taken prior to sifting and in this guideline after sifting through 4 mm. The aim of the evaluation carried out in tier 2 is to determine the concentration of respirable asbestos fibres on the basis of a *worst-case* scenario in a use situation with soil activity. Consequently an attempt is made via the sifting process to release as many fibres as possible. The methodology is also suitable for evaluating the bonding of asbestos cement. As regards the analysis of respirable asbestos fibres in conformity with Section 10.4 of NEN 5707, ultrasound vibration must be used for approximately 30 minutes.

6.3.4 Tier 3: Measurement of the asbestos fibre concentration in outdoors and indoors air

In this section two methods are described for determining the concentration of asbestos fibres in the outdoors air, i.e. one method which is carried out on the site (Section 6.3.4.1) and a laboratory simulation (Section 6.3.4.2). A user of this guideline must himself determine which method is the best that is applicable in practice to the site concerned. A summary of the advantages and disadvantages of both methods is given in Table 6.2 to back up the choice. The underpinning and practical implementation of the asbestos fibre concentration in the outdoors air on site and during laboratory simulation must be evaluated in the future.

In the following situations the human risk must also be assessed in indoors areas (houses or other buildings):

- the indoors areas are adjacent to the contaminated site (less than 100 m);
- the contaminated site is freely accessible and is regularly (at least once a day) used (entered);
- the contamination is (also) situated at ground level (available for 'tracking in' and blowing in).

The underpinning and practical implementation of this methodology must also be evaluated in the future.

6.3.4.1 Tier $3_{outdoors}$a: Outdoors air, site measurement

Evaluation takes place by making measurements of the asbestos fibre concentration in the outdoors air on the site under 'standardised conditions'. Since it must be shown convincingly in this instance that the human risk is acceptable, these 'standardised conditions' must occur under relatively conservative conditions. However, these conditions must of course be able to occur in the (future) use situation on the site. Consequently, the measurement must take place under *realistic worst-case* conditions. If it is possible or is not desirable to take measurements during 'standardised conditions' which can occur on the site in the (future) use situation (e.g. if a future situation still to be created is involved), then a use situation must be simulated if possible. When simulating activity the regulations in conformity with the Working Conditions Law must be observed.

<u>Positioning and number of measurements</u>

- The sites where measurements are taken must be selected in such a manner that a maximum fibre concentration in the air can be expected. This implies that measurement positions are selected where the highest asbestos concentrations in the soil are measured during the soil investigation in conformity with NEN 5707.
- Measurements must be taken as close as possible downwind from the source (maximum distance from the source: 5 m downwind) without this forming a hindrance to the current use or any (simulated) activities such as running, digging, etc.
- As children are an important risk group, prescribing a measurement height of 1 m or measuring at knee height could have been considered. However, for practical reasons it was decided to fall in with NEN 5707, in which the intake aperture is at a height of 1.5 m (adult breathing height). Depending on the area, the values specified in Table 6.1 (which are taken from the ISO regulation ISO/TC/SC6/WG4-N7) are applicable to the minimum number of samples. This area refers to the most contaminated spatial unit within the part site or part lot. If a use situation is simulated, the area refers to the part of the partial site that is involved in activity simulation.

Table 6.1: Minimum number of samples to be taken to determine the asbestos concentration in outdoors air (ISO regulation ISO/TC/SC6/WG4-N7)

Area of the (partial) site to be evaluated (m^2)*	**Minimum number of samples to be taken**
Up to 100	2
101-300	3
301-600	5
601-1,000	6

* The area refers to the most contaminated spatial unit within the partial site or part lot. If a use situation is simulated, the area refers to the part of the site that is involved in activity simulation.

<u>Weather conditions</u>

- The temperature must be higher than 0^o C and the soil to be evaluated must not be frozen.
- The weather must be dry, in that there has not been precipitation for a period of at least 3 days prior to the measurement.
- The wind must be light to moderate with a maximum wind force of 4 on the Beaufort scale.
- The relative air humidity must not be greater than 60%.

