ELSEVIER Journal of Hazardous Materials 61 (1998) 249–255

JOURNAL OF HAZARDOUS MATERIALS

The grey areas in soil pollution risk mapping The distinction between cases of soil pollution and increased background levels

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Abstract

The progress of soil clean up in the Netherlands is severely hindered by the lack of common agreement on how to describe the grey areas of increased background levels of pollutants. In this study practical methods are proposed in which background levels are described as distribution functions within map units of comparable homogeneity. To stimulate large scale implementation the statistical methods are simple and robust. In most applications percentiles are preferred above averages. Applications include the trigger value for further investigation and the target values for soil clean up. Special attention has been given in developing methods which avoid high sampling costs. Aspecially the described method for evaluation of soils can be re-used can lead to considerable cost reduction, while maintaining a soil protection policy of "stand still".

Keywords: Grey areas; Soil pollution risk mapping; Increased background levels

1. Introduction

Until recently, the Dutch government was convinced it could clean our soils to levels where no contamination exists. Policies changed due to financial limitations. The new policy, called ‘active soil management’, accepts the fact we have to live on soil negatively influenced by many ages of land use. Maps indicating areas with pollution risks in relation to vulnerable forms of land use, are becoming important instruments for local authorities. These maps are used for answering questions such as ‘is it possible to

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0304-3894/98/$19.00
PII S0304-3894(98)00129-0

build houses here or is soil remediation needed?' A particular problem in the soil pollution risk maps is the description of background levels of pollutants. Are these only caused by natural soil forming processes? Or can these have diffuse anthropogenic sources such as deposition of air pollutants? Is it an average value or a maximum? Which concentration level must be used to distinguish between local cases of soil pollution and increased background?

Commission of the IPO, the council of Dutch provinces, performed a definition study [1] last year. A new approach is developed to describe background levels as distribution functions within homogeneous map units, looking at texture, land use and historical development. This procedure supports practical solutions for governmental decisions in cases of re-use of contaminated soils, while maintaining a soil protection policy of at least 'stand still'.

2. Experimental

Soil pollution risk maps in the Dutch urbanised areas are generally composed of four different geographical layers of information [2]: (a) historical land use and suspected polluted sites, (b) investigated sites, including contamination levels, (c) soil texture and vulnerability in relation to the actual and future land use, and (d) background levels of soil contaminants. To produce the first three layers large-scale historical investigations are performed in which systematically for every property data on all former and potential riskfull activities are gathered, stored in databases and visualised with maps and geographical information systems. This study focused on determination methods and applications of layer d, the background values.

To establish map units in layer d and generate background values within each unit, information of the first three layers is used. In the first step, historical information on urban development from layer a is combined with maps on soil texture and land use from layer c. Examples of typical map units for background levels in Dutch cities are shown in Table 1.

The next step deals with sampling the map units. In units with expected similar load of diffuse contaminants such as heavy metals and PAH, the background levels are determined. All areas of potential point sources of these contaminants are excluded from sampling based on the information of map layers a and b. Due to the fact that in most applications of the map percentiles from the right tail of the frequency distribution are used, the quality of the map may be strongly influenced by extreme concentrations connected with non-detected point sources. Statistical tests (Dixon's *Q*-test [3]) in

Table 1
Example of different types of areas in maps with background levels

Description	Former land use	Texture	Background
new housing area	agricultural	clay	Cu
old city quarter	small trades/housing	sand/misc.	PAH, Pb
recreational area	natural park	clay/peat	Zn, As

Table 2
Sample sizes for determining P90 from the distribution of background levels ($\alpha = 0.20$)

Observed coefficient of variance	P90 < 0.5 * I (precision > 50%)	P90 > 0.5 * I (precision > 75%)
< 0.5	10	30
0.5–1.0	25	100
1.0–1.5	75	200
1.5–2.0	100	400

combination with expert judgement are used to remove data not in accordance with the local pattern of background concentrations.

