CONTAMINATED SITES

Guidelines for Assessing Banana Plantation Sites

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ISBN 0 7310 3787 1
EPA97/37
October 1997
Contact details updated August 2003

Printed on recycled paper

PREFACE

In 1992 the NSW Environment Protection Authority (EPA) released the Draft Former Banana Plantation Sites Sampling Guidelines to assist in the design of sampling programs for former banana plantation sites. In 1994, the EPA in association with NSW Agriculture and Coffs Harbour City Council carried out a detailed study of the distribution of contaminants on banana plantation sites (NSW EPA 1997).

Based on the results of the study, the EPA has revised the earlier draft guidelines to produce these Guidelines for Assessing Banana Plantation Sites.

These guidelines relate to:

- sampling former banana plantation sites to estimate the extent of contamination posed by primary contaminants, specifically arsenic and organochlorine pesticides
- validating the remediation of sites, i.e. demonstrating that cleanup criteria have been met and that the site is suitable for residential use.

The EPA expects that these guidelines will be used by:

- professional environmental consultants investigating contaminated sites
- local council officers or auditors reviewing or auditing work by consultants
- other groups interested in this area.

The EPA welcomes written comments and suggestions for improvement. These should be sent to:

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LIMITATIONS

These guidelines apply only to banana plantation sites and not to any other type of agricultural land.

These guidelines should be used in conjunction with the following:

- *Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites* (ANZECC/NHMRC 1992)
- *Contaminated Sites: Guidelines for the Vertical Mixing of Soil on Former Broad-Acre Agricultural Land* (NSW EPA 1995a)
- *Draft Guidelines for Consultants Reporting on Contaminated Sites* (NSW EPA 1995b)
- *Contaminated Sites: Sampling Design Guidelines* (NSW EPA 1995c)
- *Bananalands Contaminant Distribution Study* (NSW EPA 1995d)
- *The Health Risk Assessment and Management of Contaminated Sites* (SA Health Commission 1991, 1993, 1995)
- *Testing Soils for Pesticide Residues*. Agnote Reg 1/044 (NSW Agriculture 1988)
- *Test Methods for Evaluating Solid Waste - Physical/Chemical Methods SW-846* (US EPA 1986, 1992 revision)

DISCLAIMER

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1 INTRODUCTION

Soil surveys in the Coffs Harbour region of New South Wales conducted by New South Wales Agriculture in 1991-1992 revealed potential contamination by residual pesticides, principally arsenic and dieldrin, in land that had been used for banana cultivation.

In 1992 the NSW Environment Protection Authority (EPA) released draft guidelines for the sampling of banana plantation sites (NSW EPA 1992).

In 1994, a further study carried out by the EPA in association with NSW Agriculture and Coffs Harbour City Council (NSW EPA 1997) gave the EPA a better understanding of the distribution of contaminants on banana plantation sites. The study identified levels of arsenic contamination exceeding the health investigation level recommended by the ANZECC/NHMRC (1992) guidelines. The results suggest that former banana planatation sites should be investigated, and remediated if necessary, before being developed for housing.

Based on the results of this study the EPA has revised and replaced the 1992 draft guidelines with this document, *Guidelines for Assessing Banana Plantation Sites*. These guidelines reflect the findings of the study, which determined that:

- composite sampling is an acceptable method of sampling for banana plantation sites
- 0-75 mm is the soil depth most appropriate for dieldrin sampling
- 0-150 mm is the soil depth most appropriate for arsenic sampling.

Using this sampling regime enables a balance between the protection of human health and the environment, and a cost-effective investigation.

1.1 Scope

These guidelines focus on:

- the sampling design for investigating banana plantation sites
- the validation procedure for demonstrating that the site has been successfully remediated.

Topics such as sample handling and management and chain of custody are summarised. Detailed requirements for these topics are listed in the *Draft Guidelines for Consultants Reporting on Contaminated Sites* (NSW EPA 1995b).

1.2 Desktop study before field work

Before any field work commences on a former banana plantation site, a desktop study should be conducted. The desktop study should include:

- a full site identification — street address, DP and Lot Number
- the previous, current and proposed uses of the site
- the names of past and current owners of the site
- a review of aerial and ground-level site photographs
- the results and conclusions of any earlier site assessment
- the location of any known or suspected packing shed and/or chemical storage or mixing site, or any other probable contaminant hotspots.

