A GUIDELINE ON THE USE OF SOIL COMPOSITING IN CONTAMINATED SITE INVESTIGATIONS

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1.0 Introduction

The Ministry for the Environment's *Contaminated Land Management Guidelines No 5. Site Investigation and Analysis of Soils* (CLMG#5)(MfE 2004) contains some preliminary guidance on the use of compositing for soil samples in site investigations. A need for further guidance was identified as necessary to clarify contradictory messages on the number of sub sample numbers that can be used, and the necessity (or not) of manipulating the sample result (or guideline value) to allow for the potential dilution of a small number of highly contaminated sub-samples by less contaminated sub-samples. Linked in with these matters was the related issue of representative sampling of heterogeneous sample areas. Finally, clarifying the above contradictions also gave the opportunity to revisit the more systematic details relating to when and how composite samples should be taken.

The work described in this paper was initiated by Environment Canterbury while the author was with that organisation, using a working party, with further work conducted by Pattle Delamore Partners (PDP) under contract to Environment Canterbury, and finally by PDP under contract to Environment Waikato on behalf of the Regional Waste and Contaminated Land Forum.

The work involved a review of procedures detailed by international jurisdictions as well as academic studies (for example Gilbert 1987, British Standard BS 10175:2001, Correll 2001, British Colombia Environment 2001, NSWEPA 2005, SA EPA 2005, US EPA 1995).

2.0 What is soil compositing?

Soil composite sampling consists of collecting individual samples from different locations and mixing an equal mass of the samples (called sub-samples) together to form one composite sample. A composite sample can then be analysed, and the result will represent the arithmetic average of the constituent sub-samples.

In the context of this paper (and generally in contaminated land practice in general) soil compositing refers to grouping together of samples prior to analysis, although it can also refer to the grouping together of sample results following analysis.

3.0 Why is compositing used?

Compositing is used for the following reasons:

- to reduces the analytical costs associated with an investigation;
- to provide an average concentration when that is the objective of the investigation;
- for special cases of compositing over small areas, as a useful way to assist in the collection of representative, rather than biased samples from heterogeneous soils. This is referred to as cluster sampling to differentiate it from the more conventional compositing.

4.0 Determining when compositing can be used

Compositing should only be used when the concentrations of individual sub-samples is not required, and the loss of information associated with obtaining average concentrations is acceptable for the objectives of an investigation.

For composite sampling to be most effective, the distribution of contaminants over the affected land should be reasonably homogeneous, as the presence of significant hotspots will increase the likelihood that sub-samples may need to be analysed. Obtaining a comprehensive and accurate site history will assist in determining the possible patterns of contaminant distribution and developing a good conceptual site model.

Some matters are uncontroversial and form a 'checklist' when determining if composite sampling of a given area is appropriate at a site. These include:

1. All contaminants of concern are non-volatile or semi-volatile;
2. Compositing is not suitable for soils that are not easily mixed (eg, clay) because the laboratory only takes a small part of the mixed sample for analysis and it is essential that this is representative of the whole sample;
3. The given area to be sub-sampled must be part of the same 'statistical population', i.e. have approximately the same soil type, moisture content, drainage, and must have been subjected to the same activities associated with hazardous substances, as determined by desk top information and site inspection. Sub-samples must be taken from the same depths if exposure of receptors, e.g. humans, to contaminants is to be assessed.
4. The area allocated for collection of sub-samples comprising each composite must be determined on the basis of the investigation objectives and site conditions (as detailed in 3 above);
5. Although not strictly required, interpretation and reporting of results will be simpler if all composite samples are made up of the same number of sub-samples;
6. With the exception of cluster sampling, described in section 7.0, compositing of sub-samples must be undertaken in the laboratory, with the original samples retained for possible retesting. The laboratory must have a satisfactory Standard Operating Procedure to control the preparation and analysis of composite samples;
7. In situations where the sample result needs adjustment, the background concentration and guideline value will be relevant to the maximum number of sub-samples that should be included in each composite sample, see section 5.0 for further details;
8. A clear record of the sub-samples that contribute to each composite sample must be maintained.

The following must be included when reporting results:

1. Tables of composite analytical data must compare adjusted composite results (if appropriate for the investigation objectives) with the guideline values;
2. A map indicating the location of each sub-sample.

5.0 Restrictions on the number of sub-samples

If the result generated from analysis of a composite sample is to be manipulated, i.e. multiplied, by the number of sub-samples, then the number of sub-samples is highly relevant to the end result. In situations where the background concentration and soil guideline value are relatively close, compositing will not be appropriate as the multiplication of the sample result by the number of sub-samples is very likely to lead to the soil guideline value being exceeded – even if no contamination is present.

