NATIONAL ENVIRONMENTAL HEALTH FORUM

Composite sampling

National Environmental Health Forum Monographs

Soil Series No. 3

1998

Composite Sampling

William H. Lock

National Environmental Health Forum Monographs

Soil Series No. 3

National Environmental Health Forum

South Australia
Territory Health Services
Northern Territory Government
Commonwealth Department of Health and Family Services
Community and Health Services Tasmania
H&CS Health and Community Services
Queensland Health
Department of Health and Community Care
Australian Capital Territory
NSW Health Department
Health Western Australia
Health Department of Western Australia

1996

Printed by Glenelg Press
Published by the National Environmental Health Forum

Prepared for publication by Bill Lock
Public and Environmental Health Service
Department of Human Services

Price available on application.

Lock, William H.
Composite Sampling.

Bibliography

ISBN 0 642 25457 5.

ISSN 1326 – 9011

1. Soils – Australia – Analysis. 2. Soils – Sampling.
3. Soils – Analysis I. National Environmental Health Forum.
II Title. (Series: National Environmental Health Forum
Monographs. Soil series; no. 3).

Contents

Preface

The National Environmental Health Forum has been established by the Directors of Environmental Health from each State and Territory and the Commonwealth with a secretariat provided by the Commonwealth Department of Health and Family Services.

The National Environmental Health Forum is publishing a range of monographs in three separate series dealing with soil, water and air to give advice and guidance on a variety of important environmental health matters. This publication is the third in the soil series.

Acknowledgements

This publication has been made possible by technical assistance and funding provided by each State and Territory Environmental Health Branch and the Commonwealth Department of Human Services and Health under the auspices of Keith Bentley. Comment has been provided by reviewers from the States and Territories. Graphic design and layout assistance has been provided by Sandra Sowerby, Environmental Health Branch, South Australian Health Commission. The South Australian Health Commission library has assisted research and cataloguing for the document. Sue Newman, Belinda Kotowski, Julie Goodrich and Cheryl Orford have provided word processing and organisational skills in the compilation of the document.

Disclaimer

Published Monographs

Water series

1. Guidance for the control of Legionella (1996)
2. Guidance on water quality for heated spas (1996)
3. Guidance on the use of rainwater tanks (1998)

Soil series

1. Health-based soil investigation levels, 2nd edition (1998)
2. Exposure scenarios and exposure settings, 2nd edition (1998)
3. Composite sampling (1996)

Metal series

1. Aluminium (1998)
2. Zinc (1997)
3. Copper (1997)

Air series

1. Ozone (1997)
2. Benzene (1997)
3. Nitrogen dioxide (1997)
4. Sulfur dioxide (1998)

General series

1. Pesticides in schools and school grounds (1997)
2. Paint film components (1998)
3. Guidelines for the Control of Public Health Pests – Lice, Fleas, Scabies and other Mites, Bedbugs and Ticks (1999)
4. National standard for licensing pest management technicians (1999)

Indigenous Environmental Health series

1. Indigenous Environmental Health (1999)

Exposure series

1. Child activity patterns for environmental exposure assessment in the home (1999)

Counter Disaster series

1. Floods: An environmental health practitioner's emergency management guide (1999)

1. Introduction

Composite samples serve a useful purpose in a wide range of industries and activities, and have been used in contaminated site investigations but some authorities have expressed concerns about the use of composites, especially on suburban sites where there are relatively few samples to be taken.

The purpose of this monograph is to investigate these concerns, examine the cost savings offered by the use of composites and recommend guidelines for their use.

A composite sample is made from a number of discrete samples which have been collected from a body of material and combined into a single sample with the intention that this single sample is representative of the components of that body of material. In effect, the composite sample represents the average conditions in that sampled body of material.

Composite sampling is a common practice in mineral exploration. The body of ore is drilled to define its structure and samples are taken from locations throughout the ore body. The samples are crushed, if necessary, to a consistent granular size before mixing thoroughly. More than one composite sample is often taken for analysis as a check on the effectiveness of the mixing. Large ore bodies will require many samples and multiple composites in order to estimate the quantity of metal or mineral in the ore body and the possible value in a mining project.

