Executive summary

Health Council of the Netherlands. Risks of soil contaminants for human health: soil-testing procedures, models, standards. The Hague: Health Council of the Netherlands, 2004; publication no. 2004/15

There are a great many sites throughout the Netherlands where the soil is contaminated with heavy metals, polycyclic aromatic hydrocarbons, mineral oil, pesticides, and other organic compounds. Sixty to eighty thousand sites are in urgent need of remedial action. The estimated cost of such remedial action amounts to well over 18 billion euros. In the 1990s, the government instructed the National Institute of Public Health and the Environment (RIVM) to derive a set of soil standards. A soil-testing procedure was also developed. In this advisory report, at the request of the former Minister of Housing, Spatial Planning and the Environment (VROM), a committee of the Health Council of the Netherlands presents its verdict on the data, methods and models used by RIVM to derive these standards. It assessed these aspects together with the soil-testing procedure. In the course of this work, the Committee has restricted the scope of its investigation to those standards and procedures which relate to the protection of humans. The protection of ecosystems and the extent to which substances are distributed have been given no further consideration in this advisory report.

Soil testing

The soil-testing procedure includes a number of steps for determining whether severe contamination has occurred, whether measures need to be taken immediately, and the degree of urgency regarding possible remedial action.

In the course of a so-called exploratory investigation, a limited number of samples are taken. These are then used to measure the concentrations of a standard group of substances. If the concentration in just one of the samples exceeds the testing value (the average of the intervention value and the target value), then further investigation is mandatory.

Such further investigation involves extensive sampling of the soil to determine the severity, nature and extent of the contamination. Soil contamination is described as 'severe' when the intervention value is exceeded in a given area (or volume) of soil. If this proves to be the case then a risk assessment is carried out to investigate the various ways in which individuals at that site might be exposed to the harmful substances in question. Could children ingest contaminated soil while playing? Are vegetables being cultivated on site which could absorb these substances and could anyone consuming these vegetables ingest these substances? Are individuals at the site inhaling contaminated air? When answering these questions, the characteristics and properties of the site are taken into account. The answers to these questions determine whether measures are taken to prevent exposure to these substances. In addition, a remedial investigation is carried out to identify the appropriate remediation method and to establish a period of time within which remedial action must be completed.

Current methods for deriving standards

Testing value and intervention value

In the course of exploratory and further investigations, soil samples are tested against standards which apply throughout the Netherlands. In the case of exploratory investigations, this is the testing value, while the relevant standard for further investigation is the intervention value.

The testing value is found by calculating the average of the target value and the intervention value. The target value indicates the level at which there is a sustainable soil quality. For naturally occurring substances, this is mainly based on background levels in the Netherlands.

The intervention value is intended to protect health, both of humans and ecosystems. The intervention value is determined by calculating one value for the protection of humans and another for the protection of ecosystems. The lowest of these two values serves as the intervention value. In this advisory report, the Committee will restrict itself to the standard for the protection of human beings: the $MPC_{human,soil}$.

The derivation of the $MPC_{human,soil}$ involves several steps. The starting point is the Maximum Permissible Risk Level, as indicated by the Minister of Housing, Spatial Planning and the Environment (VROM) in the policy paper entitled *Premises for Risk*

Magagement (1989). RIVM uses data on a substance’s toxicity to calculate a concentration which is considered to correspond with the concentration identified by VROM. This concentration, the Maximum Permissible Concentration (MPC_{human}), is considered to be the highest appropriate health-based exposure level. This MPC_{human} – which is expressed either as a concentration in the air or as an amount for oral ingestion – is then converted to a concentration in the soil: the $MPC_{human,soil}$. This conversion is carried out using the CSOIL model.

The CSOIL model

The CSOIL model consists of a number of calculation rules which serve to quantify the routes through which individuals are exposed to a given substance. This quantification is used to convert the MPC_{human} to a concentration in the soil (the $MPC_{human,soil}$). The three most important routes by which exposure can take place are: ingestion of soil by children, inhalation of indoor air, and the consumption of vegetables. Averages are generally used for the values of the parameters (which make up part of the calculation rules).

The exposure to substances resulting from the ingestion of soil by children is determined by a single parameter, namely the amount of soil ingested by children on a daily basis. That quantity is derived from applied research.

CSOIL's ‘inhalation of indoor air’ module describes various environmental chemical processes by which volatile substances in the soil are transported to indoor and outdoor air. The concentrations in the indoor and outdoor air are combined to produce a single value for the exposure, based on the period of time that people spend indoors or outdoors. The processes in question include a large number of parameters.