1.3 Site-specific characteristics

These guidelines apply only to sites with the following characteristics:

- The land has been used only as a banana plantation.
- The chemicals used on the site have been the usual banana plantation agricultural chemicals in which the primary residual contaminants are arsenic and dieldrin.
- The location of the packing shed and/or the chemical storage or mixing area and any other potential contaminant hotspot areas have been identified during the desktop study.
- There is no evidence that the site topography has been significantly altered since the last banana plantation activity.
- There is no evidence that the groundwater has been contaminated by banana plantation activity.

2 INITIAL SITE ASSESSMENT

The distribution of contaminants on banana plantation sites can be broadly classified into two types:

1 relatively evenly and widely distributed contamination in the banana-growing area, i.e. over the majority of the former banana plantation site

2 localised contamination (hotspot), usually associated with the packing shed and/or chemical storage or mixing area of the former banana plantation site.

These two types of contamination require different sampling strategies, discussed in Sections 2.1 and 2.2 respectively.

2.1 Assessing former banana-growing areas

A former banana-growing area can be categorised as undisturbed or disturbed:

- undisturbed: last used for banana-growing
- disturbed: subsequently developed for another use, e.g. housing.

If the desktop study indicates that the site has the specific characterisitics listed in Section 1.3:

- See Section 2.1.1 for the recommended sampling strategy for undisturbed banana-growing areas.
- See Section 2.1.2 for the recommended sampling strategy for banana-growing areas that have been disturbed by subsequent development, e.g. housing.

2.1.1 Assessing undisturbed banana-growing areas

Minimum sampling points

See Table A for the recommended minimum number of sampling points for undisturbed banana-growing areas.

Sampling pattern

Use a square grid sampling pattern. Where the use of a square grid sampling pattern is not practicable (e.g. due to the odd shape of the site or other physical barriers), sampling points should be evenly spaced.

Table A Minimum number of sampling points for assessing undisturbed banana-growing areas

Area of site	Minimum number of sampling points
Up to 700 square metres	8
700 to 1500 sq. m	8 to 16 in proportion to the size of the area
1500 to 3000 sq. m	16 to 24 in proportion to the size of the area
3,000 to 20,000 sq. m	24 to 32 in proportion to the size of the area
Over 20,000 sq. m (2 hectares)	16 per hectare of area (equivalent to a 25-metre square grid pattern)

Sampling depth

Samples should be taken from the top **75 mm*** immediately below any vegetative or detrital layers.

Composite sampling

Composite sampling is acceptable only for undisturbed banana-growing areas where hotspots are not anticipated, i.e. areas not associated with packing sheds and/or chemical storage or mixing areas. A **maximum of 4** individual samples collected from adjacent sampling points can be combined to form a composite sample for chemical analyses. For example, 8 individual samples from a 700 sq. m block may be combined into two composite samples for chemical analysis.

2.1.2 Assessing banana-growing areas that have been disturbed for subsequent development

The sampling program for general banana-growing areas that have been developed, e.g. for housing, needs to be site-specific. Because the original banana plantation site is likely to have been disturbed by subsequent development, the sampling scheme outlined in Section 2.1.1 may not be appropriate. Except where the local council or the Public Health Unit of NSW Health specifically requires more stringent sampling, the EPA recommends that a minimum of 5 evenly spaced samples be taken from the land surrounding the development. The sampling depth will vary depending on the conditions of the soil at the sampling point:

- If there is no indication that the original soil profile has been disturbed, samples should be taken from the top 75 mm immediately below any vegetated or detrital layers.
- If the original soil has been disturbed, samples should be taken from the top 150 mm instead of 75 mm.
- If the original soil has been covered by a layer of fill material, samples should be taken from at least two depths: 0-150 mm of the fill layer and the interface between the fill and the original soil.

Do not combine the samples. Analyse each sample individually.

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* Surface soil samples are commonly collected from the 0-150 mm soil layer. However, an EPA study (NSW EPA 1997) has verified that the concentration of dieldrin in the 0-75 mm soil layer is significantly higher than in the 75-150 mm layer.