Sampling a flowing stream presents a different kind of problem since there are continuous variations of composition with time and location. Once again the composite sample is used to obtain a representative sample (average) of the stream flow over the period of variation. A sample can be taken automatically at a fixed time interval or, if the stream flow varies, after a set volume has passed the sampling point. For example, a large river such as the Murray, has a range of flow regimes, when considered in cross section, and special sampling techniques have to be adopted when sampling such a large, deep flow. A sample taken at the river bank will be different to one from the bed as will a sample from the surface.

Investigation of soils beneath a site is different again. Their composition can change gradually or abruptly in any direction; changes can be chemical or physical, natural or man-made. Material in soils can be expected to remain in the one position but groundwater and aquifers may cause movement or changes in concentration of contaminants.

Whether the composition of the sampled body of material is fixed or variable, soil, rock or water, a composite sample only represents the average conditions of the sampled body. The decision to use composite sampling in a site investigation must be taken with this in mind together with the knowledge and skill to make the best choice of samples for the composite.

2. Soil sampling

2.1 Reasons for sampling

Sampling is carried out to monitor or characterise ambient concentrations of elements or compounds in environmental media for a variety of reasons.

In contaminated sites it would be to characterise the soils on a site, generally or specifically, depending on the quality of the site history.

Further sampling is often carried out to more clearly define detected or suspected contamination and following remediation in order to verify that contaminated material has been removed and that any contamination remaining does not constitute a health or environmental risk.

Any manual, guide or book on sampling of contaminated sites should recommend that before any sampling is undertaken, the objectives of the task be defined (CCME 1993).

The sampling and analytical programme should fulfil the defined objectives, but financial constraints usually limit the number of samples and analyses. Financial considerations may be the only justification offered for the use of composite soil samples which may be most effective when the cost of analysis is high compared with the cost of sampling and there is a large number of samples.

2.2 Sample collection

The method of taking samples from a site depends upon the objectives of the task and circumstances peculiar to the site; the nature and penetrability of the ground and the accessibility of the selected locations.

Large areas of fill may be trenched using a back-hoe, which allows detailed examination of the soil profile and the opportunity to take samples from 'undisturbed' locations. It should be noted that taking samples from a trenched profile will often be judgemental, and biased, if potentially contaminated zones are visually identifiable. If the profile does not appear to be contaminated, samples may not be taken.

Hand tools are sufficient for shallow soil samples, but care is required to ensure that the sample represents the desired depth interval. A soil coring device is able to take a neat plug sample in all but loose, dry or sandy soils.

A hand or power operated auger only delivers disturbed soil samples with a reasonable chance that cross contamination will occur between soil strata.

Push tubes give a continuous core and permit 'undisturbed' samples to be taken. The penetration of the ground depends on the power source and soil resistance. Fill which has a high proportion of building rubble will frequently cause refusal of penetration, and sampling cores may not be available over the desired depth.

2.3 Sampling locations

There are three basic sampling approaches:

Judgemental

Systematic

Random

(Heyworth, 1991; EPA NSW, 1995)

2.3.1 Judgemental

By definition, this is a biased selection of locations and is used by experienced investigators where the site history is comprehensive and there is a high degree of confidence as to what contaminants may be expected in well-defined locations.

2.3.2 Systematic

Theoretically unbiased, this requires a choice of grid pattern and size together with a choice of origin for the grid layout.

2.3.3 Random

This approach is also unbiased and will take into account the number of samples required. There are a number of methods to generate locations at random over a site. (EPA NSW, 1995)

2.4 Errors in sampling

The greatest concern, in collecting soil samples, is to ensure that the samples taken represent all the soils in all strata present on the site. Consequently it is essential to be fully apprised of the conditions at the site locations and what analytes will be tested in each sample, before sampling commences.

The importance of the correct method of sampling has been emphasised by Pitard:

> "If the sampling process is not correct the sampling operation cannot be accurate, regardless of how accurate the sampling plan is. Furthermore, we cannot directly control accuracy; however, we can directly control correctness. We also know that a correct sampling operation is always accurate" (Pitard 1989b, p182)

That is to say; unless the samples are taken using the correct methods the results can never be accurate, even though the locations have been correctly chosen.