<u>Measurement period/time duration</u>

- Measurements must be made over at least 6 hours and preferably over 8 hours, in the course of which at least 2.5 m^3 of air is sucked in so as to obtain the required measuring sensitivity. The average 8 hours concentration is preferred but this is frequently not always feasible in practice. For a working day of 8 hours it is assumed that the average 6 hours concentration is identical to that for the 8 hours average.

It must be noted that the NR level (just like the MPR level) is defined as the acceptable average annual exposure. However, in the proposed assessment an average 8 hours concentration is used. Please refer to TNO report R2003/108 'Proposal for a combined system of assessment values for determining asbestos concentration in air (discussion paper)' (*J. Tempelman, 2003*) for a comprehensive justification and explanation.

<u>Recording</u>

All parameters which can have an effect on the asbestos concentration and can influence the representative nature of the investigation shall be determined and incorporated in the report.

<u>Asbestos fibre concentration assessment</u>

The asbestos concentration in the air is determined with the aid of electron microscopy. Suitable methods are [sic]: ISO 14966 (scanning electron microscopy). These standards are virtually identical in implementation. If desired, the methods based on transmission electron microscopy (NEN-ISO 10312 or NEN-ISO 13794) can also be utilised provided that the required measurement sensitivity of 1,000 fibres/m^3 of air is achieved. Measurement methods which are based on phase contrast optical microscopy are aselective and insufficiently sensitive and consequently unsuitable in this context.

If all measured asbestos concentrations in the air are significantly lower than the permissible risk level, i.e. the NR level, there are *no* site-specific human risks for the assessed (and possibly simulated) use situation or activity.

6.3.4.2 Tier $3_{outdoors}$b: Outdoors air during laboratory simulation

Sampling and pre-treatment

- Take a representative soil sample from the most contaminated spatial unit within each part location in conformity with NEN 5707. To this end take 50 batches of at least ½ kg randomly distributed over the spatial unit concerned and the soil layer to be evaluated and combine the batches into a combined sample of at least 25 kg.
- Determine the weight of the damp combined sample in conformity with Section 10.1 of NEN 5707. Dry the combined sample and determine the weight of the dried sample in conformity with Section 10.1 of NEN 5707.

Simulation measurement

The measurement arrangement is shown in Figure 6.2. The following stages must be followed:

- Place the sample in an extractor cabinet or *containment* equipped with an absolute filter and an extraction speed of at least 0.5 metres/second which complies with, or is in accordance with the requirements of the Asbestos Removal Decree and the Working Conditions Act. The area of the extractor cabinet must be at least 1 m^2, with the extraction point at a height of 1.5 (1-2) metres.
- Spread the dried sample out in a 1-2 cm deep layer over an area of 1 m^2.
- Place an adjustable fan in the extractor cabinet and align the fan so that it covers the entire area. Adjust the fan so that the airspeed over the entire area is between 3 and 5 metres/second.