2.2 Assessing potential hotspots

A potential hotspot is a localised area in which there is a high probability that the level of contamination will be noticeably greater than in surrounding areas. For banana plantation sites, potential hotspots include packing sheds and chemical storage or mixing areas. Potential hotspots may be identified through a comprehensive historical review (especially aerial photographs and an interview with the owner/occupier of the site), together with the considered, professional judgement of the site investigator.

Sample a suspected hotspot area using a 5 metre square grid pattern. Samples should be collected from the top 75 mm immediately below any vegetative or detrital layers. Do not combine the samples. Analyse each sample individually.

2.3 Chemical analysis and threshold concentrations

See Table B for the investigation thresholds for the primary contaminants in bananalands.

All chemical analyses should be carried out by a laboratory that is currently accredited by NATA (or an equivalent organisation) for that particular chemical analysis.

Table B Human health investigation thresholds for the primary contaminants in bananalands

Contaminants	Threshold concentrations (mg/kg dry weight)
Arsenic[1]	100
Lead[1]	300
DDT[2,3]	50
Aldrin/Dieldrin[3, 4]	10

Notes

1 ANZECC/NHMRC Human Health Investigation Level

2 Beard (1993)

3 These levels were presented in the Third National Workshop on the Health Risk Assessment and Management of Contaminated Sites, and have been published by the National Environmental Health Forum in Soil Series Monograph No. 1, *Health-Based Soil Investigation Levels*, P Imray, A Langley, 1996.

4 DiMarco (1993)

2.4 Evaluating the sampling results

Sampling results should be evaluated statistically. Statistical analysis can help the site investigator determine whether the site is contaminated or not contaminated. If the site is considered to be contaminated, the site investigator should recommend an appropriate course of action. The following will help the site investigator evaluate the sampling results.

2.4.1 Where the results are obtained from discrete (non-composite) sampling

1 Calculate the 95% upper confidence limit (UCL) on the average concentration for each analyte. See Appendix A for determining the 95% UCL average. If the 95% UCL average for each analyte is below the investigation threshold in Table B and none of the individual measurements is more than 25% above the investigation threshold, the sampling area can be considered uncontaminated.

2 Where the 95% UCL average is less than the investigation threshold but one or more individual sample measurements are more than 25% above the investigation threshold, each sampling point that exceeds this level must be re-investigated to determine whether or not the area constitutes a hotspot. This re-investigation will normally involve taking a number of samples in the area surrounding each sampling point in question.

3 If the 95% UCL average exceeds the investigation threshold, the site investigator can declare the area contaminated and recommend an appropriate course of action; or if the 95% UCL average only marginally exceeds the investigation threshold, the site investigator may collect additional samples in an unbiased manner, i.e. using either a random or systematic sampling pattern. The 95% UCL average is then recalculated based on the combined sampling results. Follow step (1) for decision making.

2.4.2 Where the results are obtained from composite sampling

4 If the minimum sampling requirement in Table A has been met and all composite sample measurements are less than the investigation threshold, the site can be considered uncontaminated.

5 If one or more of the composite sample measurements exceeds the investigation threshold, the sub-samples that made up the composite sample in question should be analysed individually, and:

(a) if none of the sub-samples has a concentration 25% higher than the investigation threshold, the site can be considered uncontaminated.

(b) if any of the sub-samples have a contaminant concentration 25% higher than the investigation threshold and the site investigator still believes that the site is not contaminated, the site investigator must prove that:

(i) the sub-sample does not constitute a hot spot by collecting and analysing a number of samples in the area surrounding the sampling point in question; and

(ii) the 95% UCL average of the site does not exceed the investigation threshold (by, if necessary, collecting and analysing additional samples).

6 If none of conditions in (4) and (5) applies, the site should be considered contaminated and the site investigator should recommend an appropriate course of action.

2.5 Sample handling and management

A minimum of 1 kg of soil sample is to be taken at each individual sampling point. Mix the individual sample thoroughly on a clean stainless steel tray using a disposable spatula. Following mixing, transfer the soil sample to a glass container for storage below 4°C. These containers should be suitable for storing inorganic and organochlorine compounds.

Use approximately 300 g of thoroughly mixed soil from each individual sampling point to make up a 1.2 kg (maximum) composite sample.