In contaminated sites, sampling begins with the selection of locations and continues through to the laboratory where a subsample is taken for analysis. Sampling errors can arise from any one or combination of the following factors:

- location choice
- method of collection
- contamination from tools or equipment
- cross contamination between locations
- cross contamination between vertical sections
- handling/storage/transport
- sub-sampling for analysis
- sub-sampling and mixing for composite analysis

3. Heterogeneity

Heterogeneity has been defined as the condition of a lot under which all the elements of the lot are not strictly identical. (Pitard 1989a)

Pitard (ibid) identifies two forms of heterogeneity:

1. *Constitution Heterogeneity* which is the property of the set of units under consideration, such as the set of fragments within a parcel of particulate material.
2. *Distribution Heterogeneity* which depends upon constitution heterogeneity, but also, as its name suggests, on the spatial distribution of the units within the volume occupied by the parcel.

Constitution heterogeneity, which deals with fragments, is an intrinsic property and cannot be altered.

Distribution heterogeneity concerns groups of units, which can be modified by mixing. Since mixing occurs when composites are made up distribution characteristics are changed and information is lost.

A lot (site) would have homogeneous distribution if all the groups of a given size have a strictly identical average composition. However, such homogeneity is a purely theoretical condition.

The concept of a site having truly homogeneous soil properties is patently false, and a more realistic approach is to accept that the soil particles and their composition on each site are heterogeneous.

The more homogeneous a site, the more acceptable is the use of composites in characterising the site, but even the best constructed composites only give average values, blur variations and convey the impression of homogeneity. While average values of contamination may be of some use in exposure assessment, there will be a lack of detailed information necessary for risk characterisation and the management of the site.

Any investigation of a site should be designed to show the degree of heterogeneity in terms of soil type, structure and contamination. Where a comprehensive site history has been compiled for a site, the heterogeneity will be apparent and the sampling programme should be designed to confirm the accuracy of the site history and provide data about potentially contaminated areas.

Uncertainties or gaps in a site history would normally be filled by carrying out a preliminary investigation to determine the heterogeneity of the site and allow a comprehensive sampling programme to be set up.

4. Compositing

In 'Principles of Environmental Sampling', Garner, Stapanian and Williams (1988) contribute a chapter entitled 'Composite Sampling for Environmental Monitoring' which offers guidance in planning composite sampling with comment on advantages and limitations.

- The authors suggest that composites should not be used unless "...the researcher (investigator) fully understands all aspects of the [sampling] plan of choice."
- Advantages [may] include cost savings, confidentiality and increasing the sensitivity of the method where concentrations are low (by having sufficient analyte to record a result above the level of reporting).
- Limitations include aspects of false negatives or positives and loss of information regarding any relationships between analytes in individual samples.

A significant part of the chapter is devoted to calculating the 'Relative Cost Factor' in discrete and continuous distributions, enabling optimal sampling plans to be drawn up to accommodate the number of samples and analytes in the sampling budget.

The cost aspects and optimisation of protocols are the topics most frequently addressed in publications eg. Rohlf, Akçakays and Ferraro (1994). Cost reduction appears to be the main justification for consultants to undertake composite sampling, but cost reduction does not always eventuate due to the added cost of compositing, composite quality assurance and re-testing of individual sub-samples.

Gilbert (1987) considers compositing useful if the cost of analysing individual samples is high compared with the cost of collection (p71) but the Canadian EPA regard the opposite view as one of the limitations of composite samples; "...If sampling costs are greater than analytical costs, analysing each sample individually may be more cost effective." (CCME, 1993)

Some of the reasons for using composites are not applicable or valid for contaminated site investigations eg :-

> *Increasing Sensitivity* - where individual samples are very small, a number of samples in the composite would produce a measurable amount of the analyte, when, for example, determining trace compounds in blood samples.
>
> *Confidentiality* - in the case of human blood, by pooling (compositing) samples, identification of individuals can be prevented but the proportion of infected persons can still be estimated (Garner et al. 1988)

4.1 Making up composite samples

The decision to use composite samples should be made by the person supervising the investigation. Instructions are transmitted to the laboratory detailing the analytes for each sample or composite. These instructions include details of which samples are to be composited.