Exposure via vegetables is calculated in CSOIL on the basis of an estimate of the amount of self-cultivated vegetables that residents are capable of consuming, and the level of accumulation of contaminants in the various species of vegetables. For each individual species, a weighting factor is determined for the fraction of total vegetable consumption accounted for by the species in question. The amount of contaminant in the various vegetables is calculated using bioconcentration factors (BCF). A BCF illustrates the relationship between the concentration in the vegetable and the concentration in the soil. The following approach is used when calculating the average BCF value for the accumulation of heavy metals and arsenic in vegetables. A Freundlich-type equation (borrowed from soil science) expresses the relationship between the concentration in the plant, various characteristics of the soil, and the concentration in the soil. RIVM uses two data sets, per metal and per vegetable, to fill in the values in the above equation. This produces a relationship, per metal and per vegetable, between the concentration in the plant on the one hand, and the concentration in the soil and the characteristics of the soil on the other. This data is then combined with the above-mentioned weighting factors for vegetables, which ultimately produces an average BCF value for vegetables.

CSOIL in risk assessments and in determining the urgency of remedial action

When assessing the risk in the course of further investigation, the first thing to do is to determine whether the exposure routes modelled using CSOIL are appropriate for the site in question. For example, if the surface of the site is paved, then it would be inappropriate to examine the consumption of vegetables and soil ingestion by children. In order to calculate the exposure, CSOIL would again be used (or models derived from it). However, it would now include site specific parameters such as the level of groundwater and various soil characteristics. CSOIL also has a major part to play in establishing the urgency of remedial action.

The Committee's remarks concerning current methods for deriving standards

Use of averages deprives vulnerable groups of protection

When employing the CSOIL model to translate the MPC_{human} to an $MPC_{human,soil}$, RIVM uses average values for all parameters. The Committee points out that the government's risk policy is generally based on the protection of individuals and vulnerable groups (such as children and the elderly) against exposure and vulnerability to effects. The decision to use average values implies that the policy accepts that if exposure is equivalent to the level of the $MPC_{human,soil}$, then the MPC_{human} will be exceeded in the case of an unknown (but possibly large) number of the exposed individuals. The greater the uncertainty in the assessment of exposure, the greater the risk that some of those involved will be exposed to concentrations in excess (possibly far in excess) of the MPC_{human}. The decision to use average values for the CSOIL parameters is not the only factor influencing the frequency of incidents in which the MPC_{human} is actually exceeded. The latter is also dependent on the model's predictive power and on the precision of soil-testing.

CSOIL's predictive power varies with exposure route

CSOIL's prediction of actual exposure to substances is more reliable for some exposure routes than for others. The Committee takes the view that it is most reliable when used to determine the exposure resulting from soil ingestion. In the calculation, only a single parameter is at issue. The values for this parameter are obtained from applied research. The Committee urges that, rather than using an average value for this parameter, a value be selected that offers greater protection. On the other hand, they feel that exposures from the consumption of vegetables and the inhalation of air, calculated using CSOIL, are too unreliable for the derivation of generic intervention values. The permeation coefficient alone, which is used to calculate exposure to volatile substances via inhalation, can vary by a factor of one million. Instead of an average value for this parameter, CSOIL uses a value that is quite conservative for most soil types. However, some of the other parameters in the inhalation module can produce a level of uncertainty spanning several orders of magnitude. The enormous variation in the input parameters leads to enormous variation in the final results generated by this CSOIL module. The fact that this module has not yet been validated means that there is some doubt about the model's ability to predict actual levels of exposure.

The Committee also has a number of fundamental objections to the way in which the accumulation of metals in vegetables in estimated. This derives from the fact that certain soil characteristics are not taken into consideration. Another objection relates to the data sets used to derive the Freundlich-type equations. These equations are unable to produce accurate estimates of the effect of individual soil factors, since these characteristics are strongly correlated with one another in the data set which was used. Another drawback derives from the BCF concept itself. The concentration of a contaminant in the plant is related to the concentration of that substance in the soil. This fails to take account of the existence of other contamination routes, especially atmospheric deposition, for example. In the case of the field data in question, the part played by atmospheric deposition is far from negligible. With regard to the accumulation of organic substances, the differences between the experimentally determined values and the values predicted by the model are too great to enable reliable values to be derived.

Continuing uncertainty regarding need for remedial action

Ecological or social considerations are also involved in the decision to undertake remedial action. The Committee's comments regarding whether or not it is justified to take remedial action at a given site apply solely to situations involving remedial action in response to incidents in which the MPC_{human} has been exceeded.