The most adequate sampling strategy is a random pattern in which the number of samples depends of the observed variance. Measured coefficients of variance for heavy metals and PAH in Dutch cities mostly varied between 0.5 and 3 [1]. A practical guideline for the size of the sample is given in Table 2. This guideline is based on representative lognormal distribution functions and definition of the background value as a 90-percentile. The required sample size is calculated in an iterative process based on the formulae of Conover [4] for confidence intervals of percentiles. Depending on the a priori estimation of the variance and the observed difference between the background level and risk based intervention values, the sample size increases. In areas where the background value is less than half of the intervention value, less precision is required than in areas where there is a possibility background values exceed the risk based values.

The combination of intensive historical research and the sampling programme to establish background levels is rather expensive. A less costly approach for many local authorities is to establish risk maps using all available soil quality data.

Most municipalities in Holland receive lots of reports on site investigations due to environmental legislation and regulation for building permits. In these investigations, various sampling strategies are used as systematic, stratified or judgement sampling, but mostly not random. The data include single samples and different types of composite samples, based on 2 up to 10 subsamples. For the practical applicability of soil risk maps in local government, it is important to know if these available datasets could be used or that additional tailor-made sampling schemes are required. A simulation study

Table 3
Influence of the sampling strategy on the simulated 90-percentile of the distribution of the background levels

Sampling strategy	Number of subsamples	Coefficient of variance			
		0.5	1.0	1.5	2.0
1. single samples	1	3.3	4.1	4.4	4.5
2. composite samples	3	2.8	3.4	3.7	4.3
	6	2.5	3.0	3.5	3.8
	9	2.4	2.9	3.3	3.4
3. single and composite	1–9 (random mix)	2.6	3.1	3.6	3.7

Average = 2 mg/kg, range coefficients of variance: 0.5–2.0).

was performed to estimate the effect of the different types of 'mixed' datasets on the calculated 90-percentile background values. The results are shown in Table 3.

3. Results and discussion

An example of a map with background levels of soil contaminants, established with described method, is shown in Fig. 1. Four classes of soil quality are distinguished, ranging from good quality (background values < reference value for 'multipurpose' soil quality) up to intermediate and doubtful qualities, where increased background levels are not without risks and may restrict the land use. For most applications, percentiles in the range of 80 to 90% are preferred. It is practical compromise between taking a small chance on false positives (background concentrations evaluated as point sources) to gain a large win in sampling costs. Reliable determination of higher percentiles such as P95 or P99 requires large numbers of samples.

As can be seen in Table 3, the numerical value of the high percentiles is not very sensitive to changes in sampling strategy. In general, when single samples are used, larger background values are obtained than with composite samples. The differences are small as compared to uncertainties in other stages of site-investigations and risk assessment; so, for the composition of maps with background values, the use of available 'mixed' datasets is adequate in most areas.

One of the applications of the soil pollution risk map deals with the evaluation of preliminary site investigations. To distinguish between a local point source and increased background levels 90-percentiles are recommended as trigger value for further investigation. This value is also appropriate for setting target values in clean-up operations.

The application most discussed is the use of the risk maps for evaluating the re-use of contaminated soils. Increased background levels in combination with regulations to handle excavated soil as a waste material were causing enormous costs in infrastructure and building projects.

The new governmental policy aims to stimulate the re-use of secondary waste-materials such as excavated soil, while preventing deterioration of soil quality by illegal dumping. To sample and investigate every pile of soil before it can be re-used, is not very practical. In the proposed methods, it is allowed that re-use in areas, described with soil pollution risk maps, does not necessarily imply sampling for soil protection control. In Fig. 2, an outline is given for the evaluation of soils regarding the suitability for re-use. No permit for re-use is given when the soil is part of local case of pollution or part of a (historical) suspicious site.