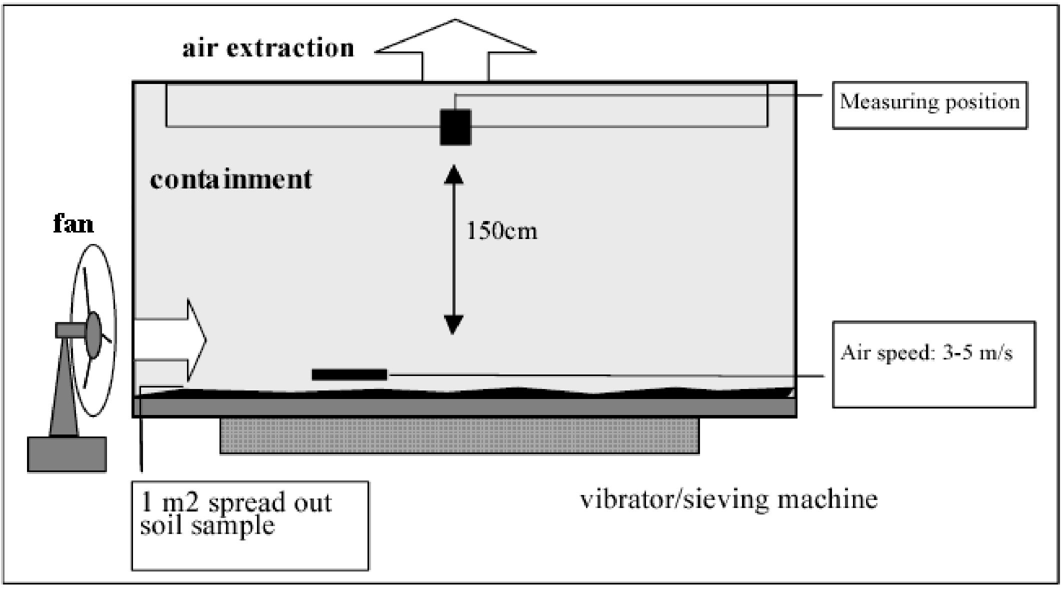

Figure 6.2: Measuring arrangement for simulation measurement in extractor cabinet or containment

As stated at the start of Chapter 6.3.4, the advantages and disadvantages of both methods are summarised in Table 6.2.

Table 6.2: Advantages and disadvantages associated with the site measurement and laboratory simulation respectively for assessing the asbestos fibre concentration in outdoors air.

Site measurement	**Laboratory simulation**
Advantages	
• Measurement under realistic use and weather conditions. • Measuring method is relatively simple and can be used by a wide target group. • Measuring method is clearly and directly applicable (by standardisation).	• Method is relatively cheap: one-off investment in measuring equipment, taking measurements relatively cheap compared with practical measurement. • Measurement is representative; combined sample originates from all the *worst-case* areas on the site. • Method is easy to standardise and results can be compared with each other. • The measuring method is *worst case* so that an under-estimate of the human risk can rarely occur. • Measuring method is independent of the weather and can be used directly at all times. • The measuring apparatus is in a small *containment* and measurement can be carried out safely and in a controlled manner (no additional working conditions measures required). • Adjusting simulation conditions is relative easy, on account of which even a bonding test can be carried out (cracking and breaking of asbestos cement material).
Disadvantages	
• Measuring result is heavily dependent on weather conditions; *worst case* is not always possible, on account of which under-estimating the human risk is possible. • Due to dependency on the weather stern criteria are stipulated for the weather conditions: on account of this a measurement is 'not always/ frequently not' possible and good conditions must (sometimes) be awaited. • Simulation of use conditions is (still) not standardised and will be difficult to achieve in practice (type of crane/bulldozer/leaf blower/plough, type of activity, duration of activity, carrying out of activity). • Measurement results are difficult to compare with each other; the result depends on the place of contamination, heterogeneity, degree of humidity, activity simulation and weather conditions. • Taking account in measurements of the Working Conditions Act and Working Conditions Decree (processing of material containing asbestos is prohibited), i.e. protective clothing, masks with P3 filter, shower cabinet, etc. • Measurement is hard due to hiring of bulldozer/ crane and taking the necessary working conditions measures. • In principle exposure risk for neighbours during measurement; additional environmental measurements needed to assess the background concentration level. • Measurement is less representative for large heterogeneous sites since a measurement can only be carried out at a limited number of places on the site.	• The measurement method is a *worst-case* simulation method and conversion to realistic practical conditions is difficult. • The test conditions are still not fully validated; additional validation research of the simulation conditions is required. • Method is complex and the protocol still needs to be worked out in detail before the method can be used by anyone. • At this time the method can only be used by TNO. • Measuring method is cheap but requires a relatively large investment in the first place; whether this investment can be repaid is dependent upon the number of future assessment situations.