The remainders of individual samples should each be kept in separate glass containers and refrigerated (below 4°C) for 2 months after the completion of the investigation. If necessary, these samples can be individually analysed to confirm earlier results or check results from individual sampling points.

All containers should be kept in an insulated coolbox during transportation and storage.

Each sample container should be clearly labelled in permanent ink* with the following information :

- name of person who collected the sample
- date and time of collection
- place of collection
- sample identification information.

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* Some marking pens and self-adhesive labels contain volatile organic chemicals. Great care must be taken to prevent contamination by these materials during sampling and labelling.

2.6 Decontaminating sampling tools

Sampling tools need to be decontaminated between sampling points using the following procedure, or equivalent, to prevent cross-contamination:

- Use a brush to remove any caked or encrusted material.
- Wash in a solution of detergent (such as Decon 90 or equivalent) and tap water.
- Rinse in an organic solvent if organochlorine pesticides are of concern.
- Triple rinse with clean tap water.
- Allow to air dry or use clean paper towel to wipe dry.

2.7 Chain of custody

A chain of custody procedure ensures the legitimacy of the sample. A chain of custody form should contain the following information:

- the name of the site
- date and time sampled
- sample identification code
- sample type (i.e. soil, water, composite sample)
- sample preservation information
- name and signature of the person who collected the sample at the site
- name and signature of courier, if appropriate
- laboratory address
- specific analyses to be performed
- date and time of delivery to the laboratory
- name and signature of the laboratory staff who receive the sample.

The chain of custody form should be included in the investigation/ validation report.

See Appendix C for an example of a chain of custody form.

3 FURTHER SITE ASSESSMENT

If the initial site assessment (Section 2) indicates that the site is contaminated, further assessment is required to delineate the vertical and the lateral extent of the contamination.

3.1 Delineating the vertical extent of widespread contamination

The bananalands contaminant distribution study carried out by the EPA (NSW EPA 1997) indicated that arsenic contamination in banana-growing areas can be widespread, i.e. while there may be no specific hotspot, a large proportion of the area may nevertheless contain arsenic concentrations exceeding the investigation threshold. In such a case, for the site investigator to be able to formulate a specific remedial action plan, the vertical concentration profile of the contaminant needs to be delineated. Table C outlines the minimum additional sampling requirements for delineating the vertical extent of contamination where widespread contamination in the surface soil has been detected.

3.2 Delineating the vertical and lateral extent of hotspot contamination

If a sampling point has a contaminant concentration significantly higher than the surrounding sampling points and the concentration exceeds the investigation threshold, the sampling point should be considered a potential hotspot requiring further investigation.

The lateral extent of a hotspot can be delineated by collecting and analysing samples at points surrounding the sampling point at which the high contaminant concentration was found. The lateral boundary of the hotspot can be defined as the point at which the contaminant concentration falls below the average concentration of the surrounding area.

The vertical extent of a hotspot can be delineated by analysing sub-surface samples. The sub-surface samples should be taken initially from the 75–150 mm, 150–300 mm and 300–500 mm soil layers. Samples taken from greater depths may be required to delineate the full vertical extent of an arsenic hotspot.

Table C Sampling scheme for assessing the vertical extent of widespread contamination

Size of the land	Minimum number of sampling points
Up to 700 sq. m	2
700–1500 sq. m blocks	2–3
1500–3000 sq. m blocks	3–5
3000–20,000 sq. m blocks	5–10
Over 20,000 sq. m (2 hectares)	1 per 2,000 sq. m

Sampling depths
Surface layer: 0–75 mm below vegetative or detrital layer
Second layer: 75–150 mm
Third layer: 150–300 mm
Fourth layer: 300–500 mm
Further depths: site-specific

Guidance for using Table C

- Do not combine samples. All samples should be analysed individually.
- Only the contaminant that fails the initial assessment (see Section 2) needs to be analysed further in this assessment.
- Where the site investigator considers that the surface soil layer (0–75 mm) has been adequately characterised during the initial assessment, the sampling of the surface layer can be omitted in this further assessment.
- The EPA's bananalands contaminant distribution study (NSW EPA 1997) indicated that dieldrin contamination and arsenic contamination in the general growing area are likely to be confined to the 0–75 mm and 0–150 mm soil layers, respectively. The site investigator can therefore analyse the depth samples progressively to minimise the cost of chemical analysis.