Composites prepared outside a laboratory would be most unlikely to provide acceptable results.

4.2 Problems of compositing

Compositing is only valid if the composite sample is a true representation of the sample components, and the corollary to this is minimal changes in physical and chemical properties with compositing.

The EPA NSW 'Contaminated Sites - Sampling Design Guidelines' (1995) has "Rules to Observe" in the section on the use of composite sampling (Appendix 1). and the SAHC 'Guidelines for the Composite Sampling of Soils' (1995), list a number of requirements for compositing samples (Appendix 2).

Both documents require or recommend samples to be from the same soil or fill horizon and the EPA NSW rule out using soils with high clay content because of difficulties in mixing sub-samples.

Neither document makes comment on moisture content, but the variability of moisture between sub-samples will affect results since sub-samples are weighed and mixed without drying but results are expressed in terms of dry weight.

In both documents the 'rules' apply to conditions or decisions made by the on-site investigator. No written information has been found which provides guidelines or protocol for laboratories which make up composites. Nor has a list been previously published of analytes which are not suitable for composited soil samples and consequently there is no procedure for laboratories to follow should an inappropriate analyte be requested for a composite sample.

5. Costs and savings

Rohlf, Akçakays and Ferraro (1994) produced a technical report 'Optimising Composite Sampling Protocols', for the US EPA, which described statistical models and procedures for optimising the number of primary sampling units. Methods were presented to find the optimal sampling protocol within the confines of a fixed budget and the least costly sampling protocol that is still reliably able to detect a specified difference in means.

The call for reports such as this demonstrates the emphasis placed on the cost saving aspects of composited samples.

A cost comparison between composite and single samples within the limitations described by the SAHC and EPA NSW, (no more than 4 sub-samples per composite), can be made as follows:

Let … C_c - total cost of composite analysis

C_i - total cost of individual sample analysis

c_c - cost of collection of each sample

c_p - cost of preparation for each sample

c_t - cost of compositing

c_a - cost of analysis and reporting

n - the number of samples in the composite

The total cost C_c for analysis of one composite sample having n subsamples

$$C_c = nc_c + nc_p + c_t + c_a \qquad (1)$$

The total cost C_i for n individual samples

$$C_i = n(c_c + c_p + c_a) \qquad (2)$$

The saving in cost per composite sample is:-

$$C_i - C_c = (nc_c + nc_p + c_a) - [n(c_c + c_p) + c_t + c_a]$$
$$= c_a(n - 1) - c_t$$

If there are x samples there are $\frac{x}{n}$ composites and the total savings will be :-

$$\frac{x}{n}[c_a(n - 1) - c_t]$$

If a fraction *L* of the composites require individual analysis of each sample, then there will be a cost of :-

$$L n.\frac{x}{n}.c_a \quad \text{or} \quad L x c_a$$

to be set off against the savings and the break-even point will be when this cost is equal to the savings. ie :-

$$L x c_a = \frac{x}{n}[c_a(n - 1) - c_t]$$

(assuming no re-sampling)

and $$L = \frac{1}{nc_a}[c_a(n-1) - c_t]$$

$$= 1 - \frac{1}{n}(1 + {}^{c_t}/_{c_a})$$

The maximum value of L is when $\frac{1}{n}(1 + {}^{Ct}/_{Ca})$ is at minimum value (${}^{Ct}/_{Ca} \rightarrow$ zero)

The minimum value of L is when $\frac{1}{n}(1 + {}^{Ct}/_{Ca}) = 1$. ie. ${}^{Ct}/_{Ca} = (n - 1)$