The uncertainties in the model and the distribution of input-parameter values can lead to substantial overestimation or underestimation of individuals’ exposure to potentially hazardous substances. The uncertainty in the $MPC_{human,soil}$ calculated using CSOIL extends to all areas of soil testing. Exploratory investigations are subject to additional uncertainty, due to the limited sampling involved. Accordingly, there may well be sites where, quite unjustifiably, no further investigation has taken place, even though actual exposure levels have exceeded the $MPC_{human.}$ Further investigation gives a better impression of the actual concentrations of substances in the soil, as a result of the more extensive sampling involved. Given the major uncertainties in the model, however, it provides no sense of the actual exposure to substances that has occurred. In addition, it has been shown that the risk assessment of any given site can vary enormously, depending on which of the current soil-testing protocols is used. This is a result of the arbitrary way in which parameter values can be modified in the model, and of which parameters are selected for extra measurements at the site, such as temperature or the level of groundwater. Thus, under the current system, the possibility cannot be excluded that remedial actions could be carried out in response to a supposedly elevated human exposure, even where there is actually little or no basis for such a suspicion. The reverse could also occur. No action is taken as exposure levels are thought to be low, while the opposite is in fact the case.

The introduction of CSOIL meant greater standardisation, which facilitated investigation of the many contaminated sites throughout the country. However, the model's predictive value for the concentrations to which individuals are exposed is unknown. As a result, it is not known to what extent decisions on whether or not to undertake remedial action (based on a supposedly elevated human exposure) were justified. The Committee was astonished to find that this model, which is so influential in practical situations, has never been properly validated.

An alternative approach

Greater focus on historical investigations

The Committee advocates a greater focus on historical investigations into the use of the site in question, as is the case prior to exploratory investigations. Such historical investigations should focus on which substances they can expect to find, where, and in what concentrations. A sampling strategy should be drawn up on the basis of the results obtained. Past experience can be of great assistance in this regard. It might be possible to draw up guidelines for certain situations, e.g. soil contamination caused by gas plants and pumping stations.

A new type of intervention value

Tests can then be carried out involving a new type of intervention value. In this context, the Committee favours the philosophy that was used when fixing the LAC threshold value for vegetables. The Agricultural Advisory Committee on Environmental Contaminants, which drew up these threshold values, appreciated the difficulty involved in assessing current risks on the basis of soil measurements and through the use of a generic approach. The essence of a threshold value is that values lower than this should not be expected to pose any health risk. If this value is exceeded, then a follow-up investigation should take place. The Committee suggests that drinking water standards be used for the inhalation route. Should measurements taken in the practical situation show the drinking water standards to be overly conservative, then the standards for the inhalation route can be adjusted upwards. In the case of vegetables, the same method can be employed as was used to derive the LAC threshold values for vegetables. In the case of metals, these values were based on the crop that was most vulnerable to accumulation, given a critical combination of soil characteristics. While they are certainly usable, the values for ingestion of soil require some modification of the assumptions concerning protection, as previously pointed out.

Measurements using contact media

When a new intervention value is exceeded, this should lead to further investigation, which should primarily involve measurements in contact media. After all, this is the only way to check whether exposure has actually occurred and whether the MPC_{human} values have been exceeded. Various methods can be used to measure exposure via inhalation. In the case of exposure via vegetables, the Committee urges that measurements be carried out using crops which are highly responsive to changes in soil concentrations of the substance in question. This approach improves the detection of possible problem situations. If one of the values in question is exceeded in these indicator crops, then more in-depth testing is required. The pot testing of contaminated soil – possibly involving indicator crops – might provide a clear picture of possible exposure through the consumption of vegetables.

In the past, measurements in contact media have regularly been used in various further investigations. Sadly, the results of these measurements have never been subjected to integrated analysis. Data of this kind would enable an assessment to be made of the degree to which intervention values overestimate or underestimate the risk involved.

In conclusion

In summary, the Committee concludes that current intervention values provide no guarantee of protection, nor are they suitable criteria for remedial action. When a new intervention value is exceeded, this should lead to further investigation, which should primarily involve measurements in contact media. Measurements in contact media can lead to substantial cost savings, by reducing the frequency of unnecessary remedial action.

The Committee urges that consideration be given to the repercussions of using Soil-use Specific Remediation Objectives (SROs) as target objectives for remedial action. The levels of intervention values for many substances are determined in accordance with the standards for the protection of ecosystems (the HC50), since these are often lower than $MPC_{human,soil}$. This means that people have an extra, inbuilt protection against these substances. However, the levels of the target objectives for remedial action (which are also calculated using the CSOIL model) are dependent on the use to which the site in question is put. The above-mentioned protection is not afforded to those with gardens or allotments, since scenarios of this kind only involve risks to people. Given the above-mentioned uncertainties inherent in CSOIL, which is also used to calculate the SROs, there is clearly a risk that even remediated soil can produce exposures that exceed the MPC_{human}.