Consideration should also be given to the intent of the sampling when determining the number of sub-samples. There is a balance to be struck between getting a representative arithmetic average of a sample area by mixing more than one sample together, and missing a potential hotspot by mixing too many samples together enabling the hotspot to be diluted beyond recognition. Thus the more sub-samples that are used to make up a single composite, the greater the potential to miss one or more sub-samples containing elevated concentrations of contaminants.

6.0 Sample result adjustment

Many guidelines on compositing, including MfE's guideline: *Site Investigation and Analysis of Soils* (MfE 2004), describe the need to adjust guideline values to reflect the potential for dilution of heavily contaminated sub-samples by less contaminated sub-samples.

In fact, a more logical way to manipulate composite sample results (where this is required) is to multiply the sample result by the number of sub-samples, and for the guideline value to remain unchanged. This better reflects why the manipulation is being made, i.e. to address the potential for individual sub-samples to contain higher concentrations of contaminants than the composite sample.

This approach is very strict and can lead to false positive errors, i.e. cases in which we incorrectly label a composite sample as above the soil guideline value when all of the sub-samples were in fact below the soil guideline value. The strictness of this manipulation stems from the fact that the variability between concentrations in each sub-sample is unknown, and from an investigation objective that any sub-samples with concentrations above the guideline value must be identified. Less strict statistical manipulations can be used with this investigation objective, but these require knowledge of the in-situ soil heterogeneity through collection and analysis of sufficient discrete soil samples.

When background concentrations are available, these can be used when calculating the manipulated result to remove their impact on the final result. The formula for use when accurate background concentrations are known is as follows:

Adjusted Sample Result = (Sample Result x Number of Samples) – (Background x (Number of Samples-1))

This formula has the potential to underestimate a high sample result if the background concentration used is an average or high-end of the range from a regional study rather than the local background. For this reason, site specific background concentrations are preferable or, alternatively, the bottom end of regional ranges.

If the background concentration of the analyte is not known (or the contaminant should not be present in background soils), then the following formula applies:

Adjusted Sample Result = Sample Result x Number of Samples

Determining whether sample results require adjustment due to averaging of sub-sample concentrations can be difficult. However, most scenarios will fit the objectives described below:

1. Compositing is permitted without adjustment of results when sampling to determine average concentrations of contaminants, for example:
   - For waste disposal acceptance purposes.
   - Where relatively uniform concentrations are expected and an arithmetic average is anticipated to provide a good estimate of a receptor's (typically a person) average exposure. Sufficient site history must be available showing even application/deposition. It is recommended that the expected low variability is verified through collection of two discrete samples in addition to the composites within an area with the same site history and soil conditions. Alternatively, some individual samples within a composite can be initially analysed as discrete samples. The discrete samples can be used to calculate the relative percent difference and judge whether the variability is too great for composite results to be used unadjusted.
   - Soil sampling to determine average exposure of humans to contaminants in a defined area of equal exposure where hotspots are not expected.
   - When establishing background concentrations in a soil group, or ambient concentrations of a contaminant.
   - Soil sampling to benchmark a site for information purposes only.
2. Composite results require adjustment if an estimate of the maximum concentration in all of the sub-samples is required, for example:
   - Soil sampling to determine indicative maximum contamination concentrations across an investigation area where limited information is available about anticipated contaminant concentrations. In this situation, hotspots may be present. Composite sampling can be used, but if assurance that all samples are below soil guideline values is required, the sample results will need to be adjusted in accordance with the number of sub-samples. Alternatively, discrete samples can be collected. This scenario relates to both site investigations and clean-up validation.

7.0 Composite / representative sampling of heterogeneous soils (cluster sampling)

When soil conditions are very heterogeneous, it can be difficult to obtain a sample that is indicative of the contamination present in the area the sample represents. In this situation, cluster sampling can be a useful technique.