When **n = 2**: $L_{max} = 1/2$ L_{min} when ${}^{Ct}/_{Ca} = 1$

When **n = 3:** $L_{max} = 2/3$ L_{min} when ${}^{Ct}/_{Ca} = 2$

When **n = 4**: $L_{max} = 3/4$ L_{min} when ${}^{Ct}/_{Ca} = 3$

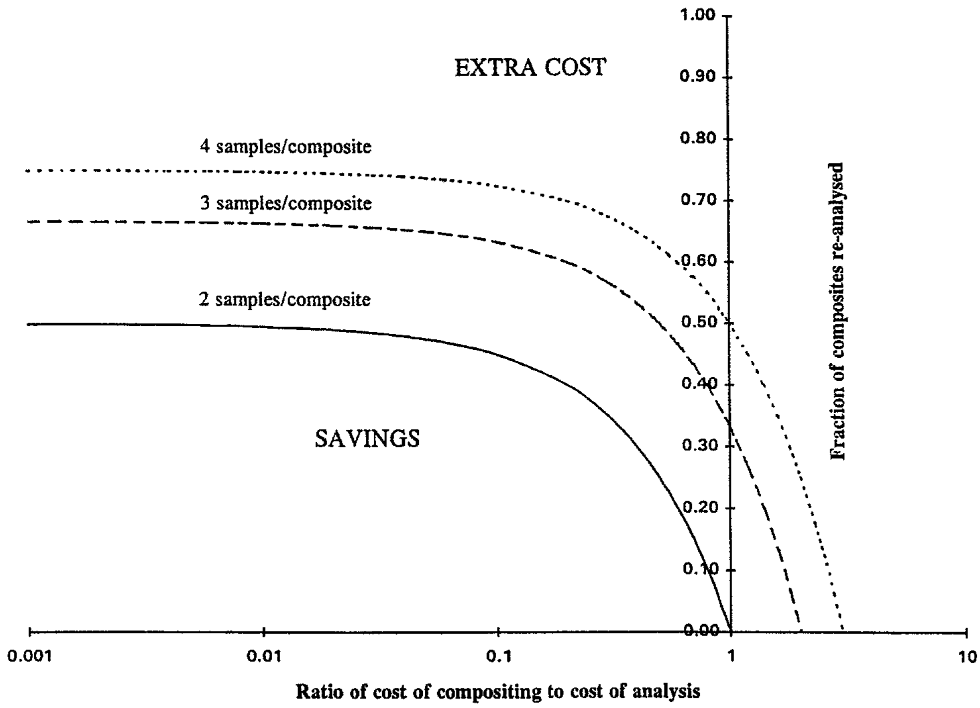
(the minimum value of L is zero)

Figure 1 plots the locus of points where the additional cost is equal to the savings (the break-even points) for 2, 3 and 4 samples per composite, taking into account the fraction of composites to be re-analysed against the costs of compositing and analysis. Below each line savings are possible, above each line there is added cost.

Figure 1 does not show the amounts involved since these depend on actual costs and the numbers of samples involved but it does indicate:

- Maximum savings will be possible if the cost of analysis (ca) is more than ten times the cost of compositing (Ct) or ${}^{Ct}/_{Ca} < 0.1$
- If the cost of analysis is less than the cost of compositing $\left({}^{Ct}/_{Ca} > 1\right)$ it will be almost impossible to make any savings (assuming no more than samples per composite)

Figure 1: Conditions for determining if compositing gives cost savings.



N.B. The abscissa of the graph is logorithmic.

It should be noted that the cost of compositing samples is factored into the costs of analysis by the laboratory where it appears as part of 'sample preparation'. Further costs are incurred in demonstrating that the compositing process has been subject to sufficient quality control measures (SAHC 1995). The unit cost of compositing can be significant, especially if there are a small number of composites.

The statement that a large difference in costs between sampling and analysis can be used as a guide to consideration of compositing has not been proven but if the equations (1) and (2) from the above are considered:

$$C_c = nc_c + nc_p + c_t + c_a$$

and $$C_i = n(c_c + c_p + c_a)$$

it can be seen that if the cost of sample collection (c_c) is much greater than the cost of analysis (c_a) then $C_c \cong C_i$

6. Discussion

The object of a contaminated site investigation is to determine the nature, degree and extent of any contamination. Until this is achieved, it is not possible to make an informed assessment of human health and environmental health risks.