4 SITE REMEDIATION

4.1 Cleanup standards

The objective of remediating a site is to make the site suitable for its current or intended use. If a former banana plantation site is to be developed for housing, the primary objective of the remediation therefore should be to protect human health and not pose an unacceptable risk to the environment. The human health investigation thresholds for the primary contaminants in Table B may be considered as the cleanup standards for sites intended for residential use.

Alternatively, the site investigator can derive cleanup standards based on a site-specific human health risk assessment. Conducting a site-specific health risk assessment requires expert knowledge and the observance of strict protocols. Site investigators who intend to conduct a site-specific human health risk assessment should contact the EPA for detailed requirements.

4.2 Remediating widespread contamination

Soil contamination in agricultural lands can be widespread. Where the level of contamination is relatively low and no other economically viable remediation method can be found, vertical mixing of the soil may be considered.

Not every banana plantation site can be remediated by vertical mixing. Factors such as the vertical contaminant concentration profile, the soil type and the potential for soil erosion must be fully considered. For detailed information about remediating a site by vertical mixing of the soil, see *Guidelines for the Vertical Mixing of Soil on Former Broad-Acre Agricultural Land* (NSW EPA 1995a).

4.3 Remediating a hotspot

If a banana plantation site is to be developed for residential use, any hotspots found on the site must be removed. The EPA encourages the use of soil treatment technology that can reduce the concentrations of the contaminants in soil to below the human health investigation thresholds. Where this approach is not practicable, the contaminated soil should be excavated for off-site disposal, with the approval of the relevant authorities, e.g. the EPA or local council.

5 SITE VALIDATION

After site remediation, validation sampling must be carried out to demonstrate that the site has been remediated to a standard that is appropriate for the proposed land use.

A validation program typically involves validating residual soil and any backfill material used. If the site has been remediated by vertical mixing, the vertical mixing process needs to be validated.

5.1 Validation criteria

A systematic sampling pattern, such as a square grid sampling pattern, should be used for validation sampling. The data obtained from the validation program should be statistically analysed.

For a former banana plantation site, or part of the site, to be validated as not contaminated, the minimum requirement is that the upper 95% confidence limit on the average concentration for each contaminant must be below the relevant cleanup standard, and none of the individual measurements has a concentration 25% higher than the cleanup standard. See Appendix A for determining the 95% upper confidence limit (UCL) average.

Where the 95% UCL average is less than the cleanup standard, but one or more individual sample measurements are more than 25% above the cleanup standard, each sampling point that exceeds this level must be reinvestigated to determine whether or not it constitutes a hotspot. This reinvestigation normally involves taking a number of samples in the area surrounding each sampling point in question.

Other site-specific validation requirements may be set by the EPA or other consent authorities.

5.2 Validating residual soil

A common remediation practice is to remove the contaminated soil for treatment or off-site disposal. After the contaminated soil has been removed, the residual soil inside the excavation pit needs to be validated. At least one validation sample should be collected from the bottom and from each of the walls of the pit. For large pits, use a 25 metre square grid sampling pattern. Residual soil must be validated as being not contaminated before any backfilling occurs.

5.3 Validating backfill material

5.3.1 Validating remediated on-site material

Remediated on-site material should be stockpiled in a clean area before backfilling. Sampling points should be evenly spaced throughout the stockpile. Samples should be collected from the core of the stockpile as well as from the surface. The number of samples required can be determined statistically using Appendix B.

5.3.2 Validating imported material

If the backfill material is to be imported, the site investigator should visit the source site and confirm that:

1 the history of the site being excavated indicates that the site is uncontaminated

2 the soil being excavated is visually clean and undisturbed.

A minimum of one composite sample from the soil being excavated should be taken and analysed for heavy metals, total petroleum hydrocarbons and pesticide-related organochlorine and organophosphate compounds. Confirm that their concentration levels are all below the environmental investigation levels recommended in the ANZECC/NHMRC (1992) guidelines.

If large quantities of fill are to be imported, sampling on a regular basis will be required. The site investigator should demonstrate either that the contaminant concentration in each sample is below environmental investigation levels or that the 95% upper confidence limit (UCL) of the average concentration of the backfill material is below environmental investigation levels.