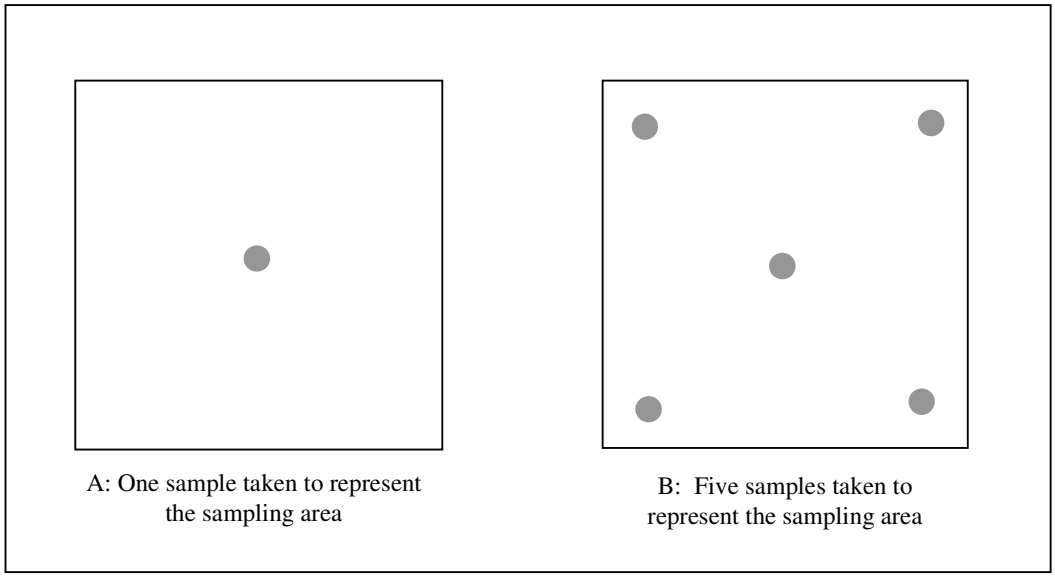

Figure 1. Sampling an area with heterogeneous soils

In Figure 1A, one discrete sample is collected to represent the sampling area. If highly variable contaminant concentrations are present within the sampling area, the analytical results will not be representative of the whole area.

In Figure 1B, five samples are collected to represent the sampling area. If all five samples are analysed, the information will provide an indication (through five data points) of the variability of contaminant concentrations in the sampling area. If all five samples are composited, the information will provide an arithmetic average of the five samples. Analysing all five samples is the most informative. However, in heterogeneous soils the composite sample (termed a 'cluster sample') is preferable to just one sample as the average of five samples provides a better basis for exposure assessment than a single sample result.

Cluster sampling allows field workers to respond to on-site conditions with minimal impact on pre-determined budgetary constraints. This technique is good for heterogeneous soil matrices where the distribution of contamination will be affected by the ground conditions. Cluster sampling is a field sampling technique used to respond to soil conditions. Cluster sub-samples are generally composited, i.e. mixed together, in the field to produce one discrete sample for submission to the laboratory for analysis.

This type of compositing should only be used for small sample areas. The larger the area, the greater the possibility of missing a relevant spatial shift in contaminant concentrations. Additionally, this technique should not be used across areas with discretely different ground conditions (different statistical populations), or where volatile contaminants are present.

Cluster sample results do not need to be adjusted as the objective of this technique is used to obtain one discrete sample.

8.0 Conclusion

Use of composite soil samples can allow for higher numbers of soil samples to be analysed for a given cost in situations where individual sub-sample results are not required. However, the loss of data must be acceptable to the objectives of the investigation, and this loss must be balanced against the analytical cost savings. Generally, compositing is most appropriate in situations where analytical costs are a significant component of a site investigation's total costs, and soil contamination levels are anticipated to be low and even.

When validation of sub-sample concentrations against soil guideline values is required, composite sample results will need to be adjusted through multiplication by the number of sub-samples.

Collection of 'cluster' soil samples is a form of compositing conducted in the field to reduce the potential for non-representative results to be gained when single discrete samples are collected from heterogeneous soils. Cluster soil sample results should not be adjusted as this would not be consistent with their objective, which is to provide a representative soil sample result for an area.

Compositing of soil samples provides a useful method to increase the potential for sampling to better represent soil conditions through collection of greater numbers of soil samples. However, in situations where analytical costs are relatively low, it is worth remembering that discrete samples will always have the advantage that the results enable the range and median as well as the average to be determined, and hotspots will not be diluted.

9.0 Acknowledgements

Environment Canterbury is acknowledged as the source of a draft version of a compositing guideline and for contracting PDP to update that draft. PDP also conducted further work on soil compositing under contract to Environment Waikato on behalf of the Regional Waste and Contaminated Land Forum (RW&CLF), and their support of this work is acknowledged. Finally, thanks to Graeme Proffitt (PDP) for assistance with the work, and for providing peer review comments on this paper.

10.0 References

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