Human health risk assessment requires quality data on every aspect of the subject site.

> "In measuring environmental parameters there is no true value, but rather a distribution of values" (Gilbert, 1987)

The site history is rarely complete and the investigation has to confirm what is known and fill the gaps in the unknown. On many sites the extent and quality of fill is the cause of greatest concern. In old metropolitan sites, fill was often not controlled and low-lying areas were built up with any material, conveniently available. Even in modern times it is not unknown for a truckload of material to be dumped on a convenient site rather than to be taken to an authorised repository.

In many instances, where little or nothing is known about the sources of fill, it has to be assumed that the fill is heterogeneous and contaminated. In such cases full descriptions of the fill strata are essential over its entire depth. The uncertain nature of fill should preclude any consideration of using composite sampling since one of the most important data sets is the degree of contaminant variation that occurs within the fill. The variability of analytes in fill and elsewhere on a site under investigation could not be properly assessed if any of the data had been derived from the analysis of composite samples. This information is essential in order to make an assessment of the possibility that some contamination has not been detected.

There are always uncertainties associated with the collection of samples. Keith (1990) expressed concern about the representativeness of samples in heterogeneous materials such as soils: "...uncertainties associated with the representativeness of these types of samples frequently far exceed those inherent in their collection and analysis."

The numerous steps and subjective decisions made when sampling soils on a site present many opportunities for errors to occur. It would seem unwise to further compound any errors by using composite samples.

The cost benefits of using composite samples have to be weighed against the chance that analysis of individual samples will be required. The direct costs of this have been estimated in this monograph but there are indirect costs incurred in lost time and these may be significant if a project is held up until further results are obtained.

It is unlikely that an investigator can make significant savings on a small suburban site where there may be only three or four composites, unless it is used to reduce the overall cost of the initial contract price resulting in an embarrassing situation when costs overrun.

7. Recommendations

7.1 Guidelines for the appropriate use of composites

- the decision to use composites should only be taken by an experienced site investigator after full consideration of the site history and, if relevant, remediation plans;
- investigators should be prepared to justify the use of composites to the auditor/assessor/regulatory authority;
- composite samples may be useful in the initial stages of an investigation but should not be considered unless there is a high degree of confidence in the site history;
- if the investigation site includes fill of uncertain origin or quality then composite sampling should not be considered because one of the objects of the investigation will be to determine the variability of contaminant concentration in the fill;
- composite sampling may be acceptable to confirm a site history which indicates no contamination or where none is expected eg. after remediation;
- no more than 4 equal-mass constituent samples shall be included in a composite sample;
- the maximum number of constituent samples will be governed by the analytical system, which must be capable of measuring at all adjusted investigation levels (Appendix 2, section 4) without creating false negative results;
- all composite samples from a site must be manufactured from the same number of constituent soil samples;
- each constituent sample must be homogenised before sub-sampling; this will require compositing of materials to be undertaken in the laboratory rather than in the field. It must be able to be demonstrated that the compositing process was subject to sufficient quality control measures to ensure that the composite adequately represents the material of the constituent samples. The NATA requirements for the analysis of individual samples must be applied to composite samples;
- the integrity of target analytes must not be compromised by the homogenisation and compositing processes;
- target analytes must be accurately identified by the site history and any group of analytes, which may include volatile or semi volatile compounds such as PAH or TPH, would not be suitable for composite sampling;
- homogenised constituent samples must be appropriately archived to allow further analysis should this be required by the assessor (ie trace-back must be possible);
- all constituent samples in a composite must be taken within the same stratum and depth interval;
- constituent samples must be taken from soil materials with similar characteristics, eg similar particle sizes and soil types, and from fill of similar origins;

- constituent samples must be taken from immediately adjacent sampling locations, ie imaginary lines joining the sampling points must not cross lines joining the sampling points of another composite. The lines connecting the sampling points for each composite must describe similarly shaped and sized areas, except where this is not geographically possible;
- constituent samples should be from the smallest area or depth interval consistent with providing adequate representation of the site or interval.