Soil originating from areas where the background is not increased as compared to the reference values for good soil quality, may be re-used anywhere without sample analysis. The quality of soil coming from areas with a slightly increased background level (quality 2) has to be compared with the quality of the soil in the area the re-use is planned. This is only paperwork if sufficient soil quality data from both areas are available. If the 50- and 90-percentiles of background contaminants in the area of soil origin are not significantly increased as compared to the corresponding percentiles in the

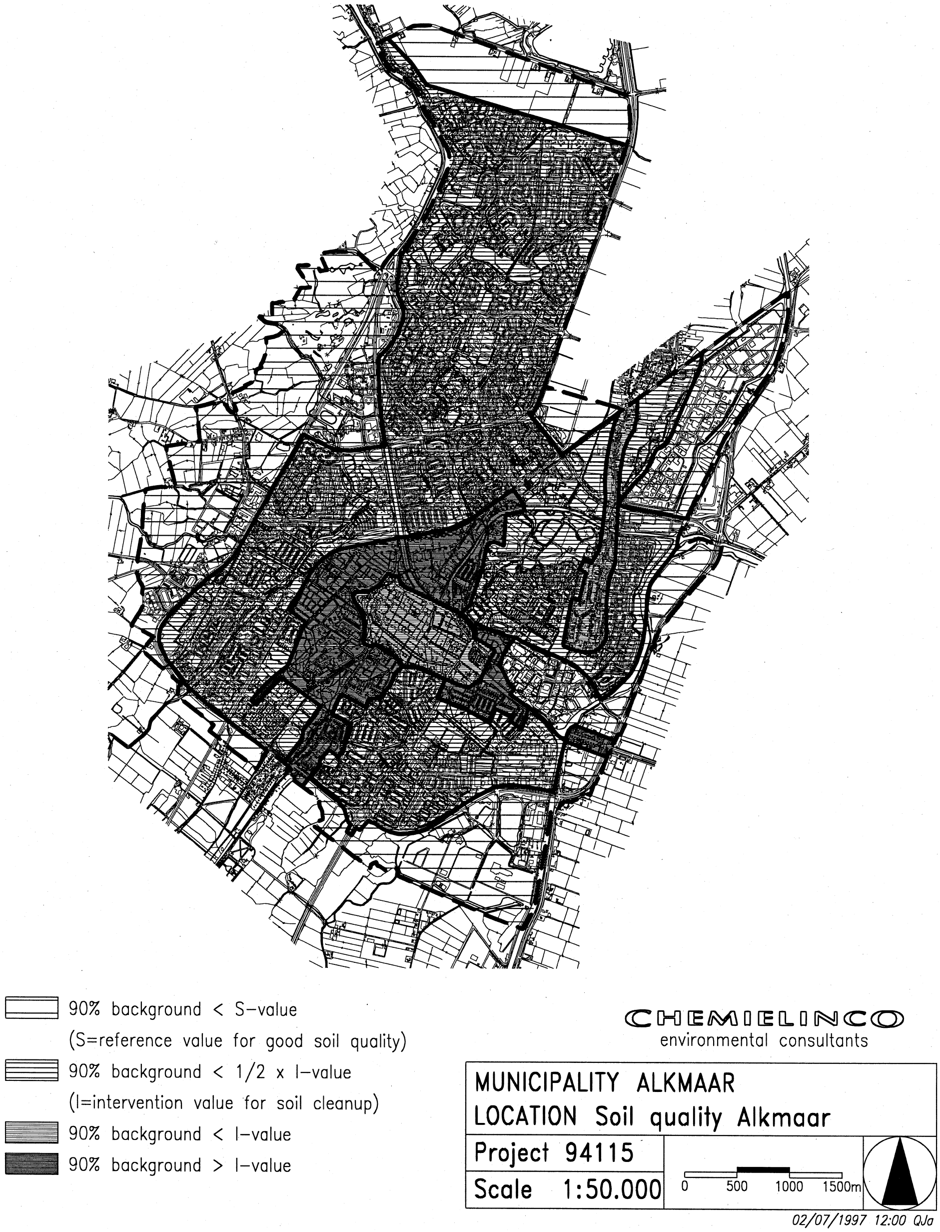

Fig. 1. Map of background values of soil contaminants in the city of Alkmaar.

application area, the soil is considered suitable for re-use. Both percentiles are used to prevent enlarging the total load of contaminants as well as preventing the occurrence of higher extreme values.