5.4 Validating remediation by vertical mixing

Systematic sampling patterns, such as square grid sampling patterns, should be used when validating that a site has been remediated by means of vertical mixing. Soil samples should be collected at two or more depths at each sampling point, including:

- at the surface (i.e. between 0–150 mm below the surface)
- at the interface between the disturbed layer (where vertical mixing has taken place) and the undisturbed layer.

The number of samples required at each sampling depth can be determined statistically using Appendix B.

Do not combine the samples. Analyse each sample individually to determine the effect of the vertical mixing process.

Sampling results from the same sampling depth can be pooled for statistical analysis. For the vertical mixing remediation to be considered successful, the sampling results of each sampling depth must meet the validation criteria described in Section 5.1.

REFERENCES

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APPENDIX A
Determining the 95% upper confidence limit (UCL) of the arithmetic average concentration

This method can be applied to many forms of contaminant concentration distributions including those that are not normally distributed. This is based on the Central Limit Theorem which states that sample means tend to exhibit a normal distribution even though the mother population is not normally distributed.

Equation used:

$$\textbf{UCL average} = \bar{x} + t_{\alpha,\, n-1}\frac{s}{\sqrt{n}}$$

Where:

UCL average	=	Upper confidence limit of the arithmetic average concentration of the sampling area at the 1-α confidence level
α	=	The probability that the 'true' average concentration of the sampling area might exceed the UCL average determined by the equation
n	=	Number of sample measurements
$\bar{x}$	=	Arithmetic average of all sample measurements
$t_{\alpha,\, n-1}$	=	A test statistic (Student's t at an α level of significance and n-1 degrees of freedom)
s	=	Standard deviation of the sample measurements

Procedure:

1 Determine the confidence level. For 95% confidence level $\alpha = 0.05$. Obtain the corresponding value of $t_{\alpha,\, n-1}$ from the table, *Values of Student's t at selected α and degrees of freedom (df)*, opposite.

2 Compute the 95% UCL average from the equation.

Values of Student's t at selected α and degrees of freedom (df)					
α	0.10	0.05	0.025	0.01	0.005
df	For the purpose of this document, df = n-1, where n is the number of sample measurements				
1	3.078	6.314	12.706	31.821	63.657
2	1.886	2.920	4.303	6.965	9.925
3	1.638	2.353	3.182	4.541	5.841
4	1.533	2.132	2.776	3.747	4.604
5	1.476	2.015	2.571	3.365	4.032
6	1.440	1.943	2.447	3.143	3.707
7	1.415	1.895	2.365	2.998	3.499
8	1.397	1.860	2.306	2.896	3.355
9	1.383	1.833	2.262	2.821	3.250
10	1.372	1.812	2.228	2.764	3.169
11	1.363	1.796	2.201	2.718	3.106
12	1.356	1.782	2.179	2.681	3.055
13	1.350	1.771	2.160	2.650	3.012
14	1.345	1.761	2.145	2.624	2.977
15	1.341	1.753	2.131	2.602	2.947
16	1.337	1.746	2.120	2.583	2.921
17	1.333	1.740	2.110	2.567	2.898
18	1.330	1.734	2.101	2.552	2.878
19	1.328	1.729	2.093	2.539	2.861
20	1.325	1.725	2.086	2.528	2.845
21	1.323	1.721	2.080	2.518	2.831
22	1.321	1.717	2.074	2.508	2.819
23	1.319	1.714	2.069	2.500	2.807
24	1.318	1.711	2.064	2.492	2.797
25	1.316	1.708	2.060	2.485	2.787
26	1.315	1.706	2.056	2.479	2.779
27	1.314	1.703	2.052	2.473	2.771
28	1.313	1.701	2.048	2.467	2.763
29	1.311	1.699	2.045	2.462	2.756
30	1.310	1.697	2.042	2.457	2.750
40	1.303	1.684	2.021	2.423	2.704
60	1.296	1.671	2.000	2.390	2.660
120	1.289	1.658	1.980	2.358	2.617
∞	1.282	1.645	1.960	2.326	2.576

WORKED EXAMPLE A

A site has been remediated. The remedial action plan states that the site will be declared clean only if the 95% UCL of the average concentration of a contaminant is less than 50 mg/kg. Twenty validation samples were collected from the site using systematic sampling.