7.2 Making up the composites

The purpose of this monograph is not to give detailed instructions to the laboratories on how composites should be made up but it is of sufficient concern to seek the development and promotion of a standard protocol.

Such a protocol would include:

- physical criteria for the acceptance of soil samples which are to be composited, having regard to the mix of particle sizes, the amount of plant material , moisture and clay content etc.;
- chemical or composition criteria to avoid making composites of dissimilar samples;
- the method(s) of homogenising each sample prior to sub-sampling and the composite, if this is also sub-sampled;
- quality controls which are able to show that homogenisation has produced a composite which is representative of the component samples;
- a system of reporting which clearly identifies results as coming from a composite and the components of each composite;
- criteria for the laboratory to express any qualifications about the results with regard to the nature of the samples, their storage, shipping etc.

As an interim measure, laboratories should, as far as practicable, provide comments on these matters with each set of composite results.

References

CCME (1993) *Guidance Manual on Sampling, Analysis, and Data Management for Contaminated Sites. Volume I: Main Report.* Canadian Council of Ministers of the Environment Report CCME EPC-NCS62E December 1993.

EPA (Environment Protection Authority NSW) (1995) *Contaminated Sites - Sampling Design Guidelines*. NSW Environment Protection Authority, Sydney.

Garner FC, Stapanian MA, Williams LR, (1988) *Composite Sampling for Environmental Monitoring*. In: Keith LH (ed) Principles of Environmental Sampling, American Chemical Society, Washington, D.C.

Gilbert RO (1987) *Statistical Methods for Environmental Pollution Monitoring.* Van Nostrand Reinhold, New York.

Heyworth JS (1991) *Sampling and Statistical Analysis for Assessing Contaminated Land Sites*. In: El Saadi, Langley (eds), Health Risk Assessment and Management of Contaminated Sites, South Australian Health Commission, Adelaide.

Keith LH (1990) *Environmental Sampling: A Summary*. Environ. Sci. Technol. 24 (5): 610-617.

Pitard FF (1989a) *Pierre Gy's Sampling Theroy and Sampling Practice, Volume I: Heterogeneity and Sampling*. CRC Press, Florida.

Pitard FF (1989b) *Pierre Gy's Sampling Theoy and Sampling Practice, Volume II: Sampling Correctness and Sampling Practice.* CRC Press, Florida.

Rohlf FJ, Akçakaya HR, Ferraro SP, (1994) *Optimising Composite Sampling Protocols.* US EPA Technical Report No. EPA/600/R-94/048.

Appendix 1 - Contaminated Sites - Sampling Design Guidelines

NSW EPA - September 1995

Rules to observe

Composite sampling must comply with the following rules. Violation of these rules could invalidate the sampling results.

Analytes

- Composites are satisfactory for inorganic substances, e.g. heavy metals, or substances of low volatility
- Volatile substances including Total Petroleum Hydrocarbons are not suitable for composite sampling.

Soil/fill type

- Samples to be composited must be collected from the same soil/fill horizon
- Soil with high clay content is not suitable for composite sampling because of the difficulty of mixing the sub-samples thoroughly.

Method of compositing

Sub-samples should be:

- equal in size
- from immediately adjacent sampling points
- evenly spaced
- composited laterally.

No more than 4 sub-samples should be included in a composite sample.

Appendix 2 - Guidelines for the composite samping of soils

Site Investigation Technical Bulletin #1 - SAHC - September 1995

Composite sampling of soils is used in contaminated site investigations mainly as a means of reducing analytical costs. However, if sampling or compositing is undertaken inappropriately the analytical results may be meaningless.

While compositing can justifiably be used for confirming that little or no contamination is present, and used for initial (Stage 1) investigations to facilitate the planning of more detailed work, composite sampling alone is generally unsuitable for the definitive assessment of site contamination due to the inherent uncertainties in the resultant data.

Whilst recognising that the judicial use of composite sampling may be of value in some stages and types of site assessment, the SA Health Commission and the Office of the Environment Protection Authority have prepared the following guidelines in order to achieve consistency in sampling methodologies and data presentation. The above agencies require that the guidelines be followed for all composite sampling included in reports submitted to them for consideration.