6.3.4.3 Tier $3_{indoors}$: indoor air

Carry out a risk assessment by assessing the quantity of sedimented asbestos fibres in accordance with draft standard NEN 2991 ‘Risk assessment in and around buildings or structures in which materials containing asbestos are processed’.
Determine the total points on the basis of the criteria in the draft standard:

- with a score below 15 points there are *no* site-specific human risks;
- with a score over 20 points there are site-specific human risks.

With a score of between 15 and 20 points asbestos fibre concentration measurements must be carried out in indoor air in conformity with draft standard NEN 2991 ‘Risk assessment in and around buildings or structures in which materials containing asbestos are processed’. In that instance there are *no* site-specific human risks for the indoor area(s) assessed if all asbestos fibre concentrations measured in the air are lower than the acceptable risk level, i.e. the NR level.

The quality and practical implementation of the measurement methods for assessing the asbestos fibre concentration in outdoor air (on site and during laboratory simulation) and in indoor air, which can take place in tier 3 of the assessment of the site-specific human risks must be evaluated in the future.

7. Conclusions and recommendations

7.1 Conclusions

The following conclusions can be drawn from this report:

- The risks of asbestos for the ecosystem are negligible. Dispersion risks only occur as a result of air movement, not on account of transport via groundwater. The human risks are especially relevant. Since the risks of asbestos are caused by inhalation of asbestos fibres, only fibre emission from the soil to the air is decisive for human exposure. The concentration of asbestos fibres in the air is determined by primary emission (the release of asbestos fibres from materials containing asbestos in or on the soil) and secondary emission (the (re)actuation (resuspension) of asbestos fibres previously released and sedimented under the influence of certain activities or weather conditions). In both instances material characteristics, such as (the extent of) bonding and the type of asbestos (chrysotile or amphibole) play a significant role.

- Exposure to asbestos can occur directly (inhalation of asbestos fibres and/or soil particles in the outdoor air) or indirectly (inhalation of asbestos fibres in indoor air). Indirect exposure is important if the contamination borders on a house or other building. In such situations a risk can occur indoors due to 'tracking in' of asbestos particles from a contaminated site to the indoor environment (via footwear and to a lesser extent clothing) and due to blowing in.

- The behaviour of asbestos in the soil differs from that of the other contaminants regulated in the Soil Protection Act. As a result, the standard procedure, based on calculation with the CSOIL exposure model, is simply not applicable. In addition to the asbestos concentration in the soil, human exposure to asbestos is determined by a large number of factors, which can be broken down into material characteristics, soil characteristics, weather influences, activity on the site and place of occurrence and extent of the contamination.

- There are two problems for determining site-specific human exposure:
  - The influence of the activities on the site and the dampness of the soil on the availability of asbestos particles in the air should be taken into account in any event for focussing the exposure scenario and the accompanying input parameters to the site involved. However, these parameters are not incorporated in the CSOIL model. Moreover, no quantitative connections are known between both these parameters and the respirable fibre concentration in the air.
  - A protocol for measuring the asbestos concentration in indoor air is indeed being developed (draft NEN 2991), but this will simply not be suitable for use for the present objective (measurement in outdoor air too).

  For the above reasons it is proposed not to use the CSOIL model to determine the human risks as a consequence of the presence of asbestos in the soil.

- As an alternative use is made of measurement results from various experiments carried out by TNO, a supplementary collation of data from the literature and from practice. The following conclusions can be drawn from these experimental data:
  - Increased fibre concentrations in the air to in excess of the MPR level (100,000 fibre equivalents per m^3 of air) are only measured in respect of heavily contaminated soils and lots with unbound asbestos (at least 10,000 mg/kg_{dw}). In such situations even minor soil activity combined with dry weather (no *worst case* conditions) is sufficient for fibre concentrations in the air in excess of the NR level (1,000 fibre equivalents per m^3 of air).

