KNOWLEDGE-BASED SAMPLING STRATEGY FOR SOIL STOCKPILES

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Summary

Over the last three years the Centre for Soil Treatment has sampled 2570 soil stockpiles for the assessment of soil quality. For all stockpiles the same sampling strategy was used. 100 increments of approximately 180 grams were taken and collected into two batch samples. Appropriate sample pre-treatment and analyses resulted in two sets of analytical results per stockpile. These paired results were statistically interpreted in order to define the heterogeneity of the original soil stockpiles. By estimating this original heterogeneity, the effectiveness of the used sampling strategy could be determined. It is concluded that the chosen sampling strategy is adequate for the majority of soil stockpiles.

1 Origin of the sampling strategy

Assessment of soil quality for soil in stockpiles is relevant in The Netherlands. This applies to a number of situations:

- Determining the reusability of soil within the framework of the Dutch Building Materials Decree.
- Determining the quality of soil from different types of soil treatment operations (bio, thermal and washing).
- Determining the quality of soil originating from remediation sites, in order to decide upon reuse, treatment or disposal in landfills.

When sampling soil in stockpiles, the precision of and confidence in the results is determined by the number of increments taken from the stockpile and the heterogeneity within the stockpile. Additionally, the sampling error, caused by all activities necessary to obtain the analytical results (sampling, sample pre-treatment, extraction / destruction and chemical analysis), is also an important source of variation. Determination of the sampling error is however costly, and therefore in most cases only the error due to chemical analysis (caused by extraction and analysis) is known. On the other side, the heterogeneity of soil stockpiles is unknown and as a consequence the inherent representativity of the final result is obscure. Nevertheless, Dutch legislation asks for a reliable determination of soil quality.

A first step towards a validated sampling strategy was made in 1996, using computerised soil models to test the effectiveness of different sampling strategies (Lamé et al. 1996). These models were based on actual environmental sampling data. By means of conditional simulation, 30 spatial distribution models for stockpiles were constructed; 10 per original set of data. In each model all potential sampling points were numerically defined (over 11 million points per model). For each set of 10 models the underlying distribution of data is the same: on the scale of the individual increments, the variation (variance) is constant between all 10 models. However, the spatial correlation (i.e. the degree of heterogeneity) increases within the group of models. Two of these models are depicted in Figures 1 and 2. Experts assumed that these 30 models represented all degrees of variability within actual soil stockpiles.

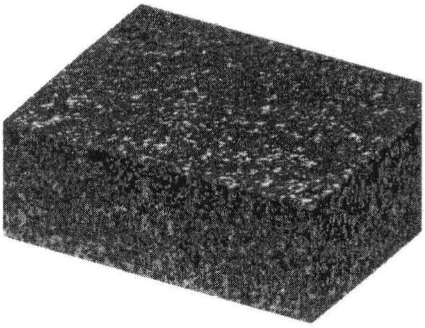

Fig. 1. Soil model with small degree of spatial correlation

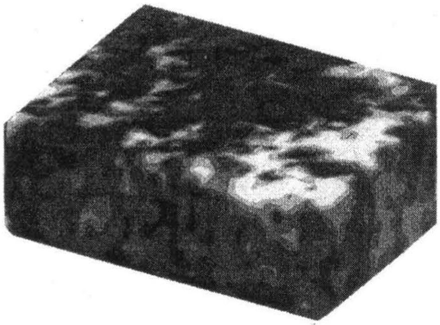

Fig. 2. Soil model with high degree of spatial correlation

Because in 1996 the amount of data and knowledge on actual soil heterogeneity was limited, a robust sampling strategy was chosen. The resulting strategy involves taking 100 increments of approximately 180 grams. Fifty of these increments are put together, resulting in two mixed samples for laboratory testing. With this sampling strategy, even strongly heterogeneous stockpiles can result in representative samples and therefore a reliable estimate of the mean concentration.

From this mathematical evaluation of different sampling strategies, the formalised soil sampling protocols of the Dutch Building Materials Decree were derived in 1998 (Staatscrnt 1998). Since then, the strategy is incorporated in the procedures for the exploratory survey (MEN (1999), to be used for soil quality mapping (VROM 1999) and for testing against the Dutch Target values (Staatscrnt 1999).

However, the sampling strategy has some inherent drawbacks. The number of increments (100) is high and as a consequence, the two laboratory samples of 9 kilograms need rather costly sample pre-treatment before a representative sample for chemical analysis is obtained. Hence, a clear need exists to validate this strategy, in order to determine the necessary number of increments, whilst maintaining overall representativity.

2 Data for validation

From 1997 up to 1999 the Centre for Soil Treatment has used the sampling strategy for the determination of soil quality in 2570 stockpiles. Thus, a large database containing 2570 sets of data for approximately 11 contaminants per set was obtained. In addition to the chemical composition, information is also available on the origin of the stockpile and basic soil physical characteristics like the clay and organic matter content.

3 Calculation of the heterogeneity

Calculation of the original heterogeneity on the scale of the increments is possible because of the availability of a large number of sets of data.

In order to pre-assess the heterogeneity in soil stockpiles, it was relevant to investigate which soil characteristics have a significant effect on the observed heterogeneity. Therefore the known characteristics of the stockpiles, such as the soil type and the whether or not the soil has been processed in a soil treatment plant were investigated. In addition to these stockpile-related characteristics, the effect of measurements of specific components was investigated.

It appeared that the variability was indeed dependent on most of these characteristics. But the effects on the variability were in most cases negligible. Only the type of contaminant investigated did have a significant effect on the calculated heterogeneity. Based on the contaminants investigated, a distinction was made between inorganic contaminants (arsenic, cadmium, chromium, copper, nickel, lead, zinc and cyanide) and organic contaminants (sum-PAH, EOX, mineral oil). In Table 1 the total number of observations for the organic and inorganic contaminants is given, together with the mean coefficient of variation.

Tab. 1. Total number of observations and mean coefficient of variation (in %) as a parameter for soil heterogeneity when analysing two samples with 50 increments each per stockpile

	Number of data	Mean coefficient of variation
Inorganic contaminants	20665	10,6
Organic contaminants	6719	20,0

The fact that a characteristic directly related to the (analytical) measurement is the only one with a significant effect on variability, implies that the sampling error can not be distinguished from the heterogeneity of the stockpile. Nevertheless, in the majority of stockpiles only a limited degree of variation was found, resulting in a sampling error that is in most cases smaller than 5%. For the organic components the maximum sampling error is much larger than for the inorganic components. Because in general the sampling error is small, no need exists to increase the number of chemical analysis.

The variability given in Table 1 is based on the actual measurements, where 50 increments per sample 'smooth' the resulting variability. Using assumptions on the sampling error, it can be calculated that for 90% of the soil stockpiles, the actual heterogeneity is less than 94% (based on inorganic components) or 410% (organic components). For the other 10% of the stockpiles, a (much) larger degree of heterogeneity was present.

Using the developed computer models, it is concluded that the sampling strategy meets the desired reliability for soil stockpiles with a maximum heterogeneity of 200%. Based on various assumptions for the sampling error, the percentage of actual soil stockpiles with less than 200% variability can be estimated. These percentages are given in table 2.

Tab. 2. Percentage of the soil stockpiles with less heterogeneity than 200% using various assumptions for the sampling error.

	Assumed sampling error			
	5%	10%	15%	20%
Inorganic components	97%	98%	98%	n.c.
Organic components	75%	77%	n.c.	82%

n.c. = not calculated

Based on the results given in Table 2, it is concluded that the sampling strategy adequately covers a large span of observed heterogeneity within soil stockpiles.

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