1. Methodology for Compositing Samples

- no more than 4 equal-mass constituent samples shall be included in a composite sample;
- the maximum number of constituent samples must be governed by the analytical system, which must be capable of measuring at the adjusted investigation levels (see below) without creating false negative results;
- all composite samples from a site must be manufactured from the same number of constituent soil samples;
- each constituent sample must be homogenised before sub-sampling; this will require compositing of materials to be undertaken in the laboratory rather than in the field. *It must be able to be demonstrated* that the compositing process was subject to sufficient quality control measures to ensure that the composite adequately represents the material of the constituent samples. NATA's requirements for signatories for the analysis of individual samples must be applied to composite samples;
- the integrity of target analytes must not be compromised by the homogenisation and compositing processes;
- homogenised constituent samples must be appropriately archived to allow further analysis should this be required by the assessor [ie traceback must be possible];
- all constituent samples in a composite must be taken within the same stratum and depth interval; compositing constituent samples from different strata in soil cores is ill advised;
- constituent samples must be taken from soil materials with similar characteristics, eg similar particle sizes, soil types and from fill of similar origins;
- constituent samples must be taken from immediately adjacent sampling locations, ie imaginary lines joining the sampling points must not cross lines joining the sampling points of another composite. The lines connecting the sampling points for each composite must describe similarly shaped and sized areas, except where this is not geographically possible
- constituent samples should be from the smallest area or depth interval consistent with providing adequate representation of the site or interval.

2. Analytes

Composite sampling is *unsatisfactory* for volatile substances such as petrol, but would be satisfactory for heavy metals, arsenic and substances of low volatility, eg chlorinated cyclodiene pesticides.

3. Reporting Composite Results

Data from composite samples must be clearly identified when quoted or provided in tables, graphs or maps; this data should carry an easily recognised code, eg '14COMP'.

A map must be provided showing the sampling points and areas of the site represented by each composite. The 'source' of a composite soil sample must *not* be represented as a point defined by an average of mapping co-ordinates.

4. Adjustment of Investigation Levels

When composite sampling is used, the contaminant investigation level will need to be modified. The investigation level (or other soil criterion) must be divided by the number of samples making up the composite to give the adjusted investigation level. This method of adjustment may give rise to false positive results but will avoid any exceedances being overlooked. *No other adjustment is seen as acceptable in health and environmental risk assessments.*

For example, if contamination by arsenic, which has a health-based investigation level [HBIL] of 100mg/kg, is being investigated and there are 4 constituent samples per composite, the HBIL should be divided by 4. Concentrations determined in composite samples should then be compared to [100/4]mg/kg, ie 25mg/kg.

This measure avoids the possibility of a false negative result. For example, if 4 samples have individual levels of 5, 5, 5, 165 mg/kg, a composite concentration of 45mg/kg appears to comply with the unadjusted HBIL of 100mg/kg. Comparison with an unadjusted HBIL obscures the presence of a localised elevation and hence the nature of contamination on the site.

It is also recognised that the use of an adjusted HBIL with composite samples may result in false positive exceedances if, for example, natural background levels are elevated but acceptable. If the background level of arsenic is ≈35mg/kg, the concentration determined in an uncontaminated composite manufactured from four samples will exceed the adjusted HBIL of 25mg/kg. In such a case, the use of composite samples without definitive individual sample analysis may lead to an unnecessary and costly further investigation.

While the average level of a contaminant on a site may be taken into account in assessing the need for remediation, the ability to appreciate what is happening on a site must not be obscured. Individual samples will always provide a clearer picture of a site than composites.

5. Cost Effectiveness

Although composite sampling is generally used to reduce analytical costs, this may not be achieved in situations where severe contamination is widespread and there is likely to be a high level of exceedances, requiring a large number of the samples to be re-analysed individually.

There are also significant laboratory costs in preparing a meaningful composite sample and in undertaking quality assurance to demonstrate that the manufactured composite adequately represents the constituent samples. The cost of analysis of a composite should be expected to exceed that for an individual sample.