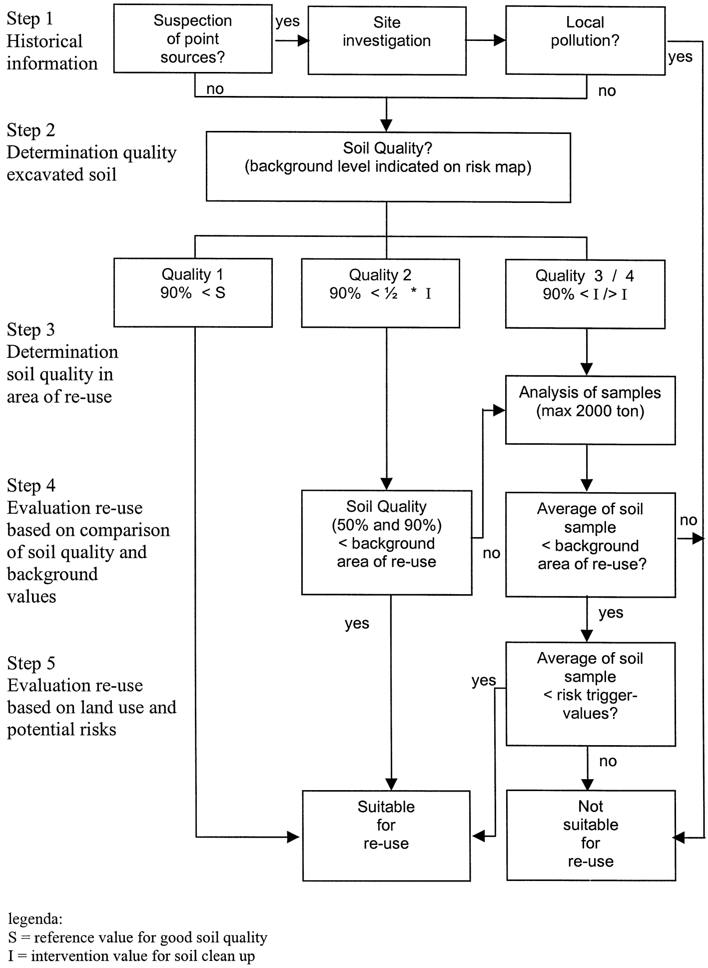

Fig. 2. Outline for the evaluation of excavated soils for determining re-use possibilities in areas described with soil pollution risk maps. Legends: = 90% Background < S-value (S = reference value for good soil quality); = 90% background < $1/2 \times I$-value (I = intervention value for soil clean-up); = 90% background < I-value; = 90% background > I-value.

In this comparison of soil qualities, it is important to limit the number of parameters to three or four relevant background contaminants; otherwise the probability is large that re-use is not allowed on some minor quality differences. For soils coming from areas with moderate to highly increased background levels (qualities 3 and 4), sampling and analysis is still required. These areas are often characterised by large soil heterogeneity and the actual quality can differ from the quality indicated on the map. Moreover, there is a possibility that limit values concerning health or environmental risks are exceeded. A sampling protocol is used in which the average of soil quantities with a maximum of 2.000 ton is determined. This average is compared with the background levels in the area of re-use as well as with the risk based trigger values, before the green light for application is given.

4. Conclusions

Most of the decisions on soil pollution in the Netherlands are taken in the grey areas of increased background levels. The progress of soil cleans up and the re-use of excavated soil is severely hindered by the lack of common agreement on how to describe them and how to use them in local government policies.

In this study, practical methods are proposed in which background levels are not seen as contourlines or numerical values, but described as distribution functions within map units of comparable homogeneity. Although in the developed concept, the use of statistical methods is unavoidable, to allow large-scale implementation, they are simplified and robust. In most applications, 90-percentiles are used instead of averages. Applications include the trigger value for further investigations and the target value in clean-up operations. Special attention has been given in developing methods, which are practical and avoid high sampling costs. The local maps with background levels can be established while using different sorts of data, already collected within other municipal tasks.

The described method for evaluation of soils to determine re-use possibilities, specially, can lead to considerable cost reductions in soil clean-up and infrastructural works, while maintaining the soil protection policy of ‘stand still’.

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