The contaminant concentrations are shown below (in mg/kg):

8, 20, 25, 30, 15, 24, 30, 38, 43, 48, 55, 40, 41, 46, 52, 55, 62, 65, 70, 80

Has the site met cleanup criteria?

Solution

1 Determine the value of **t**:

For 95% confidence, $\alpha = 0.05$

From Table A, $\mathbf{t}_{0.05, 19} = 1.729$

2 Determine the 95% UCL average:

95% UCL average = $42.4 + (1.729)(19.1) / \sqrt{20}$

$= 42.4 + 7.38$

= 49.8 mg/kg, which is less than 50 mg/kg.

The statistical analysis indicates that there is a 95% probability that the arithmetic average concentration of the contaminant will not exceed 49.8 mg/kg. The cleanup standard, therefore, has been met.

APPENDIX B
Number of samples required for determining the average concentration

Reference: *Method for Evaluating the Attainment of Cleanup Standards*, Box 6.3, Chapter 6 (EPA 230/02-89-042), Office of Policy, Planning and Evaluation, United States Environmental Protection Agency, 1989.

This method determines the number of samples needed if the objective of the sampling is to show that the average concentration of a contaminant is below an acceptable limit. The method can be applied to the sampling of an area or to the sampling of a stockpile of soil.

The method requires knowledge of the probable average concentration and standard deviation of the contaminant. This method is most applicable for validation sampling, where the average concentration and the standard deviation can be estimated from the previous sampling results.

Equation used:

$$n = \frac{6.2^{*}\,\sigma^{2}}{(C_S - \mu)^{2}} \qquad (1)$$

* based on 0.05 α risk and 0.2 β risk

Where:

- n = Number of samples needed
- σ = Estimated standard deviation of contaminant concentrations in the sampling area, in mg/kg
- μ = Estimated average concentration in the sampling area, in mg/kg
- C_S = Acceptable limit, in mg/kg

Procedure:

1 Estimate μ based on previous sampling results or by judgment. μ should have a value less than C_S.

2 Estimate σ based on previous sampling results. Where no previous sampling result is available, a crude estimate of σ can be obtained by using the following method:

(a) Estimate the lowest possible concentration, C_L, in the sampling area.

(b) Estimate the highest possible concentration, C_H, in the sampling area.

(c) Estimate σ using the following equation:

$$\sigma = \frac{C_H - C_L}{6} \qquad (2)$$

3 Determine what the acceptable limit should be.

4 Compute ***n*** using Equation (1) .

WORKED EXAMPLE B

A site is to be validated. Judging from the previous sampling results, the investigator expects that the average concentration of a particular contaminant on the site will be around 100 mg/kg. The acceptable limit is 150 mg/kg. Previous sampling indicates that the maximum and minimum concentrations are 450 mg/kg and 30 mg/kg, respectively. How many samples should be taken for validation?

Solution

σ = (450 - 30)/6 = 70 mg/kg

$$n = \frac{6.2\ (70)^2}{(150 - 100)^2}$$

= 13

The number of samples needed is 13.

Appendix C
Chain of Custody Form

CHAIN OF CUSTODY FORM Sheet ____ of ____

Investigator *(name, address, ph & fax nos.)* Contact person:	**Sample matrix**							**Sample preservation**						**Analysis**							
Site	WATER	SOIL	SLUDGE	OTHER (SPECIFY)	COMPOSITE			ICE	HNO_3/HCl	UNPRESERVED	OTHER (SPECIFY)										
Laboratory *(name, address, ph & fax nos.)* Contact person:																					
Courier *(name, address, ph & fax nos.)* Contact person:																					
Sample ID	**Laboratory ID**	**Container**	**Sampling**																		
			Date	Time																	
Investigator: I attest that the proper field sampling procedures were used during the collection of these samples.								**Sampler name:** *(print & signature)*													*(Date)*
Relinquished by: *(print & signature)*			Date		Time			Received by: *(print & signature)*						Date						Time	
Relinquished by: *(print & signature)*			Date		Time			Received by: *(print & signature)*						Date						Time	
Relinquished by: *(print & signature)*			Date		Time			Received by: *(print & signature)*						Date						Time	