- Fibre concentrations exceeding the MPR are virtually only measured at a short distance from the source and in the case of heavy soil activity, such as excavating, tipping and driving. As the distance increases the fibre concentration in the air declines rapidly and appears to be below the NR level at a distance of about 100 metres.
- For less heavily contaminated soils, in which principally *bound* materials (less than 1,000 mg/kg_{dw}) and in one single instance unbound products (less than 100 mg/kg_{dw}) are present, no asbestos fibres are encountered in the air in any of the instances, even in respect of activities such as digging, tipping and sifting.

A proposal for an intervention value is derived on the bases of these practical survey data.

- For determining the human risks, a distinction is made between:
  - chrysotile asbestos (or white asbestos) and amphibole asbestos (all other asbestos types);
  - unbound asbestos (asbestos for use in insulation, amongst other things, and loose asbestos fibres) and bound asbestos (asbestos in asbestos cement, amongst other things);
  - respirable asbestos fibres (fibres smaller than 200 μm) and non-respirable fibres.

In view of the fact that in bound materials the respirable asbestos fibres fraction in the soil is nil (usually less than 0.1%) – even in weathered materials – no fibre emission to the air will ever occur as a result of non-destructive activities. For unbound materials fibres are released from the material even if there are minor activities. In addition, the respirable fibres fraction in the soil is much higher so that a fibre emission can occur even with no activity.

Intervention value

Only overall conclusions may be drawn from the practical survey data. From these it can indeed be concluded that for unbound asbestos the intervention value of 100 mg/kg_{dw} for the sum of the concentration of chrysotile asbestos and ten times the concentration of amphibole asbestos, as incorporated in the *Interim policy for asbestos in soil, soil material and rubble (granulate)*(*VROM, 2002*), is a suitable value for 'standard' Dutch conditions and if the NR level is used. In this instance 'standard' Dutch conditions are taken to mean a situation in which activities such as digging, tipping and sifting of soil material are not systematically involved and the (top layer of the) soil is damp for a large part of the year.
For bound asbestos an increased quantity of asbestos fibres compared with the background concentration will virtually never enter the air. However, since it is difficult to determine when bound asbestos will change into less bound or unbound asbestos as a consequence of human activity or weathering, it is proposed to give this determination a role in the phase of assessing the site-specific risks.
In summary, it is proposed to use the value used in the interim policy, 100 mg/kg_{dw} for the sum of the concentration of chrysotile asbestos (also serpentine asbestos or white asbestos) and ten times the concentration of amphibole asbestos (other asbestos types), as the intervention value for both bound and unbound asbestos.
On the basis of *expert judgement* it is proposed to use a value of 25 m^2. In order to indicate a difference between a dumped lot of material containing asbestos and soil contamination, an *area* criterion (no volume criterion) of 25 m^2 is proposed on the basis of 'practical judgement'.

Assessment of site-specific human risks

- A guideline has been drafted for assessing the site-specific human risk of soil contaminated with asbestos on the basis of asbestos concentrations observed under practical conditions in the air and in the soil and on the basis of survey records. For asbestos it also holds true that it is assumed that a site-specific risk for humans is involved unless the opposite can be demonstrated ('risk, unless…'). Just as with the Remediation Urgency Methodology the framework consists of three tiers:

- Tier 1, simple assessment: investigation into the possibility/likelihood of exposure.
- Tier 2, assessment of respirable fibres in the soil: evaluation of the site-specific risks for humans irrespective of the actual use situation and environmental factors on the basis of an assessment of the respirable asbestos fibre concentration in the soil (in conformity with NEN 5707).
- Tier 3, measurement of the asbestos fibre concentration in the air.

  Outdoor air. A choice possibility is given for site-specific measurement of the asbestos fibre concentration in the outdoor air:
  - by means of taking measurements of the asbestos fibre concentration in the outdoor air on the site under 'standardised *worst-case* conditions' ($tier3_{outdoors}a$);
  - by means of taking measurements of the asbestos fibre concentration during a laboratory simulation ($tier3_{outdoors}b$) on the basis of a *worst-case* simulation of the use situation and environmental factors (availability test).

  Indoor air. If houses or other buildings border the contaminated site (distance less than 100 m) and it involves contamination with unbound asbestos, site-specific measurement of the asbestos fibre concentration in the indoor air must also take place under 'standardised conditions' in conformity with draft NEN 2991 ($tier3_{indoors}$).

Re tier 1: In assessing the site-specific human risks it is proposed to use a risk limit of 1,000 mg/kg_{dw} for *bound asbestos* for the sum of the concentration of chrysotile asbestos and ten times the concentration of amphibole asbestos (other asbestos types). As a condition it is stipulated that the bound materials do not turn into a weathered state.

Re tier 2: Irrespective of the soil use, the proportion of respirable asbestos fibres (with a diameter smaller than 3 μm and a length smaller than 200 μm) is of importance for determining the site-specific human risks. As regards the assessment in tier 2 (respirable fibres assessment), a threshold value of 4.3×10^{10} fibre equivalents/kg_{dw} is proposed. Converted into a weight concentration this corresponds in terms of order of magnitude with a threshold value of 10 mg of respirable fibres per kg of earth (dry weight) for the sum of the concentration of chrysotile asbestos and ten times the concentration of amphibole asbestos (other asbestos types).

Re tier 3: Since it must be demonstrated with some conviction that the human risk is acceptable, the 'standardised conditions' will have to be represented by relatively conservative conditions. However, these conditions must indeed be linked to the future use situation. Consequently, conditions are described in tier 3 with the aim of being able to estimate the asbestos fibre concentration in a future use situation on the basis of a *realistic worst-case* scenario. In $tier3_{outdoors}b$ *worst- case* conditions are created which in principle can be fitted with difficulty into a future use situation. The method must be seen as an availability test in which the asbestos fibre concentration in a future use situation will always turn out to be lower. Advantages and disadvantages which are summarised in Table 6.2 are associated with both methods.

7.2 Recommendations

The following recommendations are made on the basis of the present report:

- Additional practical measurements must be carried out in order in particular to investigate in more detail fibre emission in the concentration range from 100 to 10,000 mg/kg_{dw}.

- In order to be able to take account of the influence of site-specific factors on the risks for humans as a result of asbestos in the soil, further research must be undertaken into the relationship between the following factors and the emission of asbestos fibres to the air:
  - soil type;
  - soil dampness
  - soil characteristics (loam and organic matter content);
  - type of vegetation;
  - weather characteristics;
  - extent of activity in or on the soil.

  In this instance efforts will in the first instance be directed at a qualitative definition of the influence of these factors on emission. Whether a quantitative description is possible is as yet doubtful. In the first instance the feasibility of deducing qualitative and quantitative connections can possibly be investigated in a feasibility study.

- The influence of 'tracking in' of asbestos particles from a contaminated site to the indoor environment (via footwear and to a lesser extent clothing) on indoor exposure and the influence of the material and soil characteristics such as soil dampness on this process must be investigated in more detail.

- The transition from bound to unbound asbestos (processes/activities required, length of time needed) must be investigated in more detail.

- The underpinning and practical implementation of the measurement of the asbestos fibre concentration in outdoor air (on site and during laboratory simulation) and in indoor air, which can take place in tier 3 of assessing the site-specific human risks, must be evaluated.

- The conclusions from the workshop on the evaluation of the site-specific human risk of asbestos in the soil, which will be organised by the VROM Ministry, must be incorporated in any implementation.

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Appendix 2 Summary of the (draft) NEN standards mentioned in this report

NEN 5707: Soil – Inspection, sampling and analysis of asbestos in the soil and in batches of earth, ICS: 13.080.01, May 2003.

NVN 5725: Soil – Manual for carrying out preliminary investigation for exploratory, pilot and further investigation.

NEN 5740: Soil – Research strategy for exploratory research - Investigation into the environmental hygiene quality of soil and earth, 1999.

NEN 5896: Qualitative analysis of asbestos in materials with polarisation microscopy, ICS: 13.030.30, May 2003.

O-NEN 2991 (in preparation)
Risk assessment in and around buildings or structures in which materials containing asbestos are processed.

Appendix 3 Effects on health

Clinical picture details

Mesothelioma

Asbestos is the foremost cause of the occurrence of mesothelioma. For mesothelioma a link with asbestos has been made plausible in 85% of cases. Smoking behaviour does not affect the chance of the occurrence of mesothelioma. Epidemiological research and various cohort and autopsy studies suggest that the amphiboles, and crocidolite in particular, seem to have a higher carcinogenic potency than chrysotile asbestos. There is no effect level for mesothelioma. Mesothelioma can even occur after a single high exposure to asbestos or after regular exposure to relatively low concentrations. The chance of mesothelioma is proportionate to the dose and exponentially related to the time that has lapsed since the initial exposure. This means that in the event of exposure at a young age, there is a greater chance of getting mesothelioma than in later life. Consequently exposure of young persons is relatively more dangerous compared with exposure of older people (Slooff and Blokzijl, 1987). This form of cancer is relatively rare and will be found in particular in people who are exposed to asbestos over a long time in their work.

Asbestosis

Asbestosis is a chronic lung disease that is characterised by fibrosis (connective tissue formation) of lung tissue. Due to the formation of this connective tissue, there is a serious loss of elasticity and the oxygen absorbing capacity of the lungs declines. By definition asbestosis is caused by asbestos and only occurs from exposure to rather high concentrations , e.g. in work situations. The carcinogenic effects occur at both high and low concentrations. Inhalation of large quantities of asbestos over a short time at different periods causes a more severe amount of fibrosis than a more continuous exposure to the same ultimate dose of asbestos. Asbestosis forms no great problem in the event of exposure to low concentrations. The chance of the occurrence of asbestosis increases proportionately to the concentration and duration of exposure. The chance of developing asbestosis is very low and will likewise be encountered in people who have been exposed to asbestos for a long time in their work.

Lung cancer

A link with the occurrence of lung cancer has been demonstrated for all types of asbestos, including chrysotile, under certain conditions. There is no evidence of differences in response between the type of asbestos and the occurrence of lung cancer. On the other hand, lung cancer can only rarely be attributed with certainty to exposure via inhalation of asbestos fibres. Lung cancer is of course a comparatively more frequent sort of cancer and can have all sorts of causes (80-90% by smoking). The risk of contracting lung cancer through exposure to asbestos is some 10 times as great for smokers (*Brand et al., 1994; Slooff and Blokzijl, 1987*). For non-smokers the chance of lung cancer increases exponentially with age. Data from five cohort studies confirm this picture and gave no occasion to review the generally accepted assumption that death from lung cancer as a result of asbestos exposure is roughly directly proportional to the cumulative dose (Slooff and Blokzijl, 1987). There is no effect level for lung cancer.

Determining factors details

The type of asbestos

Amongst other things, the shape of the asbestos fibres and the durability and friability of the asbestos fibres are dependent on the type of asbestos (chrysotile, amosite, crocidolite); see paragraphs below.

The fibre dimensions

Internal exposure – this refers to the actual exposure of the target organs – which takes place after inhalation has occurred, and the carcinogenic potency of asbestos fibres is dependent on the dimensions (shape, length and diameter) of the fibres; see Figure 1 (Pott's theory; *Pott, 1978*).

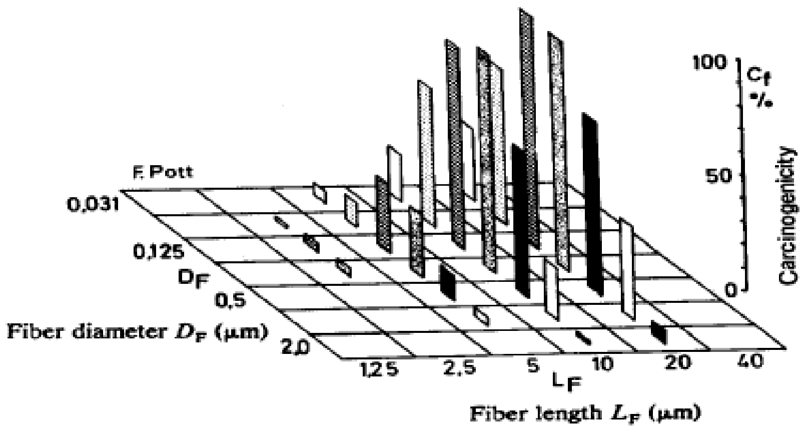

Figure 1. Chart depicting a hypothesis of carcinogenic potency of cylindrical fibers as a function of their lengths and diameters.

Figure 1: Carcinogenic potency as a function of fibre length and diameter (Pott's theory).

Carcinogenic potency increases as the fibres become longer and thinner (Slooff and Blokzijl, 1987). The higher carcinogenicity of longer fibres could have the effect of their poorer absorption by macrophages. The fibres with a length of between 5 and 40 μm (optimum 20 μm) and a diameter of between 0.1 and 1 μm (optimum 0.25 μm) are particularly carcinogenic. Due to absorption by macrophages the risks of fibres with a length shorter than 5 μm are lower by a factor of approximately 10.

The lower limit for respirability of fibres, which is relevant for internal exposure, is a fibre diameter of approximately 3 μm and a fibre length of 200 μm. Fibres with a diameter of more than some 0.6 μm are found principally in the trachea and the bronchi. From these parts of the respiratory system the fibres are removed relatively quickly (hours) via the ciliated epithelium and transported to the alimentary canal. Fibres with a length greater than 100 μm virtually always have a fibre diameter greater than 0.6 μm so that these longer fibres are removed relatively quickly.

Fibres with a diameter less than some 0.03 μm are principally trapped in the nose/pharynx. A large part of the fibres with a diameter between 0.03 and 0.6 μm penetrate into the deeper (alveolar) parts of the lung where there is no ciliated epithelium. Removal from these parts of the lung, inasmuch as this happens at all, can last months or years (*Slooff and Blokzijl, 1987*). Most fibres with a length of up to 5 μm entering the deeper (alveolar) parts of the lungs are quickly bound by macrophages. Only a small proportion of the macrophages containing these fibres will be transported to the airways lined with ciliated epithelium. Most macrophages and free fibres migrate slowly to the outskirts of the lungs (periphery) and to the pleura, where the asbestos fibres are finally contained.

Duration of exposure

The longer one is exposed to a certain quantity of asbestos fibres via the air, the greater the chance of contracting cancer. However, if one occasionally has to cope with a short-term peak load of asbestos fibres, this hardly ever results in a relevant increase of the existing risk since the contribution to the total number of fibres inhaled throughout life is very marginal (IMH, 1994).

Durability and friability of asbestos fibres

The durability and friability of asbestos fibres in an organism play an important role. The more durable and friable the fibres and the longer the time they remain in the body, the greater the carcinogenic potency. Crocidolite and amosite in particular are very durable in the body and can easily be split lengthwise in the lungs. Chrysotile is far less durable than the amphibole asbestos types. In chrysotile fibres magnesium is leached under the influence of acid, on account of which they become thinner and the structure of the asbestos is lost. The fibres gradually disappear from the lungs and then also lose their cancer-causing characteristics. As a consequence of their crimped shape chrysotile fibres also penetrate less deeply into the upper airways than amphibole fibres with the same diameter.